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Cashless Stores and Cash Users

Oz Shy

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Abstract: The emergence of cashless stores has led several cities and states to ban such stores. This paper investigates this issue by characterizing consumers who pay cash for in-person purchases and consumers who do not have credit or debit cards. I construct a model of consumer payment choice and use data on payments to calibrate the burden imposed on consumers who do not have credit or debit cards from switching to cashless stores. The conclusion provides a discussion of alternatives to cash for in-person purchases that may be needed before all brick-and-mortar stores become cashless.

JEL classification: D9, E42

Key words: cashless stores, consumer payment choice, in-person purchases, alternatives to cash

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Please address questions regarding content to Oz Shy, Research Department, Federal Reserve Bank of Atlanta, 1000 Peachtree Street NE, Atlanta, GA 30309, oz.shy@atl.frb.org.

1. Introduction

Imagine entering a store, picking up a few items, and then existing the store without going through a checkout counter. No, this isn't necessarily a theft, as a chip embedded under the buyer's arm or in her mobile device is scanned on the way out and a cashless payment is made. This sounds very efficient, however, digging into the question how consumers fund these payments reveals that not all consumers can benefit from such payment systems. This is because not all consumers have credit cards, debit cards, or even bank accounts that that are needed for funding cashless payments. On the regulatory side, the emergence of cashless stores has led several cities and states to ban such stores. Starting July, 2019, Philadelphia's new law will require most retail stores to accept cash. Cashless businesses are already banned in Massachusetts and more recently in New Jersey.[1]

This study focuses on the consumer side of this debate by investigating how consumers with and without credit and debit cards pay for their in-person purchases. Therefore, the effects of shifting to cashless stores on merchants and total welfare are not evaluated in this study because different merchants have different preferences over payment instruments, and these preferences are hard to estimate because they tend to be merchant specific. For example, small merchants in high-crime area would benefit from abandoning cash. Merchants with low profit margins may prefer cash to avoid paying high fees for processing credit cards transactions and to shorten their wait time between the sale and when the funds are credited to their bank account. Some cost estimates of transitioning to a cashless transactions are given in Garcia-Swartz, Hahn, and Layne-Farrar (2006) and references therein.

It is important to emphasize that this paper is *not* about phasing out cash or cashless society. The limited goal is to investigate how a transition to cashless stores would affect consumers in general and consumers who do not have credit or debit cards in particular. This paper also abstracts from the debate on whether large denomination notes should be eliminated in order to reduce crime, tax evasion, or to allow for negative interest rates, see Rogoff (2016) and counter

[1]See, https://www.wsj.com/articles/philadelphia-is-first-u-s-city-to-ban-cashless-stores-11551967201 and http://fortune.com/2019/04/03/cashless-stores-retail-amazon-go/.

arguments in McAndrews (2017).

The goal of this research is to identify and characterize the consumer population that would be affected the most by transitioning to cashless stores. Eliminating cash from in-person purchases would have mixed welfare consequences depending on the type of consumer. More precisely, consumers who pay cash but already have non-cash means of payments, such as credit and debit cards, may find it easy to switch to non-cash payments. In contrast, consumers who do not have credit or debit cards will be forced to purchase prepaid cards unless other non-cash means of payments become available without having to open an account in a commercial bank.

The theoretical section of this article and the calibrations focus on survey respondents who do not have credit or debit cards but reported making in-person purchases. Disregarding paper checks, these consumers are left with two options: paying cash or with prepaid cards. Using a model of differentiated payment instruments, I derive a method for calibrating the burden on these consumers associated with a hypothetical complete transition to cashless stores. In fact, recently several large sports stadiums began experimenting with cashless concession stands and ticket offices. For fans that do not carry credit or debit cards, the stadium provides reverse ATMs where consumers insert cash and get back a prepaid card.[2]

A complete transition to cashless stores would be extremely difficult in any country (if not impossible) particularly because cash use at the point-of-sale remains strong in most countries. Fung, Huynh, and Stuber (2015), Arango, Huynh, and Sabetti (2015), David, Abel, and Patrick (2016), Wakamori and Welte (2017) explore the intensity of cash use, and how cash dominates low value transactions. Studies by Bagnall et al. (2016) and Khiaonarong and Humphrey (2019) provide international comparisons of the intensity of cash use.

This article is organized as follows. Section 2 describes the data. Section 3 characterizes in-person purchases, cash users, and consumers who do not have credit or debit cards. Section 4 constructs a model of consumer payment choice and calibrates the burden of transitioning consumers who do not have credit or debit cards to a cashless stores environment. Section 5 provides a discussion of alternatives to cash for in-person purchases that may be needed before all brick-

[2]https://www.cnbc.com/2019/03/03/arthur-blanks-next-stadium-revolution-going-cashless.html.

and-mortar stores become cashless.

2. Data, variable selection, and coding

The study of consumer payment choice at the point-of-sale (POS) involves a classification of payment methods such as cash, paper checks, credit cards, debit cards, and prepaid cards. Data on "how consumers pay" are collected by consumer surveys in which consumers list all the payment instruments they have (adopt) and whether and how they use them at the POS. In particular, *diary* surveys record, either in real time or by the end of each day, all consumers' payment-related activities including dollar amount, spending type, merchant type, and payment method as well as money transfers in general and ATM cash withdrawals in particular.

The data and the R-code used in this analysis are available for downloading from the author's Webpage: www.ozshy.com (click on "Recent articles"). The data are taken from the 2017 Survey and Diary of Consumer Payment Choice (SCPC and DCPC).[3] Both, the SCPC and the DCPC are representative samples of U.S. consumers. The DCPC records transactions during three consecutive days. Transactions include purchases, bill payments, ATM withdrawals and deposits. Respondents' three day diaries were evenly distributed throughout the month of October 2017 in a way that resembles a three-period overlapping generations model.

Both, the SCPC and the DCPC have a large number of variables describing all sorts of demographics and transactions. For the purpose of this article, I will focus only on a subset of variables, some of which I describe below. From the SCPC, I use five cost assessment variables "as003a2–e2" and two binary variables "cc_adopt" and "dc_adopt" indicating whether the respondent has a credit card and a debit card, respectively, see Table 1. Respondents who took both the SCPC and the DCPC are matched via "prim_key" which is a unique ID number of survey respondents.

