Merchant Payment Steering: Evidence from the 2009 Bank of Canada Methods of Payment Survey

by:

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Abstract

Many retailers in Canada have noted the increasing burden of transaction costs, in particular the interchange fees due for every credit card transaction that they process. After the Competition Tribunal rejected in 2012 an application that might have granted retailers the right to surcharge credit cards, retailers may look for other solutions to avoid these fees. Discounting cash or debit card transactions has often been suggested as one solution since discounts are currently allowed in Canada.

The model of merchant cost incorporates the consumers' choice based on the pecuniary and non-pecuniary benefits of using cash, debit and credit cards. I estimate the choice model using data from the Bank of Canada's 2009 Methods of Payment Survey. The 2006 Merchant Survey provides data on the merchant cost.

The results suggest that discounts cost more than the retailer saves by encouraging consumers to switch to lower-cost payment methods. This finding may explain why discounts are not frequently observed among Canadian retailers. I discuss non-pecuniary steering as an alternative to discounts. Non-pecuniary steering could be used by merchants to exercise third degree discrimination based on payment choice, while discounts only allow second degree discrimination.

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1 Introduction

Many retailers in Canada have pointed out the increasing burden of transaction costs, in particular the interchange fees due for every credit card transaction that they process. In 2012, Canadian consumers made over 3 billion credit card payments for a total value of $326 billion.[1] Merchants remit about 1.5 per cent of the transaction value in credit card interchange fees, or $5 billion in 2012.[2] Interchange fees were also equal to about 0.5 per cent of nominal household demand in Canada, which, according to Statistic Canada, was $987 billion.

Retail prices incorporate the interchange fees charged to a merchant who accepts credit cards. If the decision to accept credit cards causes posted prices to increase, all consumers will pay the marked-up price. Since many credit card users enjoy the benefits of rewards programs as well as an interest-free grace period, they are compensated for some of the price increase while cash and debit card users cross-subsidize credit card users. Schuh et al. [2010] estimate that a (high income) credit card household in the US receives annually about US$750 in incentives while each (low income) household without a credit card pays US$21 due to this cross-subsidization. Rewards cards typically also have higher interchange fees than standard products. Instead of posting the marked-up price, merchants may want to recover the cost of accepting credit cards from the credit card owners, by charging different prices based on the payment method used for the purchase.

After the Competition Tribunal's rejection of an application that may have granted retailers the right to surcharge credit cards, retailers need to now look for other ways to price discriminate.[3] Discounting cash or debit card transactions has often been proposed as a solution. However, most Canadian retailers do not offer such discounts, suggesting that they do not

[1] Statistics from the Canadian Banker's Association (CBA), http://www.cba.ca/contents/files/statistics/stat_cc_db038_en.pdf

[2] Interchange fees range between 1 and 2.65 per cent of the transaction value. Visa interchange fees: http://www.visa.ca/en/aboutcan/mediacentre/interchange/pdf/visa-interchange-rates-current.pdf, MasterCard Interchange fees: http://www.mastercard.com/ca/wce/PDF/MasterCard_Canada_Interchange_Rate_Programs.pdf

[3] Competition Tribunal [2013]. In the US, a settlement was reached in 2011 and surcharges are now permitted under certain circumstances. See http://www.justice.gov/atr/cases/f262800/262875.htm

consider them profit enhancing. Briglevics and Shy [2012] show that US merchants would experience higher costs if they offered discounts. This motivates the question of whether a similar conclusion holds for the Canadian market. The answer obtained in this paper is affirmative; ad-valorem discounts are not effective in reducing the transaction costs of Canadian retailers.

Discounting in Canada does not permit third degree price discrimination. Retailers cannot reveal the discount only to consumers who present a credit card as, according to the Code of Conduct [2014], discounts must be clearly marked at the point of sale. The cost incurred through the discount will then be higher than the decrease in credit card fees. The implication is that discounts are effective neither in reducing the cross-subsidization from cash and debit to credit card users nor in decreasing the merchants' cost of accepting payments. The discounts permitted by the Code of Conduct are therefore too narrow to have a significant impact on Canadian credit card usage.

While this paper builds on closely-related ideas presented by Briglevics and Shy [2012] several important extensions are considered. Briglevics and Shy's model has a highly stylized demand side where a representative consumer is perfectly elastic to the discounts offered by the merchant. The relevant extension presented here is that consumers are heterogeneous and their response to the discount varies with its monetary value. This generalization allows me to identify the consumers who benefit from discounts and rewards. Moreover, I add the insight that discounts and surcharges are not equivalent because they constitute different degrees of price discrimination. While discounts can be used for second degree price discrimination, surcharges are a form of third degree price discrimination. My work also applies to the Canadian payments industry and therefore complements Briglevics and Shy's analysis of US data.

Another important contribution is the consideration of non-pecuniary incentives. Although surcharges are not available to Canadian merchants, non-pecuniary incentives could be used to exercise third degree price discrimination between credit card users and other consumers. Specifically, by decreasing the utility that a consumer derives from the convenience

of credit card usage, retailers may be able to steer consumers away from credit cards.

The Introduction first describes in brief the most important retail payment methods in Canada, then lays out the regulatory framework which allows the discounting, but not the surcharging, of certain payment instruments. For a more formal and detailed description the reader is referred to the Red Book published by the Committee on Payment and Settlement Systems [2011]. The existing literature is presented in Section 2, with a focus on how consumer payment choice is influenced by pecuniary and non-pecuniary incentives. The data sources and sample construction are presented in Section 3 of the paper. Section 4 deals with the model, including the merchants' objective function and the consumers' choice model. The output of the estimation and the solution of the optimization problem are listed in Section 5. The last two sections discuss the results and draw conclusions. Detailed accounts of the data-cleaning procedure and some calculus can be found in the appendices.

1.1 Methods of Payments in Canada

Most retail transactions in Canada are settled in cash, with debit cards or with credit cards.[4] Throughout this paper, I will use the abbreviation MOP for "method" or "mean of payment". Each of the three MOPs, cash, debit cards and credit cards, has unique features which the other two do not share.

Cash payments are settled in banknotes issued by the Bank of Canada and coins issued by the Royal Canadian Mint. Retailers in Canada almost universally accept cash. Other advantages of cash include the ability to control spending and the anonymity of the payment process. On the other hand, once lost or stolen, cash cannot be conveniently recovered and if a consumer or retailer accepts counterfeit currency they cannot exchanged it for legal tender. Over time, it may lose value to inflation. Also, paying with cash requires planning for withdrawals and keeping a sufficient amount on hand. Merchants can process cash transactions without a payment processor, but they also need to set aside time and labour for back-office

[4]The use of paper cheques at the POS has significantly declined over the last decades.

processing as well as to pay fees for obtaining and depositing banknotes or coins.

Almost all Canadians have adopted debit cards as part of their regular banking services while access to credit cards may depend on the consumer's credit rating.[5] For card payments, including debit and credit cards, merchants have to use a third party to process the transactions. The card owners therefore reveal part of their identity for authorization at the point of sale.

Debit cards give direct access to the funds in a bank account and provide some control over spending, since the transaction can only be settled if sufficient funds are available in the payer's account. If the personal identification number, or PIN, for the card stays protected, unauthorized use is not possible, although there is less fraud protection once the transaction has been processed. In addition to their payment functionality, debit cards are ATM[6] cards and can used to obtain cash at the point of sale ("cash back"). Debit card payments in Canada are generally final and chargebacks do not occur, which is an advantage for the merchant, but puts more risk on the consumer. On the one hand, daily spending limits protect against fraud and overspending, though on the other hand they make debit cards less convenient for very large transactions.

Credit cards offer the consumer access to short-term credit and often come with attractive rewards features. Fraudulent transactions on credit cards are covered by "zero-liability" policies, ensuring that credit card owners cannot be held liable for the associated losses. In addition, a card owner may detect the suspicious transaction on the statement and can challenge the charge before the statement is due, though the merchant may experience chargebacks for fraudulent or suspicious transactions. The amount that can be charged to a credit card often exceeds the typical daily limits for debit cards,[7] making them a popular choice for large value transactions. Credit cards can also be used for cash withdrawals ("cash advance"), although interest is charged.

[5] Lott [2005] discusses how banks use credit reports in the application process for credit cards. According to Buckland and Simpson [2009], 3 per cent of Canadian consumers were refused a credit card in 2005. The Code of Conduct [2014] requires a minimum household income to qualify for a premium ("high-spend") credit card.

[6] ATM stands for Automatic Teller Machine.

[7] Arango and Welte [2012] report that credit card limits above or equal to $10,000 are available to 42 per cent of credit card owners.

1.2 The Credit Card Industry

Before giving a brief overview of the credit card industry in Canada, let us recall how a standard electronic credit card transaction is settled. The networks of Visa and MasterCard fall under the four-party model (as opposed to the three-party model followed by, for example, American Express). The four parties in this model are the *cardholder*, the *merchant*, the *issuer* of the cardholder's credit card (most often a Canadian bank) and the *payment processor* or *acquirer*. A fifth participant is the *network provider*: Visa and MasterCard provide authorization, clearing and settlement services for the transactions performed with credit cards of their brand.[8]

When a cardholder wants to use her[9] credit card, she presents this card to the merchant. If the merchant accepts her credit card brand, he will accept her card and send the credit card information to the payment acquirer or processor who then contacts her issuing bank for authorization. Conditional on successful authorization, the merchant can charge the amount to the credit card and provide the good or service to the cardholder. The issuer then pays the payment processor for her purchase and the processor, after receipt of the funds, makes a transfer to the merchant. When the credit card statement is due, the cardholder then either pays the full value of the purchase to the issuing bank or revolves on her credit card account. In the latter case, interest is due on the outstanding balance. A number of fees are transferred between the parties involved in the transaction in addition to the purchase value, including:

1. **Interchange fee**: Portion of the transaction value, which is transferred to the card issuer. The Interchange fee is set by the credit card network and remitted by the acquirer to the issuer.

2. **Merchant discount fee**: Portion of the transaction value which the merchant pays to the acquirer (processor) to cover the cost of the transaction, including the interchange fee.

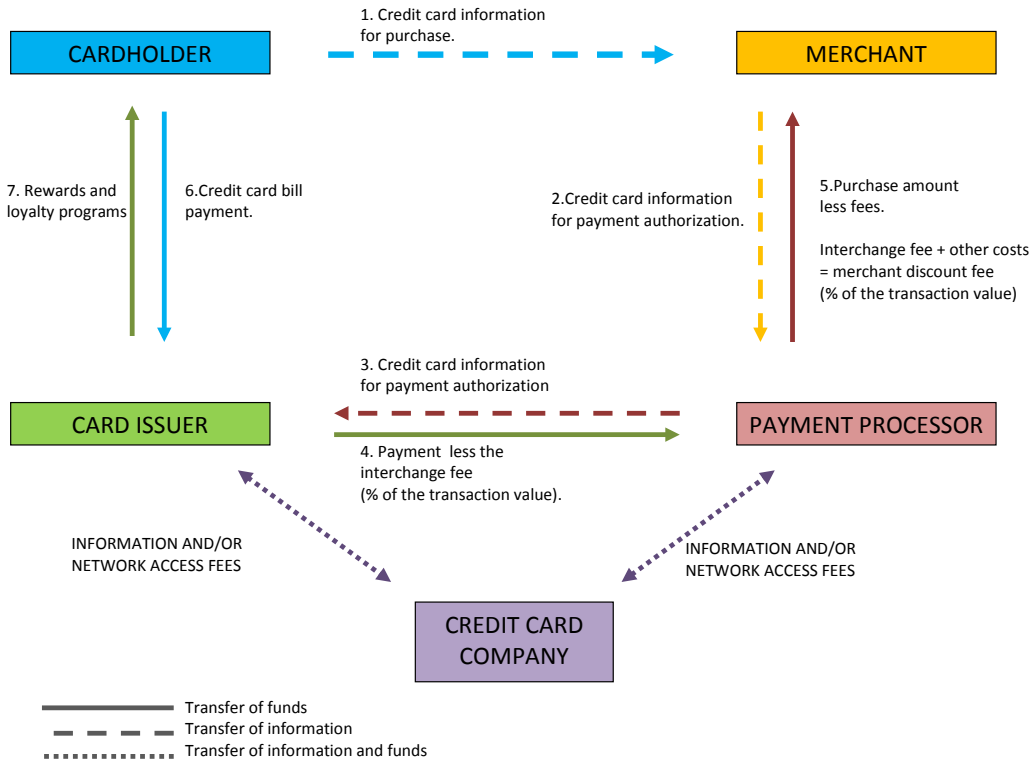
[8] In the three-party model, American Express assumes in addition to these services the role of the card issuer.
[9] Throughout, the cardholder is female and the merchant is male. This assignment is completely arbitrary.

3. **Network access fee**: Portion of the transaction value which the issuer or acquirer pays to the credit card company.

4. **Credit card rewards**: Portion of the transaction amount which the cardholder may receive as part of a loyalty program.

5. **Interest charges**: Portion of the transaction amount which the cardholder must pay if she does not pay her statement in full.

Figure 1: The Four-Party Credit Card Model



Source: Adapted from a chart in Bulmer [2009].

Visa and MasterCard dominate the credit card market in Canada. According to Bulmer [2009], their networks accounted for 64 per cent and 39 per cent of the value of all credit transactions in 2006, respectively. The remaining 6 per cent are mostly allocated to American Express and then to other card brands such as Discover or Diner's Club. The distribution of the number of credit card transactions for that year is similar, with Visa and MasterCard jointly providing 92 per cent of the transaction volume.

Historically, Canadian banks have been major players in the four-party structure, where they act as the issuers of Visa and MasterCard credit cards and as payment processors. Prior to 2008, the Visa and MasterCard networks were effectively owned by Canadian banks and the "no dual governance" policy stipulated that an issuing bank could not provide both Visa and MasterCard credit cards to its customers. A similar rule existed for payment processing services.

When Visa and MasterCard became publicly-held corporations in 2008, the Commissioner of Competition announced in a public letter [Scott, 2008] that a bank would no longer face legal action under the Competition Act if it issued or acquired the transactions of both credit card brands. The changes to the governance structure of Visa and MasterCard implied that the major acquirers and issuers had ceased to be the principal decision makers for the credit card networks. Therefore, a member or a group of members of one card association would not be able to have a negative impact on competition with the other association through dual governance. The commissioner also noted that Canadian consumers would likely benefit from increased choice if banks could issue both cards. The reasoning behind these policies was that competition would be reduced if a bank or acquirer were affiliated with both card associations, and the Canadian Competition Bureau was tasked with enforcement of the non-duality. Of the five biggest banks in Canada[10], four had issued only Visa credit cards and one, the Bank of Montreal, had provided MasterCard branded cards. MasterCard credit cards were also offered by smaller issuers and many credit unions. This historical fact explains the larger market

[10]These are: Royal Bank of Canada (RBC), Toronto Dominion Bank (TD), Bank of Nova Scotia (Scotiabank), Bank of Montreal (BMO), and Canadian Imperial Bank of Commerce (CIBC).

share of Visa, since Canadians often use a credit card issued by their main financial institution. Following the Competition Bureau's decision, two banks, namely RBC and CIBC, started to issue both brands. Similarly, Scotiabank now issues American Express credit cards.

