Explaining the Interplay Between Merchant Acceptance and Consumer Adoption in Two-Sided Markets for Payment Methods*

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Abstract

The market for payment cards is inherently two-sided. Consumers benefit from increased merchant acceptance of payment cards and vice-versa. To quantify the interdependence of consumer and merchants or network externalities, we construct and estimate a structural two-sided model of a payment choice. We exploit a unique data set consisting of the Bank of Canada's consumer Method-of-Payment diaries and the Retailer Survey of Cost of Payment surveys. We find that consumer adoption of payment cards is inelastic. When merchants face an increase in the usage cost of credit card, they reduce acceptance of credit cards in favor of debit cards, with a much smaller increase in the share of cash-only businesses. If the usage cost of cash for both sides of the market increases by an order of magnitude, cash would still be used at the point-of-sale. We also show that under full adoption and acceptance of all payment instruments by both sides of the market, consumers and merchants would continue using cash for approximately one out of five transactions.

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1 Introduction

Despite the dire warnings, the use of cash, especially at the point of sale (POS), remains strong in most industrialized countries; see Bagnall et al. (2016). The main alternatives, debit and credit cards, have a large market share but have still not supplanted cash. Understanding the usage of cash is a first-order responsibility for central banks as they are usually the sole issuer of banknotes. However, the increasing digitization of payment innovations by private entities requires that public authorities monitor these new developments and understand the implications for provision of an efficient payment system.

There are many reasons for the resiliency of cash; from the demand side or consumers there is a preference for cash, especially for small-value transactions; see Arango et al. (2015) and Wakamori and Welte (2017). The supply side has shown that consumer adoption of payment cards is ubiquitous; see Arango et al. (2012) and Fung et al. (2015). However, merchant acceptance is not universal; for example, in Canada about a third of small and medium-sized businesses do not accept any type of payment card; see Fung et al. (2017). One of the major reasons for merchant non-acceptance of payment cards is the cost of cash; see European Commission (2015) and Fung et al. (2018). Since merchant acceptance is not universal, consumers must hold cash in cases where merchants do not accept cards. Arango et al. (2015) and Wakamori and Welte (2017) illustrate that consumer perception of merchant non-acceptance of payment cards plays a large role in the continued use of cash. Further, Huynh et al. (2014) demonstrate that the lack of universal acceptance of payment cards is a determinant for the continued holding of cash by consumers. This interplay between consumers and merchants is known as two-sided markets for payment cards, and the feedback between consumers and merchants is known as network externalities; see Rysman (2009) and Rysman and Wright (2014) for further details.

Much of the early work on two-sided markets focused on theoretical modeling of platform competition and how this relates to the setting of fees; see Rochet and Tirole (2003), inter alia. Examples of empirical work on payment markets include Rysman (2007), who establishes a feedback loop between consumer usage and merchant acceptance, a necessary condition for the two-sidedness of a market. Carbó-Valverde et al. (2016) and Bounie et al. (2016) estimate empirical models based on survey data from both consumers and merchants in Spain and France, respectively. These empirical models utilize simultaneous equations with instrumental variables to estimate the cross-partial elasticities of consumer adoption and merchant acceptance. However, these methodologies are unable to quantify or identify the equilibrium source of network externalities. McAndrews and Wang (2012) articulate that there are two types of network externalities present: (1) adoption externality and (2) usage externality. In the first case, for a payment system to work, consumers require that merchants accept payment cards and merchants require that consumers have a payment card. In the second case, an increase in the usage of payment cards by consumers will have implications for merchant costs (fees) of accepting cards versus cash.

The contribution of this paper is that we develop a structural equilibrium model of interactions between consumers and merchants in two-sided markets for payment methods. We utilize rich micro data for consumers from the Bank of Canada's 2013 Methods-of-Payment (MOP) Survey, and for merchants the 2015 Retailer Survey on the Cost of

Payment Methods (RSCPM). The 2013 MOP data contain consumer adoption and usage of payment instruments, while the 2015 RSCPM contains detailed cost data and merchant acceptance of payment methods. Using this unique data, we estimate the structural parameters of the model and decompose the network externalities into the extensive (adoption) and intensive (usage) margins.

In our framework, the interaction between consumers and merchants is modeled as a two-stage game that is played every period. In the first stage, consumers and merchants simultaneously and independently make adoption and acceptance decisions about which methods of payments will be available to use in the following stage. In the second stage, consumers and merchants are randomly matched to conduct transactions. Merged parties can transact by using payment methods they chose previously. The two-sided nature of payments emphasizes the role of network effects, where consumers benefit from the increased acceptance decisions of merchants and vice versa. The benefit to consumers is the reduction in expected costs of transacting because they can choose from a wider set of payment methods with heterogeneous usage costs; i.e., they minimize costs over a larger set of options. In our model, a rational consumer conditions their adoption decisions on the expected probabilities of acceptance for each means of payment. If a given payment method is widely accepted by merchants, consumers expect to be able to use it more frequently. Similarly, merchants condition their acceptance decisions on the expected adoption probabilities of consumers of various types.

We find that in equilibrium some merchants choose to accept all means of payment in order to attract more customers. By doing so they can generate additional revenues that can contribute up to 3 percent of total sales. For consumers, adopting debit cards can result in a net cost as high as \$11 per month, while adopting both debit and credit cards can generate net benefits of up to \$48 per month. We estimate network effects by considering the response of one side of the market to changes in costs on the other side. We find that consumers are more sensitive, in terms of usage, to increases in merchant credit card costs than changes in their own costs. This is because merchants quickly reduce their acceptance of credit cards, making payment opportunities with this method less frequent. On the other hand, consumer adoption is inelastic, with consumers finding benefit in keeping all methods of payment even if they do not use them as often.

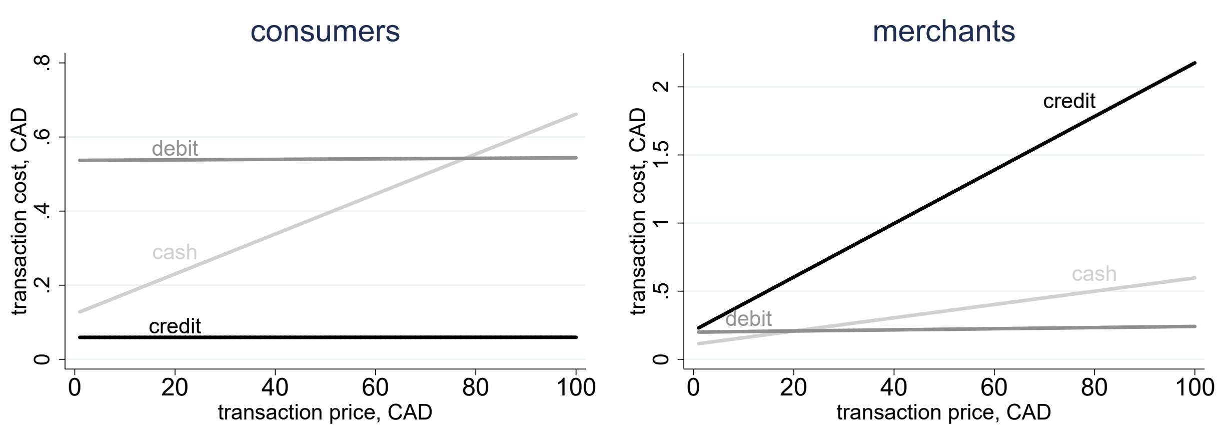
The rest of the paper is organized as follows. Section 2 provides institutional details and describes our data. This section also provides reduced-form evidence for network effects in our sample. We describe our theoretical model in Section 3. The empirical specifications and details of the estimation algorithm are provided in Section 4. Section 5 contains a discussion of the results, including an analysis of the determinants of adoption and acceptance decisions at the observed equilibrium. Section 7 discusses three counterfactual simulations examining increases in merchant credit card usage costs, increases in cash usage costs for both sides of the market, and a scenario in which consumers and merchants are subsidized to adopt and accept all methods of payment. Finally, Section 8 concludes.

2 Consumer and Merchant Payment Data

This study makes use of both consumer-side and merchant-side surveys developed by the Bank of Canada. The former is the 2013 MOP survey, which includes two components; see Henry et al. (2015). The first component is the survey questionnaire, containing information on individuals' demographics and payment card ownership. The second component is the diary survey instrument, which asked respondents to report transactions they made over a three-day period, along with many key characteristics, including method used to complete the transaction, value of transaction, and type of store the transaction was made at. The merchant-side survey used is the 2015 RSCPM, which included questions about perceptions of payment method costs and benefits, payment method acceptance, and revenue and fees broken down by payment method. More details on the 2015 RSCPM are available in Kosse et al. (2017).

Data analysis suggests that consumers and merchants view payment methods very differently in terms of their usage costs. Figure 1, based on results from Kosse et al. (2017), can be used to rank the usage costs for consumers and merchants for a given transaction size. Most glaringly, for all price points, consumers find credit cards the least costly, while merchants find them the most costly. Further, both consumers and merchants find cash cheaper than debit for smaller transactions, but more costly for larger transactions.

Figure 1: Consumer (left) and merchant (right) costs of transacting



Source: Figure 13 in Kosse et al. (2017).

Consumers almost always (99.8 percent of consumers) have a payment card of some kind, with 83 percent owning both a debit and a credit card (Table 1). On the other hand, about a fifth (22 percent) of merchants accept only cash, while 70 percent accept both types of cards. This suggests that while merchants can almost always expect consumers to carry a payment card, a consumer may not always be able to use the payment cards they have at their disposal.

Table 1: Summary of consumer adoption and merchant acceptance decisions.

variable	consumers		merchants	
	frequency	percent	frequency	percent
cash only	24	1.23	162	22.10
cash and debit	197	10.08	31	4.23
cash and credit	118	6.04	24	3.27
all methods	1,616	82.66	516	70.40
Total	1,955	100.00	733	100.00

Transactions between consumers and merchants are captured from the consumer-side diary data, and can be characterized by their price.[1] On average, transactions were priced at about \$33, and each consumer on average provided details on seven transactions over the study period (Table 2). Cash was the most common method of payment (44 percent of transactions), followed by credit card (33 percent) and debit card (23 percent).

Table 2: Summary statistics for transactions and usage of payment methods

variable	mean	p50	min	max	s.d.
transaction price	32.97	18.48	0.00	300.00	41.57
transactions per consumer	5.85	5.00	3.00	18.00	2.65

3 Empirical Model

Koulayev et al. (2016) develop a rich structural model of the two-step payment choice and use it to determine the response of consumers to a change in payment card fees. Our model advances this by adding the merchant acceptance decision structurally to the consumer-side model, meaning that the feedback loop between consumer and merchant decisions is taken into account when policy changes are simulated. Further, using consumer diary data, our consumer usage model is able to take into account the individual discrete choice of usage, and models usage as a function of transaction price. This is important because consumer rewards and merchant interchange fees, drivers in the theory of two-sided payment markets, are functions of transaction price.

Consider a market populated by merchants, s, who sell various products, and consumers, b, who purchase these products. Let N_s denote the number of merchants and N_b denote the number of consumers in the market. Consumers and merchants interact with each other with the purpose of completing day-to-day transactions. These transactions can be made using one of the three available means of payment: (1) cash, ca, (2) debit card, de, and (3) credit card, cr.[2] Let $\mathcal{M} = (\{ca\}, \{ca, de\}, \{ca, cr\}, \{ca, de, cr\})$ denote the set of all possible adoption/acceptance decisions available to consumers and merchants. Let

[1]Note that we focus only on cash, debit, and credit transactions that are \$300 or less. Further, we exclude consumers who reported fewer than three transactions in their three-day diary.

[2]We assumed away other means of payment such as checks, money orders, and e-transfers because they are more likely to be used for utility payments rather than for day-to-day transactions.

$\mathcal{M}_b \in \mathcal{M}$ and $\mathcal{M}_s \in \mathcal{M}$ denote sets of payment methods available to consumer b and merchant s, respectively. We assume that every merchant and every consumer can use cash; i.e., $ca \in \mathcal{M}_b$ and $ca \in \mathcal{M}_s$ $\forall b, s$.

