The Impact of Retail Payment Innovations on Cash Usage: Evidence from Survey Data *

Ben S.C. Fung[†] Kim P. Huynh[‡] Leonard Sabetti[§]

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Abstract

Many predict that innovations in retail payment may render cash obsolete. We investigate this possibility in the context of recent payment innovations such as contactless-credit and stored-value cards. We apply casual inference methods on the 2009 Bank of Canada Method of Payment survey, a representative sample of adult Canadians' shopping behaviour for retail consumption over a three-day period. We find that using contactless credit cards and stored-value cards lead to a reduction in the average cash ratio both in terms of value and volume. Our findings suggest that the impact on cash usage from new payment instruments may be more pronounced when they target low value transactions where consumers favor ease of use, speed and availability.

Key Words: Cash, Contactless-credit, Stored-Value Card, Treatment Effects.
JEL Classification: E41, C35, C83.

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[†]Corresponding Author: Bank of Canada, 234 Wellington St., Ottawa, ON K1A 0G9, Canada. Phone: +1 (613) 782 7686. E-mail: bfung@bankofcanada.ca.

[‡]Bank of Canada, 234 Wellington St., Ottawa, ON K1A 0G9, Canada. Phone: +1 (613) 782 8698. E-mail: khuynh@bankofcanada.ca.

[§]George Mason University, 4400 University Dr., Fairfax, VA, 22030, USA. Phone: +1 (703) 993 1151. E-mail: lsabetti@gmu.edu.

1 Introduction

Prior to past innovations in retail payment instruments such as cheques, credit cards and debit cards, the overwhelming majority of transactions were conducted with cash. Significant declines in cash usage for retail payments has prompted some observers to point to the dismal prospects for cash in light of future payment innovations. This paper investigate the impact of recent retail payments innovations, such as stored-value and contactless-credit cards, on household cash usage. These payment innovations are often described and marketed as substitutes for cash, promising fast, convenient and secure payment services at the point-of-sale.[1] However, innovations such as stored-value cards can also be complementary as they allow consumers to store cash on a payment card. Understanding the possible substitution away from cash to electronic payments is important for central banks, such as the Bank of Canada, as they are the sole supplier of cash.

To put things in context we provide a brief overview of the evolution of the payments landscape in Canada. Figure 1 shows how the usage of credit cards and debits cards has increased rapidly while cash withdrawals from automated teller machine (ATM) have fallen over the past 20 years. Table 1 provides estimates of cash usage in terms of value and volume based on aggregate network data. During this 20 year period, the share of cash has fallen. Debit and credit cards account for a large portion of the value substitution while debit has been captured a major portion of the cash volume share. However, despite the widespread diffusion of debit and credit cards the cash volume share illustrates that there is still a role for cash in retail payments.

To understand this phenomena, the Bank of Canada created the 2009 Method of Payments Survey that offers a clear picture of payment choice at the micro level. Table 2 illustrates that cash is dominant in volume and value for *micro payment* transactions i.e. less than 10 dollars. As transaction value rises, there is a shift to towards debit card in terms of volume and credit cards for value. Research by Arango, Huynh, and Sabetti (2011) show that consumer pref-

[1]Examples of stored-value cards are merchant gift cards, pre-paid VISA/Mastercard, etc. They were introduced into Canada around 2000. Contactless-credit cards were first introduced in 2006 and consist of chip embedded on the credit card. It promises convenience and speed as customers need only tap their card on a payment terminal instead of swiping the card and providing a signature for verification. For more information on the Canadian Payments landscape see the following report:
http://paymentsystemreview.ca/wp-content/uploads/Payments-Landscape-Full-Report-e3.pdf

erence for cash is correlated with speed or convenience, merchant acceptance and low costs. The main determinants of debit and credit card usage were safety, record keeping, the ability to delay payment and credit card rewards. Therefore, for card payments to compete with cash they must mimic the desirable features of cash.

Stored-value cards and contactless-credit cards were introduced to fill this niche. The attractiveness of these cards for micro payments is the speed of use (e.g. PayPass involves tapping your card at a POS terminal instead of swiping or entering a PIN code) and relative low costs for consumers. Currently, these payment innovations have minimal market share, see Table 2. Despite the relatively low market share there is a large potential for his market. For example, Borzekowski and Kiser (2008) predict that *contactless debit* in the U.S. will increase substantially in the next 10 years. Figure 2 shows that the payment profile of stored-value cards is similar to cash that is they are predominately used for low value transactions. For contactless-credit cards, see Figure 2, the profile is similar at intermediate transaction values (20-50 dollars) to debit.

To gauge the impact of these innovation on cash usage, we use data from the 2009 Bank of Canada Method of Payment (MOP) survey. Using casual inference methods we find that: one, the average treatment effect of stored-value cards results in a decrease of roughly 12 percent in the cash ratio in terms of value and 15 percent for volume; two, the average treatment effect of contactless-credit card results in a decrease of 13 percent in the cash ratio both in terms of value and volume; three, sensitivity analysis suggests the findings are robust to varying degrees of unobserved heterogeneity.

These results coincide with an overall decrease in bank notes in circulation. Figure 3 shows that the notes in circulation as a ratio of GDP has varied between three percent to five percent since 1961. After declining from roughly five percent of GDP in 1981 to a trough of just below three percent in 1981, it has remained fairly stable over the past 30 years. However, the trend by denominations offers a different perspective. Bank notes of $20 or less which are considered principally for retail transactions, have declined steadily since 1961 from roughly 3.5 to 1.2 percent. Meanwhile, bank notes of denominations of $50 and above often held for store-of-value or precautionary purposes, have seen an increase from 1.4 to 2.5 percent over this period. Over the last 40 years, there has been a considerable decline in the use of bank

notes for retail transactions. The decline in small value notes is consistent for many countries. Amromin and Chakravorti (2009) conduct a survey of cash usage in 13 countries (including Canada). They segment bank notes into low, medium and high denominations and conduct panel data estimates. They confirm that small value denominations are falling for transaction purposes. Larger denominations are increasing to serve as a store of value function.