Most of the variables are taken from the DCPC which records actual transactions. In particular, I restricted the analysis to 9192 "in-person" (in-person $= 1$) payments made by 2257 respondents;

[3]The survey and the diary are conducted in collaboration of the Federal Reserve Banks of Atlanta, Boston, Richmond, and San Francisco (Cash Product Office). The data and assisting documents (codebooks) are publicly available for downloading from the Federal Reserve Bank of Atlanta Website: https://www.frbatlanta.org/banking-and-payments/consumer-payments.aspx, and are summarized in Greene and Stavins (2018b) and Kumar, Maktabi, and O'Brien (2018). Similar surveys are conducted by the Bank of Canada, see Henry, Huynh, and Shen (2015).

and then further restricted to 7313 payments made by 2062 respondents in six merchant categories (merch $= 1$ to 6) using the five major payment methods (pi $= 1$ to 5): "cash," "check," "credit card," "debit card," and "prepaid card," see Table 2.[4] Other variables used include "amnt" (dollar amount of each payment), "age" and "income_hh" (household income), and "ind_weights" which are individual sample weights.

Finally, a note about the use of sample weights. The data contain weights for all respondent ("ind_weights") that can be used to match the data with the adult U.S. population (18 and older). I indicate when the reported statistics are computed with weights either by (weighted) or (w) inside tables. Otherwise, the reported statistic is not weighted. In general, statistics on small subsamples or subgroups are reported without weights, because these subsamples may be correlated with some demographic variables upon which the weights are computed.[5]

3. In-person purchases, card adoption, and cash users

This section uses the data described in Section 2 to characterize consumers who pay cash for in-person purchases. Figure 1 shows how respondents' use of the five main payment instruments for in-person purchases vary with the payment amount. The top panel shows that about 70 percent of all payments not exceeding $5 were made with cash. This ratio drops to about 50 percent for payment amounts between $5 and $10. Uneven spacing on the x-axis reflects the relative number of payments in the relevant dollar amount range.

Perhaps the most striking empirical result, shown on the bottom panel in Figure 1, is that the average share of cash payments (again by volume of in-person purchases) is above 8 percent for payment amounts between $100 and $400.

[4]The merchant categories are: 1. Grocery stores, convenience stores without gas stations, pharmacies, 2. gas stations, 3. sit-down restaurants and bars, 4. fast food restaurants, coffee shops, cafeterias, food trucks, 5. general merchandise stores, department stores, other stores, and 6. general services: hair dressers, auto repair, parking lots, laundry or dry cleaning, etc.

[5]Table 2 provides a good example where the weighting can potentially reduce accuracy. A comparison between the percentage of payments % and the corresponding weighted value % (w) shows that the difference between the two increases when the sample size is restricted according to respondents' card adoption profile. For example, the column on the right (prepaid) shows that the difference is $(2.5 - 2.1)$ for the All sample, and increases to $(12.2 - 6.5)$ for respondents who do not have credit or debit cards. Note that card adoption is correlated with household income which itself is a component in the construction of sample weights.

3.1 Who doesn't have a card?

Table 1 is divided into columns according to respondents' possession (labeled as "adoption" in the data) of credit and debit cards. The column on the right shows that 3.4 percent of the respondents (4.7 weighted) reported not having any credit or debit card. 66.9 percent (67.2 weighted) have both cards, 16.4 percent (19 weighted) do not have credit cards (but may or may not have debit cards), and 17.9 percent (17.4 weighted) do not have debit cards (but may or may not have credit cards). It must be emphasized that the card adoption profiles displayed in Table 1 apply only to the 2062 respondents who actually made in-person purchases during their diary days (which is a subsample of all survey respondents).[6]

The bottom part of Table 1 reveals that age is not related to card adoption. In contrast, household income is related to card adoption in the following way: The weighted average of household income of respondents who have both credit and debit card is \$97,819 and drops down to $\$49,268$ for respondents who do not have any credit or debit card. Median household income drops from \$67,500 (with both cards) to \$22,500 (with no cards).[7]

Figure 2 displays respondents' card adoption profile with respect to their yearly household income not exceeding \$120,000. Uneven spacing on the x-axis reflects the relative number of respondents in the relevant income category. This figure shows that higher household income is correlated with credit card adoption. The sharp increase in credit card adoption from zero to \$50,000 household income is expected given that credit card issuers in the United States base their credit card approval (as well as credit line) on cardholders' household income. Interestingly, Figure 2 shows that the non-adoption of cards remains between 2 and 3 percents even at higher household income levels up to \$70,000, which is higher than the median 2017 U.S. family income \$61,372. In fact, regrouping all income categories below the 2017 median income shows that the average nonadoption rate of cards was 8.5 percent. This means that 8.5 percent of respondents with household income below the median level could not pay with debit or credit cards for their

[6]For all the 3099 survey respondents (including those who did not take part in the diary), 65.2 (63.2 weighted) percent had both credit and credit cards. 21.7 (23.3 weighted) percent did not have a credit card. 23.6 (17.8 weighted) did not have a debit card, and 7.7 (6.8 weighted) percent did not have credit or debit cards.

[7]Median household incomes displayed in Table 1 are multiples of \$500 because respondents reported their income bracket rather than exact values.

in-person purchases.

Table 1 shows that the average monthly number of in-person payments (volume) made by a respondent who does not have any debit or credit card was 21.7 (18.18 weighted) which is about half of the 39.12 (39.88 weighted) monthly number of payments made by a respondent who has both cards. In dollar value, the average payment made by respondents with no cards was $32.62 ($35.09 weighted) which is not much different than the $34.76 ($33.71 weighted) average payment value made by respondents who have both cards.

3.2 Card adoption and the use of cash

Table 2 displays how the use of cash varies with respondents' adoption (possession) of credit and debit cards. 32.6 (30.4 weighted) percent of the payments made by respondents who carry both cards were made with cash, compared with 86.4 (93.1 weighted) percent of cash payments made by respondents who do not have credit or debit cards.

In dollar value, the average cash payment made by respondents who carry both credit and debit cards was $14.12, compared with $29.59 average cash payment made by respondents who do not have any debit or credit cards. This is because respondents who have both cards use cash mostly for low-value purchases whereas respondents who do not have credit or debit cards use cash for most of their purchases including high value payments.

The bottom four rows in Table 2 show how respondents with no credit or debit cards allocate their purchase payments between cash and prepaid cards, which are the only practical means of payment available to them.[8] For these respondents, 86.4 percent of the payments were made with cash and 12.2 percent were made with prepaid cards. These observations are used in calibration of the analytical consumer payment choice model developed in Section 4.