For the consumer, the Visa and MasterCard brands offer similar benefits in terms of acceptance and choice among different cards, but merchants notice some differences. For example, the basic card acceptance fees are lower for MasterCard than for Visa, but MasterCard makes it harder to gauge the interchange fees when the card is presented. The reason is that interchange fees may depend on the specific type of card that the consumer holds. For example, premium cards, which offer very high rewards to the consumer, are costlier for the merchant than standard products. Visa branded cards usually have logos that distinguish the card types, while this is not the case for all MasterCard cards where standard and premium products may have the same look. According to information provided by the Canadian Federation of Independent Businesses (CFIB) on their website[11], MasterCard is currently working on re-branding its products to address this issue.

In addition to the changes in the issuing business, processing operations have also undergone some restructuring. Until 2000, a merchant would process all his credit card payments through a bank, likely the one where he had his business account. Since then many financial institutions have outsourced the processing of payments to third parties. As an example, the payment processor Moneris is a joint investment of RBC and BMO, while CIBC and Scotiabank have sold their processing operations. TD still offers merchant services, as does the Desjardins group, a large association of credit unions.

1.3 Debit Card Networks

Most debit cards in Canada are issued by Canadian banks as part of a chequing account package. Debit cards can be used for electronic funds transfers and to withdraw cash from an ATM. Both types of transactions occur through networks which the card issuer is affiliated

[11] http://www.cfib-fcei.ca/cfib-documents/DIN0798.pdf, retrieved on March 18, 2014.

with, including the card issuer's own network and shared networks. The Interac network is the dominant[12] shared debit card network in Canada; it processes over 4 billion debit card transaction annually for a total value of nearly $200 billion.[13] Cardholders are charged by the issuer for using the networks, with generally lower or no fees when the card issuer's network is used. The Interac Association has been operating under a consent order since 1996 which stipulates that it must operate on a cost-recovery basis. The Interac Association collects, based on its calculated operating cost, so-called switch fees from both the card issuer and the payment acquirer. The acquirer then usually charges a flat fee to the merchant for each Interac transaction.

In recent years, Visa and MasterCard have rolled out debit card products which do not fall under the consent order. Merchants typically pay an ad-valorem fee to their acquirers for these debit cards transactions.

1.4 Merchant Rules and Code of Conduct in Canada

The credit card companies impose several rules on merchants who want to accept transactions through their network.

a Non-discrimination: the merchant treats all customers the same, regardless of which credit card they present.

b Honour all cards: the merchant accepts all credit cards from a specific network, including premium rewards cards with higher card acceptance fees

c No surcharge: the merchant never adds a fee for a credit card transaction.

d No steering: the merchant does not encourage (”steer”) consumers to use another, cheaper payment method when presented with a credit card.

[12] In 2010, the Competition Bureau confirmed that Interac held a dominant position in the market and that the non-profit model was still appropriate (http://www.competitionbureau.gc.ca/eic/site/cb-bc.nsf/eng/03198.html). Statistics on market share of Interac in the Canadian debit card market are unavailable.

[13] Statistics retrieved from Interac's website: http://interac.ca/en/total-transactions on April 30, 2014.

These merchant rules are the subject of debate amongst regulators, industry stakeholder and the research community.

A complaint against Visa and MasterCard brought forward to the Canadian Competition Tribunal by the Competition Bureau and other recent legislative efforts highlight the relevance of this debate for Canada. In Canada, the Competition Bureau is an agency tasked with the administration and enforcement of federal law governing business conduct. Jurisdiction in these matters lies with the Competition Tribunal, a specialized court within the judicial system of Canada. In 2013, the Competition Tribunal dismissed an application intended to change the merchant rules and recommended regulation of the credit card industry instead.[14]

Specifically, the application filed by the Commissioner of Competition [2010] had argued that the rules impede and restrain competition in the credit card industry and that the level of interchange fees is supracompetitive, meaning that the fees are higher than they would be in a more competitive environment. The allegation was that imposing the rules constitutes resale price maintenance. Surcharging credit cards would steer consumers away from credit card payments towards other MOPs the merchant accepts (cash or debit cards in most cases), by providing a financial incentive to consumers. These financial incentives are intended to coordinate consumer payment choice with merchants' preferences similar to how credit card reward programs align consumer behaviour with the interest of the card networks and issuers.

The last rule above ("No steering") is now obsolete since Visa and MasterCard have signed the Code of Conduct for the credit card and debit card industry in Canada (See Code of Conduct [2014].). The code allows the merchant to offer a discount to consumers and thus steer them towards the discounted MOP, away from credit cards (and any other MOP). Surcharging is not permitted by the code. However, the discount must be clearly advertised at the point-of-sale and thus is granted to all consumers, as opposed to only those who present a credit card.

[14] See Competition Tribunal [2013] for the reasons to dismiss the case.

The purpose of the code is to ensure that merchants are aware of the costs associated with accepting payment cards and to give them flexibility in choosing the lowest cost payment option and which payment cards to accept. For example, an acquirer cannot force a merchant to bundle debit card and credit card services, or Visa and MasterCard services, or any combination thereof. The code also sets out minimum notification periods for fee changes or the addition of new products.

The Code of Conduct had already been signed by the credit card networks before the Commissioner of Competition filed the application to change the rules. As a reaction, Visa and MasterCard cited discounts several times in favour of maintaining the remaining merchant rules and argue that discounts are "arithmetically" equivalent to surcharges, see Elzinga [2012]. The Bureau argued that discounts are not as effective as surcharges, see Winter [2012], and that this equivalence assumes an unrealistic frictionless environment. In their closing statement, the Competition Tribunal [2013] appear to side with the Commissioners as they are not convinced that discounts are an effective or practical means towards a merchant's goal to influence transaction costs. The closing statement also states clearly that the raised concerns about the credit card industry are serious and should be addressed in a regulatory (though not judicial) framework.

The tribunal found that the rules do not constitute resale price maintenance and rejected the application, however. Following the tribunal's decision, a recently introduced Senate bill (S-202 [2013]) to cap interchange fees underlines the call for a regulatory solution. These developments confirm that the matter of discounts and surcharges remains largely unresolved and that careful research and policy analysis is needed before, if at all, the regulation of the payment industry in Canada is changed.

2 Literature

Over the last 20 years, many contributions have been made to the theoretical and empirical literature on retail payments. Briglevics and Shy [2012] is the most relevant publication on merchant steering with discounts. The consumer model presented in section 4.3 is inspired by the rich literature addressing the determinants of consumer payment choice, in particular the role of reward programs. The model for the retailer's cost in section 4.2 uses previous Bank of Canada estimates of the retailers' costs, published in Arango and Taylor [2008b].

Central banks have a strong policy interest in the safety and efficiency of the retail payment system (Bank for International Settlements [2003]) and have led a number of studies on retail payments. Since many central banks started to obtain micro data on consumer payment behaviour, their researchers have been able to investigate in detail how attitudes, preferences and socio-demographics shape consumer payment choice. Consumer surveys often provide the data, and recently, there has been an effort to introduce payment diaries to the data collection process. Seven of these initiatives, namely for Canada, the US, Australia, Germany, Austria, France and the Netherlands, are documented and compared by Bagnall et al. [2013]. At the same time, payment networks have become a prime example of a two-sided market since their profitability depends critically on consumer demand and merchant acceptance. For example, Rochet [2003] discusses two-sided platforms in general and payment networks in particular. The payment network must choose not only a total price for a transaction, but must also split the cost between merchants and consumers in such a way that the number of transactions is maximized. Since the demand and supply sides are not equally elastic to transaction charges, the optimal price structure will be asymmetric. The usual result for the credit card market is that merchants carry the larger burden of the cost, while consumers are often rewarded (a negative cost) when they make credit card transactions.

When the Cash Discount Act legalized cash discounts in the US in 1981, Ingene and Levy [1982] asked whether merchants could use discounts and avoid the high costs of credit card transactions. In their model, the consumer chooses between credit cards and paper-

based payment instruments, namely cash and paper cheques.[15] Merchants strive to maximize the value of sales net of the interchange fee and the interest cost of delayed payments and discounts. The model provides a way for merchants to calculate the optimal discount if their own costs and the consumers' response to discounts can be reliably estimated. Ingene and Levy [1982] assume that cash transactions are of no cost to the merchant and, if that is not true, they overestimate the size of the optimal discount. When Grant [1985] revisits their calculation using data from the UK on the cost of accepting means of payment, he concludes that cash discounts are far less profitable than implied by Ingene and Levy. Grant's paper also highlights the need for accurate measurements of merchants' transaction cost.

Briglevics and Shy [2012] take advantage of US data from the Survey of Consumer Payment Preferences to extend Ingene and Levy's work. They use data on the merchants' cost of accepting card payments, obtained from the Federal Reserve Board's Payment Card Network Survey. Their work takes into account that typical transaction values differ for each method of payment and payment shares vary by merchant type. They also extend the available means of payment to include debit cards. Further, given the thirty-year lag between the amendment of the Cash Discount Act and their work, Briglevics and Shy pose the question of why cash discounts are not observed although they have been legal for such a long time. Discounts for debit cards have been allowed since 2011 when the US Department of Justice and the major credit cards companies reached a settlement, making the profitability of debit card discounts a relevant research question.[16]

Lacking reliable data on discounts, Briglevics and Shy [2012] assess the situation where a consumer's payment choice is perfectly elastic to the discount and argue that, even under this assumption, cash and debit discounts would still not be profitable for the merchant since the cost of offering these discounts is too high. Their main insight is that permitting discounts does not have the potential to change the current payment patterns in the US, since most

[15] Although introduced in 1975, debit cards were not frequently used by US consumers in the 1980s. See Evans and Schmalensee [2005].

[16] The settlement is for example discussed by Shy and Stavins [2013].

merchants have no incentive to offer discounts.

Turning to consumers, loyalty and rewards programs have been shown to be important determinants of payment choice. The probability of credit card usage increases when the card owner has access to a rewards program (the intensive margin). Further, among consumers with a rewards programs credit card usage also rises with the level of available rewards (the extensive margin).

Ching and Hayashi [2010b] study the influence of price incentives in the form of rewards on consumer payment choice. They estimate a payment choice model and include data on attitudes and perceptions to control for possible endogeneity of rewards and credit card usage. In their counterfactual experiment where the rewards programs are removed, about 10 per cent of the consumers switch to another means of payment. While Ching and Hayashi rely on the respondent's memory for data on payment frequencies, other papers have taken advantage of payment diaries in which the consumers record their transactions over a period of time. Using Canadian diary data, Arango et al. [2011] provide insight into how consumer choice is driven by incentives, and Wakamori and Welte [2012] incorporate unobserved heterogeneity and supply side factors into the model. All three papers use variants of logit choice models for the consumer behaviour.

In Ching and Hayashi [2010b], rewards programs enter the model as an indicator variable, and they measure the intensive margin of credit and debit cards rewards. They attribute the weaker response to debit card rewards to the lower levels of rewards for debit cards than credit cards. Wakamori and Welte estimate the intensive margin of the percentage points of the transaction value that consumers can earn using their main credit card. Their generalized logit model captures different substitution patterns away from cash and debit due to incentives to use credit cards. In Arango et al. [2011] the level of rewards varies along two dimensions, percentage points of rewards and transaction amount. Therefore, they can estimate the elasticity of the consumer to the dollar value of financial incentives. In contrast to Wakamori and Welte, cash and debit card shares are equally elastic to increased preferences to use credit

cards, a property imposed by the standard multinomial logit model.

Modelling choice with a probit model provides another way to avoid the restrictions of the logit model. Simon et al. [2010], who use payment diary data from Australia, estimate a series of probit models to understand the effect of rewards program. They conclude that rewards programs facilitated the growth of Australian credit cards usage in the nineties, and that the reform of the payment system in 2003 likely slowed it down. These reforms were initiated by the Reserve Bank of Australia (RBA) to address concerns that the price structure for debit and credit cards was not competitive and caused inefficiency in the payments system. As a result, interchange rates were capped and merchants started surcharging card payments.

Whether such policy can improve the payment system relies on understanding the merchants' cost of accepting payments. In 2006, the Bank of Canada conducted a survey of merchants which Arango and Taylor [2008b] use to estimate fixed and variable costs of accepting cash, debit and credit cards. One of their important findings is that debit cards are less costly than cash at transaction values above $40 and that credit cards are universally the most expensive method of payment for the retailers.

Most published work that takes an empirical approach abstracts from competition in the retail sector and sometimes also from the two-sided nature of payment networks, in particular, when only one-sided data on the four-party structure (see Figure 1.2) are available. The hypotheses generated by models for two-sided markets are therefore difficult to test.[17] Since there is no general agreement among theorists about how discounts and surcharges influence the social cost of making payments, empirical work could help strengthen and refine their models.

Researchers have indeed succeeded in empirically supporting some of the predictions which follow from the theory. Rysman [2009] gives a good overview of the two-sided mar-

[17] See for example Rochet and Tirole [2004]. Some hypotheses about two-sided payment imply that the optimal relative prices charged to the consumers and merchants are inversely related to their relative price elasticities. The failure of the Coase Theorem states that the joint surplus of consumers and retailers cannot be maximized through bargaining about the price structure of a credit card transaction, the optimal prices must be set by the network. Positive feedback effects suggest that if more consumers hold cards, then more retailers accept cards and vice versa.

ket approach and establishes a correlation between which card consumers in a geographic region prefer and how many local merchants accept this card. He thus provides evidence for a feedback loop between merchants and consumers, necessary for network externalities.

Jonker [2011] concludes, based on the analysis of a Dutch retailer survey, that greater competition will lead to widespread acceptance of payment cards and that merchants will surcharge means of payment that are costly to them. Her work shows that surcharges can actually increase the number of transactions processed through a network because more merchants adopt the costly payment method. Competition between merchants could prevent excessive surcharging.

Motivated by the theoretical work of Rochet and Tirole [2008], Bounie et al. [2014] provide empirical evidence that consumer preferences are the main motivation for merchants to accept card payments even if they incur high costs for card transactions.

The proponents of the no-surcharge rule often present the following argument: interchange fees are part of the asymmetric pricing that allows the payment network to generate positive externalities and possibly an increase in welfare. If surcharges were allowed, fewer consumers would use the payment method and the positive network effect could be neutralized. Economides and Henriques [2011] show that this conclusion may not be correct in all markets and that the optimality of the no-surcharge-rule depends on a number of factors, supporting, for example, Jonker's hypothesis that competition between retailers could act as a restraint mechanism.

A careful review of the literature reveals that there is little scholarly work on the effect of discounts for payment method usage (or any two-sided platform) and much more on surcharges. Shy and Stavins [2013] state that data on discounts is difficult to obtain because discounting merchants are rare and consumers are unfamiliar with the concept.

On the one hand, Briglevics and Shy [2012] provide some evidence that allowing discounts will not significantly impact the US payments landscape. On the other hand, Rochet and Tirole [2002] argue that the no-surcharge rule is crucial for the optimal functioning of the credit card

system. Discounts and surcharges would therefore not be equivalent.

In the model presented in Section 4, consumers are heterogeneous and their response to the discount varies with its monetary value. By contrast, Briglevics and Shy assume a representative consumer who is perfectly elastic to the discount. Since the policy simulation in this study is conducted with Canadian data, the conclusion also holds valid for the Canadian payments industry as opposed to Briglevics and Shy's analysis of US data.

3 Data

The data used in this thesis are derived from two Bank of Canada surveys; (1) the 2009 Method of Payment (MOP) Survey and (2) the 2006 Merchant Survey. These surveys are an accepted resource for information about consumer payment behaviour and merchant cost of accepting payments in Canada, and are often cited by policy experts and economists (among them, Bulmer [2009], Frankel [2012],Elzinga [2012]).