Consumers and merchants represent two sides of the market, and we assume their interaction takes the form of a two-stage game played every time period. In the first stage, consumers and merchants simultaneously and independently decide about the combination of payment methods to adopt/accept. In the second stage, consumers and merchants are randomly matched with each other for every transaction. We provide a detailed discussion of the optimization problem for each side and define equilibrium below.

Consumers. Consumers can be of two types: informed and uninformed. Informed consumers know the acceptance decisions of each seller, while uninformed consumers know only the average probability of acceptance among all merchants. In what follows, we discuss the role of informed consumers in the model. Then, we structurally model interactions between merchants and uninformed consumers and estimate the size of the informed market in a reduced form. The way we model the contributions of informed and uninformed consumers to merchant revenues is discussed later in this section.

Informed consumers. At the POS, it is the consumer who decides which payment method to use. Merchants thus prefer the method of payment that is least costly to accept at the POS, and have an incentive to accept only that method. Since we observe merchants who accept all three means of payments, we can infer that there must be some benefit to acceptance that would compensate for the increase in costs. This is the so-called "must-take" effect; see Rochet and Tirole (2011).

This benefit may arise from an increase in the number of transactions, which can occur if (1) consumers who walk away when their method of payment is not accepted are now allowed to use that method, or (2) the merchant attracts new customers. To model case (1) we would need to estimate the demand for transactions as a function of transaction cost, which would require strong assumptions and richer data. Instead, we assume an inelastic demand for transactions, and model merchant benefits from newly attracted consumers in case (2).

If some consumers are attracted by a particular merchant's acceptance combination, our random matching assumption is violated because these consumers use some form of a directed search. Since there are multiple ways a consumer can acquire information about the merchant acceptance choice and we do not have data to identify informed and uninformed consumers, we model revenues generated by the group of informed consumers in reduced form. In other words, we assume that every merchant faces a trade-off between attracting new consumers and incurring higher usage costs when deciding to accept a larger set of payment instruments. The intercept in merchant acceptance of a particular bundle thus captures the difference between extra revenues generated by informed consumers and the fixed cost of accepting this bundle. With this in mind, we now turn to modeling the uninformed consumers.

Uninformed consumers. In our model, consumers[3] make two decisions: the first-stage decision to adopt a particular combination of payment methods to use in the second stage, $\mathcal{M}_b$; and the second-stage usage decision, which depends both on $\mathcal{M}_b$ and the first-stage acceptance decision of the merchant the consumers are matched with. We begin with the second-stage decision.

Each consumer is exogenously endowed with a set of transactions to complete, $\mathcal{J}_b$. We assume inelastic demand for transactions, which is summarized in the following assumption.

Assumption 1: *Every consumer b is endowed with a set of transactions $\mathcal{J}_b$, all of which must be completed. The number of transactions (cardinality of $\mathcal{J}_b$) and their prices, p_{bj}, $j \in \mathcal{J}_b$, are exogenous.*

Transacting is costly and the cost depends on both the number of transactions and their values. Each consumer type b is characterized by observable demographics, X_b, which maps into a pair of cost function parameters per payment method, m, $c_{0bm}(X_b)$, and $c_{1bm}(X_b)$, such that the cost of a transaction with price p_j is given by

$$c_{bmj}(p_j) = c_{0bm} + c_{1bm}p_j + \varepsilon_{bmj}, \tag{1}$$

where ε_{bmj} is a cost innovation at the POS.

Assumption 2: *A vector of consumer usage cost innovations $\varepsilon_{bj} = (\varepsilon_{b,ca,j}, \varepsilon_{b,de,j}, \varepsilon_{b,cr,j})$ is given by random draws from joint distribution $F_\varepsilon(\cdot|\theta^{b2})$ known up to a parameter vector, θ^{b2}, i.e., $\varepsilon_{bj} \overset{iid}{\sim} F_\varepsilon(\cdot|\theta^{b2})$.*

Consumers then choose method m^* for transaction j by choosing the cheapest method from the intersection $\mathcal{M}_b \cap \mathcal{M}_s$. Note that in the first stage, when the adoption decision is made, the consumer can evaluate only the expected minimum, i.e., the adoption decision occurs prior to the realization of the second-stage errors,

$$\mathbb{E}_\varepsilon \left[\min_{m' \in \mathcal{M}_b \cap \mathcal{M}_s} \{c_{bm'j}(p_j)\} \right]. \tag{2}$$

Since consumers and merchants make their first-stage decisions simultaneously, both must form expectations about the likely choices of the other side of the market. Let $\mathbb{E}\Pr(\mathcal{M}_s)$ denote the consumer's belief that a randomly chosen merchant accepts $\mathcal{M}_s \subset \mathcal{M}$. Then, a consumer can calculate the expected cost of transacting in the second stage as a function of their own adoption decision and the likely decisions of the merchants as follows. Let $EC_b(\mathcal{M}_b)$ denote the expected cost of completing all transactions in the set $\mathcal{J}_b$ in stage 2 if the consumer chooses $\mathcal{M}_b$ in the first stage. For example, if the consumer chooses $\mathcal{M}_b = ca$, then the expected cost is given simply by $EC_b\left(\mathcal{M}_b = \{ca\}\right) = \sum_{j \in \mathcal{J}_b} c_{b,ca,j}(p_j)$.

[3] For the sake of brevity, we refer to uninformed consumers simply as "consumers" for this section.

If the consumer chooses $\mathcal{M}_b = \{ca, de\}$, then the expected cost consists of several terms as shown in (3). The first and second terms measure expected cost when the intersection of $\mathcal{M}_b$ and $\mathcal{M}_s$ is given by a singleton. This may happen if merchants accept cash only or if they accept cash and credit, but not debit card. The third and fourth terms describe situations where both of the payment methods adopted by the consumer are accepted by the merchant ($\mathcal{M}_s = \mathcal{M}_b$) in the third line and $\mathcal{M}_b \subset \mathcal{M}_s$ in the fourth one.

$$EC_b(\mathcal{M}_b = ca, de) = \sum_{j \in \mathcal{J}_b} \left(\begin{array}{l} \mathbb{E}\Pr(\mathcal{M}_s = \{ca\}) \times c_{b,ca,j}(p_j) \\ + \mathbb{E}\Pr(\mathcal{M}_s = \{ca, cr\}) \times c_{b,ca,j}(p_j) \\ + \mathbb{E}\Pr(\mathcal{M}_s = \{ca, de\}) \times \mathbb{E}\left[\min_{m' \in \{ca,de\}} c_{b,m',j}(p_j) \right] \\ + \mathbb{E}\Pr(\mathcal{M}_s = \{ca, de, cr\}) \times \mathbb{E}\left[\min_{m' \in \{ca,de\}} c_{b,m',j}(p_j) \right] \end{array} \right). \quad (3)$$

Note that given consumer expectations $\mathbb{E}\Pr(\mathcal{M}_s = \{ca\})$, $\mathbb{E}\Pr(\mathcal{M}_s = \{ca, cr\})$, $\mathbb{E}\Pr(\mathcal{M}_s = \{ca, de\})$, and $\mathbb{E}\Pr(\mathcal{M}_s = \{ca, de, cr\})$, the expected total transaction cost is defined for any $\mathcal{M}_b \in \mathcal{M}$. We assume rational expectations so that $\mathbb{E}\Pr(\mathcal{M}_s) = \frac{1}{N_s}\sum_{s=1}^{N_s} \Pr(\mathcal{M}_s)$. In other words, consumers' expectations match average merchant acceptance.

In the first stage, consumers choose a combination of payment methods to adopt. In order to adopt a particular payment method, consumers must pay adoption cost, $\tilde{f}_{b\mathcal{M}_b}$, and may receive adoption benefits, $B_{b\mathcal{M}_b}$, which is given by loyalty programs. The net cost (benefit) from adoption is thus $F_{b\mathcal{M}_b} \equiv B_{b\mathcal{M}_b} - \tilde{f}_{b\mathcal{M}_b}$. Note that $F_{b\mathcal{M}_b}$ can be both positive (if the benefit from adoption is greater than cost) or negative (if the cost of adoption exceeds its benefit).

Then we can describe the consumer decision in the first stage as

$$\min_{\mathcal{M}'_b} \left\{ EC_b(\mathcal{M}'_b) - F_{b\mathcal{M}'_b} \right\}, \quad (4)$$

where total cost is the sum of the expected transaction cost in the second stage and the fixed adoption cost net of fixed adoption benefits.

Assumption 3: *A vector of consumer fixed adoption cost components (one for each possible combination of payment methods) is given by draws from the joint distribution known up to a parameter vector,* θ^b, *i.e.,* $\left(\tilde{f}_{b,\{ca\}}, \tilde{f}_{b,\{ca,de\}}, \tilde{f}_{b,\{ca,cr\}}, \tilde{f}_{b,\{ca,de,cr\}}\right) \overset{iid}{\sim} F_{1b}(\cdot|\theta^b)$.

Note that the distribution of $\tilde{f}_{b\mathcal{M}_b}$ determines the distribution of $F_{b\mathcal{M}_b}$; i.e., the distribution of the adoption costs (benefits) is F_{1b} with mean shifted by $B_{b\mathcal{M}_b}$. Ex ante adoption probability for combination of payment methods $\mathcal{M}_b$ is then,

$$\Pr(\mathcal{M}_b) = \Pr\left(EC_b(\mathcal{M}_b) - F_{b\mathcal{M}_b} \leq EC_b(\mathcal{M}'_b) - F_{b\mathcal{M}'_b} \ \forall \mathcal{M}'_b \subset \mathcal{M} \right), \quad (5)$$

where we assume that cash is included in every $\mathcal{M}_b$ at no cost. For a given parameter vector, we use $F_{1b}(\cdot|\theta^b)$ to evaluate equation (5).

Merchants. Each merchant is characterized by a pair of usage cost function parameters per method of payment, $c_{sm0}(X_s)$ and $c_{sm1}(X_s)$, $m \in \mathcal{M}_s$, where c_{sm0} denotes cost per transaction and c_{sm1} denotes cost per value of the transaction, and X_s is a vector of observable merchant characteristics, e.g., size, location, industry, etc. Similar to the consumer side of the market, per transaction cost for merchant s is given by

$$c_{smj}(p_j) = c_{0sm} + c_{1sm}p_j + \varepsilon_{smj}. \tag{6}$$

Note that due to the linearity of the merchants' payoff function and our assumption that it is the consumer who decides on the method to use in the second stage, the distribution of ε_{smj} is irrelevant for the merchants' first-stage decisions.

The key distinction from the consumer side is that in the second stage, when merchants and consumers are randomly matched with each other, it is the consumer decision as to which method of payment to use from $\mathcal{M}_b \cap \mathcal{M}_s$. Merchants cannot refuse to accept any method of payment provided they are in $\mathcal{M}_s$, i.e., were chosen for acceptance in the first stage of the game. This is summarized in the following assumption.

Assumption 4: *If a merchant s accepting $\mathcal{M}_s$ meets a consumer b, who chose to adopt $\mathcal{M}_b$ in the first stage, the usage decision is made by the consumer from the set $\mathcal{M}_b \cap \mathcal{M}_s$.*

In other words, the merchant payoffs are completely determined by their first-stage acceptance decisions. For example, if a merchant decides to accept $\mathcal{M}_s = \{ca, de\}$, its expected cost *per transaction* in the second stage is given by

$$\begin{aligned}
ETC_{bj}(\mathcal{M}_s = \{ca, de\}) =& \mathbb{E}\Pr(\mathcal{M}_b = \{ca\}) \times c_{s,ca,j}(p_j) \\
&+ \mathbb{E}\Pr(\mathcal{M}_b = \{ca, cr\}) \times c_{s,ca,j}(p_j) \\
&+ \mathbb{E}\Pr(\mathcal{M}_b = \{ca, de\}) \times \begin{bmatrix} \Pr\left(c_{b,ca,j}(p_j) \le c_{b,de,j}(p_j)\right) \times c_{s,ca,j} \\ \left(1 - \Pr\left(c_{b,ca,j}(p_j) \le c_{b,de,j}(p_j)\right)\right) \times c_{s,de,j} \end{bmatrix} \\
&+ \mathbb{E}\Pr(\mathcal{M}_b = \{ca, de, cr\}) \times \begin{bmatrix} \Pr\left(c_{b,ca,j}(p_j) \le c_{b,de,j}(p_j)\right) \times c_{s,ca,j} \\ \left(1 - \Pr\left(c_{b,ca,j}(p_j) \le c_{b,de,j}(p_j)\right)\right) \times c_{s,de,j} \end{bmatrix}.
\end{aligned}$$

The expected cost from participating in the market given acceptance combination $\mathcal{M}_s = \{ca, de\}$ is then

$$EC_s\Big(\mathcal{M}_s = \{ca, de\}\Big) = \frac{1}{N_s} \sum_{b=1}^{N_b} \sum_{j \in \mathcal{J}_b} ETC_{bj}(\mathcal{M}_s = \{ca, de\}). \tag{7}$$

Similar to consumers, merchants form beliefs $\mathbb{E}\Pr(\mathcal{M}_b)$ about consumers. However, we assume that merchants have more information available to them. Specifically, merchants are assumed to know each consumer's set of transactions $\mathcal{J}_b$ and thus form expectations $\mathbb{E}\Pr(\mathcal{M}_b) = \Pr(\mathcal{M}_b)$ for every consumer b.