3.3 Percentage use of cash by individual respondents

The percentage use of cash displayed in Table 1, Table 2, and Figure 2 were constructed based on payments made by respondents with different card adoption profiles. More precisely, transactions

[8]The reader may wonder how respondents, who do not have debit cards, can report payments made with paper checks. However, this may not be an issue because respondents who get paid with paper checks can, in some places, use these checks to pay for purchases even if they do not have a bank account.

of respondents with the same card adoption profile were grouped together. This section digs deeper into consumer payment choice by analyzing the distribution of respondents' percentage use of cash.

Figure 3 displays five box plots where each plot is restricted to respondents who share the same card adoption profile. The solid horizontal line in each box marks the median percentage use of cash (for in-person purchases) relative to the payment instruments available to the respondent within each card adoption category. For instance, the second plot focuses on respondents who carry both credit and debit cards. Within that group, half of the respondents used cash for less than 20 percent of their transactions. The bottom edge of this box marks the lower quartile (25^{th} percentile) which happens to be zero for that group. This implies that at least a quarter of respondents who carry both credit and debit cards did not use cash for in-person purchases. The upper edge of this box marks the upper quartile (75^{th} percentile) which is 57.14 percent. That is, three-quarters of these respondents used cash for less than 57.14 percent of their transactions.

In contrast to respondents who carry both cards, the box plot on the right in Figure 3 shows that all respondents who do not have any credit or debit card pay cash, with the exception of a few outliers marked by the small circles. These outliers correspond to the few paper check and prepaid card payments made by respondents in that group, see the bottom four rows in Table 2

The 'notches' displayed on sides of each box plot correspond to the 95-percent confidence intervals around the median percentage cash use. Therefore, a comparison of any pair of box plots in which notches do not overlap implies that there is strong evidence (with 95 percent confidence) that the corresponding two medians are unequal. Figure 3 reveals statistically significant differences in the medians of cash percentage use among respondents with different card adoption profiles, except for the overlap between respondents who do not have credit cards (third box plot) and respondents who do not have debit cards (fourth box plot).

More detailed statistics associated with each of the five subsamples (box plots) displayed in Figure 3 are as follows:

All respondents (in-person purchases): First quartile is 0 percent, median is 33.3 percent (half of all respondents paid cash for less than one-third of their transactions). The average is 39.4 percent,

and the third quartile is 75 percent.

Respondents with both cards: First quartile is 0 percent, median is 20 percent (half of these respondents paid cash for less than 20 percent of their in-person purchases). The average is 32.7 percent, and the third quartile is 57.1 percent.

No credit card: First quartile is 0 percent, median is 66.7 percent (half of these respondents used cash for less than two-thirds of their transactions. The average is 57.4 percent, and the third quartile is 100 percent. That is, a quarter of respondents in this group paid cash for all their in-person purchases.

No debit card: First quartile is 14.8 percent. Median is 66.7 percent (half of respondents in this group paid cash for less than two-thirds of their transactions . The average is 58.3 percent, and the third quartile is 100 percent. That is, a quarter of these respondents paid cash for all their in-person purchases.

No credit and no debit card: All quartiles correspond to 100 percent cash users, and the average is 87.4 percent. Therefore, with only few outliers, respondents with no credit or debit cards paid cash for all their in-person purchases.

4. Consumer cost of switching from cash to prepaid cards

This section constructs a Hotelling-type payment differentiation model for an economy with N buyers who have access to two payment instruments: Cash and prepaid cards. Therefore, the model applies to the group of consumers (characterized on the right-most column in Table 1) who do not have credit or debit cards, and therefore must use cash or prepaid cards for their in-person purchases. As indicated on the bottom of Table 2, within the group of survey respondents who do not have credit or debit cards, 86.4 percent of in-person purchases were paid for with cash and 12.2 percent with prepaid cards. These two numbers will be used in the calibration of the model. That is, the calibration is based on the observation these consumers have demonstrated *revealed preference* for paying cash over paying with prepaid cards for 86.4 percent of their in-person purchases.

4.1 A model of consumer payment choice

There are N consumers (in-person payers/buyers) who are uniformly distributed on the $[0,1]$ interval, as illustrated on the top part of Figure 4. Let c^c denote the cost of adopting and paying cash, and c^p the cost of adopting and paying with prepaid cards. The parameter $\delta > 0$ (to be calibrated below) denotes the payment instrument differentiation parameter. The choice of payment instrument by each consumer type $x \in [0,1]$, illustrated on the top part in Figure 4, is derived from the following payer-specific loss function of adopting and using one of the two means of payment:

$$L_x = \begin{cases} c^c + \delta x & \text{use cash for all in-person purchases} \\ c^p + \delta(1-x) & \text{use prepaid cards for all in-person purchases.} \end{cases} \tag{1}$$

Therefore, δx measures the non-monetary cost (disutility) of paying cash for consumer type x whereas $\delta(1-x)$ measures the consumer's non-monetary cost (disutility) of paying with a prepaid card. Low values of δ reflect consumers who do not distinguish very much between the two payment instruments. High values of δ reflect strong preference for one payment instrument over the other.

Each consumer type x chooses to pay with the payment instrument that minimizes the loss function (1). Therefore, payers indexed by $x \in [0, \hat{x}]$ pay cash because $c^c + \delta x \leq c^p + \delta(1-x)$. In contrast, payers indexed by $x \in (\hat{x}, 1]$ use prepaid cards because $c^c + \delta x > c^p + \delta(1-x)$. The loss function (1) and the top part in Figure 4 imply that payers who are indifferent between paying cash and paying with a prepaid card, denoted by $\hat{x}$, are determined from

$$c^c + \delta\hat{x} = c^p + \delta(1-\hat{x}), \quad \text{hence} \quad \hat{x} = \frac{1}{2} + \frac{c^p - c^c}{2\delta}. \tag{2}$$

The top part of Figure 4 and equation (2) imply that $\hat{x}$ decreases with an increase in the cost of cash (an increase in c^c). In this case, $\hat{x}$ moves to the left which means that the number of cash payers declines. Similarly, an increase in c^p moves $\hat{x}$ to to the right thereby increasing the fraction of consumers who pay cash. In the extreme case where $c^c = c^p$ so adopting and using the two means of payments are equally costly, $\hat{x} = \frac{1}{2}$. In this case, half of the N consumers pay cash and the other half pay with prepaid cards.