3.1 The 2009 Methods of Payment Survey

In 2009, the Bank of Canada conducted the Methods of Payment Survey (MOP) of consumer payment behaviour.[18] This rich micro data set has been used in several Canadian studies to model consumer payment choice at the point-of-sale; see for example Arango et al. [2011] and Wakamori and Welte [2012].

The survey consists of two parts: a survey questionnaire and a three-day shopping diary. The questionnaire collects information that allows construction of a demographic profile of the respondents and their preferences and habits regarding methods of payment (MOPs). Since the respondents provide detailed information about their rewards programs, the 2009 MOP data can be used to estimate how demand for payment instrument usage responds to financial incentives.

[18] A full survey report and contact information are available in Arango and Welte [2012].

In the dairies, participants record their daily purchases, including transaction values and the chosen method of payment along with information about the point-of-sale. A particularly convenient feature of the dairy data is the inclusion of alternatives for each transaction, thus a list of payment instruments that the merchant accepts. In the estimation of consumer demand for payment instruments, the choice set can be defined in a manner consistent with the available methods of payment at the point of sale and with the cards owned by the consumer.

3.1.1 Rewards

The rewards variable is constructed by matching the credit card names with publicly available information on rewards and loyalty programs for credit cards issued in Canada. This information is obtained by Arango et al. [2011] from the issuers' websites and the Financial Consumer Agency of Canada (FCAC).[19]

For cash-back cards the rewards are the percentage of the transaction amount which would be credited to the consumer i for using the credit card. In the case of other loyalty programs such as frequent traveller cards, the loyalty points are converted to a percentage of the transaction amount.

The dollar value of rewards for a transaction t is calculated by multiplying the ad-valorem rewards $R_{i,credit}$ of consumer i's credit card by the transaction value p_{it}; this is given by

$$r_{i,credit,t} = R_{i,credit} * p_{it}. \tag{1}$$

If the consumer does not have a credit card, the rewards are set to zero.

3.1.2 Attitudinal variables

In the questionnaire, respondents rated the usage of cash, credit cards, and debit cards on a five-point scale in terms of ease of use, cost and record-keeping capabilities. Each index for

[19]The FCAC maintains a data base of credit cards issued in Canada (See `http://itools-ioutils.fcac-acfc.gc.ca/STCV-OSVC/ccst-oscc-eng.aspx`.).

credit card and debit card usage is obtained by

$$a_{i,j,l} = \log\left(\frac{s_{i,j,l}}{s_{i,cash,l}}\right) \tag{2}$$

where $s_{i,j,l}$ is the rating of respondent i for payment method j, (j = credit or debit), and l denotes the attribute, namely ease of use, cost or record keeping. The rating for cash is used for the normalization, since cash is available for all transactions and to all respondents. Taking logarithms results in attitudinal ratings which are symmetric around 0. In particular, if MOP j is given the same rating as cash, then $a_{i,j,l}$ equals 0. Two respondents with opposing views on cash and a payment card have indices of the same magnitude and of opposing signs. As an example, if one respondent rates cash as very easy to use (rating 5) and credit as very difficult (rating 1), the other respondent's ratings are inverse, namely 1 for the ease of use of cash and 5 for credit cards. Accordingly, the index for the first respondent is 1.6904 and the index for the second respondent is -1.6904, the negative of the first's index. This example also shows that the indices range between -1.6904 and 1.6904.

3.2 The 2006 Merchant Survey

The second data source is the 2006 Merchant Survey which contacted about 500 merchants in Canada by telephone to collect data on their cost of accepting means of payment. Arango and Taylor [2008b] present a model of the merchants per transaction cost when accepting cash, debit and credit cards. Their work suggests that merchants consider cash generally cheaper to accept than credit cards, but that debit cards may be less costly than cash at higher transaction values.

The reason is that the costs associated with cash depend on the transaction value, while the fees for a debit card transaction are constant. They also find that the cost of accepting payments varies with the bargaining power of the merchants, since chains and stores with high sales volume often face lower unit costs than independent businesses and small stores.

The merchant data allows separation of the different components of the cost occurred by the merchant; these are, roughly, labour costs, processing fees charged by the acquirer or financial institution, theft or counterfeit, chargebacks (only applicable credit cards) as well as the foregone interest while funds are in transit ("float").

Arango and Taylor also confirm that merchants universally accept cash. Their acceptance rate for credit and debit cards is over 90 per cent, which interestingly is higher than the perceived acceptance in the MOP data set, (see Tables 14 and 15). One possible explanation is that some of the MOP respondents did not realize that cards would have been accepted or felt that, due to the low transaction value, cards were not an appropriate choice. On the other hand, this discrepancy could occur because the retailers in the merchant survey were not weighted by the number of transaction processed. As a consequence, card-accepting businesses would be over-represented in the 2006 Merchant data compared to the stores frequented by the respondents in the 2009 MOP Survey.

Arango and Taylor estimate a model for merchants' marginal transaction costs which take the form $a + bp$ with MOP specific constants a and b and variable transaction value p. In the estimation, I impute the merchant cost using Arango and Taylor's estimates.

3.3 Descriptive Statistics

The cleaned 2009 MOP data set[20] used for the estimation of the choice models consists of 7,137 transaction conducted by 1,999 consumers. Descriptive statistics are provided in Tables 1 and 2. The average transaction value set is just under $30, with many transactions falling in the range below $5 (20 per cent) or below $10 (39 per cent). Most frequently, a purchase takes place at a store with two to five cashiers and is to buy groceries. About half of the transactions (52 per cent) are in cash, 27 per cent are conducted with debit cards and the remaining 21 per cent with credit cards. The respondents are, on average, 44 years of age and live in households with incomes slightly above $60,000. Most are residents of Ontario or

[20] Appendix A outlines the cleaning procedures.

Quebec, Canada's most populous provinces. They hold $66 in cash and have one debit card and two credit cards. Regarding perceptions, they consider cash significantly less costly than payment cards, but less suited for record keeping. Debit and credit cards compare differently to cash in terms of ease of use; on average, debit cards are about as easy to use as cash, but credit cards are perceived as slightly easier to use than cash. In the data, the average value of rewards earned for a credit card transaction is around 30 cents among the credit card owners with a rewards program.

Table 1: Transaction Sample

	Mean	Std.Dev.	Min	Max
Payment shares				
Cash	0.519	0.010	0	1
Credit	0.209	0.008	0	1
Debit	0.271	0.009	0	1
Acceptance				
Cash	1	0	1	1
Credit	0.720	0.010	0	1
Debit	0.883	0.006	0	1
Transaction value				
Value ($)	29.600	0.788	0.15	300
below 5	0.209	0.008	0	1
below 10	0.385	0.010	0	1
Rewards	0.294	0.015	0	4.695
Point of sale				
Size of store				
One cashier	0.308	0.010	0	1
Two to Five cashiers	0.456	0.010	0	1
Six or more cashiers	0.236	0.008	0	1
Type of Good				
Groceries	0.370	0.010	0	1
Entertainment or Meal	0.246	0.008	0	1
Gasoline	0.063	0.006	0	1
Number of transactions		7,137		

Source: 2009 Bank of Canada Methods of Payment Survey, weighted estimates.

Table 2: Respondent Sample

	Mean	Std.Dev.	Min	Max
Sociodemographics				
Age	43.675	0.604	18	75
Income	6.303	0.103	1	10
Province				
BC	0.083	0.008	0	1
AB	0.083	0.014	0	1
SK	0.080	0.009	0	1
MB	0.065	0.008	0	1
ON	0.396	0.020	0	1
QC	0.220	0.016	0	1
NB	0.026	0.008	0	1
NS	0.025	0.003	0	1
PEI	0.008	0.001	0	1
NFL	0.014	0.002	0	1
Methods of Payments				
Cash holdings	65.816	3.482	0	1000
Credit card				
Ease	0.036	0.007	-1.609	1.609
Record keeping	0.505	0.024	-1.609	1.609
Cost	-0.404	0.023	-1.609	1.609
Number of cards	2.291	0.078	1	14
Credit limit	4.628	0.126	0	7
Revolver	0.286	0.017	0	1
Debit card				
Ease	-0.005	0.009	-1.609	1.609
Record keeping	0.498	0.027	-1.609	1.609
Cost	-0.395	0.021	-1.609	1.609
Number of cards	1.356	0.024	0	9
Number of respondents		1,999		

Source: 2009 Bank of Canada Methods of Payment Survey, weighted estimates.

4 Model and Estimation Strategy

This section explains the pricing problem faced by the merchants. A merchant seeks to set ad-valorem discounts for debit or cash transactions at a level where the overall cost of accepting payments is minimized. For a specific transaction, this cost is a function of the method of payment chosen by the consumer, of the transaction value and of the discount. Consumers' demand for using methods of payment is modelled as a discrete choice problem. The determinants of their payment choice are discounts, rewards, but also demographics, personal preferences and attitudes as well as transaction features such as purchase amount and type of good. The residual demand for goods is inelastic to the discount offered for cash or debit, implying that consumers will not switch stores or change their consumption pattern when discounts are offered.

4.1 Notation

The following notation and indices are used throughout:

Transactions are vectors $T = (p, \vec{x}, \vec{z}, \vec{a}, \vec{r})$ where p is the transaction value (in dollars), $\vec{x}$ the demographic information of the consumer, $\vec{a}$ her attitude towards the available means of payment, $\vec{z}$ a vector of point-of-sale features such as the type of good or the size of the store, and finally $\vec{r}$ the rewards that could be earned using a specific method of payment. By abuse of notation, $p(T)$ is the dollar value of a transaction T. Consumers are indexed with i, methods of payments with j and transactions with t. The index 1 stands for cash (cs), 2 for credit cards (cc) and 3 for debit cards (dc).

Discounting schemes are vectors $\vec{d} = (d_{cs}, d_{cc}, d_{dc})$ with non-negative entries and all discounts are ad-valorem (a percentage of the transaction amount). *Merchants' costs* are functions of three variables: the method of payment j, the transaction value p and the discounts $\vec{d}$ offered by the merchants. They are written as $V_j(p(T), \vec{d})$.

4.2 The Merchants' Optimization Problem

Merchants minimize the cost of accepting payments, conditional on facing consumers with certain preferences for choosing their method of payment. The merchants consider discounts for cash and debit cards, but not credit cards. All discounts are ad-valorem, that is, a percentage of the transaction value and the possible discounting schemes are vectors $\vec{d} = (d_{cs}, d_{cc} = 0, d_{dc})$ with non-negative entries. For each transaction t made by consumer i , the probability of choosing j is a function $pr_j(T), T = (p_t, \vec{x}_i, \vec{z}_{it}, \vec{a}_{ij}, r_{ijt}, d_j)$ with the notation introduced above in 4.1.

If the transactions $(T, \vec{d}) = (p, \vec{x}, \vec{z}, \vec{a}, r, \vec{d})$ are distributed according to a density ν and mop_T are the choices available for transaction T, then the merchant chooses $\vec{d}$ to minimize

$$E(\pi) = \int_T \sum_{mop_T} pr_{mop}(T, \vec{d}) * V_{mop}(p(T), \vec{d})\, d\nu(T). \tag{3}$$

The unit cost of processing a method of payment does not depend on discounts offered for other methods. In particular, the cost functions V_{cs} and V_{dc} shall be constant in d_{dc} and d_{cs}, respectively. Furthermore, the density of transactions does not depend on the discounting scheme $\vec{d}$ chosen by the merchant; in other words, discounting does not attract more or a different kind of transaction than that the merchant would process without the discount.

A boundary solution of the optimization problem occurs when one of the discounts is equal to zero. If discounts always lead to higher transaction costs, then the optimum is the corner solution $\vec{d} = \vec{0}$.[21]

4.3 The Payment Choice Model

A model for consumer payment choice is needed to solve the optimization problem stated in section 4.2. The dependent variable in such a model is discrete and takes values among the means of payment J_{it} which are available for a transaction t. Two well-known models for

[21] Appendix B lists the first order conditions of the optimization problem.

discrete outcome variables are the multinomial logit and the multinomial probit models, as discussed in Train [2003], among others.

Suppose the utilities for using MOPs are affine combinations of observables and random error terms. Specifically, for consumer i, $i =, 1, \ldots, N$ and transaction t, $t = 1, \ldots, \tau_i$ the utility from choosing payment method $j \in J_{it}$ is

$$u_{ijt} = \alpha_j + T_{ijt} * \beta_j + \epsilon_{ijt}, \tag{4}$$

where α_j is a constant and β_j is a vector of coefficients, both specific to the alternative j. In this decomposition, $v_{ijt} = \alpha_j + T_{ijt} * \beta_j$ is called the systematic component. The error terms ϵ_{ijt}, $j = 1, \ldots, J_{it}$ are random variables following a joint distribution F and the means of the error terms are equal to zero i.e. $E(\epsilon_{ijt}|T_{ijt}) = 0$. Note that the coefficient β depends only on the alternative j and not on the individual i or the transaction t. The model henceforth does not aim at extracting unobserved heterogeneity of consumers or transactions, but can potentially extract substitution effects between alternatives j and j' through the correlation of the error terms $\epsilon_{\cdot,j,\cdot}$ and $\epsilon_{\cdot,j',\cdot}$. The probability that MOP j is chosen by i for transaction t is the probability that j yields greater utility than other available MOPs j':

$$Prob(u_{ijt} > u_{ij't} \; \forall j' \in J_{it} \setminus \{j\}). \tag{5}$$

As consequence of the linear utility specification, the inequality is equivalent to

$$u_{ijt} > u_{ij't} \Leftrightarrow \alpha_j - \alpha_{j'} + T_{ijt} * \beta_j - T_{ij't} * \beta_{j'} > \epsilon_{ij't} - \epsilon_{ijt}. \tag{6}$$

The key to calculating the choice probabilities is the joint cumulative distribution function of the random variables $\epsilon_{ij't} - \epsilon_{ijt}$. Since the probabilities only depend on the difference between the $|J_{it}|$ error terms, a normalization must be chosen. Cash is designated as the reference category and has the index $j = 1$. With this choice, v_{i1t} and $E(u_{i1t})$ are equal to 0.

The estimation of the coefficients α_j and β_j will be by maximum likelihood estimation. Let θ be the vector of parameter values $(\alpha_2, \beta_2, \alpha_3, \beta_3)$ and $pr_{ijt}(\theta)$ the probability that individual i chooses j for transaction t, given θ.

Given observations (T_{ijt}, γ_j) where $j \in J_{it}$ and $\gamma_{ijt} = 1$ if j is chosen and 0 if j is not chosen, the individual level likelihood is

$$\mathcal{L}_i(\theta) = \prod_{i=1}^{\tau_i} \prod_{j \in J_{it}} pr_{ijt}(\theta)^{\gamma_{ijt}}. \tag{7}$$

For the calculation of the overall likelihood, each individual level likelihood is weighted by the survey weight of the individual:

$$\mathcal{L}(\theta) = \sum_{i=1}^{N} w_i \log \mathcal{L}_i(\theta) = \sum_{i=1}^{N} w_i \sum_{i=1}^{\tau_i} \log(\prod_{j \in J_{it}} pr_{ijt}(\theta)^{\gamma_j}). \tag{8}$$

If the likelihood function is globally concave in the parameter θ then there is a unique θ^* where it assumes a global maximum and the parameter vector is identified. Global concavity depends on the functional form of the choice probabilities. The logit and probit specifications exhibit global concavity.