In the first stage, merchants decide which means of payment to accept. Similar to the consumer side, each combination of payment methods has acceptance cost, $\tilde{f}_{s\mathcal{M}_s}$, and acceptance benefit, $B_{s\mathcal{M}_s}$. Then the merchant's decision can be expressed as the following cost minimization problem,

$$\min_{\mathcal{M}'_s} \left\{ EC_s(\mathcal{M}'_s) - F_{s\mathcal{M}_s} \right\}, \tag{8}$$

where $F_{s\mathcal{M}_s} = B_{s\mathcal{M}_s} - \tilde{f}_{s\mathcal{M}_s}$. We assume that the first-stage innovations $\tilde{f}_{s\mathcal{M}_s}$ are draws from a joint distribution known up to a parameter vector.

Assumption 5: *A vector of consumer fixed acceptance cost components (one for each possible combination of payment methods) is given by draws from the joint distribution known up to a parameter vector, θ, i.e.,* $\left(\tilde{f}_{s,\{ca\}}, \tilde{f}_{s,\{ca,de\}}, \tilde{f}_{s,\{ca,cr\}}, \tilde{f}_{s,\{ca,de,cr\}}\right) \overset{iid}{\sim} F_{1s}(\cdot|\theta^s)$.

We assume that, differently from consumers, merchants' benefit component is given by extra profit generated by the group of informed consumers, which we discuss next.

Merchant profit from informed consumers. As described above, we estimate the effect of informed consumers in reduced form, assuming they distribute their purchases among the merchants who accept their favorite method of payment. One way to think about this auxiliary model structure is in terms of Bresnahan and Reiss (1991), where markets can support only a given number of competitors and the profit per incumbent decreases with the number of entrants up until no new entry is profitable. In our setting, an increase in the number of merchants accepting all means of payments would distribute profits from the informed sub-population across a larger number of merchants.

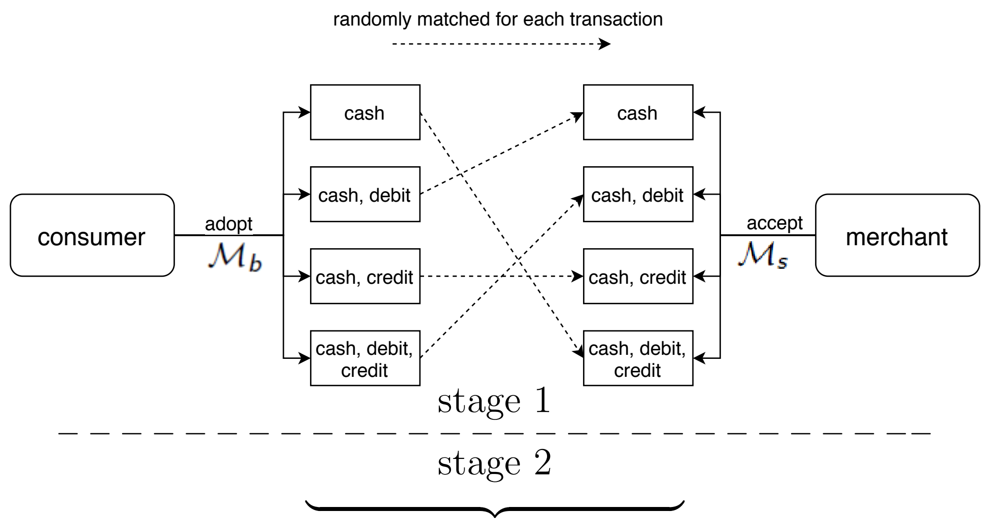
Let $\Pi(\mathcal{M}_s)$ denote the total profit from transacting with informed consumers who patronize payment combination $\mathcal{M}_s$. If there are $n^*_{\mathcal{M}_s}$ merchants accepting combination $\mathcal{M}_s$, each of them in equilibrium receives

$$B_{s\mathcal{M}_s} = \frac{1}{n^*_{\mathcal{M}_s}} \Pi(\mathcal{M}_s). \tag{9}$$

In estimation we will recover $F_{s\mathcal{M}_s} = B_{s\mathcal{M}_s} - \tilde{f}_{s\mathcal{M}_s}$. Then, by using external information on the cost component $\tilde{f}_{s\mathcal{M}_s}$ reported as the cost of a payment processing terminal, we can extract the pure benefit component, $B_{s\mathcal{M}_s}$. This will be important in the counterfactual analysis when the merchant acceptance probabilities change. For example, if more merchants begin accepting a given combination of payment methods, the estimated benefit must be divided between a larger number of merchants, which would reduce the per-merchant benefit and vice versa. We will return to the discussion of informed consumers in Section 5.

Equilibrium. Our equilibrium concept is subgame perfect Nash equilibrium. Figure 2 provides a sketch of the two-stage game.

Figure 2: Two-stage model of interactions between merchants and uninformed consumers



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

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

Equilibrium of the game is defined in terms of merchant acceptance probabilities, $\Pr(\mathcal{M}_s)$, and consumer adoption probabilities, $\Pr(\mathcal{M}_b)$. In equilibrium, individual (uninformed) consumer decisions, based on their expectations $\mathbb{E}\Pr(\mathcal{M}_s)$, result in adoption probabilities $\Pr(\mathcal{M}_b)$. The realizations of consumer adoption probabilities, in turn, must be consistent with the merchants' perceptions, $\mathbb{E}\Pr(\mathcal{M}_b)$. In other words, in equilibrium we have consumer and merchant adoption/acceptance probabilities consistent with the expectation of the other side of the market and resulting second-stage usage probabilities, i.e.,

$$\begin{cases} \text{Consumers:} & \mathbb{E}\Pr(\mathcal{M}_s) = \frac{1}{N_s}\sum_{s=1}^{N_s}\Pr(\mathcal{M}_s) \\ \text{Merchants:} & \mathbb{E}\Pr(\mathcal{M}_b) = \Pr(\mathcal{M}_b)\ \forall \mathcal{M}_b, b \\ \text{Usage:} & \Pr\left(m|j,\mathcal{M}_b,\mathcal{M}_s\right) = \Pr\left(m = \arg\min_{m'\in\mathcal{M}_b\cap\mathcal{M}_s} c_{bm'j}(p_{bj})\right). \end{cases} \tag{10}$$

We now move to the discussion of our empirical specification and estimation method.

4 Specification and Estimation

In our model we estimate the parameters of three distributions of cost innovations. The first distribution of cost shocks is $F_\varepsilon(\cdot|\theta^{b2})$, which describes second-stage consumer usage cost innovations. The second set of parameters characterizes the distribution of the first-stage consumer adoption cost innovations, $F_{1b}(\cdot|\theta^{b1})$. Finally, the parameters of the merchant first-stage acceptance cost innovations, $F_{1s}(\cdot|\theta^{s1})$, describe the distribution of the first-stage merchant acceptance cost innovation.

In what follows we will provide estimation results for several alternative specifications of the distributions. In our main specification, we assume that F_ε is type 1 extreme value (T1EV), while F_{1b} and F_{1s} belong to normal distributions. We also experiment with all distributions defined as T1EVs. Finally, for robustness analysis we estimate a specification where all three distributions are assumed to be normal.

4.1 Solution algorithm

We estimate the parameters of the model using maximum simulated likelihood. Our nested fixed-point algorithm computes one equilibrium for a given vector of parameter values $(\theta^{2b}, \theta^{1b}, \theta^{1s})$ characterizing the distributions of cost innovations. It begins with an initial guess for consumer adoption and merchant acceptance probabilities. Given beliefs about average merchant acceptance probabilities, $\mathbb{E}\Pr(\mathcal{M}_s)\ \forall \mathcal{M}_s$, a consumer's expected total second-stage usage cost function can be computed as

$$EC_b(\mathcal{M}_b) = \sum_{j \in \mathcal{J}_b} \left[\sum_{\mathcal{M}_s} E\Pr(\mathcal{M}_s) \times \int \cdots \int \left(\max_{m \in \mathcal{M}_b \cap \mathcal{M}_s} c_{0bm} + c_{1bm} p_{bj} + \varepsilon_{bmj} \right) dF_\varepsilon \right]. \tag{11}$$

For example, if F_ε is T1EV, equation (11) becomes

$$EC_b(\mathcal{M}_b) = -\sum_{j \in \mathcal{J}_b} \left[\sum_{\mathcal{M}_s} \mathbb{E}\Pr(\mathcal{M}_s) \times \log \left(\sum_{m \in \mathcal{M}_b \cap \mathcal{M}_s} \exp(-c_{0bm} - c_{1bm} p_{bj}) \right) \right],$$

which makes it very convenient for numerical optimization.

Parameter values for the first-stage distribution of consumer adoption cost innovations, θ^{b1}, and the vector of $EC_b(\mathcal{M}_b)$ computed above can be used to update type-specific consumer adoption probabilities:

$$\Pr(\mathcal{M}_b) = \int \cdots \int \mathbb{1} \left(EC_b(\mathcal{M}_b) - F_{b\mathcal{M}_b} \leq EC_b(\mathcal{M}_b') - F_{b\mathcal{M}_b'}\ \forall \mathcal{M}_b' \right) dF_{1b}. \tag{12}$$

We update the merchant side of the market by setting beliefs equal to the current iteration values of consumer adoption probabilities, i.e., $E\Pr(\mathcal{M}_b) = \Pr(\mathcal{M}_b)$. Expected usage cost to merchants for a particular transaction in the second stage can be computed as

$$ETC_{bj}(\mathcal{M}_s) = \sum_{\mathcal{M}_b \in \mathcal{M}} \mathbb{E}\Pr(\mathcal{M}_b) \times \Pr\left(c_{bmj}(p_{bj}) \leq c_{bm'j}(p_{bj})\ \forall m' \in \mathcal{M}_b \cap \mathcal{M}_s \right) \times (c_{0sm} + c_{1sm} p_{bj}).$$

Note that, similar to the expected maximum property, we can compute second-stage usage probabilities analytically; i.e., per-transaction expected merchant usage cost is

$$ETC_{bj}(\mathcal{M}_s) = \sum_{\mathcal{M}_b \in \mathcal{M}} \mathbb{E}\Pr(\mathcal{M}_b) \times \frac{\exp(-c_{0bm} - c_{1bm} p_{bj})}{\sum_{m' \in \mathcal{M}_s \cap \mathcal{M}_b} \exp(-c_{0bm} - c_{1bm} p_{bj})} \times (c_{0sm} + c_{1sm} p_{bj}), \tag{13}$$

so the expected total stage 2 cost for merchants is

$$EC_s\left(\mathcal{M}_s\right) = \frac{1}{N_s}\sum_{i=1}^{N_b}\sum_{j\in\mathcal{J}_b} ETC_{bj}(\mathcal{M}_s). \tag{14}$$

Given parameter values for the distribution of first-stage cost innovations, θ^{1s}, we can calculate acceptance probabilities for each merchant as follows:

$$\Pr(\mathcal{M}_s) = \int\cdots\int \mathbb{1}\left(EC_s(\mathcal{M}_s) - F_{s\mathcal{M}_s} \leq EC_s(\mathcal{M}_s') - F_{s\mathcal{M}_s'}\ \forall\mathcal{M}_s'\right) dF_{1s}. \tag{15}$$

Consumer perceptions are updated by setting $\mathbb{E}\Pr(\mathcal{M}_s) = \frac{1}{N}\sum_{s=1}^{N_s}\Pr(\mathcal{M}_s)\ \forall\mathcal{M}_s$. This operation completes one iteration of our solution algorithm. We then return to equation (11) and repeat the iterations until convergence is reached for both adoption and acceptance probabilities.