Next, in view of the top part in Figure 4 and the payers' loss functions (1), the equilibrium total

(aggregate) loss for all the $N\hat{x}$ consumers who pay cash and the $N(1-\hat{x})$ who pay with prepaid cards are

$$TL_2^c = N\int_0^{\hat{x}} (c^c + \delta x)\, dx = N\left(\hat{x}c^c + \frac{\hat{x}^2\delta}{2}\right) \quad \text{and} \tag{3}$$

$$TL_2^p = N\int_{\hat{x}}^{1} \left[c^p + \delta(1-x)\right]\, dx = N\left[(1-\hat{x})c^p + \frac{1-\hat{x}^2}{2}\,\delta\right], \tag{4}$$

where the subscript "2" denotes values when consumers have access to two means of payments: cash and prepaid cards

Suppose now that all stores and merchants become cashless, so cash cannot be used for in-person purchases. Then, all $N\hat{x}$ consumers who previously paid cash must purchase and use prepaid cards for all their in-person purchases. This regime is illustrated on the bottom part of Figure 4 where all N consumers indexed on entire interval $[0,1]$ pay with prepaid cards. The total (aggregate) loss of all formerly cash users who are now forced to pay with prepaid cards, previously given in (3), changes to

$$TL_1^c = N\int_0^{\hat{x}} \left[c^p + \delta(1-x)\right]\, dx = \frac{N\hat{x}}{2}\left[2c^p - \hat{x}\delta + 2\delta\right]. \tag{5}$$

where subscript "1" denotes values when the only available payment instrument is prepaid cards. Note that the transition to cashless stores has no effect on the loss of consumers who paid with prepaid cards before the transition (4) and hence $TL_1^p = TL_2^p$.

4.2 Calibration of the model to the data

The costs associated with adopting and using payment instruments (reflected by the parameters c^c and c^p in the model) have been estimated several times in the literature and can potentially be used to calibrate the model's unknown differentiation parameter δ. The bottom four rows in Table 2 reveal that payers who do not have credit or debit cards paid cash for 86.4 percent of their in-person purchases. In view of the top panel in Figure 4, this means that $\hat{x} = 0.864$.[9] Substituting $\hat{x} =$

[9]Note that 86.4 percent is the fraction of payments paid with cash and not the fraction of consumers who paid cash. However, for the sake of this calibration, I assume that 86.4 percent of consumers who do not have debit or credit cards

0.864 into (2) defines the following relationship between the payment instruments' cost difference $c^p - c^c$ and the payment instruments' differentiation parameter δ

$$\delta = \frac{125}{91}(c^p - c^c) \approx 1.37(c^p - c^c), \text{ for } c^p \geq c^c. \tag{6}$$

The goal of this calibration is to provide a method for estimating the burden on cash users who do not have credit or debit cards if all stores and merchants were to become cashless. Using the above model, the burden resulting from transitioning to cashless stores can be estimated by subtracting total loss of cash users (3) from total loss of the same consumers after they all switch to paying with prepaid cards (5). To compute the loss difference, substituting $\hat{x} = 0.864$ and δ from (6) into (3) and (5) yields

$$\Delta TL^c = TL_1^c - TL_2^c = N\,\frac{31609c^p - 15047c^c}{22750} > 0 \quad \text{if} \quad \frac{c^c}{c^p} < 2.1. \tag{7}$$

Therefore, the calibration of the model shows that cash payers incur a loss from a transition to cashless stores if the ratio of the cost of cash to the cost of prepaid card is below 2.1. In particular, (7) includes the case where the cost of cash is exactly twice the cost of prepaid cards ($c^c = 2c^p$). Intuitively, in view of the bottom part of Figure 4, this happens because consumers on the left who are indexed by small x (close to 0) bear higher consumer-specific disutility from handling prepaid cards, and these consumers would prefer paying cash even when cash is twice as costly.

Taking a step further with the calibration requires the use of fee estimates for cash and prepaid cards (c^c and c^p). Figure 5 displays results from cost assessment questions given to respondents in the 2017 SCPC. Respondents were asked to rank each payment instrument on the scale of 1 to 5. Perhaps the most striking finding in Figure 5 is that respondents consistently find cash to be the least costly payment instrument. Moreover, this assessment is independent of whether respondents have (adopt) or do not have credit or debit cards. In addition, the cost ranking displayed in Figure 5 is consistent with previous surveys given in 2015 and 2016 where cash was also ranked as the least costly payment instrument, see Table 13 in Greene and Stavins (2018a).

Figure 5 also shows that respondents rank prepaid cards as the second-highest costly payment

pay cash and all others pay with prepaid cards before stores become cashless.

instrument. Attempting to compare the cost of cash to that of prepaid cards using precise numbers would be somewhat speculative. Appendix A describes the complexity of assessing the user fees associated with GPR prepaid cards. However, for the sake of this analysis, Figure 5 provides sufficient evidence that $c^c < c^p$ for most users, in which case (7) implies that $\Delta TL^c > 0$. That is, a complete transition to cashless stores impose a measurable burden on consumers who do not have credit or debit cards.

5. Conclusion: A discussion of cost and cash alternatives

The paper developed a method of quantifying the burden associated with a hypothetical full transaction to cashless stores. The first step was to identify cash users who will be affected the most by this transition. The second step was to quantify the cost of this transition by focusing the analysis on consumers who do not have credit or debit cards. It should be noted that a complete cost-benefit analysis of transitioning to cashless stores must also estimate the effect on merchants who pay fees for processing card payments.

In addition, when considering the cost and benefit of transitioning to cashless stores, it is important to focus on all consumers including those who carry credit or debit cards, but still use cash for some of their in-person purchases. Using the same 2017 DCPC dataset, Kumar, Maktabi, and O'Brien (2018) report that cash is used for 39 percent of all in-person transactions, 30 percent of all transactions, and 55 percent of all transactions less than $10. In addition, cash is used across all age groups. These findings are consistent with Table 2 which restricts the sample to in-person purchases made from six merchant categories.

A comprehensive discussion of cashless stores should also consider some innovative options currently not available to U.S. consumers, such as:

(a) Rogoff (2016) (pp. 98–100) explores the possibility of introducing subsidized debit cards. These cards could also be issued with a mobile device option. A complete solution must also specify whether such a card will be linked to (and funded by) a commercial bank account or a government-provided (or behalf of the government) bank account, and whether these ac-

counts maintain 100-percent reserves in order to eliminate any risk.[10]

(b) Fung and Halaburda (2016), BIS (2018), and Khiaonarong and Humphrey (2019) analyze Central Bank Digital Currency (CBDC) intended to replace currency notes and coins for the general public.