4.4 Logit Model

In the logit model, the errors ϵ_{ijt} are independent and identically distributed according to a Type I extreme value distribution. The choice probabilities are then given by

$$pr_{ijt} = \frac{\exp(v_{ijt})}{\sum_{j' \in J_{it}} \exp(v_{ij't})} \tag{9}$$

where $u_{ijt} = v_{ijt} + \epsilon_{ijt}$ and the systematic component is linear[22] in the observables. Having this closed-form expression makes the logit model a popular discrete choice model. The marginal effects for the logit model are included in Appendix B.2.1.

[22] Strictly speaking, v_{ijt} is affine in the observables, because I am adding a choice specific constant term.

4.4.1 Independence from Irrelevant Alternatives

For any two alternatives $j, j' \in J_{it}$, the ratio of the choice probabilities is

$$\frac{pr_{ijt}}{pr_{ij't}} = \frac{\exp(v_{ijt})}{\sum_{j' \in J_{it}} \exp(v_{ij't})} * \frac{\sum_{j' \in J_{it}} \exp(v_{ij't})}{\exp(v_{ij't})} = \exp(v_{ijt} - v_{ij't}). \tag{10}$$

This ratio depends only on the alternatives j and j'. A choice model in which the relative odds of choosing between two alternatives do not depend on any of the other possible choices is said to have the property of *Independence from Irrelevant Alternatives (IIA)*. One of advantages of the IIA property for the payment choice model is not having to account for the exclusion of cheques and prepaid cards from the MOP data set; the model would still capture correctly how the consumer chooses between cash, debit and credit card payments. On the other hand, it is debateable that the substitution effects between any two of these three MOPs are identical. IIA implies that the relative odds of choosing cash over debit are the same regardless of whether credit cards are accepted. For example, debit and credit cards are both electronic means of payment which could make them closer substitutes for each other than for cash. However, debit cards and cash also help to constrain spending and avoid interest payments, a feature that they share with each other, but not with credit cards.

4.5 Probit Model

In the probit model, the error terms ϵ_{ijt} follow a multivariate normal distribution with mean zero and symmetric positive definite covariance matrix Σ. For a probit model with three alternatives, the marginal effects are given by formula (31) in Appendix B.2.2. Recall that the choice probabilities are given by (5) which is now a cumulative probability of a $(|J_{it}| - 1)$ - variate normal distribution. In each of the comparisons, solely the differences between the error terms matter and scaling the random utilities by the same factor does not change the choice probabilities. This observation implies that at most the covariance matrix Σ^r of the random variables $\epsilon_j - \epsilon_{j'}$ can be identified and that it is necessary to fix the scale of the

random utilities.

Here is one possible normalization in the case of three alternatives: up to a sign, there are three error differences, namely $\epsilon_1^r = \epsilon_1 - \epsilon_2$, $\epsilon_2^r = \epsilon_1 - \epsilon_3$, and $\epsilon_3^r = \epsilon_2 - \epsilon_3$. The third difference is a linear combination of the first two since $\epsilon_3^r = \epsilon_2^r - \epsilon_1^r$. To fix the scale, the variance of ϵ_1^r is set to 0.5. The free parameters are now $(\Sigma^r)_{22}$ and $(\Sigma^r)_{12}$. Instead of estimating these two free parameters, estimation of the Choleski factor of Σ^r is preferred, since numerical solvers may not respect the positive-definiteness of the covariance matrix Σ^r in every step.

When the error terms are independent and identically distributed (iid), Σ is a multiple of the identity matrix and the probit model has the IIA property. It is easy to check that the corresponding Choleski factor Δ of Σ^r is of the form

$$\Delta = \begin{pmatrix} 1 & 0 \\ 0.5 & \sqrt{0.75} \end{pmatrix}.$$

This hypothesis can be tested using a linear test of the estimated entries of the Choleski factor. It can also be tested using the likelihood ratio of the restricted and unrestricted likelihood, where the number restrictions imposed is equal to two since the constraints apply to Σ^r and not to Σ.

Another advantage of the probit model is that, with a fully general covariance matrix, the diagonal entries of Σ can account for unequal variance of the utilities; in the logit model this can only be achieved by introducing a random scale coefficient.

The biggest technical issue is that the cumulative densities of the (multivariate) normal distribution do not have a closed form solution and therefore must be evaluated using numerical integration. The probit model with three alternatives requires the evaluation of a bivariate normal which can fortunately still be evaluated in an efficient manner.[23]

[23]To do so, I programmed a MATLAB program that utilizes a slight modification of the function BVNcdf. The original BVNcdf function was graciously provided T.H. Jorgensen `http://www.econ.ku.dk/phdstudent/jorgensen`.

4.6 Simulation of the Effect of Discounts on Choice Probabilities

The key assumption for the simulation of payment choice under discounts is that consumers derive the same utility from discounts as from credit card rewards. This assumption cannot be tested with the data available from the 2009 MOP survey. The Code of Conduct [2014], which explicitly permits Canadian merchants to offer discounts according to payment choice, only became effective in August 2010, ten months after the time period covered by the survey. The survey also does not ask any questions about discounts. Since rewards and discounts are both financial incentives to use a particular method of payment, consumers should derive the same benefit from a monetary unit of credit card rewards and the same unit given as a discount.

As pointed out by Ching and Hayashi [2010a], there are, though, several reasons why the coefficient on rewards may not adequately capture how consumers' demand for credit card usage responds to financial incentives. Consumers could sign up for a rewards program since they appreciate the convenience and ease of use or since their issuer has identified them as credit card intensive and offered the rewards program. The reverse effect is also possible: rewards program members may perceive credit cards as more positive because they are encouraged to use them. Following Ching and Hayashi [2010a] attitudinal data, demographics and revolver[24] status are included to control for these unobserved preferences.

The estimation of the consumer choice model yields coefficients $\hat{\theta}_{cc}$ and $\hat{\theta}_{dc}$, respectively, for the utility of using credit card and debit card choice, along with estimates of their standard errors.[25] Since the discounts have the same effect as rewards, they enter the utility functions linearly with coefficient $\theta_{disc} = \theta_{cc,rewards}$.

Following Chapter 15 in Greene [2012], a Monte Carlo experiment with S (=10,000) draws is used to simulate the effect of discounts and establish the statistical significance of the induced change in consumer payment choice.

[24] A revolver is a credit card owner who carries a balance beyond the due date of the credit card statement, thus incurring interest charges.

[25] It is a general result for maximum likelihood estimators that the coefficients follow asymptotically a normal distribution with mean $[\theta_{cc}, \theta_{dc}]$ and covariance matrix Γ obtained from a sandwich estimator. One of the references for the proof is Chapter 14 in Greene [2012].

I begin by drawing S coefficients $[\theta^s_{cc}, \theta^s_{dc}, \theta^s_{disc}]$ from their normal distributions. The first step is to evaluate the overall fit of the model, done by calculating S simulated choice probabilities for each transaction. This results in an $N \times S \times 3$ matrix of choice probabilities $[\pi^s_n]_{j=cs,cc,dc}$. Averaging over transactions nested within simulations results in a matrix of S payment mixes $\Pi = [\hat{\pi}^s_{cs}, \hat{\pi}^s_{cd}, \hat{\pi}^s_{dc}]$. In this average, every transaction is weighted by the survey weight w_i of the corresponding consumer. The weighting in this step is necessary because the choice model is estimated using the weighted average of individual level likelihoods in equation (8). The average $\hat{\pi}_{mop}$ and the standard deviation over the simulations are estimates for the overall shares of cash, debit and credit card transactions and the standard errors of these shares.

The policy simulation analyses the effect on payment choice of offering a discount of $d\%$. The utility of the discounted MOP is increased by $\theta^s_{disc} * d/100 * p$ and the choice probabilities are recalculated with the changed utilities. Again, I average first over transactions and then over simulations to find the payment shares under the discounting regime.

It is necessary to look at both the absolute and the relative changes in payment shares. For each of the simulations, I take the average over the transaction-level differences between the predicted probabilities without and with the discounts. The result of that step consists of a matrix whose rows contain the payment mixes for the simulations, $[\hat{\delta}^s_{cs}, \hat{\delta}^s_{cc}, \hat{\delta}^s_{dc}] = [\hat{\pi}_{cs} - \hat{\pi}^{disc}_{cs}, \hat{\pi}_{cc} - \hat{\pi}^{disc}_{cc}, \hat{\pi}_{dc} - \hat{\pi}^{disc}_{dc}]^s$. Taking the average over each column (thus, over all simulations s) yields the estimate of the proportion of switchers for each of the three MOPs. The weighted standard deviation of each column provides an estimate for the standard error of $\hat{\delta}_{mop}$ and can be used to test for statistical significance of the change to the payment mix.

For each method of payment, an estimate for the relative difference (the switching rate) is $\hat{\delta}_{mop}/\hat{\pi}_{mop}$. These estimated switching rates are distributed as the ratio of two asymptotically normal variables. The first and second moments for this type of random variable can be complicated or not defined, since for example the Cauchy distribution arises as a special case. Therefore no indication of statistical significance for the relative changes will be given.

The procedure above is repeated for sub samples of the transaction set, replacing the survey weight w_i by 0 if the transaction is not in the sub sample. For the calculation of marginal effects I proceed as follows: for each of the coefficient draws s, the marginal effects on the transaction level are given by equations (30) and (31). The simulated marginal effects are formed in the same fashion as the probabilities, thus by first taking the weighted average over all transactions and then the mean of these aggregate marginal effects over simulations s.

The final set of simulations concerns the removal of rewards programs and consumers' willingness to pay (WTP) for certain payment instrument attributes, such as ease of use. The willingness to pay rewards dollars for ease of use is the maximum value of rewards that a person would be willing to give up for more convenient credit card usage. Since rewards and ease of use enter the utility specification linearly, the WTP is the ratio of the coefficients on ease of use and rewards dollars.

In the simulation, the baseline transaction is a \$50 purchase at an average-sized grocery store (two to five cash registers) where all means of payment are accepted. Setting the rewards earned for a credit card transaction to zero measures the intensive margin of the rewards programs, that is, by how much the aggregate propensity to use a credit card increases because of the rewards program. The sample is first split into different income groups and then by credit card ownership. I consider credit card owners with a rewards program separately, because other right-hand-side variables could be correlated with the propensity to earn credit card rewards.

Finally, I define the rewards equivalent of ease of use (REU) as the reduction in ease of use that has the same effect on credit card usage as the removal of the rewards programs. I calculate the REU for all card owners and for the subset of rewards program members. Finally, I use bootstrapping to calculate a confidence interval for REU.

5 Results

In this section, I describe the estimated payment choice model and the solution of the merchant's optimization problem. Although the consumers react significantly to financial incentives, the solution is trivial as the merchant's transaction costs strictly increase in the presence of non-zero discounts.

5.1 Payment Choice Model

Tables 4 and 5 present the results of estimating four different payment choice models. In the first two, the logit model and the iid probit model, the error terms are independent and identically distributed (iid). The relative sizes of the coefficients are similar in both models and they share almost the same set of significant variables except for the constant term. The difference in the significance and relative size of the constant terms could be explained by the fact that the error terms in the logit model have a heavier right tail while the error terms in the probit model are symmetric around zero. The next two probit models have either a completely general covariance structure (the unstructured probit) or allow the error terms to be heteroscedastic, but independent (the independent probit). Since the iid probit model is a special case of the latter two where restrictions are imposed on the covariance matrix, the likelihood ratio can be used to test whether the errors in the probit model are iid or not. The likelihood ratio test statistics and their corresponding p-values are given in Table 3.

Table 3: Likelihood ratio

	# of parameters	Log likelihood	df	χ^2 statistic	p-value
IID Probit	55	-4443.0	0	0	
Independent Probit	56	-4438.181	1	9.719	< 0.01
Unstructured Probit	57	-4435.241	2	15.591	< 0.01

Note: df are the degrees of freedom of the χ^2 test statistic for H_0: the errors are iid. The p-value is the probability that H_0 holds, given the χ^2 statistic.

Table 4: Payment choice model: credit card

Model	**Logit**		**IID P**		**IP**		**UP**	
	β	s.e	β	s.e	β	s.e	β	s.e
Credit card								
Constant	-0.75**	0.33	-0.26**	0.13	-0.04	0.13	-0.17	0.15
TV								
Value ($)	0.04***	0.00	0.02***	0.00	0.02***	0	0.02***	0.00
Value^2/1000	-0.12***	0.02	-0.06***	0.01	-0.06***	0.01	-0.07***	0.01
below 5	-1.50***	0.23	-0.78***	0.12	-0.76***	0.12	-0.86***	0.13
below 10	-0.90***	0.16	-0.51***	0.08	-0.49***	0.08	-0.56***	0.09
Rewards	0.23**	0.12	0.12**	0.05	0.13***	0.01	0.15***	0.01
Point of sale								
Size of store								
2 to 5 cashiers	0.11	0.12	0.06	0.06	0.06	0.06	0.07	0.06
6 or more	0.38***	0.15	0.21***	0.07	0.21***	0.07	0.23***	0.07
Type of Good								
Groceries	-0.63***	0.12	-0.33***	0.06	-0.29***	0.05	-0.32***	0.06
Enter./Meal	-0.66***	0.14	-0.37***	0.07	-0.34***	0.07	-0.38***	0.07
Gasoline	0.27	0.23	0.18	0.12	0.14	0.12	0.16	0.13
MOP								
Cash hold./100	-0.34***	0.05	-0.17***	0.02	-0.17***	0.02	-0.20***	0.02
Credit card								
Ease	0.66***	0.18	0.31***	0.06	0.31***	0.06	0.35***	0.06
Record keeping	0.67***	0.08	0.34***	0.03	0.32***	0.03	0.37***	0.03
Cost	0.59***	0.08	0.31***	0.03	0.27***	0.02	0.29***	0.03
Number of cards	0.07***	0.02	0.04***	0.01	0.04***	0.01	0.04***	0.01
Credit limit	0.28***	0.12	0.12**	0.05	0.13***	0.05	0.15***	0.05
Revolver	-1.05***	0.10	-0.56***	0.04	-0.50***	0.03	-0.56***	0.04
Demographics								
Age	-0.03***	0.00	-0.02***	0.00	-0.02***	0.00	-0.02***	0.00
Income	-0.01	0.02	0.00	0.01	0.00	0.01	0.00	0.01
Province								
AB	-0.52**	0.24	-0.31***	0.10	-0.33***	0.1	-0.38***	0.10
SK	-0.31	0.23	-0.18	0.10	-0.14	0.1	-0.16	0.11
MB	-0.07	0.25	-0.05	0.12	-0.06	0.11	-0.06	0.12
ON	-0.40**	0.18	-0.24***	0.09	-0.25***	0.08	-0.27***	0.09
QC	-0.30	0.19	-0.20**	0.09	-0.21**	0.08	-0.25***	0.09
NB	0.30	0.37	0.12	0.15	0.10	0.14	0.14	0.15
NS	0.07	0.32	0.02	0.12	-0.02	0.12	-0.03	0.13
PEI	-0.56	0.58	-0.32	0.17	-0.28	0.17	-0.31	0.18
NFL	0.59	0.43	0.28*	0.17	0.26	0.17	0.31*	0.18

Note: *, **, *** denote the 0.1, 0.05 and 0.01 significance levels, respectively. IID P: Probit with identically and independently distributed errors. IP: Probit with heteroskedastic errors. UP: Probit with fully general covariance matrix. Choleski decomposition of the covariance matrix is as diagonal entries, (1,b) and off-diagonal entry c. The table continues on the next page.