The rest of this paper will proceed as follows: Section 2 will describe the micro data used in detail while Section 3 describes the empirical methodology. Section 4 highlights the results of the paper and Section 5 offers concluding remarks.

2 2009 Means of Payment (MOP) Survey

In order to provide a rich picture of the retail payment landscape, the Bank of Canada conducted an extensive micro survey of Canadians. The Bank of Canada 2009 MOP survey was conducted in November of 2009. Stratified random samples of adult Canadians aged 18 to 75 years old were drawn from access panels to obtain a national representative sample. The inclusion of an offline panel ensured coverage of the segment of the population without internet access. Survey respondents completed a survey questionnaire (SQ) and a three-day shopping diary (DSI), which was optional for participants from the online panel. The SQ included questions on demographics, banking and card information, perceptions on method of payment attributes and cash management or spending habits. The DSI collected records of payment behavior such as type of good purchased, value of transaction, payment method used, and whether any cash was obtained during the transaction. The survey comprised roughly 6,800 SQ respondents, and 3,180 DSI which generated over 15,000 transactions. Finally, sample weights were designed to combine both online and offline samples using the Statistics Canada 2009 Canadian Internet Use Survey (CIUS) and a random digital dialing telephone survey.

The survey specifically asks respondents whether their main credit card was embedded with the contactless feature and whether the feature was used for transaction purposes. Questions about stored-value cards also appear in the survey. Table 2 shows the market shares in volume and value for each retail payment instrument used by individuals in the 2009 MOP Survey. It shows that cash still accounts for about half of all consumer spending in terms of volume

but only about 20 percent in terms of value. Credit cards and debit cards account for about the remaining half in terms of volume, and 76 percent in terms of value. As can be seen, the shares of contactless-credit and stored-value cards are both very small. In 2009, the share of the contactless-credit card transactions was 1.2 and 0.9 percent in volume and value, respectively. Stored-value card purchases represented 1.1 and 1.6 percent in volume and value, respectively.

We construct two measures of cash usage based on value and volume. For each individual in the DSI, we compute the cash value share or the ratio of total value of cash purchases to total value of all purchases. The second measure, the cash volume share is the ratio of total number of cash purchases to total number of all transactions. We suspect the effect on volume could be more important as the use of payment innovation is more greatly concentrated at the lower transaction value spectrum. We use these measures as opposed to a measure of cash holding, whether at the start of the diary or some average, due to the endogeneity between cash holding and spending. A large cash holding may be party motivated by the anticipation of incurring a large purchase or may be due to precautionary motives. Another issue is that cash holdings is also strongly linked to economic transactions above and beyond retail locations. As a result, we exclusively focus on cash spending at retail locations as a proportion of total spending, and abstract from cash holdings. We only include respondents in our sample who conducted at least three transactions in the DSI. Conditioning on this sample, the average respondent conducts about six transactions, or roughly two per day. Although a diary of longer duration may have resulted in richer payment histories, the costs of collecting such information as well as the limitations of survey completion rates and fatigue effects, made three days the most practical length. For a practical suggestion on diary length see Jonker and Kosse (2009).

Table 3 distinguishes users of contactless-credit and stored-value cards (innovators) between individuals who do not (non-innovators). The sample of innovators is more skewed towards the higher income and education brackets, and also spends more on average in the DSI and carries higher average bank account balances. Table 4 highlights the cash value and volume shares across innovators and non-innovators. The average non-user of contactless, with access to a credit card, spends roughly 32 percent of total value of purchases using cash while this number falls to 12 percent for contactless users. The average stored-value card user spends roughly 17 percent of total value using cash compared to 37 percent for the average non-user.

In terms of volume, the average non-innovator conducts roughly half of all purchases in cash. The ratio of number of cash purchases to the total number of purchases in the DSI falls to 33 percent for the average contactless-user and to 29 percent for the average stored-value card user. Lower cash ratios in terms of both value and volume between payment innovators and non-innovators is also consistent across demographic groups, such as by income levels. Table 4 also highlights a correlation between cash ratios in value and volume and some observable variables. For instance, the cash ratios are declining as income rises, and as debit and credit cards are more often accepted during one's shopping history. Furthermore, higher rankings of cash in terms of perceptions such as record keeping are associated with higher cash ratios in value and volume. The correlation across age seems to exhibit a U-shaped pattern, with higher cash usage seen across young adults under 25 and the elder over 55. The results are in line with previous studies such as Stavins (2001), inter alia.

From the DSI we can observe some interesting empirical facts about the use of contactless-credit and stored-value cards in relation to the traditional payment methods, cash, debit and credit. For example, Table 5 shows that the use of stored-value cards varies across types of purchases but that the bulk of purchases, roughly 43 percent, fall in the category of entertainment or meals, which also includes popular coffee outlets. Contactless-credit card purchases are overwhelmingly used for groceries, 56 percent, and at gasoline stations, 24 percent. Interestingly, the share of contactless-credit purchases in the retail goods category falls to roughly three percent, compared to 22 percent for credit cards. The lower use of contactless-credit feature relative to the traditional swipe-method for this class of purchases which are generally larger on average and more time-intensive suggests both reduced availability from the merchant side and less demand for facilitating the speed of the transaction from the consumer side.