Finally, unlike the U.S., some countries have managed to achieve some ubiquity in the use of cashless payment instruments based on apps installed on mobile devices. Ubiquity relies on market dominance of one or two mobile money transmitters that charge low (near zero) fees to merchants who accept payments using these services. This seems to be the direction China is taking via the dominance of WeChat and Alipay, and in Kenya via M-Pesa.[11] This solution is still incomplete because it relies on having payers fund their payments via their local bank accounts, which implies that consumers with no bank accounts or tourists cannot benefit from these services.

Appendix A GPR prepaid cards user fees

The user fees for general purpose reloadable (GPR) prepaid cards vary significantly among providers. Some offer monthly plans with fixed monthly fees ranging from zero to around $9.95. Some also offer pay-as-you-go plans with per-transaction fees that could reach $2.[12] In addition, even within a given plan, user fees vary significantly among card holders because they are highly correlated with the user-specific number of card activities, see Hayashi and Cuddy (2014).

If all stores were to become cashless, users would probably subscribe to monthly plans that do not charge a fee for each purchase. However, plans often charge fees for reloading cash via ATMs or at participating retail stores. Reloading fee could reach $3.95 per load. Table B in Hayashi, Hanson, and Maniff (2015) reports that prepaid card users load their cards 2.45 times in an average month (non-overdrafters), among these 1.76 are direct deposits and 0.69 are cash loads. Finally,

[10] Baradaran (2015) advocates reenlisting the U.S. Post Office in its historic function of providing bank services.

[11] See, https://web.wechat.com, https://intl.alipay.com, and https://www.safaricom.co.ke/personal/m-pesa in Kenya which is based on local kiosks that convert cash to mobile money and vice versa. Unlike China, similar services in the United States have not achieved ubiquity for a variety of reasons such as lack of consumer adoption, merchant acceptance, and software that limits transactions to person-to-person money transfers. These include PayPal https://www.paypal.com, SquareCash https://cash.app, Venmo https://venmo.com, Zelle https://www.zellepay.com, and some others.

[12] In fact, some of prepaid cards are bundled with other bank-like services, see for example Netspend https://www.netspend.com and the BlueBird card https://www.bluebird.com. These include options for direct deposit of income and bill payments.

ATM balance inquiry fee is often $0.50, and some plans impose a 90-day inactivity fee that could reach $5.95.

References

Arango, Carlos, Kim Huynh, and Leonard Sabetti. 2015. "Consumer Payment Choice: Merchant Card Acceptance Versus Pricing Incentives." *Journal of Banking and Finance* 55:130–141.

Bagnall, John, David Bounie, Kim Huynh, Anneke Kosse, Tobias Schmidt, Scott Schuh, and Helmut Stix. 2016. "Consumer Cash Usage: A Cross-Country Comparison with Payment Diary Survey Data." *International Journal of Central Banking* 12 (4):1–61.

Baradaran, Mehrsa. 2015. *How the Other Half Banks: Exclusion, Exploitation, and the Threat to Democracy*. Harvard University Press.

BIS. 2018. "Central Bank Digital Currencies." Bank of International Settlements.

David, Bounie, François Abel, and Waelbroeck Patrick. 2016. "Debit card and demand for cash." *Journal of Banking and Finance* 73:55–66.

Fung, Ben and Hanna Halaburda. 2016. "Central Bank Digital Currencies: A Framework for Assessing Why and How." Bank of Canada Staff Discussion Paper, No. 2016-22.

Fung, Ben, Kim Huynh, and Gerald Stuber. 2015. "The Use of Cash in Canada." *Bank of Canada review* 2015 (Spring):45–56.

Garcia-Swartz, Daniel, Robert Hahn, and Anne Layne-Farrar. 2006. "The Move Toward a Cashless Society: A Closer Look at Payment iIstrument Economics." *Review of Network Economics* 5 (2).

Greene, Claire and Joanna Stavins. 2018a. "The 2016 and 2017 Surveys of Consumer Payment Choice." Federal Reserve Bank of Atlanta, Research Data Report No. 2018-3.

———. 2018b. "The 2017 Diary of Consumer Payment Choice." Federal Reserve Bank of Atlanta, Research Data Report No. 2018-5.

Hayashi, Fumiko and Emily Cuddy. 2014. "General Purpose Reloadable Prepaid Cards: Penetration, Use, Fees, and Fraud Risks." Federal Reserve Bank of Kansas City Research Working Paper No. 14-01.

Hayashi, Fumiko, Josh Hanson, and Jesse Maniff. 2015. "Driver of Choice? The Cost of Financial Products for Unbanked Consumers." Federal Reserve Bank of Kansas City Research Working Paper No. 15-15.

Henry, Christopher, Kim Huynh, and Rallye Shen. 2015. "2013 Methods-of-Payment Survey Results." Bank of Canada Discussion Paper No. 2015-4.

Khiaonarong, Tanai and David Humphrey. 2019. "Cash Use Across Countries and the Demand for Central Bank Digital Currency." IMF Working Paper No. 19/46.

Kumar, Raynil, Tayeba Maktabi, and Shaun O'Brien. 2018. "2018 Findings from the Diary of Consumer Payment Choice." Federal Reserve Bank of San Francisco.

McAndrews, James. 2017. "The Case for Cash." ADBI Working Paper No. 679.

Rogoff, Kenneth. 2016. *The Curse of Cash*. Princeton University Press.

Wakamori, Naoki and Angelika Welte. 2017. "Why Do Shoppers Use Cash? Evidence from Shopping Diary Data." *Journal of Money, Credit and Banking* 49 (1):115–169.