Table 5: Payment choice model: debit card

Model	**Logit**		**IID P**		**IP**		**UP**	
	β	s.e	β	s.e	β	s.e	β	s.e
Debit card								
Constant	0.42	0.26	0.33***	0.132	0.32***	0.1	0.32***	0.11
TV								
Value ($)	0.03***	0.00	0.02***	0.00	0.02***	0	0.02***	0.00
Value^2/1000	-0.09***	0.02	-0.05***	0.01	-0.05***	0.01	-0.05***	0.01
below 5	-0.94***	0.14	-0.52***	0.08	-0.47***	0.08	-0.54***	0.08
below 10	-0.78***	0.12	-0.49***	0.07	-0.44***	0.06	-0.50***	0.07
Point of sale								
Size of store								
2 to 5 cashiers	0.08	0.10	0.05	0.05	0.06	0.05	0.06	0.05
6 or more	0.32***	0.12	0.20***	0.05	0.19***	0.05	0.21***	0.05
Type of Good								
Groceries	0.27***	0.10	0.14***	0.05	0.11**	0.05	0.11**	0.05
Enter./Meal	-0.33***	0.12	-0.20***	0.06	-0.19***	0.05	-0.22***	0.05
Gasoline	0.04	0.20	0.06	0.11	0.04	0.1	0.07	0.10
MOP								
Cash hold/100	-0.01***	0.00	-0.24***	0.01	-0.21***	0.00	-0.23***	0.01
Credit card								
Ease	0.68***	0.17	0.34***	0.06	0.30***	0.05	0.33***	0.06
Record keeping	0.35***	0.07	0.19***	0.03	0.19***	0.03	0.21***	0.03
Cost	0.23***	0.07	0.13***	0.03	0.12***	0.02	0.14***	0.02
Number of cards	0.22***	0.05	0.12***	0.02	0.10***	0.02	0.10***	0.02
Demographics								
Age	-0.02***	0.00	-0.01***	0.00	-0.01***	0.00	-0.01***	0.00
Income	-0.04**	0.01	-0.02***	0.01	-0.01	0.01	-0.01**	0.01
Province								
AB	-0.46**	0.20	-0.31***	0.09	-0.31***	0.08	-0.33***	0.09
SK	0.17	0.19	0.04	0.08	0.02	0.08	0.03	0.08
MB	-0.18	0.23	-0.15	0.10	-0.13	0.1	-0.14	0.10
ON	-0.20	0.14	-0.14**	0.07	-0.15**	0.07	-0.15**	0.07
QC	-0.50***	0.15	-0.30***	0.07	-0.28***	0.07	-0.30***	0.07
NB	0.45	0.28	0.21*	0.11	0.16	0.11	0.20*	0.11
NS	-0.46	0.27	-0.28**	0.12	-0.27**	0.11	-0.29**	0.12
PEI	0.25	0.38	0.11	0.15	0.07	0.15	0.08	0.15
NFL	0.68**	0.32	0.34**	0.15	0.27*	0.15	0.31**	0.15
b					0.12	0.05	0.4	0.04
c							0.65	0.04
Log likelihood	-4423.652		-4443.036		-4428.181		-4435.24	
Parameters	55		55		56		57	

Note: *, **, *** denote the 0.1, 0.05 and 0.01 significance levels, respectively. IID P: Probit with identically and independently distributed errors. IP: Probit with heteroskedastic errors. UP: Probit with fully general covariance matrix. Choleski decomposition of the covariance matrix is as diagonal entries, (1,b) and off-diagonal entry c.

5.2 Simulation

I conduct the simulations with the unstructured probit model. The simulated results are presented in Tables 6, 7 and 8, the first three rows of which report results for the entire population while the rows below focus on subsamples. The first subsample includes only transactions where merchants accept all means of payments and consumers have access to all three methods of payment. The results are presented in rows three to five. Rows six to fourteen present the changes in different types of goods, namely groceries, gasoline and purchases in the meals and entertainment categories, while the next nine rows break the sample down by size of the store. Finally, the sample is partitioned by transaction value.

In Table 6, column one contains the observed frequency shares and column two the frequency share predicted by the model. Comparing columns one and two assesses the fit of the model. Columns three to six show how the payment shares are allocated under discounts of 1%, 5%, and 10%, respectively, on cash purchases, while columns seven to ten shows this for debit discounts. The last column provides the weighted size of the subsample under consideration. Table 7 lists the relative changes for each method of payment, compared to the baseline prediction (no discounts) of the model. Table 8 contains the absolute changes and their significance levels.

Table 6: Unstructured Probit: Simulated payment shares

		Data	Model	Cash discount			Debit discount			Population size
				1%	5%	10%	1%	5%	10%	
All transactions	cash	0.519	0.519	0.528	0.577	0.648	0.513	0.494	0.472	6811
	credit	0.209	0.193	0.189	0.169	0.138	0.185	0.155	0.124	
	debit	0.271	0.289	0.283	0.254	0.213	0.302	0.352	0.404	
Unrestricted Choice	cash	0.417	0.423	0.434	0.492	0.580	0.418	0.398	0.376	4656
	credit	0.291	0.270	0.265	0.237	0.194	0.259	0.214	0.169	
	debit	0.292	0.307	0.301	0.271	0.226	0.323	0.387	0.455	
Type of good										
Groceries	cash	0.471	0.473	0.483	0.536	0.613	0.467	0.444	0.420	2518
	credit	0.180	0.165	0.162	0.143	0.115	0.157	0.126	0.097	
	debit	0.350	0.362	0.355	0.321	0.272	0.377	0.430	0.483	
Gasoline	cash	0.314	0.285	0.299	0.365	0.463	0.277	0.250	0.218	1676
	credit	0.392	0.370	0.363	0.332	0.284	0.359	0.316	0.259	
	debit	0.295	0.346	0.338	0.302	0.253	0.363	0.435	0.523	
Meal Entertainment	cash	0.715	0.728	0.734	0.759	0.793	0.725	0.712	0.695	1609
	credit	0.126	0.107	0.105	0.094	0.079	0.105	0.095	0.083	
	debit	0.159	0.165	0.161	0.147	0.129	0.170	0.194	0.222	
Store size										
1 cashier	cash	0.575	0.575	0.584	0.629	0.689	0.569	0.549	0.526	2096
	credit	0.193	0.177	0.173	0.154	0.127	0.171	0.150	0.125	
	debit	0.232	0.249	0.243	0.217	0.184	0.259	0.301	0.349	
2- 5 cashiers	cash	0.578	0.578	0.586	0.628	0.688	0.573	0.556	0.537	2685
	credit	0.185	0.169	0.166	0.149	0.122	0.163	0.137	0.110	
	debit	0.237	0.253	0.248	0.224	0.190	0.264	0.307	0.354	
6+ cashiers	cash	0.333	0.331	0.343	0.411	0.519	0.324	0.301	0.277	1609
	credit	0.277	0.260	0.255	0.229	0.185	0.247	0.197	0.149	
	debit	0.390	0.409	0.401	0.360	0.296	0.429	0.502	0.574	
Value										
below 5	cash	0.901	0.913	0.913	0.915	0.918	0.912	0.910	0.907	1424
	credit	0.023	0.012	0.012	0.012	0.011	0.012	0.012	0.012	
	debit	0.077	0.075	0.075	0.073	0.070	0.076	0.078	0.081	
5 to 10	cash	0.731	0.747	0.750	0.763	0.777	0.745	0.736	0.724	1197
	credit	0.085	0.064	0.063	0.060	0.056	0.064	0.062	0.061	
	debit	0.184	0.188	0.186	0.177	0.167	0.191	0.202	0.216	
10 to 25	cash	0.475	0.470	0.478	0.512	0.554	0.465	0.443	0.414	1715
	credit	0.193	0.172	0.169	0.158	0.145	0.169	0.160	0.148	
	debit	0.333	0.358	0.353	0.330	0.302	0.366	0.397	0.437	
25 to 50	cash	0.300	0.304	0.320	0.391	0.487	0.295	0.259	0.217	1255
	credit	0.333	0.302	0.296	0.267	0.227	0.294	0.259	0.216	
	debit	0.368	0.394	0.384	0.343	0.286	0.411	0.482	0.567	
50 to 100	cash	0.186	0.147	0.167	0.275	0.453	0.138	0.105	0.078	840
	credit	0.407	0.425	0.417	0.369	0.288	0.404	0.319	0.221	
	debit	0.407	0.427	0.416	0.356	0.259	0.458	0.576	0.700	
above 100	cash	0.085	0.068	0.095	0.303	0.624	0.056	0.033	0.022	380
	credit	0.532	0.493	0.483	0.390	0.221	0.443	0.251	0.110	
	debit	0.383	0.440	0.423	0.307	0.156	0.501	0.717	0.869	

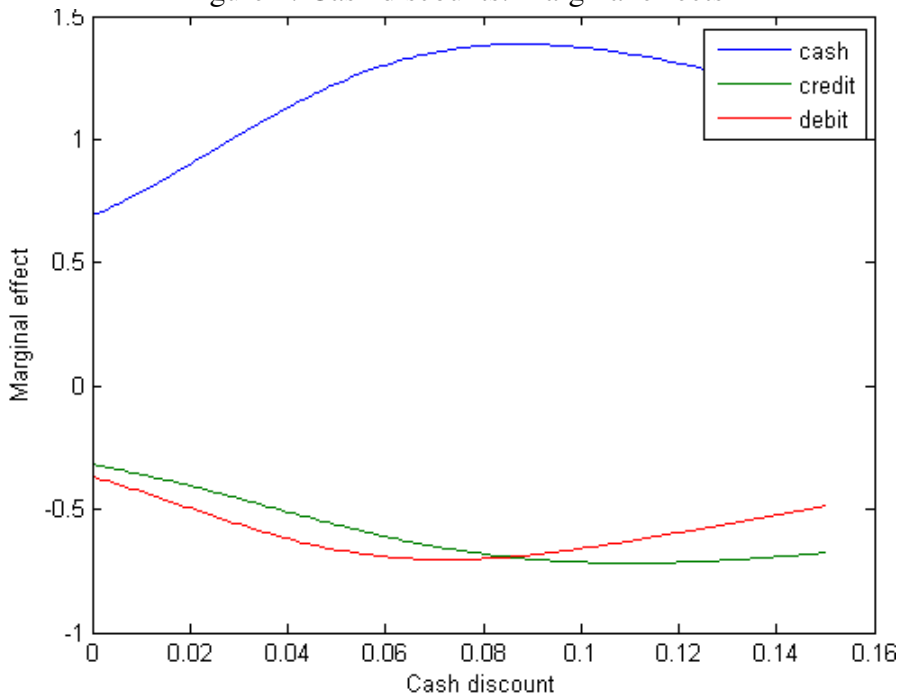
Table 7: Unstructured Probit: Relative changes in payment shares

		Cash discount			Debit discount		
		1%	5%	10%	1%	5%	10%
All transactions	cash	0.019	0.113	0.250	-0.010	-0.048	-0.090
	credit	-0.019	-0.121	-0.282	-0.039	-0.196	-0.358
	debit	-0.021	-0.122	-0.261	0.045	0.218	0.400
Unrestricted Choice	cash	0.026	0.162	0.371	-0.012	-0.059	-0.112
	credit	-0.019	-0.120	-0.282	-0.041	-0.205	-0.374
	debit	-0.019	-0.118	-0.264	0.053	0.262	0.484
Type of good							
Groceries	cash	0.022	0.133	0.297	-0.013	-0.061	-0.111
	credit	-0.021	-0.132	-0.304	-0.049	-0.237	-0.413
	debit	-0.019	-0.114	-0.250	0.040	0.187	0.333
Gasoline	cash	0.051	0.284	0.627	-0.025	-0.122	-0.235
	credit	-0.017	-0.101	-0.231	-0.028	-0.147	-0.299
	debit	-0.023	-0.125	-0.268	0.050	0.258	0.513
Meal Entertainment	cash	0.008	0.043	0.089	-0.004	-0.022	-0.045
	credit	-0.022	-0.126	-0.268	-0.023	-0.119	-0.228
	debit	-0.021	-0.109	-0.220	0.034	0.176	0.347
Store size							
1 cashier	cash	0.017	0.095	0.198	-0.009	-0.045	-0.084
	credit	-0.022	-0.128	-0.280	-0.030	-0.153	-0.292
	debit	-0.024	-0.129	-0.260	0.043	0.212	0.402
2- 5 cashiers	cash	0.014	0.086	0.191	-0.008	-0.038	-0.071
	credit	-0.019	-0.120	-0.278	-0.038	-0.190	-0.350
	debit	-0.020	-0.117	-0.249	0.043	0.213	0.396
6+ cashiers	cash	0.037	0.242	0.568	-0.021	-0.091	-0.163
	credit	-0.017	-0.117	-0.289	-0.049	-0.242	-0.427
	debit	-0.019	-0.121	-0.276	0.048	0.228	0.402
Value							
below 5	cash	0.001	0.003	0.006	-0.001	-0.003	-0.006
	credit	-0.008	-0.037	-0.073	-0.002	-0.009	-0.019
	debit	-0.007	-0.033	-0.064	0.007	0.035	0.072
5 to 10	cash	0.004	0.020	0.040	-0.003	-0.016	-0.032
	credit	-0.012	-0.061	-0.120	-0.005	-0.026	-0.052
	debit	-0.012	-0.059	-0.117	0.014	0.070	0.144
10 to 25	cash	0.017	0.088	0.177	-0.012	-0.059	-0.119
	credit	-0.015	-0.078	-0.157	-0.013	-0.068	-0.137
	debit	-0.015	-0.078	-0.157	0.022	0.110	0.222
25 to 50	cash	0.053	0.285	0.601	-0.030	-0.148	-0.286
	credit	-0.022	-0.118	-0.249	-0.028	-0.142	-0.285
	debit	-0.024	-0.130	-0.273	0.045	0.224	0.440
50 to 100	cash	0.136	0.867	2.075	-0.065	-0.284	-0.467
	credit	-0.020	-0.132	-0.324	-0.049	-0.251	-0.480
	debit	-0.027	-0.167	-0.393	0.071	0.348	0.639
above 100	cash	0.400	3.463	8.197	-0.173	-0.519	-0.681
	credit	-0.020	-0.208	-0.552	-0.100	-0.491	-0.778
	debit	-0.039	-0.301	-0.646	0.139	0.630	0.976