4.2 Model predictions and observed data

Our model generates three sets of policy functions: (1) optimal usage probabilities in the second stage, (2) optimal consumer first-stage adoption probabilities, and (3) optimal merchant first-stage acceptance probabilities.

In the data, for each consumer we observe a set of transactions with prices as well as the POS payment method decision. We denote these data as $(U_{bj1}, U_{bj2}, U_{bj3})$, such that $U_{bjm} \in \{0,1\}\ \forall m$ and $U_{bj1} + U_{bj2} + U_{bj3} = 1$. We also see the realization of the first-stage consumer adoption decisions. Let these data be denoted with the following vector $\left(A_{b,\{ca\}}, A_{b,\{ca,de\}}, A_{b,\{ca,cr\}}, A_{b,\{ca,de,cr\}}\right)$ per consumer type. Finally, on the merchant side we see first-stage merchant acceptance decisions denoted as $\left(A_{s,\{ca\}}, A_{s,\{ca,de\}}, A_{s,\{ca,cr\}}, A_{s,\{ca,de,cr\}}\right)$ per merchant type.

Using our model predictions and available data on both sides of the market, we construct the following likelihood function for estimation,

$$\begin{aligned}\mathcal{L}(\theta) = &\prod_{b=1}^{N_b}\Pr(\mathcal{M}_b)^{A_{b\mathcal{M}_b}}\times\\ &\prod_{b=1}^{N_b}\times\prod_{j\in\mathcal{J}_b}\prod_{m\in\{ca,de,cr\}}\Pr(c_{bmj} = \min_{m'\in\mathcal{M}_s\cap\mathcal{M}_b} c_{bm'j})^{U_{bjm}}\times\\ &\prod_{s=1}^{N_s}\prod_{\mathcal{M}_s\subset\mathcal{M}}\Pr(\mathcal{M}_s)^{A_{s\mathcal{M}_s}},\end{aligned} \tag{16}$$

where the first line is for consumer adoption probabilities, the second line matches usage decisions, and the third line is for merchants' acceptance decisions.

5 Estimation Results

Table 3 summarizes parameter estimates for five alternative specifications of the model. Our first specification (column (LL) in Table 3) assumes that all cost innovations are independent and identically distributed T1EV deviates. For all other specifications, we assume normally distributed errors for consumers and merchants in both stages, allowing us to estimate variance parameters in all stages. Model NN (1) and NN (2) differ only in that the variance of cash usage is assumed to be 0 in the former. Model NN (3) builds on NN (2) by allowing more flexibility in merchant fixed costs—an intercept is included to better fit merchants with smaller revenues.

Note that our structural model can accommodate consumers and merchants choosing all four potential combinations of payment methods, but we excluded combination $\{ca, cr\}$ from the choice set for both sides of the market. The main reason is that while it is theoretically possible, in practice, consumers who have a credit card also have a debit account. Credit card balances must be paid, and routine use of cash for this purpose appears to be a quite cumbersome process. This is particularly true given that a consumer already approved for a credit card almost certainly would qualify for a debit account. It is conceivable that consumers who report having cash and credit in fact also have a debit account, albeit from a different, possibly non-Canadian bank. On the merchant side, given the cost of processing credit card transactions is strictly higher than the cost for debit cards, it seems unreasonable to combine cash with a more expensive payment instrument such as credit cards while not accepting debit cards. Therefore, in estimation we reclassify consumers and merchants reporting the $\{ca, cr\}$ combination as those adopting/accepting all means of payment, i.e., $\{ca, de, cr\}$.[4]

Results suggest that an average consumer in our sample spends about \$11 a month to have cash and debit in her wallet, relative to holding only cash. Consumers who adopt all means of payment instead receive a relative benefit of about \$48 a month. For merchants, fixed acceptance cost is estimated as a function of size measured in revenue. The presence of negative fixed costs in our results suggests that we are estimating an amalgamation of both costs and benefits. To disentangle the two, we use data from the merchant survey to estimate fixed costs using merchants' self-reported bank fees associated with accepting debit or credit cards as well as payment card terminal rental fees. Table 4 summarizes these data by size of merchant and reports the implied net benefits of acceptance as the difference between self-reported costs and the cost estimates from our model. Benefits from the informed group of consumers increase as a function of merchant size. For example, a large merchant (sales of about \$7.5 million) can receive a net benefit of about \$200,000 per year for accepting all methods of payment. On the other hand, for small merchants having annual sales of \$50,000, accepting all means of payment can generate about \$400 in gross benefits, which leaves about \$200 in net benefits after paying bank fees and terminal rental fees.

[4]An earlier version of this paper conducted estimation by allowing all four combinations of payment instruments for both sides of the market. Estimation results are qualitatively similar and, perhaps more importantly, the results of our counterfactual simulations are virtually unaffected. These estimation results and simulations are available upon request.

Table 3: Estimation results

	LL	NN (1)	NN (2)	NN (3)
buyers				
mean cost: $F_{b,\{ca,de\}}$	-0.17	0.95	3.29	1.08
	(0.22)	(2.56)	(1.89)	(5.11)
mean cost: $F_{b,\{ca,de,cr\}}$	-0.37	-3.70	-0.77	-4.80
	(0.21)	(0.92)	(0.15)	(1.52)
variance of $F_{b,\{ca,de\}}$	1.64	14.08	13.62	4.12
		(18.69)	(11.55)	(5.18)
variance of $F_{b,\{ca,de,cr\}}$		6.37	0.84	3.22
		(2.91)	(0.09)	(1.19)
variance of usage cost, cash	1.64	0.00	0.10	0.31
			(0.02)	(0.03)
variance of usage cost, debit		0.34	0.37	0.78
		(0.02)	(0.02)	(0.03)
variance of usage cost, credit		0.13	0.00	
		(0.02)	(0.02)	
sellers				
$F_{0s,\{ca,de\}}$ (const.)				9.28
				(4.75)
$F_{1s,\{ca,de\}}$ (slope)	1.01	0.21	0.09	-5.95
	(0.06)	(0.07)	(0.06)	(2.36)
$F_{0s,\{ca,de\}}$ (const.)				1.17
				(0.64)
$F_{1s,\{ca,de,cr\}}$ (slope)	-3.77	-5.94	-6.09	-10.16
	(0.03)	(0.09)	(0.10)	(2.53)
variance of $F_{s,\{ca,de\}}$	1.64	2.76	2.76	5.27
		(0.78)	(0.71)	(3.58)
variance of $F_{s,\{ca,de,cr\}}$		14.77	14.33	5.74
		(1.16)	(1.18)	(2.58)
F-value	-12,897.92	-12,525.05	-12,460.51	-12,065.38

Notes: Specification *LL* assumes T1EV deviates in both stages for both sides of the market. Specifications NN (1) through NN (3) report estimation results for normally distributed errors in both stages for both sides of the market. Every next specification relaxes some of the restrictions on the parameter values where specification NN (3) is the richest model. NN(3) assumes two components to the fixed acceptance costs: a component that is constant as a function of the merchant size, $F_{0s,\mathcal{M}_s}$, and a component that is interacted with the merchant size, $F_{1s,\mathcal{M}_s}$.

Table 4: Summary of fixed-cost estimates, self-reported costs, and implied benefits, CAD

size, sales	CA&DE			CA&DE&CR		
	acceptance costs		benefit	acceptance costs		benefit
	reported	estimate		reported	estimate	
50k	171.8	8,495.2	-8,323.4	236.3	-177.2	413.5
175k	315.0	6,522.7	-6,207.8	477.0	-3,544.0	4,021.0
375k	779.7	3,366.7	-2,587.0	1,241.6	-8,930.9	10,172.6
625k	603.8	-578.2	1,182.1	1,387.6	-15,664.6	17,052.1
875k	817.8	-4,523.2	5,341.0	1,631.2	-22,398.2	24,029.4
3,000k	1,256.0	-38,055.4	39,311.4	3,552.3	-79,634.1	83,186.4
7,500k	1,890.4	-109,064.8	110,955.2	2,950.6	-200,839.7	203,790.3

Notes: "Reported" calculates the average fixed cost as measured by the sum of bank fees associated with accepting debit or credit cards and terminal rental costs. Terminal rental costs are assumed to be the same for both "CA&DE" and "CA&DE&CR" bundles. "Estimate" is the net fixed cost implied by the model estimates in Table 3, NN (3). "Benefit" is the implied benefit of acceptance as measured by the difference in reported cost and estimated net cost.

As an indicator of model fit, we predict merchant acceptance as a function of sales (Figure 3) and consumer adoption as a function of total expenditure (Figure 4), and compare with their respective sample estimates. We find that model predictions are generally in line with the data for both adoption and acceptance, with small deviations particularly in merchants with fewer sales and consumers with smaller expenditures.

Figure 3: Model fit for three acceptance combinations, merchants

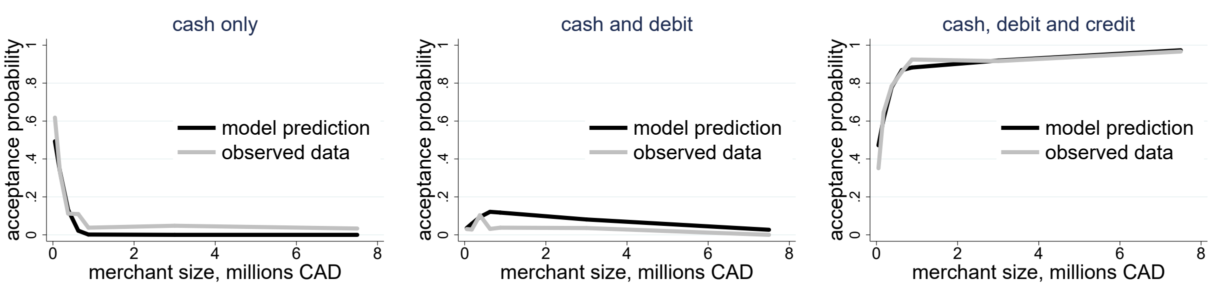
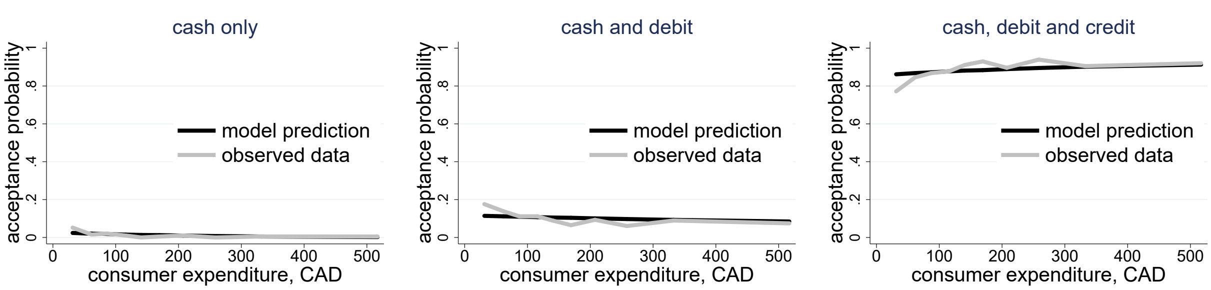


Figure 4: Model fit for three adoption combinations, consumers



6 Elasticities and Network Effects

In this section, we analyze consumer and merchant response to increases in their usage, adoption, and acceptance costs. With our structural model, we can examine how each side reacts to increases in its own cost, as well as increases to costs on the other side of the market. With this we analyze network effects in the two-sided market for payments.

6.1 Usage costs

To identify the key drivers of consumer adoption and merchant acceptance decisions, we calculate local responses to small perturbations in the second-stage usage costs for consumers and merchants.