Table 6 characterizes the average transaction value by payment method, comparing both weekday and weekend, and morning and afternoon or evening. The data reveal how purchases in the morning are on average smaller than when conducted in the afternoon, and similarly, purchases are on average larger on the weekend than on a weekday. The average transaction value of a stored-value card purchase in general matches closest with the average transaction values for cash purchases, but are slightly larger. This result may be explained by the fact that stored-value card purchases are used slightly more often for gasoline and retail goods pur-

chases relative to cash. Average contactless-credit purchases are consistently smaller than the average credit card purchases, but this relationship is most evident when comparing among AM purchases. The average morning contactless-credit card is roughly a third of the average morning credit card purchase. Demand for convenience and speed tends to be higher for morning shopping.

The descriptive statistics offer preliminary suggestive evidence that payment innovation, defined by usage of contactless-credit and stored of value cards, is leading to a reduction of cash usage. However, we also observe that payment innovators are not a random sample from the broader population and the decision to use payment innovation may not be exogenous to cash usage. In the next section we discuss how empirically we can conduct a more appropriate assessment.

3 Empirical Methodology

From our descriptive statistics we find that respondents holding less cash are most likely to use innovative payment choices. This raises the endogeneity issues of whether innovation drives cash usage or vice-versa. Also, there maybe a selection issue whereby a third, unobserved factor, causes an individual both to select an innovative feature and simultaneously to use less cash. An example could be an individual's preference for technology. Under a scenario of selection bias, the causal effect of payment innovation on cash usage may be confounded. The advantage of the 2009 MOP Survey is that beyond pertinent observable characteristics for each individual, whether demographics, banking profile or shopping behaviour, the inclusion of perceptions on payment attributes captures what otherwise would be unobserved heterogeneity. We can estimate the relationship using an OLS regression

$$CR_i = \mathbf{X_i}\beta + \delta PI_i + u_i, \tag{1}$$

where CR_i is cash ratio, PI_i takes a value of one if the individual uses innovation and zero otherwise, and $\mathbf{X_i}$ is the vector of observables. In order to obtain an unbiased estimate of $\hat{\delta}$, the causal parameter, we require that PI is strictly exogenous. However, this assumption is usually not tenable as the adoption of innovation may have feedback effects, see the work of two-sided markets by Rysman (2007).

Therefore, the usage of payment innovation is non-random so we need to control for selection. A common approach, suggested by Duca and Whitesell (1995), is to estimate a two-system equation which models the outcome or cash ratio and the selection or payment innovation:

$$\begin{aligned} CR_i &= \mathbf{X_i}\beta_1 + \delta PI_i + u_i, \\ PI_i^* &= \mathbf{X_i}\beta_2 + \rho \mathbf{W_i} + \epsilon_i. \end{aligned} \tag{2}$$

Where PI_i^* represents the latent utility from using payment innovation or

$$PI_i = \begin{cases} 1, & \text{if } PI_i^* > 0 \\ 0, & \text{otherwise} \end{cases}. \tag{3}$$

However, this methodology requires variables, $\mathbf{W_i}$, that are correlated with the probability of payment innovation but does not directly affect cash usage. In the econometric literature this shifter is known as an exclusion restriction. The robustness of the results will hinge on the quality of these exclusion restrictions which can be difficult to ascertain.[2] Without exclusion restrictions, identification depends on strong assumptions of normality and functional forms, which may not be tenable.[3]

An alternative way to disentangle these issues of selection is to use panel data to account for unobservables. In Lippi and Secchi (2009) or Fujiki and Tanaka (2009), the authors use the panel structure of their data, Italian and Japanese household data, respectively, to control for unobserved heterogeneity. Unfortunately, our study does not contain panel data and so this feature cannot be exploited.

3.1 Program Evaluation Approach

As an alternative to using parametric treatment effects model (2), we draw from the program evaluation literature and adopt the potential outcome or counterfactual framework, see Imbens and Wooldridge (2009) for a more complete treatment. With respect to both measures of cash

[2]Attanasio, Guiso, and Jappelli (2002) in their study of Italian household data use provincial variation in the number of bank branches and ATMs as an exclusion restriction. They argue that the geographical variation in banking should affect adoption but not money demand.

[3]Other examples of this methodology are Stix (2004), Schuh and Stavins (2010), inter lia. Our attempt to implement this procedure resulted in implausible estimates, due to the parametric specification that the error terms follows a bivariate normal distribution.

usage in terms of value and volume, we can define $CR_i(PI_i)$ as the cash ratio for individual i, which can take on either of two values, $CR_i(1)$ for innovators ($PI_i = 1$) and $CR_i(0)$ for non-innovators ($PI_i = 0$). The causal impact can be defined as a counterfactual, $CR_i(1) - CR_i(0)$, the difference between cash ratios for individual i as a payment innovator and as non-innovator. However, we only observe either $CR_i(1)$ or $CR_i(0)$. Instead we compare the cash ratio for a payment innovator with a non-innovator where both share the same observable characteristics.

We can state this quantity as taking the expectation of the difference in cash ratios between innovators and non-innovators, conditional on a set of observables, known as the average treatment effect (ATE) and average treatment effect on the treated (ATT):

$$\tau_{ATE|\mathbf{X}} = E[CR_i(1) - CR_i(0)|\mathbf{X_i}], \tag{4}$$

$$\tau_{ATT|\mathbf{X}} = E[CR_i(1) - CR_i(0)|\mathbf{X_i}, PI = 1]. \tag{5}$$

The ATE ($\tau_{ATE|X}$) represents the causal effect for a randomly drawn individual across the entire sample whereas the the ATT ($\tau_{ATT|X}$) conditions on the sample of innovators. $E(\cdot)$ denotes the expectations operator, a weighted average. From a policy perspective, the later quantity may be more relevant for individuals in the sample who are more likely to become payment innovators. The group of innovators is typically referred to as the treatment group, whereas the non-innovators would be the control group.