Table 8: Unstructured Probit: Absolute changes in payment shares

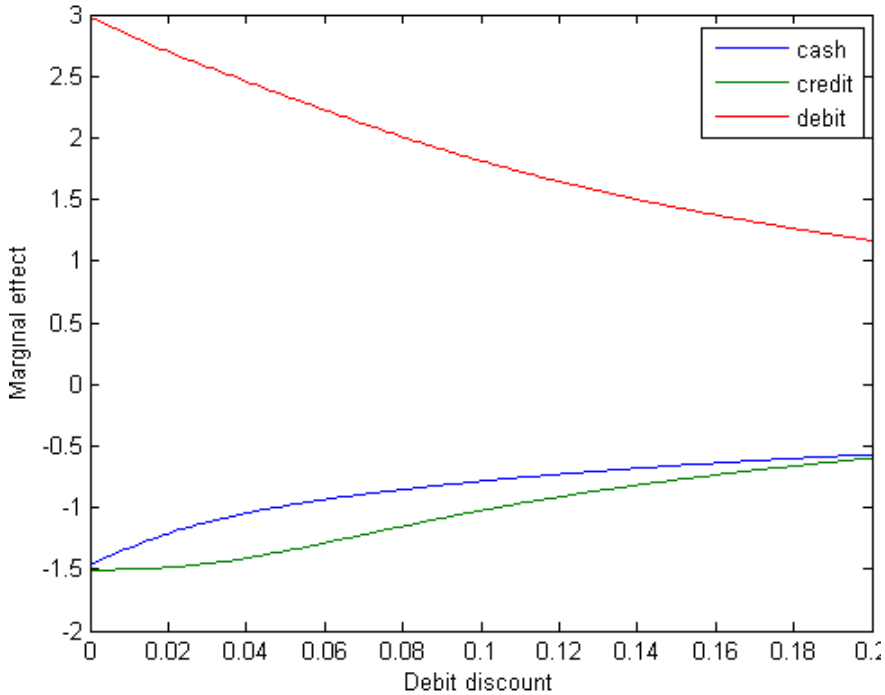
		Cash discount			Debit discount		
		1%	5%	10%	1%	5%	10%
All transactions	cash	0.010**	0.058**	0.130**	-0.005**	-0.025**	-0.046***
	credit	-0.004	-0.023**	-0.054**	-0.008***	-0.038***	-0.069***
	debit	-0.006**	-0.035**	-0.075***	0.013**	0.063***	0.115***
Unrestricted Choice	cash	0.011***	0.069***	0.157***	-0.005**	-0.025**	-0.048***
	credit	-0.005**	-0.032***	-0.076***	-0.011***	-0.055***	-0.101***
	debit	-0.006**	-0.036**	-0.081***	0.016***	0.080***	0.148***
Type of good							
Groceries	cash	0.010***	0.063**	0.141***	-0.006**	-0.029***	-0.052***
	credit	-0.003	-0.022**	-0.050**	-0.008***	-0.039***	-0.068***
	debit	-0.007***	-0.041***	-0.090***	0.014***	0.068***	0.121***
Gasoline	cash	0.014***	0.081***	0.178***	-0.007***	-0.035***	-0.067***
	credit	-0.006**	-0.037***	-0.086***	-0.010**	-0.054***	-0.111***
	debit	-0.008***	-0.043***	-0.093***	0.017***	0.089***	0.177***
Meal Entertainment	cash	0.006	0.031	0.065	-0.003	-0.016	-0.033
	credit	-0.002	-0.014	-0.029	-0.002	-0.013	-0.024
	debit	-0.003	-0.018	-0.036	0.006	0.029	0.057
Store size							
1 cashier	cash	0.010***	0.055**	0.114**	-0.005**	-0.026**	-0.048***
	credit	-0.004	-0.023**	-0.049**	-0.005	-0.027**	-0.052**
	debit	-0.006**	-0.032**	-0.065**	0.011**	0.053**	0.100***
2- 5 cashiers	cash	0.008**	0.050**	0.110**	-0.005	-0.022**	-0.041**
	credit	-0.003	-0.020	-0.047	-0.006**	-0.032**	-0.059**
	debit	-0.005**	-0.030**	-0.063**	0.011**	0.054**	0.100***
6+ cashiers	cash	0.012***	0.080***	0.188***	-0.007***	-0.030***	-0.054***
	credit	-0.004	-0.030***	-0.075***	-0.013***	-0.063***	-0.111***
	debit	-0.008***	-0.050***	-0.113***	0.020***	0.093***	0.165***
Value							
below 5	cash	0.001	0.003	0.006	-0.001	-0.003	-0.005
	credit	0.000	0.000	-0.001	0.000	0.000	0.000
	debit	0.000	-0.002	-0.005	0.001	0.003	0.005
5 to 10	cash	0.003	0.015	0.030	-0.002	-0.012	-0.024
	credit	-0.001	-0.004	-0.008	0.000	-0.002	-0.003
	debit	-0.002	-0.011	-0.022	0.003	0.013	0.027
10 to 25	cash	0.008**	0.041*	0.083	-0.005**	-0.028***	-0.056***
	credit	-0.003	-0.013	-0.027	-0.002	-0.012	-0.024
	debit	-0.006**	-0.028	-0.056	0.008	0.039*	0.079**
25 to 50	cash	0.016***	0.087***	0.183***	-0.009***	-0.045***	-0.087***
	credit	-0.007***	-0.036***	-0.075***	-0.008**	-0.043***	-0.086***
	debit	-0.010***	-0.051***	-0.107***	0.018***	0.088***	0.173***
50 to 100	cash	0.020***	0.128***	0.306***	-0.010***	-0.042***	-0.069***
	credit	-0.009***	-0.056***	-0.138***	-0.021***	-0.107***	-0.204***
	debit	-0.011***	-0.072***	-0.168***	0.031***	0.149***	0.273***
above 100	cash	0.027***	0.235***	0.556***	-0.012***	-0.035***	-0.046***
	credit	-0.010***	-0.103***	-0.272***	-0.049***	-0.242***	-0.383***
	debit	-0.017***	-0.132***	-0.284***	0.061***	0.277***	0.429***

Figure 2: Cash discounts: marginal effects



Note: Simulated marginal effect of cash discounts on MOP choice.

Figure 3: Debit discounts: marginal effects



Note: Simulated marginal effect of debit discounts on MOP choice.

5.3 Removing Rewards and the Willingness to Pay for Ease of Use

All probabilities are calculated for a transaction of $50 value at a grocery store with two to five cashiers, where cash and both payment cards are accepted. The aggregation is over respondents in each income category.

Table 9: Willingness to Pay Ease for Rewards, Card Users

	Rewards as observed P(credit)			No rewards P(credit)			Rewards equiv.		
	median	95 percent CI		median	95 percent CI		median	95 percent CI	
Low Inc.	0.174	0.160	0.187	0.169	0.156	0.182	0.052	0.044	0.063
Medium Inc.	0.278	0.264	0.293	0.267	0.264	0.293	0.114	0.103	0.124
High Inc.	0.393	0.378	0.408	0.377	0.363	0.393	0.130	0.122	0.138

Note: Obtained from 1000 bootstrap repetitions.

Table 10: Willingness to Pay Ease for Rewards, rewards program members

	Rewards as observed P(credit)			No rewards P(credit)			Rewards equiv.		
	median	95 percent CI		median	95 percent CI		median	95 percent CI	
Low Inc.	0.222	0.198	0.249	0.208	0.185	0.234	0.162	0.146	0.181
Medium Inc.	0.342	0.325	0.359	0.321	0.305	0.338	0.180	0.172	0.188
High Inc.	0.459	0.441	0.475	0.437	0.419	0.452	0.172	0.164	0.179

Note: Obtained from 1000 bootstrap repetitions.

Table 11: Credit card usage, Card owners without rewards

	median	95 percent CI	
Low Inc.	0.156	0.139	0.175
Medium Inc.	0.202	0.183	0.222
High Inc.	0.251	0.228	0.274

Note: Obtained from 1000 bootstrap repetitions.

5.4 Optimal Discounting

The previous section establishes that discounts could lead to significant changes in consumer payment choice if the discount is large enough. The merchant on the other hand must carefully consider whether the costs of offering the discount balance the benefits of processing a lower number of the most costly transactions. The answer will depend on the distribution of the merchants' transaction and their clients' preferences. The observed demographics, attitudes, cash management habits and shopping patterns are, by assumption, not affected by the discounts and merchants do not change their prices when they offer discounts. The distribution of transactions in the merchants' objection function $E(\pi)$ defined in (3) is therefore independent of the discount. The empirical version of the merchants' optimization problem is given by

$$\max_{d_{cs}\geq 0, d_{dc}\geq 0} \sum_{T} w_{i(T)} \sum pr_{mop}(T, \vec{d}) * V_{mop}(p(T), \vec{d}), \tag{11}$$

where T is a transaction in the data set and $w_{i(T)}$ the sampling weight of the transactor. The results of Arango and Taylor [2008b] serve as rough estimates for the transaction costs:

$$V_{cs} = 0.075 + 0.0047 * p + d_{cs} * p, \tag{12}$$

$$V_{cc} = 0.08 + 0.02 * p, \tag{13}$$

$$V_{dc} = 0.07 + 0.12 + d_{dc} * p. \tag{14}$$

where p is the transaction value. The constant term summarizes cost items that do not depend on the transaction size, such as tender time and costs associated with deposits or coin orders.

In the case of debit cards, the constant also contains the fixed fee of \$0.12 for a debit card transaction, since in Canada, unlike in other countries, payment processors do not charge proportional fees for debit cards transactions. The proportional fees for credit cards are payment processing fees (to a large extent the interchange rate) and costs for charge backs. For cash, the proportional part accounts for processing coins and bills, as well as the risk of theft and

counterfeits.

From this specification, cash is always less costly than credit cards. However, it is not always the cheapest MOP since at transaction values of about $40, debit cards become the least costly to accept. Merchants would also not be willing to offer a discount of more than 2% since their goal is to keep average transaction costs below the cost of credit card payment. Credit card fees can sometimes be as high as 3 percent, but even in this case the discount is constrained to the interval between zero and 3%.

As the decision to discount is ultimately up to the merchant, the optimization problem is not only solved for the whole sample (corresponding to the entire retail sector), but also in sub samples defined by certain merchant characteristics.

This strategy can answer the following questions:

(1) Is there a discount that would lower the average transaction cost for all transactions?

(2) Does the answer differ by retail sector or size of store?

(3) Is it profitable to discount only transactions above or below a certain value?

The answer is negative for all questions. In each case, the merchant would incur losses if a non-zero discount were offered. Hence, the optimization problem only has a corner solution where all discounts are equal to zero.

6 Discussion and Policy Implications

The results in Section 5 can explain why merchants in Canada do not take advantage of the provisions in the Code of Conduct for the credit and debit card industry and offer discounts to steer consumers away from credit cards to other means of payments. Yet, the relevance of the conclusions and policy implications depend on whether the model can accurately capture the effect of discounts on payment choice and merchant cost. The first and second parts of this section assess the econometric model for the demand side (the consumers). The third and

fourth subsections look at the statistical significance of the policy simulation. In the last part, I outline empirical and conceptual limitations.

6.1 Payment Choice Model

I estimate a payment choice model which can accommodate flexible substitution patterns between different means of payment. As reported in Table 6, the model performs well at fitting the overall frequencies and, since acceptance and card ownership are controlled for, it also fits well in the sub sample where all means of payment would have been available for the transaction. Similarly, the fit is good for each type of good and each size of store. There are slight overestimates of cash and debit card usage for lower transaction values and underestimates of card usage for high transaction values.

The most important variable for the policy simulation, financial incentives in the form of rewards, is highly significant. All coefficients related to the size of the transaction, the transaction value, its square and the indicator variables for small transaction values, are significant. Overall, larger transaction values increase the utility of card payments and more so for credit cards than for debit cards.

For grocery shopping, debit cards are the most popular, followed by cash; this ranking is captured by a significantly negative coefficient for these transactions in the credit card equation and a positive one in the debit card equation. Meal and entertainment purchases carry negative coefficients in the debit and credit card equations, indicating a propensity to pay in cash.

Perceptions are important predictors of payment choice: the more positive the light in which consumers see a mean of payment, the more likely they are to use it. Liquidity constraints matter, too: Larger typical cash holdings are associated with choosing cash more often, as well as higher monthly limits with higher credit card usage. Revolving on a credit card account reduces the utility of credit card payments. Intensity of card usage also increases for respondents who own either more debit or more credit cards.

In terms of demographics, younger people like cards more than their elders. Some of

the indicator variables for the place of residence are also significant. British Columbia was chosen as reference category, and the sign of the coefficient on a province variable compares the usage of credit or debit cards in that province to the usage in British Columbia.

Income is not a strong predictor in the payment choice models in Tables 4 and 5, at least not in the usually hypothesized way of higher income being a predictor of more frequent use of payment cards, in particular credit cards. The model already controls for card adoption which may be different across income groups. One possible explanation would be that at the intensive margin there are no significant differences in card usage. In other words, income would influence MOP adoption, but not the decision at the point of sale. Some other right-hand-side variables such as credit card rewards, credit cards limits, revolver status and number of credit cards vary with income and can cause the observed difference in credit card usage (see Table 11). Income levels depend on the province and hence the indicators for the provinces could capture part of the income effect.

6.2 Significance of Relaxing IIA

In two of my model the errors, of the random utilities are not iid. The more general error structure adds complexity to the model and increases the computational burden in the estimation. If the iid model is appropriate then the estimates for the covariance structure at the bottom of Table 5 should not reject

$$H_0 : \text{“the errors are independent and identically distributed.”}$$

For the *unstructured probit model*, the Choleski factor Δ of the error differences $[\epsilon_1 - \epsilon_2, \epsilon_3 - \epsilon_2]$ under H_0 is

$$H_0 : \Delta = \begin{pmatrix} 1 & 0 \\ 0.5 & \sqrt{0.75} \end{pmatrix},$$

while under H_1

$$H_1 : \Delta \neq \begin{pmatrix} 1 & 0 \\ 0.5 & \sqrt{0.75} \end{pmatrix}.$$

The estimated Choleski factor is

$$\hat{\Delta} = \begin{pmatrix} 1 & 0 \\ 0.402 & 0.647 \end{pmatrix}$$

and with the standard errors in Table 5 we can reject H_0 because the joint bivariate normal 95% confidence interval of $[b, c]$ does not contain the point $[0.5, \sqrt{0.75}]$. This conclusion is also confirmed by the likelihood ratio statistic which compares the iid probit with the unstructured probit.

For the *independent probit* , the parameter b is described completely in terms of c as $b = \sqrt{0.5 + c - c^2}$ and H_0 is $c = 0.5$. The hypothesis that errors are iid is again rejected, since 1 does not lie in the 95% confidence region of the estimated value of 0.123. Again, the likelihood ratio test confirms this rejection.

The intuition behind the rejection of the IIA hypothesis is ambiguous. Since the covariance structure is not iid, some unobserved correlation between the preferences for two different methods of payments could exist, or the overall scale of the utilities could vary across the population. For the present work, the correlation structure between the error terms is crucial since the IIA property of the logit would a priori force a structure on the relative changes in Table 7. For example, a cash discount would have the same relative effect on debit card payments as on credit card payments, the only source of difference being perceived acceptance or card ownership. Inspection of the estimated changes in the rows labelled as "Value", reveals that the simulated elasticities are not the same, in particualr at higher transaction values.[26]

In comparison, the logit model has the "best" likelihood function. On the other hand, since IIA is rejected for the probit model, the simple logit model may not be appropriate

[26]Log odds ratios are available on request.

either. A mixed logit model or a generalized logit model as in Wakamori and Welte [2012] could accordingly be estimated.

6.3 Effectiveness of Discounts

Overall, cash discounts and debit discounts have a significant effect on the estimated payment choice, but the effect is less significant for lower transaction values, since, by construction, the incentive to switch is greater for higher transaction values. Purchase values in the meals and entertainment category tend to be low, with averages below $20, and thus steering is not very effective here. Gasoline purchases, which are higher in value, have higher estimated switching probabilities. Merchants, however, also forgo larger amounts in revenues on these discounted transactions.