Variable	All	CC_and_DC	No_CC	No_DC	No_CC_no_DC
Number of respondents	2062	1379	339	370	70
% of total	100.0	66.9	16.4	17.9	3.4
Number of respondents (w)	2062	1387	392	358	97
% of total (w)	100.0	67.2	19.0	17.4	4.7
Number of payments	7313	5220	982	1113	147
% of total	100.0	71.4	13.4	15.2	2.0
Number of payments (w)	7313	5352	1096	942	171
% of total (w)	100.0	73.2	15.0	12.9	2.3
Monthly payments per respondent	36.65	39.12	29.93	31.08	21.70
Monthly payments per respondent (w)	36.65	39.88	28.91	27.21	18.13
Monthly value $ per respondent	1234	1360	832	1047	708
Average payment $ value	33.66	34.76	33.66	33.68	32.62
Monthly value $ per respondent (w)	1201	1352	1201	865	886
Average payment $ value (w)	32.78	33.71	32.78	32.87	35.09
Average HH income	81653	90689	42813	75868	29897
Average HH income (w)	86402	97819	55425	69708	49268
Median HH income	67500	67500	27500	55000	22500
Average age	51	51	44	57	47
Average age (w)	49	49	47	51	57
Median age	52	52	43	58	47

Table 1: Payments for in-person purchases and respondents' adoption of credit and debit cards.
Notes: (w) refers to weighted data to fit the U.S. adult population. Numbers are computed for the subsample of respondents who actually made in-person purchases, see Footnote 6. Monthly values are estimated by dividing by 3 days and then multiplying by 31 days.

Subsample	Variable	Cash	Check	Credit	Debit	Prepaid
All	Number of payments	2732	120	1910	2369	182
	%	37.4	1.6	26.1	32.4	2.5
	% (w)	35.7	1.1	26.7	34.4	2.1
	Monthly number per respondent	13.69	0.60	9.57	11.87	0.91
	Average payment $ value	15.72	185.93	49.39	34.50	26.72
CC_and_DC	Number of payments	1702	61	1460	1887	110
	%	32.6	1.2	28.0	36.1	2.1
	% (w)	30.4	0.8	29.7	37.1	1.9
	Monthly number per respondent	12.75	0.46	10.94	14.14	0.82
	Average payment $ value	14.12	303.75	49.21	34.48	18.21
No_CC	Number of payments	510	16	0	412	44
	%	51.9	1.6	0.0	42.0	4.5
	% (w)	51.5	0.8	0.0	44.7	3.0
	Monthly number per respondent	15.55	0.49	0.00	12.56	1.34
	Average payment $ value	20.98	40.13	0.00	34.07	43.59
No_DC	Number of payments	593	42	432	0	46
	%	53.3	3.8	38.8	0.0	4.1
	% (w)	57.7	2.7	36.6	0.0	3.0
	Monthly number per respondent	16.56	1.17	12.06	0.00	1.28
	Average payment $ value	18.84	75.66	49.42	0.00	38.70
No_CC_no_DC	Number of payments	127	2	0	0	18
	%	86.4	1.4	0.0	0.0	12.2
	% (w)	93.1	0.4	0.0	0.0	6.5
	Monthly number per respondent	18.75	0.30	0.00	0.00	2.66
	Average payment $ value	29.59	100.16	0.00	0.00	46.51

Table 2: Number of payments and average dollar value per respondent for in-person purchases sorted by payment instrument and respondents' adoption of credit and debit cards.
Notes: (w) refers to weighted data to fit the U.S. adult population. Monthly values are estimated by multiplying by 31 days and then dividing by 3 diary days.

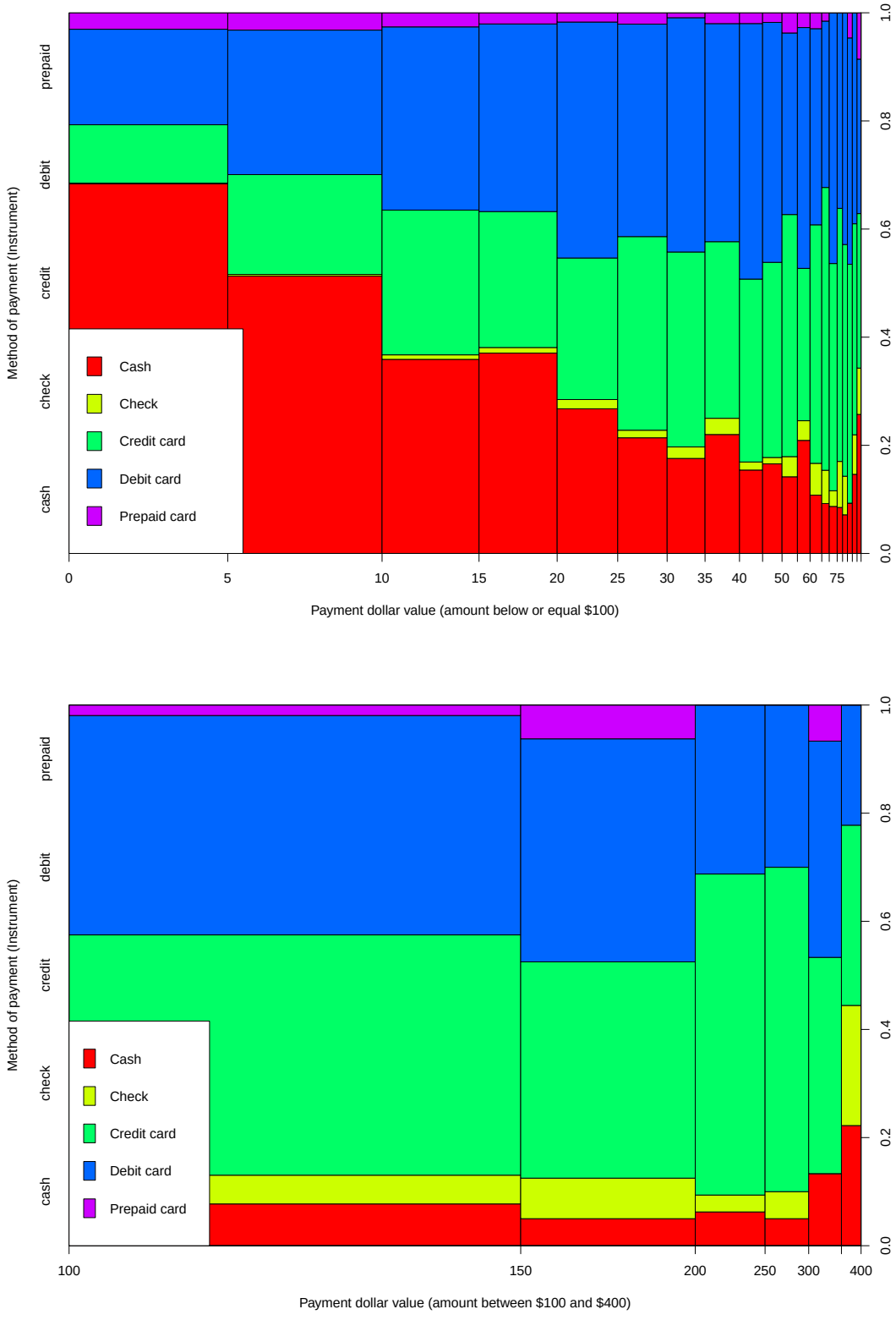

Figure 1: Respondents' use of payment instruments for in-person purchases by dollar amount.
Top: 6911 payments not exceeding $100 made by 2028 respondents.
Bottom: 381 payments between $100 and $400 made by 323 respondents.
Note: Unequal spacing reflects relative number of transactions within the amount range.