In practice, we can estimate the $\tau_{ATE|X}$ and $\tau_{ATT|X}$ by comparing innovators and non-innovators with the same propensity score, $p(PI_i = 1|\mathbf{X_i})$, which denotes the probability that individual i uses payment innovation conditional on observable characteristics. This technique, known as propensity-score matching (PSM), allows for simple estimation of the desired causal impact because it reduces the matching problem from a vector of observable characteristics to a simple unit-dimensional measure. We can write the PSM estimators for $\tau_{ATE|X}$ and $\tau_{ATT|X}$ as,

$$\widehat{ATE} = \hat{\tau}_{ATE|X} = \frac{1}{N}\sum_{i=1}^{N}\frac{[PI_i - \hat{p}(X_i)]CR_i(PI_i)}{\hat{p}(X_i)[1 - \hat{p}(X_i)]}, \tag{6}$$

$$\widehat{ATT} = \hat{\tau}_{ATT|X} = \frac{1}{N_1}\sum_{i=1}^{N}\frac{[PI_i - \hat{p}(X_i)]CR_i(PI_i)}{1 - \hat{p}(X_i)}, \tag{7}$$

where N_1 is the number of individuals using payment innovation, i indexes over the total sample of N individuals. Intuitively these estimators can be interpreted as an average of cash ratios

weighted by propensities to use payment innovation. We use *psmatch2* to implement the estimation in *Stata*, see Leuven and Sianesi (2003), with the propensity score estimated, denoted by $\hat{p}(X_i)$, using the flexible Logit specification.

A technical assumption required is the overlap assumption, individuals with the same characteristics must be observed both participating and non-participating in payment innovations, or $0 < p(PI_i = 1|\mathbf{X_i}) < 1$. Intuitively, otherwise we would not have a comparison group for this subset of the sample. This later assumption is verified by comparing the propensity scores of the two groups. Upon visual inspection, we find that the two distributions have substantial overlap, results are available upon request.

Our analysis is undertaken in the spirit of Mulligan and Sala-i-Martin (2000) who model the extensive and intensive margins of money demand. They explicitly model the decision to adopt a bank account (extensive margin) and find that it affects one-half of the interest elasticity especially at low interest rates. The intensive margins are important if there are large variations in the interest rates. However, at low interest rates the extensive margins dominate since there is a lot of heterogeneity or variation across households.

3.2 Sensitivity Analysis: Rosenbaum Bounds

Crucial to the validity of our results is the assumption known in the literature as ignorability of treatment, that conditional on $\mathbf{X}$, the decision to use payment innovation is random, or in other words, that it is exogenous to the cash ratio decision. Known as unconfoundedness or selection on observables, the assumption requires that two individuals with the same observable characteristics will both be just as likely to participate in innovation. In order for this assumption to hold, there must not exist any remaining factor beyond our current set of control variables that systematically causes two identically observed individuals to differ in their odds of using payment innovation, referred to as hidden bias.

In practice, we cannot directly test the unconfoundedness assumption. However, we can offer some guidance on how much of an impact on the decision to use payment innovation some unobserved factor must have in order to render our results insignificant using the Rosenbaum bounds sensitivity analysis, as described in Rosenbaum (2002). The Rosenbaum bounds (RB), are framed in terms of ratio of propensities to use innovation for two matched individ-

uals, a payment innovator and a non-innovator, with the same observed characteristics. The probability of payment innovation can be written as:

$$p(PI_i|\mathbf{X_i}) = F(\mathbf{X_i}\beta + \gamma u_i), \tag{8}$$

where u denotes an unobserved variable, γ is a scalar and F denotes a cumulative density function. Assuming there is no hidden bias, $\gamma = 0$, then the log-odds ratio $p(PI_i|\mathbf{X_i})/p(PI_i|\mathbf{X_i}) = 1$ where $\mathbf{X_i} = \mathbf{X_j}$. If hidden bias exists then $\gamma > 0$ so that the log-odds ratio $p(PI_i|\mathbf{X_i})/p(PI_i|\mathbf{X_i}) \neq 1$. Sensitivity analysis evaluates how increasing the extent to which an unobserved factor impacts the ratio of propensities between two matched individuals reduces the statistical significance of the treatment effect. The RB is the upper bound on how much hidden bias can be tolerated. We use the *rbounds* program to implement the procedure, see Gangl (2004).

4 Results

Propensity score estimates for the first stage are displayed in Table 7. The treatment effect results are summarized in Table 8 and Table 9 for contactless-credit and stored-value cards, respectively. We include results from a simple model controlling for demographics only and a full model which controls additionally for shopping characteristics from the DSI, and perceptions on payment method attributes. To capture additional heterogeneity we include each respondent's cash ratio relative to the average within a demographic strata, following Stango (2000). The appendix contains a more complete description of the variables used. We define the treatment group as users of payment innovation during the DSI, in one case contactless-credit and the other stored-value card. Both cases have as control group non-users of payment innovation, however, the control group for contactless-credit users excludes individuals without access to credit cards.

Overall, the results suggest that using recent payment innovations are negatively impacting cash usage, in terms of both value and volume. Specifically, the $\widehat{ATE}$ on the cash value share is roughly -13 and -11 percent for contactless-credit and stored-value cards, respectively. The $\widehat{ATE}$ on the cash volume share is roughly -13 and -14 percent, respectively. For an average non-innovator in the DSI who spends \$64 in cash transactions, the treatment estimates would imply that cash spending would drop to \$38 if they had used contactless-credit card and \$44

if they had used a stored-value card. Similarly, the number of cash transactions would fall by close to one transaction on average.

4.1 Sensitivity Analysis

These results are quite significant but are smaller than the difference in means obtained from analyzing Table 4 and than the model that can only account for demographics. Results from OLS are similar but have large confidence intervals. Controlling for additional observable characteristics in the full model seems to reduce potential bias. The Rosenbaum bounds range from 1.35 to 2.61 and suggest that our results are quite tolerant to unobserved bias. Only the results for the impact on the cash value share due to stored-value cards are somewhat less convincing, which seems to intuitively follow from the fact that stored-value cards are mostly used for small value transactions.