When all MOPs are available for the transaction, cash is used less frequently compared to when the choice is restricted, and discounts overall tend to be more effective in steering consumers to the discounted MOP (debit or cash).

The payment choice model can simulate substitutability patterns from debit to cash, and from credit to debit, which are usually hypothesized as being higher than the substitutability between credit and cash. Charts 2 and 3 plot the average marginal effects on MOP choice of cash and debit discounts, respectively. Cash discounts up to 6% have a stronger effect on debit card usage (Chart 2), while in turn debit card discounts appear to affect credit card users more strongly (Chart 3). Cash discounts have the strongest effect at about 5% compared to other values between 0% and 5%. By contrast, the marginal effect of debit card discounts declines with the size of discount.

By and large, the results are in agreement with other results found in the literature. That discounts cannot reduce merchants' cost of transacting is consistent with Briglevics and Shy who find that for most merchants a 1% discount would not be profitable even if half of the consumers were steered away from costlier means of payment. Judging by the marginal effects in Charts 2 and 3, a discount between 0% and 3% would actually re-allocate at most 12 per

cent of all transactions to the discounted method of payment.

6.4 Non-pecuniary Incentives

If merchants cannot use discounts to reduce their cost of accepting payments, what else can they do? An oversimplified suggestion would be to stop accepting credit cards, which, although consistent with some of the assumption in this paper, in reality is not a viable option. Retailers would lose customers who insist paying with a credit card. The retailer may therefore want to know if non-pecuniary incentives could steer consumer payment choice as effectively as rewards and discounts without imposing additional cost. If L is such an incentive entering the utility of using credit cards additively, willingness to pay for the incentive L can be measured by comparing the coefficient on L with the coefficient on rewards:

$$WTP = -\frac{\beta_L}{\beta_R}.$$

In other words, WTP is the dollar value of rewards that consumers are willing to give up to gain an extra unit of the incentive L. Among the determinants of payment choice, ease of use is the only transaction characteristic that significantly enters the decision process and that the retailer can, within means, influence. For example, he could refuse to accept contactless credit card payments or deliberately slow down the processing of credit card payments. With the results in Table 4, an estimate for the willingness to pay for ease of use of credit card payments is $WTP_L = 2.4$. In other words, each \$1 of rewards is worth a decrease of 0.42 units of the ease of use measure. Going back to the definition in (2), the rating of credit cards relative to cash would therefore have be smaller by a factor of $e^{-0.42} \cong 0.66$. For instance, if credit card usage was previously rated as 5 on a five-point Likert scale, then the rating would be reduced to about 3.

In the diaries, respondents state the most important reasons they choose a method of payment for their transaction. Ease of use is a reason for about 99 per cent of the cash and debit

transactions, but significantly less often for credit transactions, at 82 percent of the cases. On the other hand, about 70 per cent of the credit transactions are motivated by rewards, and this proportion rises to 89 percent when ease is not given as a reason. Consumers therefore substitute between convenience and pecuniary incentives.

The rewards equivalent of ease of use (REU) measures by how much a credit card's ease of use must be lowered to obtain the same overall probability of paying with that card as when no rewards are offered. A $\$50$ grocery shopping trip at a store with two to five cashiers is fixed as the benchmark case. Since high rewards are typically given to consumers whose annual income is above a certain threshold, the REUs should vary across income categories.

Table 9 reports in the first three columns the predicted share and its 95 per cent confidence interval when the respondents obtain the rewards as observed. The next three columns show the same statistics under the assumption that the rewards programs have been cancelled. Finally, the last three columns give the estimated REU for the subpopulation and a 95 per cent confidence interval. Table 10 repeats the same procedure for those respondents who collect rewards on their credit cards. In both tables, only merchants and consumers with a full choice set (cash, credit and debit) are considered.

The perceived ease of credit card usage would have to shift between 0.06 and 0.15 to have the same effect on credit card usage as cancelling all rewards programmes. As expected, higher income people have a higher REU because they have access to rewards more often. When the estimation is conducted on the respondents who actually have access to a rewards program, the REUs in Table 10 are similar across income categories. All credit card users, once they earn rewards, would therefore face similar trade-offs between the dollar value of rewards and ease of use. The REU for a medium income user with a rewards program is 0.176. The corresponding change in the perception of credit card usage is a factor of $\exp((-0.176) = 0.84$. Such a shift would have credit cards appear as significantly inferior to cash and debit cards in term of ease of use.

6.5 Rewards Programs

Credit card owners with high income are more likely to collect rewards when they use their credit card. However, those with a medium or low income react slightly more sensitively to the cancellation of the rewards program (see Table 10). For a $50 transaction at a grocery store, about 6 per cent of these credit card users would use another means of payment, if they lost their rewards. In the higher income category, only about 4 per cent would choose cash or debit instead, if they had no rewards. Higher income may thus be associated with lower elasticity of credit card usage to financial incentives.

Table 10 contains the estimated effect on credit card usage when all rewards programs are cancelled. The changes are small, on the order of 2 per cent. This sharply contrasts with the much larger figures obtained by other researchers. Simon et al. [2010] predict an overall shift of 23 per cent when credit card rewards programs are removed, based on Australian payment diary data. As they point out, issuers in Australia do not discriminate with respect to income or credit history when they offer membership in a loyalty program to a consumer, so that membership in a rewards program can be treated as exogenously given. Comparing column one in Table 9 with column four in Table 10 shows that, even after setting the rewards to zero, those who have a rewards program still choose credit cards significantly more often. Credit cards rewards are therefore correlated with other right-hand-side variables in the Canadian model.

The overall results are also lower than in Ching and Hayashi [2010b], who find that removing credit card rewards would lead to a decrease of 11 per cent in the probability that US cardholders use their credit cards for a grocery store transaction. On the other hand, payment choice in their paper is not directly observed, rather consumers state, based on memory, which method of payment they would most commonly choose for a grocery purchase.

The predicted propensity to use credit cards is lower among the credit card users without rewards than what the simulation yields for the loyalty program members when their rewards programs are cancelled. The differences are significant; a high-income person with rewards

is almost twice as likely to choose a credit card as that same person without rewards, as a comparison of Table 11 with Table 10 shows. Hence, rewards should not be looked at in isolation. Indeed, the credit card usage of rewards and non-rewards samples shows differences of the same order as Ching and Hayashi [2010b] or Simon et al. [2010].

6.6 Limitations

The present analysis is limited in a four ways by the available data and these limitations should be kept in mind when interpreting the results. To start, the data available on the supply side, namely the merchants, pose the most serious challenges. The marginal costs of cash, debit and credit card payments are adopted from the analysis of the survey data in Arango and Taylor [2008a] and are, in the authors' own words, "back-of-the-envelope" calculations. Also, although micro data on the merchant level was collected, the 2006 Merchant Survey did not allow for the estimation of cost functions that incorporate merchant characteristics such as size, revenue or industry type. Consequently, the imputed cost structure on the supply side is highly stylized.

Second, unavailability of data on changes in the shopping behaviour of consumers due to discounted prices also poses conceptual challenges. Merchants tend to operate in environments where lowering prices likely attracts more consumers while, at the same time, retailers are likely to respond to their competitors' discounts with discounts of their own, at least within small geographical areas. The analysis assumes perfectly inelastic (residual, thus specific to individual merchants) demands, due to lack of data on the actual demand elasticities individual merchants face. No consumer switching between merchants is therefore taken into account.

Third, when predicting the probability of MOP choice, the self-reported amount of cash a person typically holds enters as a predictor. This variable, however, is measured with considerable noise. The simulations of steering do not take into account the possibility that an individual is unable to respond to a cash discount due to lack of sufficient balances to pay for the transaction in cash. While it is feasible to impose this restriction, the restriction is un-

likely to fully capture the desired behavioural response. If cash discounts are more common, individuals will tend to hold larger cash balances as well.

Fourth, in the estimation procedure the choice set is adjusted in such a way as to capture the cases in which not all MOPs are available to the consumer for payment (due to lack of merchant acceptance or unavailability on the consumer side). These data on acceptance, however, are reported by the consumer and may not be reliable. Missing variables may bias the results due to sample selection. Briglevics and Schuh [2013] discuss a simple model which captures forward-looking adjustments to cash holdings ("cash withdrawals"). Schmidt-Dengler et al. [2013] find that, when card acceptance is uncertain, consumers hold more cash. Their work reveals an interesting link between the main limitations in this work, namely to account for cash balances and perceived acceptance.

In addition to these data limitations, two conceptual limitations arise. (i)The key assumption that the marginal utility of discounts is equal to the marginal utility of rewards cannot be tested form the available data. My discussion in Section 4.6 also addresses the issue that the model may not accurately capture how payment choice responds to rewards. Therefore, even if the key assumption is correct, the policy simulation would not accurately predict the effect of discounts. (ii)Finally, the usual policy-simulation critique applies: since the estimation is performed on data generated under a particular market structure and regulatory environment, simulation results should be interpreted with caution for alternative market structures and regulatory environments.

7 Conclusion

Ad-valorem discounts on cash and debit payments are not efficient in steering consumers away from credit card payments (arguably the most expensive MOP for merchants). Discounts do have the consequence of steering consumers away from all the non-discounted MOPs and this steering is more effective, due to the ad-valorem feature, in both absolute and relative

terms when the transaction values rises. However, the gains from steering consumer choice are found to be small compared to the overall cost of offering discounts, and the optimal solution for the merchant appears to be to avoid discounts; a conclusion consistent with the observation that discounts are rarely offered in Canada. When they are offered, transaction cost may not be the merchant's main motivation. Merchants could explore non-pecuniary incentives to steer consumer choice, although it is not clear how such incentives could be put in action. For example, merchants who actively slow down the processing of certain credit cards payments could be found in violation of their agreement with the payment processor, in particular with the "no-discrimination" clause. Moreover, clients could be turned away by what they perceive as bad customer service, and the merchant would see a marked decrease in revenue when wealthy credit card users stay away.

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A Data Appendix

The 2009 Bank of Canada MOP Survey consists of two parts: a survey questionnaire and a three-day diary. Originally, there were around 6,900 respondents to the questionnaire, and about half of them proceeded to the diary. Arango and Welte [2012] describe the survey instruments (survey questionnaire and diary) and the data collection process, and include tables of the key variables in the data set. More information can be obtained through the contacts in that survey report.

For the construction of the sample used in the estimation of the consumer choice model, additional data cleaning and manipulation were necessary. In order to calibrate the 2009 MOP survey sample to a representative sample of the Canadian population, a sampling weight is necessary to correct the sampling bias. Arango and Welte [2012] also outline how the weights were constructed.

A.1 Sample Construction

The sample excludes consumers who have missing information regarding their perceived acceptance, demographics and typical cash management, all of which are key variables in this study. Since the goal is to understand merchant steering at the point of sale, online, mail and telephone purchases are omitted from the sample. For the same reason, person-to-person transactions where no cashier is present are also excluded.

Of the originally 3,135 transaction diaries, only 86 per cent of these respondents have a complete record of their demographics and state their perceptions regarding means of payment and payment usage habits. The entries missing most often are those about carrying debt on a credit card and about typical cash holdings; both are unavailable for about 5 per cent of the records. In addition, 6 per cent of the respondent entries do not allow constructing for how they perceive credit and debit cards relative to cash. For about 13 per cent of the credit card owners, information on the level of rewards offered by their main credit card is unavailable.

The diaries contain about 16,000 transaction records, of which 12,709 are cash, debit or credit transactions, take place at a store or point-of-sale with cash registers and have a valid transaction amount. An incomplete list of payment alternatives is the greatest source of missing data in the diary, affecting 30 per cent of the transactions. Transactions above $300 and respondents who indicated cash holdings above $1000 are considered outliers and are dropped from the estimation sample. The final data set consists of 7,137 complete transaction performed by 1,999 respondents. If restricted to those consumers who have credit and debit cards, the data set is comprised of 1,779 respondents who made 6,443 transactions.

A.1.1 Comparison of raw and clean data

Tables 12, 13, 14 and 15 describe the respondent sample and their transactions. In the raw data, sample size varies with the number of observations available for each variable. In the cleaned data, the sample sizes those mentioned above, with the exception of rewards which are only calculated for credit card transactions.

Cleaning the data removes some variability from the observations, so that most estimates in the clean data set have a smaller range and a smaller sample deviation. The average respondent is between 44 and 45 years of age and most respondents live in Ontario or Quebec. Age and place of residence are similar in original, clean and card owner samples, and so are the perceptions of ease of use, cost and ability to keep records of transactions for each payment instrument. By construction, the card owners have more debit and credit cards and revolve more often on their credit cards. It appears that members of the clean and card owner samples have higher incomes compared to those who do not own payment cards or who give incomplete responses.

Cash holdings are the respondent level variable most affected by the cleaning procedure. The average cash holdings are reduced by almost $25 to a level of $65 in the cleaned data set, since the cleaning procedure discards all who report habitually carrying more than $1000 on them.

Turning to the transactions, in the cleaned data set about 52 per cent of all purchases are conducted with cash, 21 per cent with a credit card and 27 percent with debit cards. The share of cash transactions is higher in the original data set since most non-store transactions are dropped and these are often conducted in cash (see Table 16 in Arango and Welte [2012]). Non-store transactions may also be conducted in the absence of a payment terminal, which explains why credit cards are accepted more commonly in the cleaned data.

If respondents enter a cash withdrawal as a cash transaction, this record is also dropped from the sample because all withdrawals are eliminated in the cleaning procedure. The discarded purchases above $300 in value constitute less than 1.1 per cent of the sample, but their exclusion is necessary for proper convergence of the estimator.

The assumption that cash is always accepted is valid because all transactions in the sample take place at a store. Credit cards are perceived as accepted for about 72 per cent of all transaction and debit cards for 88 per cent. Card owners either perceive cards as more commonly accepted or tend to shop at locations that accept cards more frequently.

Table 12: All respondents

Respondent Characteristics	Raw Data				Cleaned Data			
	Mean	Std.Dev	Min	Max	Mean	Std.Dev	Min	Max
Sociodemographics								
Age	44.915	0.473	18	75	43.675	0.604	18	75
Income	5.859	0.086	1	10	6.303	0.103	1	10
Province								
BC	0.082	0.007	0	1	0.083	0.008	0	1
AB	0.082	0.009	0	1	0.083	0.014	0	1
SK	0.074	0.006	0	1	0.080	0.009	0	1
MB	0.069	0.007	0	1	0.065	0.008	0	1
ON	0.380	0.016	0	1	0.396	0.020	0	1
QC	0.241	0.013	0	1	0.220	0.016	0	1
NB	0.025	0.006	0	1	0.026	0.008	0	1
NS	0.023	0.002	0	1	0.025	0.003	0	1
PEI	0.010	0.003	0	1	0.008	0.001	0	1
NFL	0.014	0.002	0	1	0.014	0.002	0	1
Methods of Payments								
Cash holdings	88.017	15.056	0	200000	65.816	3.482	0	1000
Credit card								
Ease	0.023	0.007	-1.609	1.609	0.036	0.007	-1.609	1.609
Record keeping	0.434	0.020	-1.609	1.609	0.505	0.024	-1.609	1.609
Cost	-0.404	0.019	-1.609	1.609	-0.404	0.023	-1.609	1.609
Number of cards	2.188	0.059	1	14	2.291	0.078	1	14
Credit limit	4.573	0.098	0	8	4.628	0.126	0	7
Revolver	0.256	0.013	0	1	0.286	0.017	0	1
Debit card								
Ease	-0.010	0.006	-1.609	1.609	-0.005	0.009	-1.609	1.609
Record keeping	0.433	0.021	-1.609	1.609	0.498	0.027	-1.609	1.609
Cost	-0.411	0.018	-1.609	1.609	-0.395	0.021	-1.609	1.609
Number of cards	1.336	0.021	1	10	1.356	0.024	0	9
Number of respondents	variable				1,999			

Source: 2009 Bank of Canada Methods of Payment Survey, weighted estimates.