Table 5 (top three rows) summarizes elasticity of buyer adoption probabilities to usage costs in the second stage. In other words, we compute the following elasticity measure for consumers:

$$\mathcal{E}_{\Pr(\mathcal{M}_b),C_{bm}} \equiv \frac{\partial \mathbb{E}\Pr(\mathcal{M}_b)}{\partial C_{mb,\cdot}} \frac{C_{mb,\cdot}}{\mathbb{E}\Pr(\mathcal{M}_b)} \; \forall m, \mathcal{M}_b.$$

The bottom three rows of Table 5 list measures of merchant responsiveness to increase in consumer usage costs. Our goal is to quantify merchant response to an exogenous change in consumer adoption probabilities. To do this we define our "elasticity-like" measure of sensitivity. Note that consumer adoption probabilities must add up to 1. Therefore, we first compute one-step consumer response to an increase in own-usage costs, i.e., $\frac{\partial \mathbb{E}\Pr(\mathcal{M}_b)}{\partial C_{b,m}}$, and then use this "exogenous variation" to calculate one-step merchant response.[5] In other words, we calculate the following measure of merchant responsiveness to changes in consumer usage cost and subsequent change in consumer adoption probabilities:

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

Results are reported in Table 5 below.

[5]Note that our measure is not identical to a normal price elasticity because the change in usage costs will affect the entire distribution of consumer adoption probabilities. Therefore, merchants respond to the change in the distribution instead of to the change in an isolated adoption probability for a single means of payment.

Table 5: Consumer and merchant response to increased buyer usage costs

	$\partial C_{b,cash}$	$\partial C_{b,debit}$	$\partial C_{b,credit}$
$\partial \mathbb{E}\Pr(\mathcal{M}_b = \{ca\})/\cdots$	-0.690	0.584	0.072
$\partial \mathbb{E}\Pr(\mathcal{M}_b = \{ca, de\})/\cdots$	-0.144	-0.099	0.039
$\partial \mathbb{E}\Pr(\mathcal{M}_b = \{ca, de, cr\})/\cdots$	0.026	0.003	-0.006
$\partial \mathbb{E}\Pr(\mathcal{M}_s = \{ca\})/\cdots$	0.072	0.091	-0.024
$\partial \mathbb{E}\Pr(\mathcal{M}_s = \{ca, de\})/\cdots$	0.542	0.675	-0.182
$\partial \mathbb{E}\Pr(\mathcal{M}_s = \{ca, de, cr\}/\cdots)$	-0.103	-0.129	0.035

Notes: Each element of the matrix illustrates the 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 $\mathcal{E}_{\Pr(\mathcal{M}_s=x),C_{b,m}} \equiv \left[\sum_{y\in\mathcal{M}} \frac{\partial \mathbb{E}\Pr(\mathcal{M}_s=x)}{\partial \mathbb{E}\Pr(\mathcal{M}_b=y)} \times \frac{\partial \mathbb{E}\Pr(\mathcal{M}_b=y)}{\partial C_{b,m}}\right] \times \frac{C_{b,m}}{\mathbb{E}\Pr(\mathcal{M}_s=x)}\ \forall m, \mathcal{M}_s$, where the change in $\Pr(\mathcal{M}_b)$ is induced by an increase in buyer usage costs (see discussion above).

We also conduct a similar exercise to illustrate responsiveness of consumer adoption and merchant acceptance probabilities to changes in the usage cost of sellers. The first three rows in Table 6 summarize own elasticity, calculated as

$$\mathcal{E}_{\Pr(\mathcal{M}_s),C_{sm}} \equiv \frac{\partial \mathbb{E}\Pr(\mathcal{M}_s)}{\partial C_{sm}} \frac{C_{sm}}{\mathbb{E}\Pr(\mathcal{M}_s)}\ \forall m, \mathcal{M}_s,$$

while the bottom three rows report cross-cost elasticity, i.e., consumer short-run response to change in merchant usage cost in the second stage:

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

Table 6: Consumer and merchant response to increased merchant usage costs

	$\partial C_{s,cash}$	$\partial C_{s,debit}$	$\partial C_{s,credit}$
$\partial \mathbb{E}\Pr(\mathcal{M}_s = \{ca\})/\cdots$	-0.266	0.114	0.383
$\partial \mathbb{E}\Pr(\mathcal{M}_s = \{ca, de\})/\cdots$	-0.642	-0.290	2.425
$\partial \mathbb{E}\Pr(\mathcal{M}_s = \{ca, de, cr\}/\cdots)$	0.166	0.018	-0.477
$\partial \mathbb{E}\Pr(\mathcal{M}_b = \{ca\})/\cdots$	-0.107	0.011	0.246
$\partial \mathbb{E}\Pr(\mathcal{M}_b = \{ca, de\})/\cdots$	-0.035	-0.004	0.103
$\partial \mathbb{E}\Pr(\mathcal{M}_b = \{ca, de, cr\})/\cdots$	0.006	0.000	-0.015

Notes: Each element of the matrix illustrates the 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 $\mathcal{E}_{\Pr(\mathcal{M}_b=x),C_{s,m}} \equiv \left[\sum_{y\in\mathcal{M}} \frac{\partial \mathbb{E}\Pr(\mathcal{M}_b=x)}{\partial \mathbb{E}\Pr(\mathcal{M}_s=y)} \times \frac{\partial \mathbb{E}\Pr(\mathcal{M}_s=y)}{\partial C_{s,m}}\right] \times \frac{C_{s,m}}{\mathbb{E}\Pr(\mathcal{M}_b=x)}\ \forall m, \mathcal{M}_b.$, where the change in $\Pr(\mathcal{M}_s)$ is induced by an increase in seller usage costs.

As expected, consumer adoption probabilities and merchant acceptance probabilities are decreasing in own-usage costs (negative elements on the diagonal in the top rows of Table 5 and Table 6). For example, consumer adoption of only cash would decrease by 0.7 percent in response to a 1 percent increase in cash usage cost, i.e., $\mathcal{E}_{\Pr(\mathcal{M}_b=\{ca\}),C_{b,cash}} = -0.7$.

On the other hand, adoption increases by about 0.6 percent for the same increase in the usage cost of debit, i.e., $\mathcal{E}_{\Pr(\mathcal{M}_b=\{ca\}),C_{b,debit}} = 0.6$. Similar analyses can be done for other adoption bundles, although they tend to be of smaller magnitudes. In particular, elasticity of adoption of all methods of payment is smaller relative to other bundles, perhaps reflecting that consumers are already near full adoption and would need a severe cost increase to convince them to get rid of payment cards.

Similar observations can be made for the merchant side of the market. In particular, merchants respond by reducing the probability of cash-only acceptance decisions by 0.3 percent when their own-usage cost of cash increases by 1 percent. Merchants are particularly sensitive to increases in credit card costs; a 1 percent increase in these costs would lead merchants to decrease their acceptance of credit cards by 0.5 percent, increase their acceptance of cash and debit by 2.4 percent, and increase their acceptance of cash only by 0.4 percent.

Finally, as discussed above, the bottom three rows of Table 5 and Table 6 present measures of responsiveness of adoption/acceptance decisions on one side of the market to increases in the usage costs of the other side of the market. We find that merchants tend to be more responsive to consumer cost increases than the reverse, at least with respect to $\{ca, de, cr\}$ and $\{ca, de\}$ bundles. For the cash-only bundle, consumers respond to increases in merchant usage costs more than the reverse, but only for cash and credit costs.

6.2 Adoption and acceptance costs

To illustrate the effects of changes in the fixed adoption or acceptance costs for the first-stage consumer and merchant decisions, we calculate elasticity-like measures for each side of the market. These calculations are analogous to the one conducted for usage costs in the previous section. Results for the change in adoption (buyer side) costs are summarized in Table 7, while results for the change in acceptance (seller side) costs are summarized in Table 8

Table 7: Consumer and merchant response to increases in consumer adoption costs

	$\partial F_{b,\{ca,de\}}$	$\partial F_{b,\{ca,de,cr\}}$
$\partial \Pr(\mathcal{M}_b = \{ca\})/\ldots$	0.199	3.411
$\partial \Pr(\mathcal{M}_b = \{ca, de\})/\ldots$	-0.368	1.528
$\partial \Pr(\mathcal{M}_b = \{ca, de, cr\})/\ldots$	0.040	-0.223
$\partial \Pr(\mathcal{M}_s = \{ca\})/\ldots$	0.011	-0.058
$\partial \Pr(\mathcal{M}_s = \{ca, de\})/\ldots$	0.081	-0.430
$\partial \Pr(\mathcal{M}_s = \{ca, de, cr\})/\ldots$	-0.016	0.082

On the consumer side, as expected, an increase in adoption costs for a bundle decreases the probability of adopting this combination, with the effect being more pronounced for combination $\mathcal{M}_b = \{ca, de\}$ (about 0.4 percent decline) than for combination $\mathcal{M}_b = \{ca, de, cr\}$ (about 0.2 percent decline). The trend is similar for merchants, but with larger magnitudes (3.1 percent decline for $\mathcal{M}_s = \{ca, de\}$ and 1.0 percent decline for $\mathcal{M}_s = \{ca, de, cr\}$).

Table 8: Consumer and merchant response to increases in merchant acceptance costs

	$\partial F_{s,\{ca,de\}}$	$\partial F_{s,\{ca,de,cr\}}$
$\partial \Pr(\mathcal{M}_s = \{ca\})/\ldots$	0.137	0.766
$\partial \Pr(\mathcal{M}_s = \{ca, de\})/\ldots$	-3.052	4.853
$\partial \Pr(\mathcal{M}_s = \{ca, de, cr\})/\ldots$	0.451	-0.956
$\partial \Pr(\mathcal{M}_b = \{ca\})/\ldots$	-0.153	0.288
$\partial \Pr(\mathcal{M}_b = \{ca, de\})/\ldots$	-0.099	0.121
$\partial \Pr(\mathcal{M}_b = \{ca, de, cr\})/\ldots$	0.014	-0.018

Consumers and merchants are also responsive to changes in fixed costs on the other side of the market. For example, merchants would tend to reduce their acceptance of credit cards in response to changes in fixed costs that would increase adoption on the consumer side.

Our results are in line with the findings from experimental payment economics; see Camera et al. (2016) and Arifovic et al. (2017). In an experiment to ascertain the adoption cost of payment methods, Camera et al. (2016) find that buyers are pivotal in the diffusion of electronic payments and that sellers were more responsive than buyers despite having to pay a cost to adopt the electronic payment technology. Arifovic et al. (2017) find the presence of strong network externalities in their two-sided market experiments and that buyer adoption choices are based on beliefs of seller acceptance of the new payment methods and vice-versa.

6.3 Equilibrium usage probabilities

Thus far we have discussed the determinants of consumer adoption and merchant acceptance decisions. A similar analysis can be done for the equilibrium usage probabilities. Figures 5 and 6 illustrate several elasticity-like measures of responsiveness of each side of the market to small increases in the cost structure. Table 9 in Appendix A provides additional details on own- and cross-cost elasticities with respect to key structural parameters in the model.