For concreteness, we relate the RB to observable factors. For the case of $\widehat{RB} = 2$, if an unobserved factor caused a payment innovator to be twice as likely to innovate than a non-innovator, our results would lose statistical significance. Following Bharath, Dahiya, Saunders, and Srinivasan (2009), we can solve for the magnitude of a change in an observed covariate necessary to obtain $\widehat{RB} = 2$. Based on the logit model, the ratio of propensities should change by a factor of

$$\widehat{RB} = \exp(\beta_k s_k n), \tag{9}$$

where β_k is the logit coefficient and s_k is the standard deviation of variable k. Setting this quantity equal to $\widehat{RB} = 2$, we can solve for n for each continuous variable in our model. For example, *ceteris paribus*, for an individual from a matched pair age would have to increase by 7.5 years or merchant card acceptance would have to increase by 30 percent for the treatment effects to become insignificant. These findings suggest our results may remain statistically significant even in the presence of unobserved factors.

4.2 Robustness

Table 10 provides a summary of the robustness for various treatment and control groups. We find that the results are qualitatively the same when the treatment group is defined as users of

payment innovation with the control group being either defined as non-users, or non-adopters. Furthermore, the results are similar when we classify the control group as adopters of payment innovation but who are not observed to use them during the course of the diary. There is only a marginally negative impact when the treatment group is adopters of payment innovation and control group is non-adopters. However, when we exclude the users of payment innovation, the impact from adoption is zero. Exhausting the possible cases demonstrates that the impact is primarily due to using payment innovation. In the case of contactless-credit, adoption is not necessarily a choice of the individual and those who have this feature may not use them. Adoption of stored-value cards is also not necessarily a permanent feature of one's portfolio and therefore the impact from solely adopting this payment feature may not be evident.

5 Conclusion

We investigate the effects of innovations of retail payment instruments on the use of bank notes in Canada. We also find some evidence that recent innovations in Canada such as contactless credit cards and stored-value cards have led to a reduction in cash usage. We find that stored-value cards are primarily used for low-value transactions, under $10, while contactless-credit cards are mostly used for intermediate-value transactions, ranging from $10 to $ 40.

These results confirm the hypothesis that payment innovations have led to a decrease in cash usage. The increasing popularity of credit cards and debit cards over the past 20 years have resulted in a shrinking share of bank notes in retail transactions, both in terms of volume and value. However, the advent of contactless-credit cards and stored-value cards, which are designed to be more convenient and less costly, pose a major threat to cash usage. Borzekowski and Kiser (2008) "predict that contactless debit will take market share from cash, checks, and credit, and that the age/cohort effect alone is unlikely to cause debit card use to increase substantially over a 10-year period."

One of the limitations of using the 2009 MOP Survey data in this type of study is that it can provide only a snapshot of the impact of innovation on cash usage. In 2009, the contactless-credit card was in nascent stage of deployment and therefore our results may be underestimating the current impact. The Canadian Financial Monitor is a household dataset that is

conducted on a biannual basis. To better understand the impact of innovation on cash usage, it would be useful to consider how innovation affects cash usage over time. We leave this issue for future research.

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A Appendix

A.1 Variable List

Demographics:

- *Income*: The SQ asks, "which of the following categories best describes your current annual household income?"
- *Education*: The SQ asks, "what is the highest level of education you have completed?"
- *Age*: The SQ asks, "In what year were you born?"
- *Family size*: The SQ asks, "How many family members, including yourself, live in your household?"
- *Gender*: The SQ asks, "What is your gender?"
- *Homeowner or renter*: The SQ asks "Do you rent or own your home?"
- *Bank account balance*: The SQ asks "What was the lowest balance and the highest balance in your main bank account in the last month?" From these responses we obtain an average bank account balance.

- *Survey access panel*: We control for whether respondents stemmed from the Offline panel.

DSI:

- *Credit/Debit card accepted:* The DSI asks the respondent for each method of payment respectively, "Which method of payment would NOT have been accepted?" For each individual, we calculate the share of transactions for which both credit and debit were accepted.

- *Type of Transaction*: For every transaction, the DSI asks the respondent, "What was the main type of goods or service purchased during this transaction?" The following categories: gasoline, goods/retail, services, hobby/sports, entertainment, other. For each individual, we calculate the share of purchases made of each type relative to the total number of purchases.

- *Weekend*: The DSI asks the respondent for each transaction to report the day of the week on which it was made. Based on this, we calculate the share of weekend purchases for each individual.

- *Time of day*: The DSI asks the respondent for each transaction to report the time of day on which it was made. Based on this, we calculate the share of PM purchases for each individual.

Perceptions:

- *Ease of Use:* The SQ asks the respondent "When making a payment, in your opinion how easy is it for you to use each of the following methods of payment? Please use a scale from '1' to '5', where '1' means it is "not at all easy to use" and '5' means it is 'very easy to use.' We calculate the perception for cash relative to credit and debit.

- *Record Keeping:* The SQ asks the respondent "In your opinion how useful are (or would be) the following methods of payment in terms of helping you to keep a record of your spending. Please use a scale from '1' to '5', where '1' means it is "not at all useful" and '5' means it is 'very useful.'We calculate the perception for cash relative to credit and debit.

- *Cost:* The SQ asks the respondent "Taking into consideration costs such as withdrawal fees, account fees, and interest paid, in your opinion how costly is it (or would it be) to make a payment using the following methods of payment. Please use a scale from '1' to '5', where '1' means it is "not at all costly" and '5' means it is 'very costly.' We calculate the perception for cash relative to credit and debit.