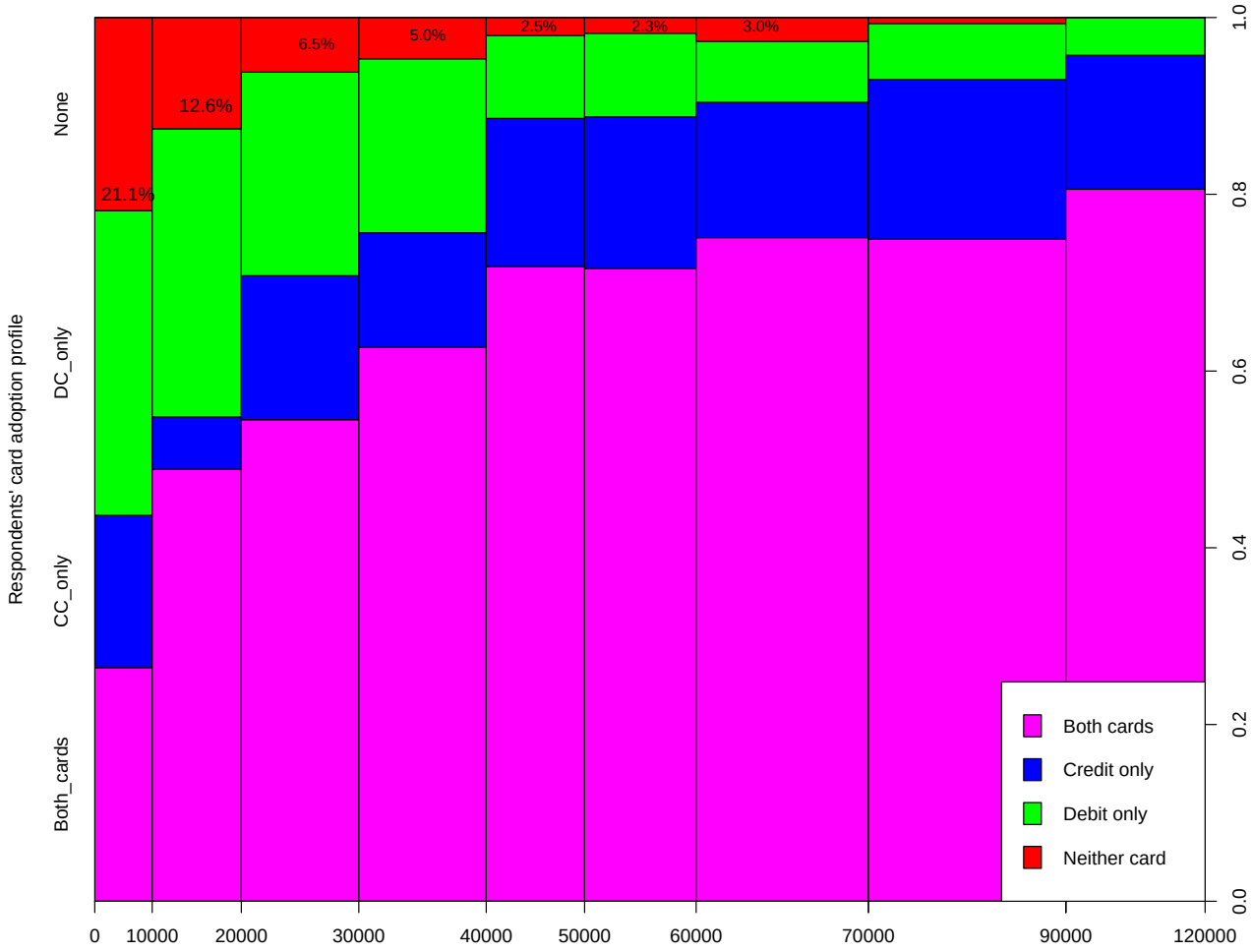

Figure 2: Respondents' card adoption profile by household income.
Notes: The figure is restricted to the 83.98 percent of the respondents whose household income does not exceed $120,000. Unequal spacing reflects relative number of respondents within the income group.