First, we define $\mathcal{E}^{\text{IM}}_{\Pr(\text{use m}),\theta}$ $m \in \mathcal{M}$ as an immediate response of equilibrium usage probability to change in parameter θ. Note that this measure is defined only for buyer usage costs $C_{b,m}$ $m \in \mathcal{M}$ as neither adoption nor acceptance probabilities change. In other words, the immediate response is a partial derivative of the consumer second-stage usage decisions with respect to own-usage costs. We normalize the derivative by the ratio of usage cost level and current equilibrium usage probability. Let $\overline{PM}_s$ and $\overline{PM}_b$ denote vectors of ex ante (prior to realization of random innovations) acceptance and adoption probabilities, respectively. Let $\Pr(\text{use m}, \overline{PM}_b, \overline{PM}_s)$ denote joint probability of first- and second-stage choices, such that $\overline{PM}_s = \big(PM_{s,\{ca\}}, PM_{s,\{ca,de\}}, PM_{s,\{ca,de,cr\}}\big)$ and $PM_{s,\{ca\}}$ is a shortcut for $\Pr(\mathcal{M}_s = \{ca\})$ and $\overline{PM}_b$ defined similarly. Then, with an abuse of notation, we can describe our measure of an immediate response as follows:

$$\mathcal{E}^{IM}_{\Pr(\text{use m}),\theta^{IM}} = \mathbb{E}_{b,j}\left[\frac{\partial \Pr(\text{use m}, \overline{PM}_b, \overline{PM}_s)}{\partial \theta^{IM}}\right] \times \frac{\theta^{IM}}{\Pr(\text{use m})}, \tag{17}$$
$$\theta^{IM} \in (C_{b,ca}, C_{b,de}, C_{b,cr})\ \forall b.$$

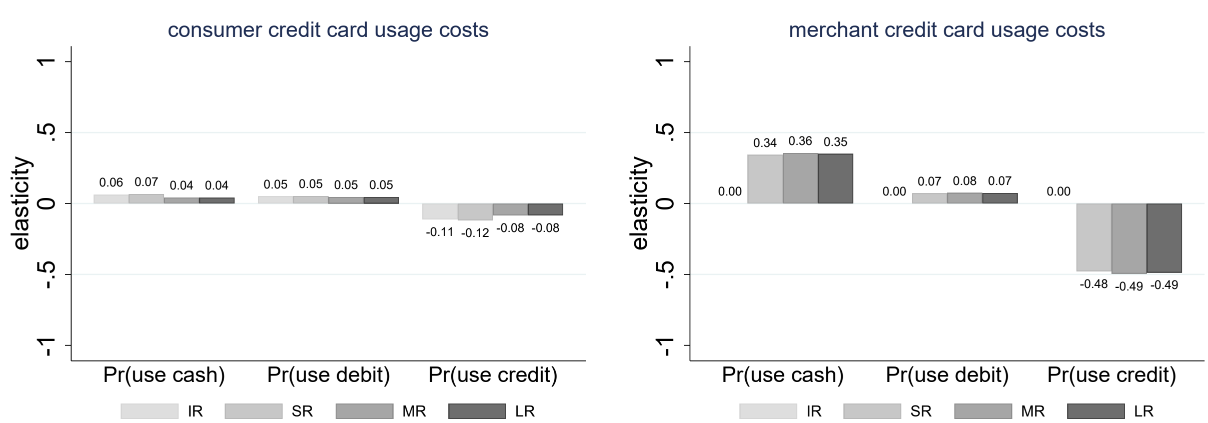
This measure of an immediate response measures adjustments on the intensive margin, as neither buyers nor sellers can adjust their adoption and acceptance decisions. Other elasticity-like measures discussed above allow changes on the extensive margin on one or both sides of the market.

Next we study change in the usage probability in the short run, when only the side whose parameter is perturbed has time to adjust its adoption/acceptance decisions, $\mathcal{E}^{\text{SR}}_{\Pr(\text{use m}),\theta}$ $m \in \mathcal{M}$. For the short-run elasticity with respect to change in buyer adoption costs, we allow only the consumer side to adjust its adoption decisions and keep merchant acceptance choices unchanged. For example, short-run elasticity of cash usage probability with respect to consumer fixed cost of cash and debit is a change in usage probability when only the consumer side adjusts its decisions. From the merchant point of view, consumers will use cash less (more) frequently, but merchants don't have time to adjust their own acceptance decisions. The change in usage probability of cash multiplied by the ratio of fixed cost and current usage probability would then determine the short-run elasticity measure; i.e.,

$$\mathcal{E}^{SR}_{\Pr(\text{use m}),\theta_i} = \mathbb{E}_{b,j}\left[\begin{array}{c}\dfrac{\partial \Pr(\text{use m}, \overline{PM}_b, \overline{PM}_s)}{\partial \theta_i} \\ + \displaystyle\sum_{x\in\mathcal{M}} \dfrac{\partial \Pr(\text{use m}, \overline{PM}_b, \overline{PM}_s)}{\partial PM_{i,x}} \dfrac{\partial PM_{i,x}}{\partial \theta_i}\end{array}\right] \times \frac{\theta_i}{\Pr(\text{use m})}, \tag{18}$$
$$\theta_i \in (F_{i,\{ca,de\}}, F_{i,\{ca,de,cr\}} C_{i,ca}, C_{i,de}, C_{i,cr}),\ i = s, b.$$

The measure of short-run elasticity illustrates the response of one side of the market when both the usage and adoption/acceptance decisions can be adjusted (but only on the side on which cost parameters were increased). This change in policy functions on one side of the market becomes a surprise to the other side of the market.

Figure 5: Response of consumer usage decisions to an increase in own-usage cost of credit cards (left) and merchant usage cost of credit cards (right)



Our medium-run measure of elasticity allows each side of the market to adjust its adoption/acceptance decisions only once. This elasticity is defined as

$$\mathcal{E}^{MR}_{\Pr(\text{use m}),\theta} = \mathbb{E}_{b,j}\left[\begin{array}{c} \dfrac{\partial \Pr(\text{use m}, \overline{PM}_b, \overline{PM}_s)}{\partial \theta} \\ + \displaystyle\sum_{x \in \mathcal{M}} \dfrac{\partial \Pr(\text{use m}, \overline{PM}_b, \overline{PM}_s)}{\partial PM_{b,x}} \dfrac{\partial PM_{b,x}}{\partial \theta} \\ + \displaystyle\sum_{x \in \mathcal{M}} \dfrac{\partial \Pr(\text{use m}, \overline{PM}_b, \overline{PM}_s)}{\partial PM_{s,x}} \dfrac{\partial PM_{s,x}}{\partial \theta} \end{array}\right] \times \frac{\theta}{\Pr(\text{use m})}, \tag{19}$$

$$\theta \in (F_{b,\{ca,de\}}, F_{b,\{ca,de,cr\}}, C_{b,ca}, C_{b,de}, C_{b,cr}, F_{s,\{ca,de\}}, F_{s,\{ca,de,cr\}}, C_{s,ca}, C_{s,de}, C_{s,cr}).$$

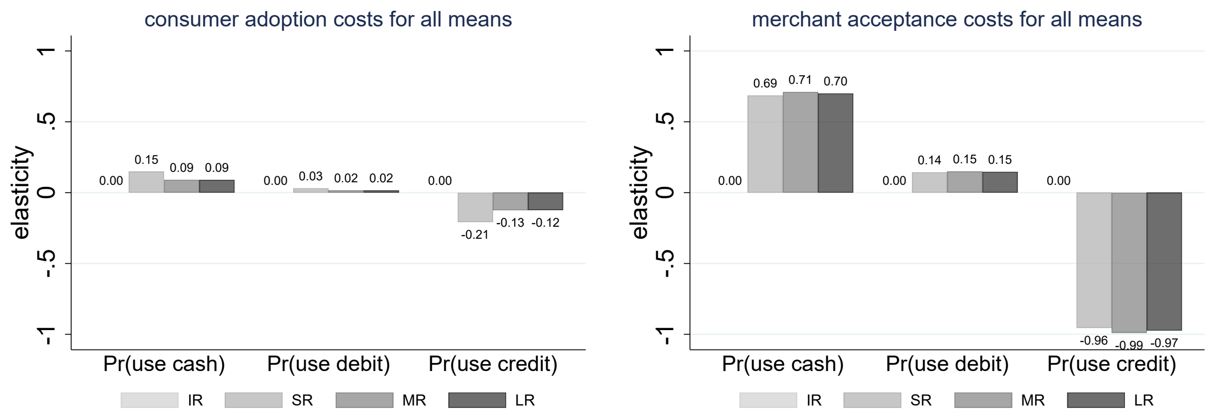
Intuition behind the medium-run measure of responsiveness is in illustrating how long it may take to get to a new equilibrium. Under this scenario each side can adjust its decisions in both stages. However, since this is done only once, the resulting policy adjustment is unlikely to be optimal and would require further adjustments up until a new equilibrium is reached.

Finally, new equilibrium usage probabilities would determine our long-run elasticity measure, which would fully account for the network effects on both sides of the market. Let θ^* be the original parameter value and $\theta^{**} = \theta^* + \epsilon$ for small enough ϵ; i.e.,

$$\mathcal{E}^{LR}_{\Pr(\text{use m}),\theta} = \mathbb{E}_{b,j}\left[\frac{\Pr(\text{use m}, \overline{PM}^{**}_b, \overline{PM}^{**}_s) - \Pr(\text{use m}, \overline{PM}^{*}_b, \overline{PM}^{*}_s)}{\theta^{**} - \theta^*}\right] \times \frac{\theta^*}{\Pr(\text{use m})}. \tag{20}$$

Note that the long-run response can be either larger or smaller depending on the sign of the network effects. By comparing the short- and long-run responses, we can see the direction and magnitude of the network effects between two sides of the market. According to our estimation results, network effects can work in the same or in an opposite direction to the direct effects (immediate and short-run elasticity) and on average accounts for about a 16 percent difference between the short-run and long-run elasticity (see Appendix A). There is a large difference in magnitudes between the network effects. In particular, perturbations in consumer-side parameters result in a much larger network effect, as measured by the difference in the short- and long-run elasticity of usage probability. Network effects coming from the merchant side of the market are usually small and range between 0 and 2 percent.

Figure 6: Response of consumer usage to an increase in own fixed cost of adopting all means of payment (left) and merchant fixed cost of adopting all means of payment (right)



As suggested by the results illustrated in Figures 5 and 6, immediate and short-run responses can be different from the long-run elasticities. This difference emphasizes the importance of having a structural model for making correct equilibrium predictions. Reduced-form models or models using linear approximations to consumer and merchant policy functions (e.g., as a system of simultaneous equations) can be informative about the changes on the intensive margin or in the short run on each side of the market. In order to accurately account for equilibrium effects, however, one needs to account for network externalities by modeling them explicitly.

By comparing the left and right panels in Figure 5 and Figure 6, we find that consumers respond more strongly to changes in merchant costs than their own. This is counterintuitive on the face of it, but is consistent with our knowledge of costs and the underlying model. With credit cards being significantly cheaper to use for consumers than cash and debit, they are very inelastic to credit card cost increases. Since their usage changes very little, their adoption and the resulting reaction from merchants changes little as well, leaving the entire system largely unchanged. On the other hand, credit cards are very expensive for merchants, except for small transactions. Since usage is consumer driven, merchants can react to an increase in usage cost only by reducing their acceptance of credit cards, and they do so significantly at the current level of costs (see Table 8). As a result, consumers have a significantly reduced chance of finding a merchant with credit card machines, and credit card usage is reduced. For a full summary of network effects in the short and long run, see Table 9 in Appendix A.

The analysis of local responses provided above should inform us about the likely short-run changes in the adoption/acceptance decisions by each side of the market and resulting equilibrium usage probabilities. To study the long-run response or responses to large changes in costs, we have to make out-of-sample predictions. This is done in the section that follows.

7 Counterfactual Simulations

In this section, we conduct three counterfactual exercises: First, we vary the usage cost of credit cards; second, we increase the usage cost of cash for consumers and merchants; and third, we simulate ubiquitous adoption and acceptance of payment cards.

7.1 Varying the usage cost of credit cards

The counterfactual simulation in this section has been motivated by the ongoing discussion on merchant card fees. For example, the level of merchant credit card fees in Canada has been subject to voluntary agreed-upon price reductions by the major credit card networks.[6] The theory of Rochet and Tirole (2011) shows how merchants may accept the added cost of cards in order to avoid losing customers, allowing issuers to charge socially inefficient fees. The merchant indifference test (MIT) was designed based on this theoretical framework and was subsequently used in Europe (European Commission 2015) to provide guidance on the fee level that makes merchants indifferent between cards and other methods of payment. Unfortunately, Fung et al. (2018) highlight that the MIT does not account for the feedback effects between merchant and consumer decisions that would occur as a result of changes in the costs of one (or more) sides of the market. The same criticism can be applied to a reduced-form analysis conducted in Rysman (2007) or a simultaneous equations estimation with instrumental variables performed by Carbó-Valverde et al. (2016). These studies do not model consumer and merchant decisions explicitly and can only be informative about local responses by each side of the market to small perturbations in the costs. To compute out-of-sample predictions induced by large changes in the cost structure, or long-run equilibrium effects, one would need to use a structural model analogous to the one presented in the earlier sections of this paper.

In addition to accounting for the equilibrium effects, our model allows us to disentangle direct and network effects of changes in the parameter values. We can apportion changes in the acceptance, adoption and usage probabilities into the extensive margin, when adoption and acceptance decisions can be adjusted, and the intensive margin, when only the usage decision can be changed at the POS.

In our counterfactual analysis, we consider changing merchants' usage cost of credit cards. In particular, we vary the *per-value* cost of credit from 0.0001 to 0.05 (more than twice its true value) and compute market equilibrium for these alternative proportional values of the merchant usage cost. Shy and Wang (2011) discuss why most payment card networks charge proportional fees. Note that a decrease in the merchant usage costs makes credit more attractive as the cost declines.