- *Risk/Fraud:* The SQ asks the respondent "In your opinion, how likely is it (or would it be) that you will experience fraud in the next year when using the following methods of payment? Please use a scale from '1' to '5', where '1' means it is "not at all likely" and '5' means it is 'very likely.' We calculate the perception for cash relative to credit and debit.

Group: We define strata according to age and income groups, and then construct relative measures of cash value and volume share for each respondent in terms of the average cash share of their respective stratum.

Table 1: Volume and Value Shares for Cash, Credit Cards and Debit Cards

	Value			**Volume**		
	Cash	Debit Card	Credit Card	Cash	Debit Card	Credit Card
1989	0.375	0.001	0.623	0.743	0.001	0.256
1999	0.332	0.269	0.399	0.679	0.190	0.131
2009	0.194	0.300	0.506	0.498	0.297	0.205

Note: Numbers displayed are in proportions. Cash proportions are based on projections using ATM withdrawals. The source of the data is derived from the Bank for International Settlements.

Table 2: 2009 Means of Payment Survey

	Value				**Volume**			
TV	Overall	< 10	10-40	40 +	Overall	< 10	10-40	40 +
Cash	0.211	0.744	0.397	0.109	0.513	0.797	0.429	0.168
Debit	0.437	0.168	0.359	0.330	0.271	0.125	0.351	0.382
Credit	0.328	0.065	0.225	0.537	0.191	0.047	0.204	0.417
Contactless-Credit	0.012	0.003	0.011	0.013	0.009	0.003	0.009	0.022
Stored-Value	0.011	0.019	0.009	0.011	0.016	0.028	0.008	0.012

Note: Numbers displayed in proportions, based on 12,271 transactions in DSI.

Table 3: Who is Using New Payment Instruments?

	Contactless-Credit		**Stored-Value**	
	No Use	Use	No Use	Use
Less 30K	0.104	0.042	0.160	0.041
30K-50K	0.188	0.094	0.205	0.180
50K-80K	0.244	0.276	0.244	0.198
Over 80K	0.463	0.588	0.391	0.581
High School	0.210	0.123	0.252	0.203
Some College	0.440	0.370	0.458	0.426
Post-Secondary	0.350	0.506	0.291	0.371
Bank Balance	3338.92	3942.93	2986.36	3027.05
Total Spending DSI	221.62	261.45	205.80	247.11
Respondents	1779	126	2051	134

Note: Statistics are computed for respondents with three or more retail purchases in DSI. Bank Balance and Total Spending DSI are in dollars. Income, education statistics are in proportions. Non-users of contactless-credit exclude respondents without access to a credit card.

Table 4: Cash Ratios in Value and Volume

	Value				**Volume**			
	NI	CL	NI	SVC	NI	CL	NI	SVC
Overall	0.317	0.121	0.368	0.173	0.484	0.327	0.521	0.293
Less 30K	0.469	0.178	0.501	0.296	0.600	0.239	0.615	0.363
30K-50K	0.370	0.129	0.424	0.108	0.527	0.336	0.559	0.234
50K-80K	0.284	0.121	0.360	0.152	0.456	0.345	0.518	0.300
Over 80K	0.278	0.116	0.289	0.191	0.456	0.324	0.466	0.303
Bank balance $<$1000	0.357	0.080	0.410	0.162	0.502	0.263	0.538	0.258
Bank balance 1000 to 2000	0.288	0.211	0.345	0.170	0.450	0.396	0.495	0.305
Bank balance 2000 -4500	0.341	0.133	0.364	0.168	0.501	0.380	0.525	0.247
Bank balance $>$4500	0.278	0.086	0.328	0.194	0.480	0.288	0.517	0.373
Age $<$25 years	0.371	0.084	0.411	0.288	0.502	0.141	0.536	0.337
Age 25 - 35 years	0.244	0.068	0.296	0.092	0.401	0.228	0.431	0.236
Age 35- 45 years	0.319	0.168	0.337	0.164	0.494	0.443	0.509	0.267
Age 45- 55 years	0.297	0.099	0.336	0.163	0.495	0.343	0.523	0.270
Age $>$ 55 years	0.365	0.156	0.446	0.219	0.522	0.345	0.585	0.385
Cards accepted (-)	0.443	0.170	0.484	0.245	0.657	0.488	0.671	0.412
Cards accepted (+)	0.219	0.090	0.265	0.144	0.351	0.226	0.389	0.245
Record keeping (-)	0.261	0.107	0.293	0.156	0.440	0.273	0.462	0.296
Record Keeping (+)	0.394	0.145	0.451	0.203	0.546	0.423	0.588	0.287

Note: Numbers displayed in percent. NI:non-innovators, CL: contactless-credit users, SVC: stored-value users. Based on DSI. Record keeping (+) denotes favorable view towards using cash for record keeping purposes. Cards accepted (+) denotes above average number of retail locations during diary accepted both debit and credit.

Table 5: Transaction Type Across Payment Methods

	Cash	SVC	Debit	Credit	CL
Groceries	0.327	0.243	0.426	0.327	0.562
Gasoline	0.043	0.067	0.088	0.124	0.235
Retail Goods	0.066	0.090	0.134	0.218	0.031
Services	0.028	0.010	0.031	0.049	0.019
Hobby/Sports	0.036	0.014	0.045	0.056	0.012
Entertainment/Meals	0.338	0.429	0.176	0.133	0.086
Other	0.162	0.148	0.100	0.093	0.056
Number of Transactions	5676	210	3391	2832	162

Note: Numbers are in proportions.Based on 12,271 transactions in DSI.

Table 6: AM versus PM, Weekday vs. Weekend

		Cash	SVC	Debit	Credit	CL
Week	AM	10.97	4.92	47.23	68.00	24.15
	PM	15.76	36.88	39.55	79.90	51.48
Weekend	AM	14.08	8.67	45.71	70.88	42.08
	PM	18.15	34.34	46.63	92.73	55.04

Note: Numbers are in dollars. Based on 12,271 transactions in DSI.