Table 13: Card owners

Respondent Characteristics

	Raw Data				Cleaned Data			
	Mean	Std.Dev	Min	Max	Mean	Std.Dev	Min	Max
Sociodemographics								
Age	45.287	0.453	18	75	43.726	0.528	18	75
Income	6.300	0.082	1	10	6.688	0.096	1	10
Province								
BC	0.086	0.008	0	1	0.089	0.009	0	1
AB	0.079	0.007	0	1	0.077	0.009	0	1
SK	0.078	0.007	0	1	0.079	0.009	0	1
MB	0.065	0.007	0	1	0.061	0.008	0	1
ON	0.387	0.016	0	1	0.412	0.020	0	1
QC	0.240	0.014	0	1	0.219	0.017	0	1
NB	0.022	0.004	0	1	0.020	0.004	0	1
NS	0.024	0.002	0	1	0.024	0.003	0	1
PEI	0.008	0.001	0	1	0.008	0.002	0	1
NFL	0.011	0.002	0	1	0.011	0.002	0	1
Methods of Payments								
Cash holdings	90.618	18.375	0	200000	65.595	2.965	0	1000
Credit card								
Ease	0.029	0.009	-1.609	1.609	0.044	0.009	-1.609	1.609
Record keeping	0.532	0.023	-1.609	1.609	0.612	0.026	-1.609	1.609
Cost	-0.494	0.022	-1.609	1.609	-0.490	0.026	-1.609	1.609
Number of cards	2.676	0.053	1	14	2.771	0.067	1	14
Credit limit	5.601	0.053	0	8	5.586	0.063	0	7
Revolver	0.321	0.015	0	1	0.349	0.018	0	1
Debit card								
Ease	-0.008	0.008	-1.609	1.609	-0.004	0.010	-1.609	1.609
Record keeping	0.457	0.021	-1.609	1.609	0.511	0.025	-1.609	1.609
Cost	-0.400	0.018	-1.609	1.609	-0.385	0.021	-1.609	1.609
Number of cards	1.390	0.021	1	10	1.393	0.024	0	9
Number of respondents	variable				1,799			

Source: 2009 Bank of Canada Methods of Payment Survey, weighted estimates.

Table 14: All respondents

Transaction Characteristics

	Raw Data				Cleaned Data			
	Mean	Std.Dev	Min	Max	Mean	Std.Dev	Min	Max
Payment shares								
Cash	0.550	0.007	0	1	0.519	0.010	0	1
Credit	0.189	0.005	0	1	0.209	0.008	0	1
Debit	0.246	0.006	0	1	0.271	0.009	0	1
Acceptance								
Cash	1	0	1	1	1	0	1	1
Credit	0.645	0.008	0	1	0.720	0.010	0	1
Debit	0.837	0.005	0	1	0.883	0.006	0	1
Transaction value								
Value ($)	38.910	1.371	0	7879.3	29.600	0.788	0.15	300
below 5	0.179	0.005	0	1	0.209	0.008	0	1
below 10	0.323	0.006	0	1	0.385	0.010	0	1
Rewards	0.456	0.041	0	75.032	0.294	0.015	0	4.695
Point of sale								
Size of store								
One cashier	0.323	0.007	0	1	0.308	0.010	0	1
Two to five cashiers	0.425	0.008	0	1	0.456	0.010	0	1
Six or more cashiers	0.247	0.006	0	1	0.236	0.008	0	1
Type of Good								
Groceries	0.291	0.006	0	1	0.370	0.010	0	1
Entertainment or Meal	0.197	0.005	0	1	0.246	0.008	0	1
Gasoline	0.067	0.004	0	1	0.063	0.006	0	1
Number of transactions	variable				7,137			

Source: 2009 Bank of Canada Methods of Payment Survey, weighted estimates.

Table 15: Card owners

Transaction Characteristics								
	Raw Data				Cleaned Data			
	Mean	Std.Dev	Min	Max	Mean	Std.Dev	Min	Max
Payment shares								
Cash	0.514	0.007	0	1	0.499	0.010	0	1
Credit	0.228	0.006	0	1	0.241	0.008	0	1
Debit	0.240	0.006	0	1	0.260	0.009	0	1
Acceptance								
Cash	1	0	1	1	1	0	1	1
Credit	0.826	0.005	0	1	0.838	0.008	0	1
Debit	0.855	0.005	0	1	0.894	0.007	0	1
Transaction value								
Value ($)	40.283	1.448	0	7879.3	30.068	0.787	0.15	300
below 5	0.183	0.005	0	1	0.206	0.008	0	1
below 10	0.323	0.006	0	1	0.377	0.010	0	1
Rewards	0.473	0.043	0	75.032	0.301	0.015	0	4.695
Point of sale								
Size of store								
One cashier	0.311	0.007	0	1	0.297	0.009	0	1
Two to five cashiers	0.426	0.008	0	1	0.458	0.010	0	1
Six or more cashiers	0.259	0.007	0	1	0.244	0.008	0	1
Type of Good								
Groceries	0.287	0.006	0	1	0.366	0.010	0	1
Entertainment or Meal	0.216	0.006	0	1	0.262	0.009	0	1
Gasoline	0.067	0.004	0	1	0.059	0.005	0	1
Number of transactions	variable				6,443			

Source: 2009 Bank of Canada Methods of Payment Survey, weighted estimates.

B Calculus and Formulas

B.1 The Merchant's Optimization Problem

The Lagrangian of the optimization problem is

$$\begin{aligned} L(\vec{d},\vec{\lambda}) &= \int_T \sum_{mop_T} pr_{mop}(T,\vec{d}) * V_{mop}(p(T),\vec{d})\, dT \\ &\quad - \left(\vec{\lambda} * [d_{cs}-1, -d_{cs}, d_{dc}-1, -d_{dc}]\right) \end{aligned}$$

The first order conditions are:

$$\int_T \frac{\partial pr_{cs}}{\partial d_{cs}} V_{cs} + pr_{cs} * \frac{\partial V_{cs}}{\partial d_{cs}} + \frac{\partial pr_{dc}}{\partial d_{cs}} V_{dc} + (-\frac{\partial pr_{cs}}{\partial d_{cs}} - \frac{\partial pr_{dc}}{\partial d_{cs}}) V_{cc} d\,T - \lambda_1 + \lambda_2. \quad (15)$$

$$\int_T \frac{\partial pr_{dc}}{\partial d_{dc}} V_{dc} + pr_{dc} * \frac{\partial V_{dc}}{\partial d_{dc}} + \frac{\partial pr_{cs}}{\partial d_{dc}} V_{cs} + (-\frac{\partial pr_{dc}}{\partial d_{dc}} - \frac{\partial pr_{cd}}{\partial d_{dc}}) V_{cc} d\,T - \lambda_3 + \lambda_4. \quad (16)$$

$$\lambda_1 \geq 0, d_{cs} < 1, \lambda_1 * (d_{cs} - 1) = 0. \quad (17)$$

$$\lambda_2 \geq 0, d_{cs} > 0, \lambda_2 * (d_{cs}) = 0. \quad (18)$$

$$\lambda_3 \geq 0, d_{dc} < 1, \lambda_3 * (d_{cs} - 1) = 0. \quad (19)$$

$$\lambda_4 \geq 0, d_{dc} > 0, \lambda_4 * (d_{cs}) = 0. \quad (20)$$

To have an interior maximum, i.e. $0 < d_{cs} < 1$ and $0 < d_{dc} < 1$, it is necessary that

$$\int_T \frac{\partial pr_{cc}}{\partial d_{cs}} (V_{cc} - V_{cs}) + pr_{cs} * \frac{\partial V_{cs}}{\partial d_{cs}} + \frac{\partial pr_{dc}}{\partial d_{cs}} (V_{dc} - V_{cs}) d\,\nu(T) = 0,$$

$$\int_T \frac{\partial pr_{cc}}{\partial d_{dc}} (V_{cc} - V_{dc}) + pr_{dc} * \frac{\partial V_{dc}}{\partial d_{dc}} + \frac{\partial pr_{cs}}{\partial d_{cs}} (V_{cs} - V_{dc}) d\,\nu(T) = 0.$$

Since discounts increase the cost of accepting a particular MOP and also increase the likelihood that the MOP is chosen, the positivity constraints on the discounts imply that the derivatives of each MOP's costs and probability with respect to its discount are positive; that is:

$$\frac{\partial pr_{cs}}{\partial d_{cs}} > 0, \frac{\partial V_{cs}}{\partial d_{cs}} > 0,$$
$$\frac{\partial pr_{dc}}{\partial d_{dc}} > 0, \frac{\partial V_{dc}}{\partial d_{dc}} > 0.$$

On the other hand, offering a discount for a MOP will decrease the probability of other MOPs being chosen

$$\frac{\partial pr_{dc}}{\partial d_{cs}} < 0, \frac{\partial pr_{cs}}{\partial d_{dc}} < 0,$$
$$\frac{\partial pr_{cc}}{\partial d_{cs}} < 0, \frac{\partial pr_{cd}}{\partial d_{dc}} < 0.$$

The first order conditions (15) and (16) can be re-arranged

$$\int_T \frac{\partial pr_{cc}}{\partial d_{cs}}(V_{cc} - V_{cs}) + \frac{\partial pr_{dc}}{\partial d_{cs}}(V_{dc} - V_{cs}) d\,T = -\int_T pr_{cs} * \frac{\partial V_{cs}}{\partial d_{cs}} d\,\nu(T), \tag{21}$$
$$\int_T \frac{\partial pr_{cc}}{\partial d_{dc}}(V_{cc} - V_{dc}) + \frac{\partial pr_{cs}}{\partial d_{cs}}(V_{cs} - V_{dc}) d\,T = -\int_T pr_{dc} * \frac{\partial V_{dc}}{\partial d_{dc}} d\,\nu(T). \tag{22}$$

Under the assumption that credit card are the most expensive method of payment for the merchant, signs can be assigned to the individual parts of the first order condition:

$$\int_T \underbrace{\frac{\partial pr_{cc}}{\partial d_{cs}}(V_{cc} - V_{cs})}_{(-)*(+)=(-)} + \underbrace{\frac{\partial pr_{dc}}{\partial d_{cs}}(V_{dc} - V_{cs})}_{(-)*(\pm)=(\mp)} d\,T = \underbrace{-\int_T pr_{cs} * \frac{\partial V_{cs}}{\partial d_{cs}}}_{(-)*(+)*(+)=(-)} d\,\nu(T), \tag{23}$$
$$\int_T \underbrace{\frac{\partial pr_{cc}}{\partial d_{cs}}(V_{cc} - V_{dc})}_{(-)*(+)=(-)} + \underbrace{\frac{\partial pr_{cs}}{\partial d_{dc}}(V_{cs} - V_{dc})}_{(-)*(\mp)=(\pm)} d\,T = \underbrace{-\int_T pr_{dc} * \frac{\partial V_{dc}}{\partial d_{dc}}}_{(-)*(+)*(+)=(-)} d\,\nu(T). \tag{24}$$

For ad-valorem discounts, these equations can be furthered simplified. Without loss of gener-

ality the baseline costs are now normalised in such a manner that $V_{cs}(\vec{0}, p) = 0$.

$$\int_T \underbrace{\frac{\partial pr_{cc}}{\partial d_{cs}}(V_{cc} - d_{cs} * p(T))}_{(-)*(+)=(-)} + \underbrace{\frac{\partial pr_{dc}}{\partial d_{cs}}(V_{dc} - d_{cs} * p(T))}_{(-)*(\pm)=(\mp)} \, d\, T = \underbrace{-\int_T pr_{cs} * p(T)}_{(-)*(+)*(+)=(-)} \, d\, \nu(T), \quad (25)$$

$$\int_T \underbrace{\frac{\partial pr_{cc}}{\partial d_{cs}}(V_{cc} - V_{dc})}_{(-)*(+)=(-)} + \underbrace{\frac{\partial pr_{cs}}{\partial d_{dc}}(d_{cs} * p(T) - V_{dc})}_{(-)*(\mp)=(\pm)} \, d\, T = \underbrace{-\int_T pr_{dc} * p(T)}_{(-)*(+)*(+)=(-)} \, d\, \nu(T). \quad (26)$$

An optimal interior solution for cash discounts is therefore the discount where the sum over the expected decrease of the gaps between the cost of cash and card transactions equals the total amount of cash spent (and mutatis mutandum for the optimal debit discount). If the amount of cash (or debit) card transactions on the right-hand-side is large, then a significant marginal effect on the probabilities or a large gap between cash and card (between debit and cash/credit) is necessary for an interior solution to exist.

B.2 Marginal Effects for the Discrete Choice Models

B.2.1 Logit model

The choice probabilities in the logit model are given by

$$pr_{ijt} = \frac{\exp(v_{ijt})}{\sum_{j' \in J_{it}} \exp(v_{ij't})}$$

where $u_{ijt} = v_{ijt} + \epsilon_{ijt}$ and the systematic component is linear in the observables. Let x_{njt} be an attribute of alternative j faced by consumer i for transaction t. Then, if j is in J_{it}, the marginal effects of a change in x_{njt} on the choice probabilities are

$$\frac{\partial pr_{ijt}}{\partial x_{njt}} = (1 - pr_{ijt}) pr_{ijt} * \beta_{jt}, \quad (27)$$

$$\frac{\partial pr_{ij't}}{\partial x_{njt}} = -(pr_{ij't}) pr_{ijt} * \beta_{jt} \text{ if } j' \in J_{it} \setminus \{j\}. \quad (28)$$

B.2.2 Probit model

In the probit model, the error terms ϵ_{ijt} follow a multivariate normal distribution $N(0, \Sigma)$ where Σ is a symmetric positive definite matrix. The choice probabilities are

$$Prob(v_{ijt} + \epsilon_{ijt} > u_{ij't}\epsilon_{ij't}\ \forall j' \in J_{it} \setminus \{j\}). \tag{29}$$

Let x_{njt} be an attribute of alternative j faced by consumer i for transaction t. For simpler notation, re-order the choices to obtain $j = 1$ and drop the individual level and transaction level indices. Then the marginal effects of a change in x_1 on the choice probabilities is given by

$$\frac{\partial pr_k}{\partial x_1} = \phi(\frac{v_k - v_1}{\sigma(\epsilon_k - \epsilon_1)}) * \Phi\left(\frac{v_k - v_{k'} - (v_k - v_1) * \frac{\sigma(\epsilon_k - \epsilon_{k'})}{\sigma(\epsilon_k - \epsilon_1)}}{\sqrt{(1-\rho^2)}\sigma(\epsilon_k - \epsilon_{k'})}\right)\frac{\partial(v_k - v_1)}{\partial x_1}, \tag{30}$$

$$\text{where} \{1, k, k'\} = \{1, 2, 3\},$$

$$\frac{\partial pr_1}{\partial x_1} = -\frac{\partial pr_2}{\partial x_1} - \frac{\partial pr_3}{\partial x_1}. \tag{31}$$