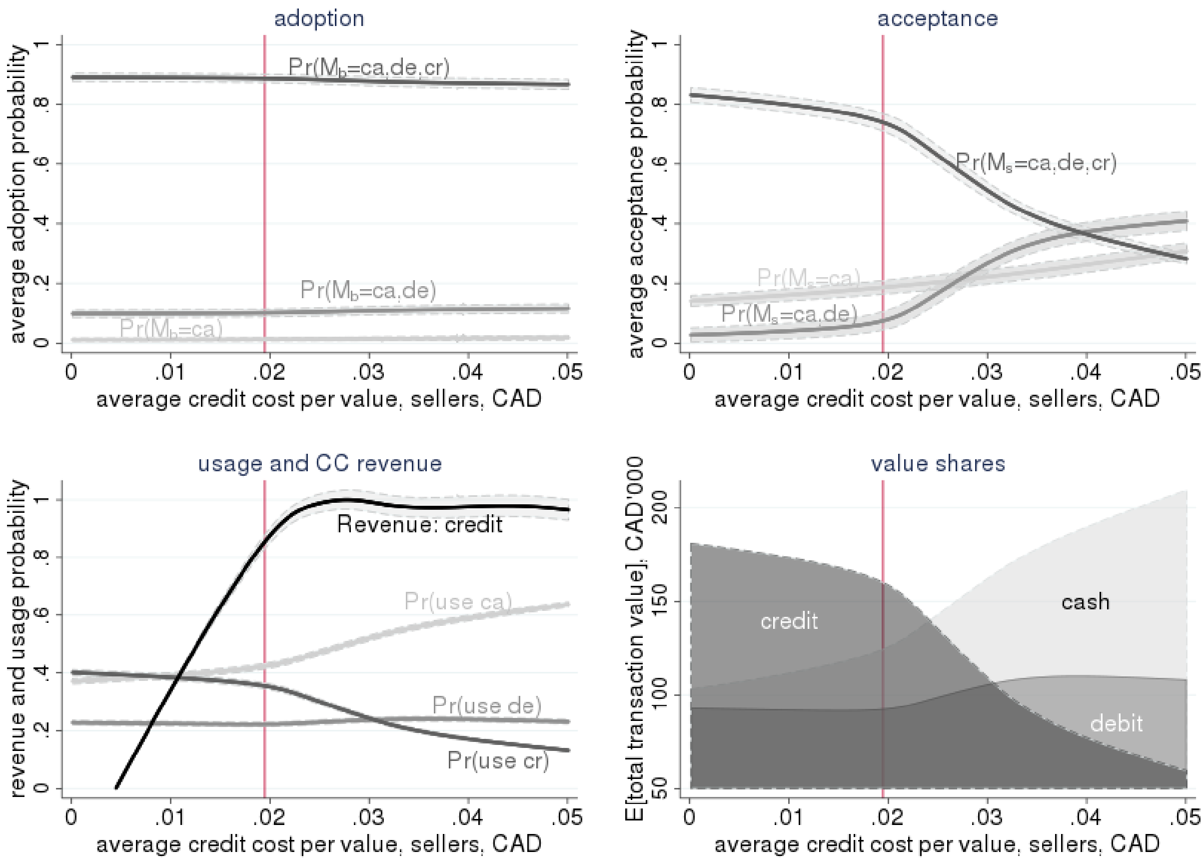
Figure 7 illustrates the sequence of equilibrium adoption and acceptance probabilities, usage probabilities, and expected total transaction values, which can occur for alternative

[6] On November 4, 2014, the Department of Finance announced individual voluntary proposals to reduce their credit card fees to an average effective rate of 1.50 percent for the next five years: `https://www.fin.gc.ca/n14/14-157-eng.asp`.

On August 9, 2018, the Department of Finance announced that VISA and Mastercard were expected to reduce average interchange rates for businesses by up to 15 per cent from their highest levels in 2014: `https://www.fin.gc.ca/n18/18-069-eng.asp`.

values of per-value cost of credit.

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



Notes: The top-left panel describes consumer long-run response to changes in the per-value usage cost of credit for merchants. The top-right panel illustrates changes in the equilibrium merchant acceptance probabilities. The bottom-left panel describes usage probability and expected revenue from the merchant card fee (assuming current value of the merchant card fee is 1.5 percent). The bottom-right panel compares the expected total value of transactions for each means of payment in our sample. Total expected value is a sum of all transaction prices weighted by the corresponding usage probabilities. Gray areas show 95 percent confidence intervals. The red line is at factual equilibrium.

According to the top-left panel of Figure 7, when the per-value merchant usage cost of credit increases, consumers change their adoption decisions very little. This finding appears consistent with adoption cost estimates in Table 3. According to our estimates, adopting cash and debit costs about \$11 per month, while adopting all three means of payment would bring a benefit of about \$48 per month.[7] This, in turn, is consistent with the fact that only 10 percent of consumers choose cash and debit only, while all three means of payment are adopted by about 83 percent of consumers in our sample. To

[7]An important caveat is that our counterfactual simulation keeps the level of adoption costs (benefits) fixed at estimated value. It is conceivable that credit or debit card providers would change their loyalty programs and fees in response to a changing equilibrium. As a result, our simulation is a partial equilibrium scenario, which provides an upper bound on the likely response by each side of the market.

recapitulate: when the cost of payment methods is not too large, consumers may find it optimal to keep the same level of adoption even when a significantly smaller fraction of merchants accept credit.

Since an increase in the per-value cost of credit directly affects merchants' usage costs, it is not surprising to find that merchants respond to this innovation. The top-right panel of Figure 7 illustrates the likely patterns of substitution in merchant acceptance decisions. In particular, the probability of accepting all means of payment declines from 0.73 (factual) to less than half that level (0.36) when the usage cost of credit doubles. Merchants instead move toward accepting either cash only (slight increase from 0.19 to 0.26) or cash and debit (large increase from 0.08 to 0.37).

The bottom-left panel of Figure 7 describes changes in the expected usage probabilities for each means of payment. Not surprisingly, the probability of using credit declines two times from about 0.35 to 0.17. This reduction is almost entirely associated with the increased usage of cash, while there is a very small increase in the usage of debit cards. This can be explained by the relatively high usage cost of debit for consumers.

Another interesting exercise can be done using the bottom-left panel. Assume that the per-value cost of credit for merchants consists of the true costs plus the merchant interchange fee (mif); i.e.,

$$c_{1,s,cr} = \bar{c}_{1,s,cr} + \mathrm{mif},$$

where $c_{1,s,cr}$ is the coefficient on transaction price in equation (6). Further, assuming that the current level of the merchant fees is about 1.5 percent, we can calculate the expected total transaction value for credit cards and apportion it into merchant cost and the revenue for the credit card provider. The black line labeled "Revenue: credit" illustrates the levels of revenue collected by the credit card provider in each of the market equilibria. Interestingly, at the observed equilibrium, the red line, revenue is not maximized. Without knowing the marginal costs of the credit card provider it is hard to tell whether profit is maximized at the current level of the interchange fee. However, we can claim that if the true marginal cost of the credit card provider is sufficiently close to zero, then the profit is not maximized at the observed level of interchange fee. In other words, the payment card networks may be operating at a price below the profit-maximizing level based on the credit card market for small and medium-sized businesses.

Last but not least, we show how the distribution of expected total transaction value across alternative payment methods evolves when we simulate counterfactual equilibria by changing merchant usage cost of credit. This exercise is documented in the bottom-right panel of Figure 7. Relative to the observed equilibrium, a twofold increase in usage cost of credit for merchants would reduce total expected transaction value for credit by about 70 percent. Most of the substitution occurs with cash, increasing the total expected transaction value of cash by 86 percent. Debit card usage also increases by about 12 percent relative to the observed outcome.

7.2 Increasing the usage cost of cash

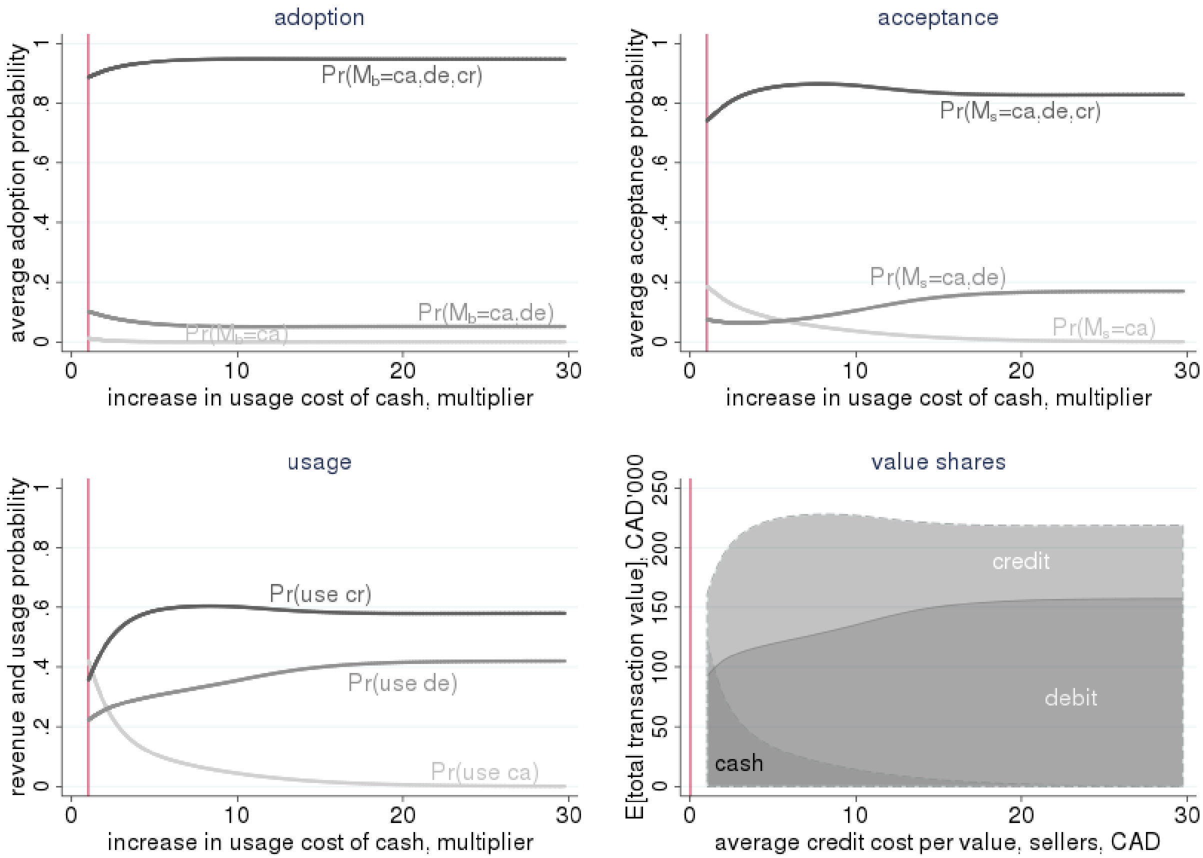
This counterfactual considers how consumers and merchants would behave when the usage cost of cash increases. Our model treats cash as a baseline method of payment that is always adopted by consumers and accepted by merchants. Thus, to conduct this counterfactual we increase the cost of cash so that it becomes costly relative to payment cards, dropping the usage of cash to essentially zero. Specifically, we increase the per-transaction cost of cash for both consumers and merchants and observe their substitution patterns in adoption, acceptance, and usage. This could represent, for example, a decrease in the number of ATMs in a person's neighborhood, increasing the travel costs to obtain cash and so increasing the per-transaction cost of using cash. For merchants, significantly smaller volumes of cash transactions in the economy of scale are likely to result in higher per-transaction usage costs of cash. Equivalent counterfactuals could be produced by decreasing payment card costs rather than increasing cash costs – or some combination of the two.