Table 7: Logit Propensity Score

	Contactless-Credit		Stored-Value	
	Demo	Full	Demo	Full
30k-50k	0.331	0.856	1.058*	0.741
	0.55	1.02	0.5	0.64
50k- 80k	1.013	1.638	0.796	0.231
	0.58	1.23	0.52	0.76
More than 80k	0.89	1.839	1.327*	0.667
	0.67	1.31	0.54	0.93
Some college	0.175	0.168	-0.002	0.091
	0.54	0.55	0.4	0.4
Post secondary	0.607	0.639	0.198	0.209
	0.54	0.53	0.46	0.48
West	-0.999**	-0.311	0.329	0.033
	0.38	0.55	0.3	0.51
Quebec	-0.514	-0.357	-0.529	-0.505
	0.39	0.41	0.46	0.44
Atlantic	0.195	0.185	-0.659	-0.684
	0.41	0.42	0.38	0.42
Age	0.081	0.081	-0.004	0.01
	0.06	0.06	0.06	0.07
Age squared	-0.001	-0.001	0	0
	0	0	0	0
Family Size	0.434***	0.452***	0.088	0.123
	0.12	0.13	0.15	0.16
Male	0.078	0.049	-0.096	-0.167
	0.33	0.34	0.27	0.27
Not Married	0.201	0.347	-0.214	-0.276
	0.35	0.37	0.3	0.32
Employed Full-Time	-0.062	-0.093	0.316	0.28
	0.43	0.46	0.38	0.39
Renter	0.511	0.623	-0.267	-0.149
	0.37	0.39	0.33	0.34
Ease of use		-0.337		-0.182
		2.09		1.2
Fear of fraud		-1.358*		0.756
		0.54		0.42
Cost		1.660*		-1.131
		0.66		0.62
Record keeping		-0.12		-0.156
		0.62		0.57
Share of PM purchases		-0.188		0.041
		0.51		0.5
Share of weekend purchases		0.355		0.132
		0.42		0.36
Share of groceries		-0.005		-0.324
		0.77		0.55
Share of gasoline		1.495		-0.765
		1.37		1.03
Share of enteratinment		0.116		0.986
		0.8		0.71
Card acceptance		-1.895		2.165
		3.8		3.72
Respondents	1905	1905	2185	2185

Note: Standard errors in parentheses. The 1, 5, and 10 percent level of significance are denoted via ***, **, *, respectively. Estimates obtained using survey weights. The base category for income is Less than 30K, for education is High School, and for region is Ontario. The estimation sample for contactless-credit excludes respondents without access to credit cards.

Table 8: Contactless-Credit Impact on Cash

	Value		**Volume**	
	Demo	Full	Demo	Full
OLS	-0.171	-0.136	-0.146	-0.108
	(-0.231,-0.111)	*(-0.197,-0.075)*	*(-0.228, -0.063)*	*(-0.167, -0.049)*
ATE	-0.153	-0.137	-0.149	-0.130
	(-0.191,-0.115)	*(-0.179,-0.095)*	*(-0.202, -0.096)*	*(-0.187, -0.074)*
ATT	-0.141	-0.123	-0.131	-0.104
	(-0.179,-0.104)	*(-0.159,-0.087)*	*(-0.181, -0.082)*	*(-0.155, -0.054)*
RB	1.81	1.60	2.43	2.09

Note: 95 percent confidence intervals displayed in parentheses and are constructed with 1000 bootstrap replications. Demo denotes Demographics while Full is Demographics + DSI + Perceptions.

Table 9: Stored-Value Card Impact on Cash

	Value		**Volume**	
	Demo	Full	Demo	Full
OLS	-0.144	-0.127	-0.191	-0.181
	(0.201, -0.0870)	*(0.183,-0.071)*	*(-0.249, -0.134)*	*(-0.237, -0.125)*
ATE	-0.126	-0.115	-0.157	-0.145
	(-0.172,-0.081)	*(-0.164,-0.065)*	*(-0.199,-0.115)*	*(-0.189,-0.102)*
ATT	-0.113	-0.097	-0.150	-0.131
	(-0.155,-0.070)	*(-0.138,-0.055)*	*(-0.190,-0.109)*	*(-0.171,-0.092)*
RB	1.46	1.35	2.61	2.29

Note: 95 percent confidence intervals displayed in parentheses and are constructed with 1000 bootstrap replications. Demo denotes Demographics while Full is Demographics + DSI + Perceptions.

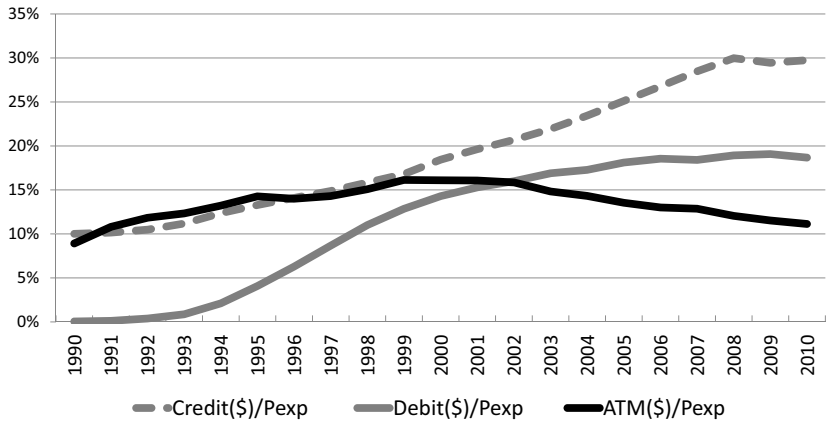
Table 10: Treatment and Control Groups

	Non-adopters	Adopters non-users	Users
	N_N	N_{AN}	N_U
Contactless Credit Card	1487	292	126
Stored-Value Cards	1621	461	103