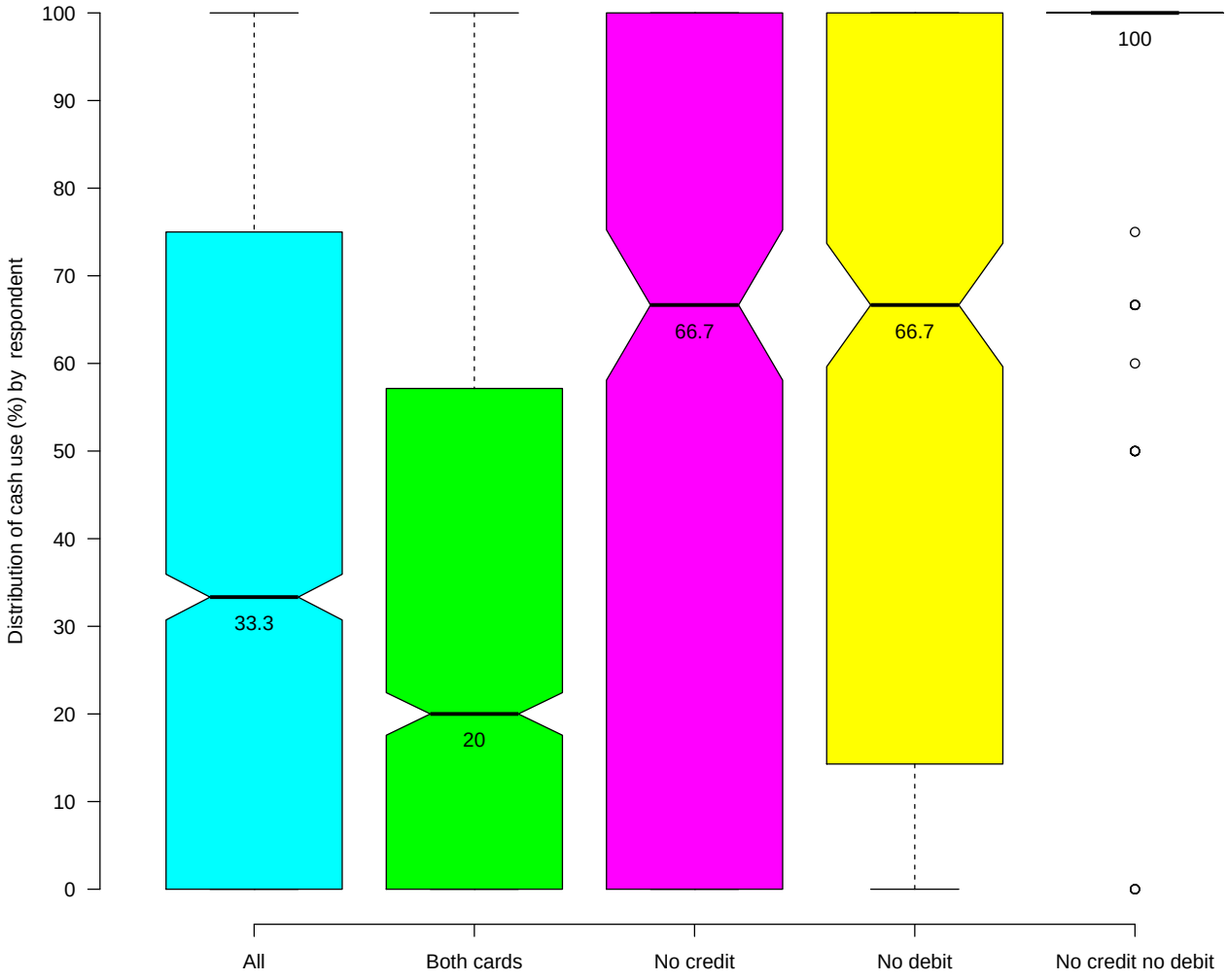

Figure 3: Distributions of percentage cash use for in-person purchases by individual respondents according to their card adoption profile.

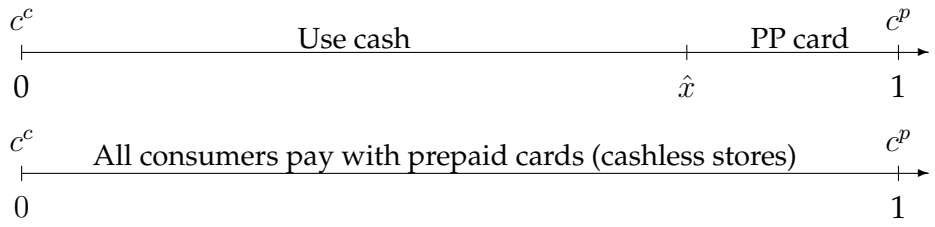

Figure 4: *Top*: Equilibrium allocation of payers (consumers) between cash users and prepaid card users. *Bottom*: Cashless stores (all consumers pay with prepaid cards)

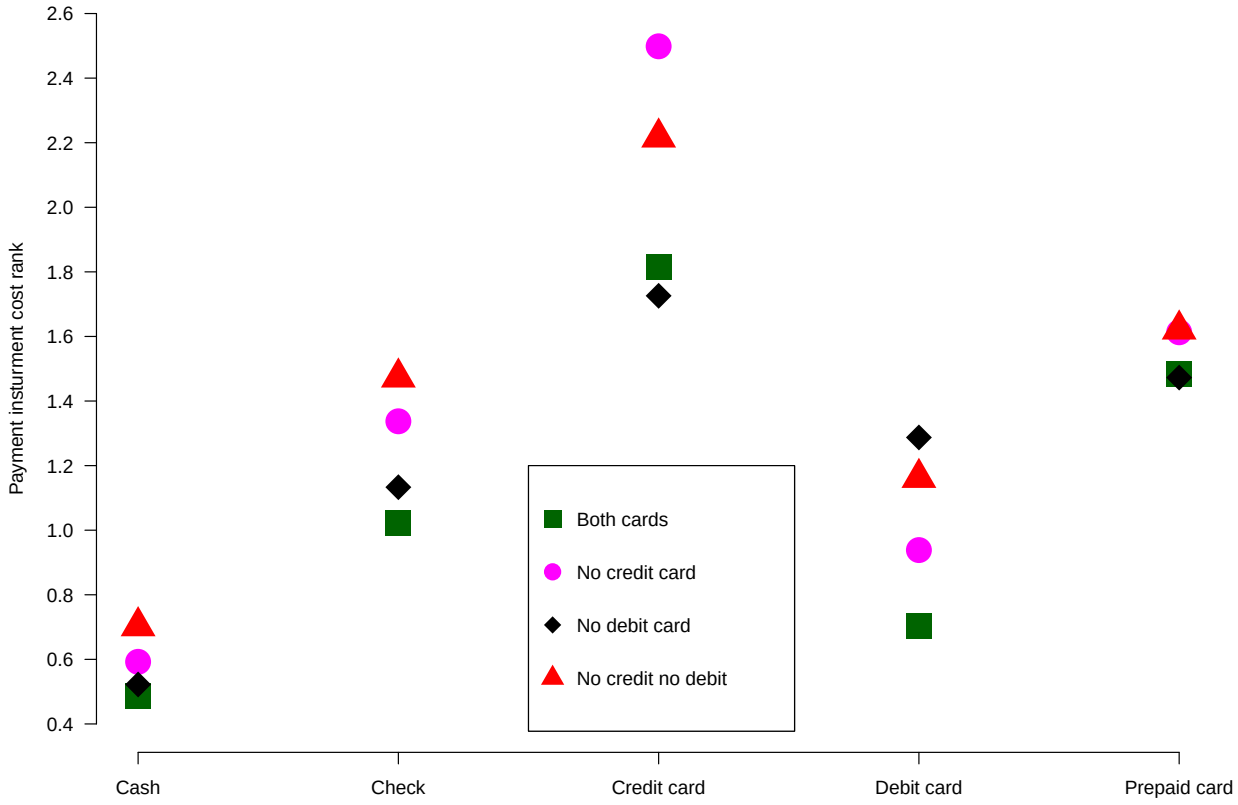

Figure 5: Respondents' cost assessment of adopting and using five payment instruments.
Note: Respondents are grouped according to their card adoption profile.