In Figure 8 we start at the initial state on the left axis, where the per-transaction cost of cash on average is about 12 cents for consumers and 18 cents for merchants. Moving along the x-axis, we increase the per-transaction cost for both sides of the market in multiples from 1 to 30 times the initial level. We find that cash costs need to be increased drastically—around 17 times the initial level—to stop cash from being used. [8]

As consumers decrease their cash usage, they adjust their adoption decisions slightly by never adopting cash only (already a rare occurrence), becoming slightly more likely to adopt all methods of payment (95 percent), and slightly less likely to adopt cash and debit (5 percent). On the merchant side, cash-only merchants tend to become cash and debit only. Acceptance of all three means of payment sees a slight increase and then decrease, leveling off at a point just slightly above the initial state. Finally, as cash becomes very expensive, cash transactions are substituted for both debit and credit card transactions, which end with 42 percent and 58 percent shares, respectively.

[8] We define cash as no longer being used if its equilibrium usage probability falls below 0.01.

Figure 8: Equilibrium response to increase in usage cost of cash



Notes: The top-left panel describes the consumer long-run response to an increase in per-transaction usage cost of cash for both sides. The top-right panel illustrates the response in the equilibrium acceptance probabilities for merchants. The bottom panels describe resulting equilibrium usage probability and total expected value of transactions conducted by each means of payment. The red line shows factual equilibrium.

These counterfactual simulations may seem esoteric for Canada. However, one sign that this evolution has started is the closure of about 5 percent of bank branches in the period 2012-2017.[9] The reduction in physical branches increases the cost of accessing cash, especially in rural areas. The latest statistics from the 2017 MOP survey indicate that the volume of cash transactions at the POS declined from 53 to 32 percent during the period from 2009 to 2017; see Henry et al. (2018). There has been substitution away from cash toward electronic methods of payment such as debit and credit cards. However, there are some cases where these electronic methods of payment are not available due to lack of infrastructure—for example, in remote and sparsely populated areas. As a result, Engert et al. (2018) discuss that if a public authority wanted to ensure 100 percent access to these digital payments, there might be scope in issuing central bank digital currency.

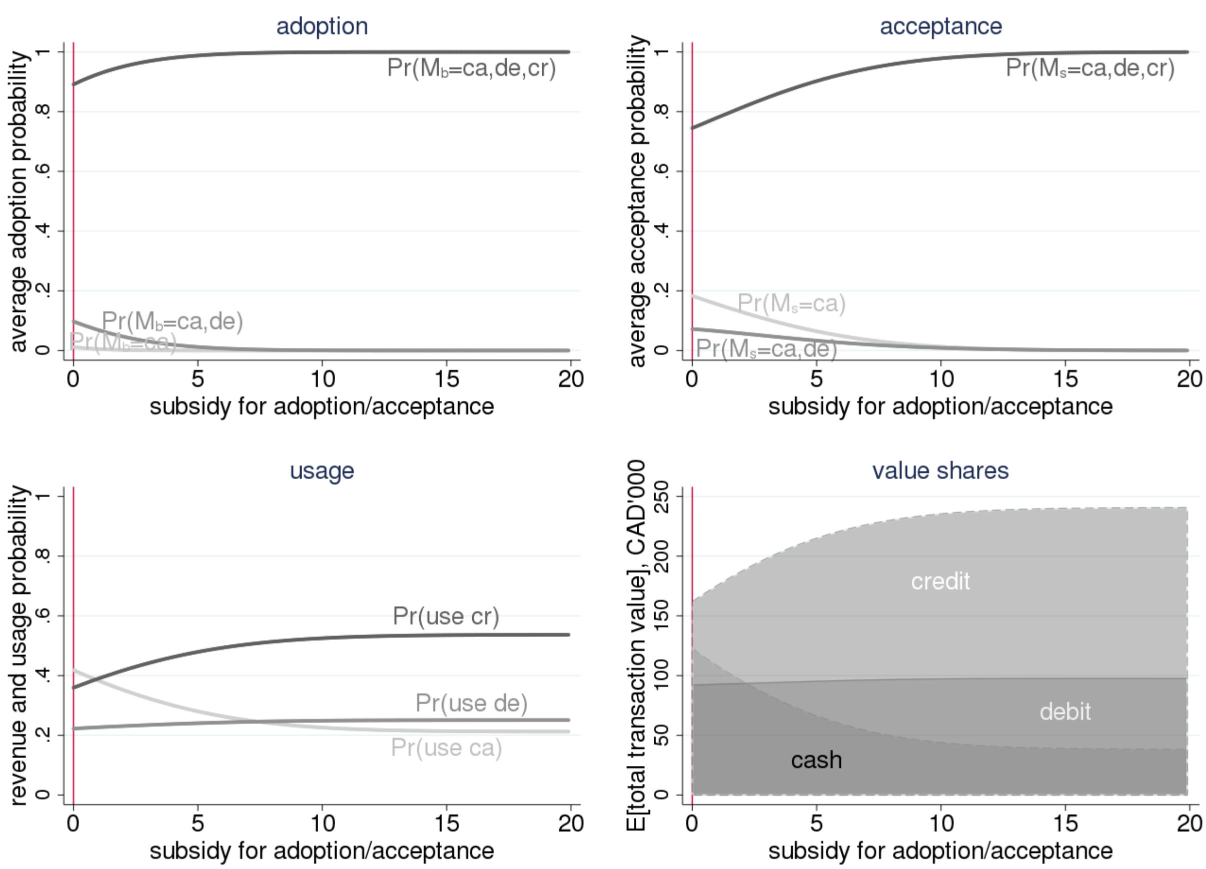
[9]Statistics based on Canadian Bankers Association aggregate banking statistics `https://www.cba.ca/bank-branches-in-canada`.

7.3 Ubiquitous adoption and acceptance of payment cards

In the previous experiment we simulated increasing the cost of cash to reach a "cashless" equilibrium where consumers and merchants stop using the default means of payment, cash. Similar results can be obtained by reducing costs of the substitute means such as debit and/or credit.

While it is possible to drive cash out if its usage costs increase, it is not clear what would be the preference for cash usage in a market where both sides can use any of the three means of payment under the factual usage costs. To identify the preference for cash usage, we simulate a policy experiment where adoption and acceptance decisions of both consumers and merchants are subsidized. In particular, we calculate a sequence of equilibria in which we gradually reduce the adoption and acceptance costs of consumers and merchants by effectively subsidizing the first-stage choices of all three means of payment. The results of the simulation are reported in Figure 9.

Figure 9: Equilibrium response to subsidized adoption/acceptance of all means



Notes: The top-left panel describes the consumer long-run response to a subsidy to adoption cost for all means of payment. The top-right panel illustrates the response in the equilibrium acceptance probabilities for merchants. The bottom panels describe the resulting equilibrium usage probability and total expected value of transactions conducted by each means of payment. The red line shows factual equilibrium.

The key takeaway from the simulation exercise is that cash usage can be reduced considerably if consumers can freely choose out of the three means of payment in the second stage. However, even when both sides of the market can use any of the payment methods, cash may not disappear. In particular, with full acceptance and adoption of all means of payment, the usage of cash levels off at about 20 percent. This result illustrates that cash provides characteristics such as privacy or finality that may be valued by consumers and/or merchants; see Kahn et al. (2005).

8 Conclusions

We developed and estimated a structural equilibrium model of interactions between consumers and merchants in a two-sided market for payment methods. Our estimates suggest that consumers who adopt cash and debit incur a cost of \$11 per month, while consumers who have all three means of payment in their wallets would instead enjoy about \$48 per month in benefits. The difference in results could be due to the cost of withdrawing cash or debit card or account fees while most credit cards may offer rewards. On the merchant side, we find that accepting all methods of payment can generate up to 3 percent of additional revenue by attracting additional customers.

In terms of elasticities, consumers and merchants reduce their adoption and acceptance probabilities for the payment methods when usage costs increase. Consumers are most elastic to the usage cost of cash and least elastic to credit cards, whereas merchants are most elastic to credit, followed by cash and debit. Both merchant and consumer elasticities of acceptance/adoption probability with respect to increases in the usage cost on the other side of the market are lower than 1 in absolute value. On balance, the merchant response to an increase in consumer usage costs appears larger than the consumer response to an increase in the merchant usage costs. In terms of the fixed cost of adoption, we find that the highest own-cost elasticity is related to the combination of cash and debit (-0.4) followed by cash, debit and credit (-0.2). On the merchant side, the results are much larger: -3.1 for cash and debit, and -1.0 for full acceptance.

An analysis of the equilibrium usage probabilities suggests that the network effects originating on the consumer side of the market are stronger than those coming from the merchant side. In other words, the best way to affect equilibrium usage probabilities is to design policies directed toward the consumer side.

Finally, we conduct three counterfactual policies in which we encourage the usage of credits cards while discouraging cash: one, we decrease the per-value transaction cost of using credit cards; two, we increase the usage cost of cash for consumers and merchants; and three, we subsidize consumers and merchants to encourage the ubiquitous adoption and acceptance of payment cards. In all cases, results indicate that these scenarios may not lead to a cashless society in the foreseeable future. Therefore, one must focus on other attributes of payments, such as privacy or finality, to understand the persistent usage of cash vis-à-vis payment cards.

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A Elasticity of usage decisions with respect to structural parameters

Table 9: Elasticity of usage decisions with respect to structural parameters

measure	fixed adoption/acceptance costs				usage costs					
	buyers		sellers		buyers			sellers		
	$F_{b,\{ca,de\}}$	$F_{b,\{ca,de,cr\}}$	$F_{s,\{ca,de\}}$	$F_{s,\{ca,de,cr\}}$	$C_{b,ca}$	$C_{b,de}$	$C_{b,cr}$	$C_{s,ca}$	$C_{s,de}$	$C_{s,cr}$
$\mathcal{E}^{\text{IM}}_{\text{Pr(use ca)},\cdots}$					-0.41	0.17	0.06			
$\mathcal{E}^{\text{IM}}_{\text{Pr(use de)},\cdots}$					0.18	-0.79	0.05			
$\mathcal{E}^{\text{IM}}_{\text{Pr(use cr)},\cdots}$					0.39	0.31	-0.11			
$\mathcal{E}^{\text{SR}}_{\text{Pr(use ca)},\cdots}$	-0.02	0.15	-0.25	0.69	-0.43	0.18	0.07	-0.14	0.01	0.34
$\mathcal{E}^{\text{SR}}_{\text{Pr(use de)},\cdots}$	-0.02	0.03	-0.21	0.14	0.18	-0.80	0.05	0.01	-0.04	0.07
$\mathcal{E}^{\text{SR}}_{\text{Pr(use cr)},\cdots}$	0.04	-0.21	0.45	-0.96	0.42	0.32	-0.12	0.17	0.02	-0.48
$\mathcal{E}^{\text{MR}}_{\text{Pr(use ca)},\cdots}$	-0.01	0.09	-0.26	0.71	-0.36	0.27	0.04	-0.14	0.01	0.36
$\mathcal{E}^{\text{MR}}_{\text{Pr(use de)},\cdots}$	-0.01	0.02	-0.22	0.15	0.20	-0.78	0.05	0.01	-0.04	0.08
$\mathcal{E}^{\text{MR}}_{\text{Pr(use cr)},\cdots}$	0.02	-0.13	0.47	-0.99	0.32	0.19	-0.08	0.17	0.02	-0.49
$\mathcal{E}^{\text{LR}}_{\text{Pr(use ca)},\cdots}$	-0.01	0.09	-0.25	0.70	-0.36	0.27	0.04	-0.14	0.01	0.35
$\mathcal{E}^{\text{LR}}_{\text{Pr(use de)},\cdots}$	-0.01	0.02	-0.21	0.15	0.20	-0.78	0.05	0.01	-0.04	0.07
$\mathcal{E}^{\text{LR}}_{\text{Pr(use cr)},\cdots}$	0.02	-0.12	0.46	-0.97	0.32	0.19	-0.08	0.17	0.02	-0.49
	52%	-40%	-2%	2%	17%	52%	-37%	-2%	0%	2%
network effect	16%	-48%	-1%	2%	11%	3%	-12%	-2%	-1%	2%
	-41%	40%	2%	-2%	-25%	-42%	30%	2%	1%	-2%

Notes: network effect is calculated as percentage difference between short-run elasticity measure and its long-run value, i.e., $(\mathcal{E}^{\text{LR}}_{\text{Pr(use m)},\cdots} - \mathcal{E}^{\text{SR}}_{\text{Pr(use m)},\cdots})/|\mathcal{E}^{\text{SR}}_{\text{Pr(use m)},\cdots}|$. Network effect may either amplify the direct effect or make it weaker depending on the signs of these effects.