Case	1	2	3	4	5
Treatment Group	N_U	N_U	N_U	$N_U + N_{AN}$	N_{AN}
Control Group	$N_{AN} + N_N$	N_N	N_{AN}	N_N	N_N
ATE: Contact-less Credit Card	(-)***	(-)***	(-)***	(-)*	0
ATE: Stored-Value Card	(-)***	(-)***	(-)***	(-)*	0

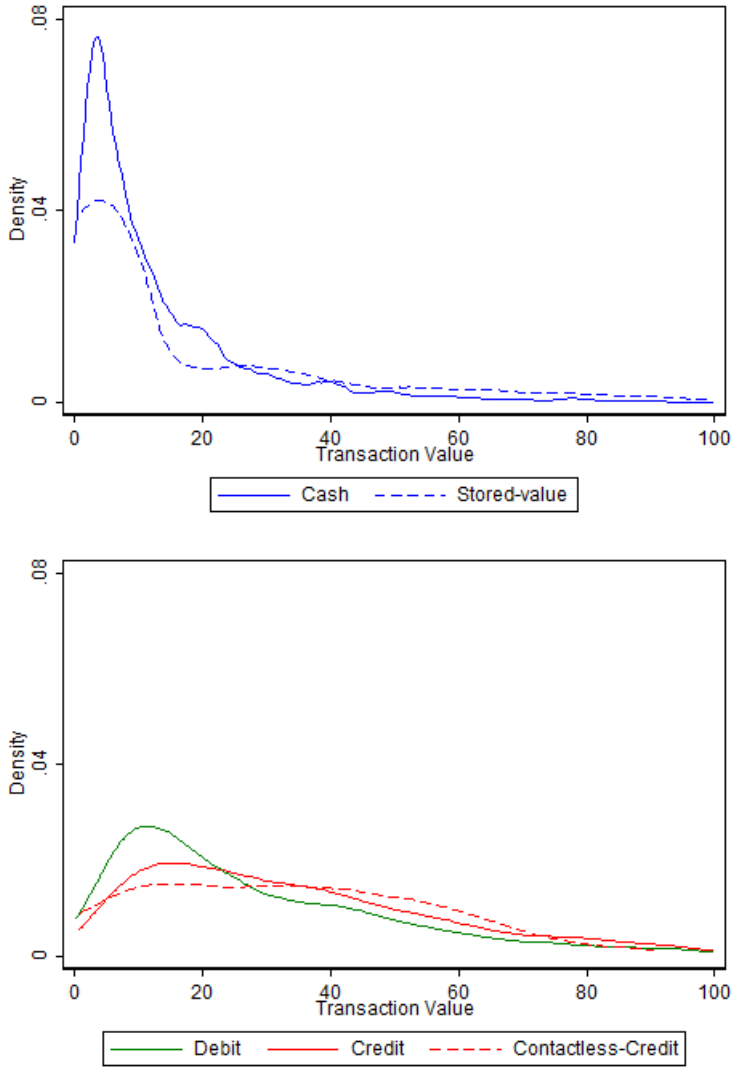
Note: We define non-adopters (N_N) as respondents who do not have access to the technology during the diary. Adopters non-users (N_{AN}) defines respondents who have access but do not report using the technology. Users (N_U) are respondents who report using the technology at least once during the diary. ATE are the average treatment effects.

Figure 1: Payment Shares



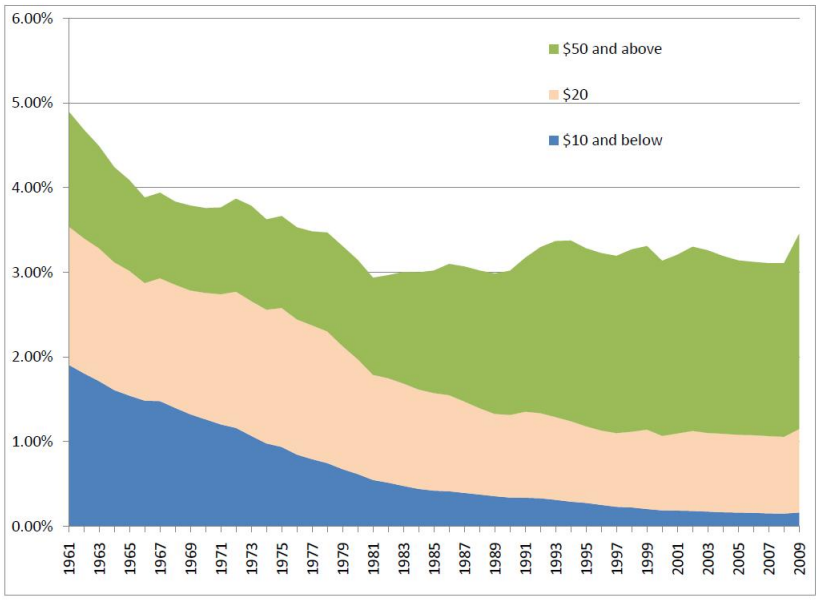
Source: Bank of Canada. Value of debit, credit card and ATM cash withdrawals relative to personal expenditures.

Figure 2: Payment Choice Densities



Note: These densities illustrate the probability of using a payment choice at certain transaction value. For example, the probability of using cash is highest for transaction values less than 20 dollars. The transaction value is truncated at 100 dollars and the number of DSI transactions is 11,471.

Figure 3: Notes in Circulation as a Ratio to GDP



Source: Bank of Canada. This figure illstrates the value of bank note as a ratio to GDP in terms of three denominations: small (10 dollars and below), medium (20 dollars) and large (50 dollars and above).