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Cashless Store and Cash Users

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Abstract The emergence of cashless stores has led several cities and states to ban such stores. This article investigates this policy issue by characterizing consumers who pay cash for in-person purchases and banked and unbanked consumers who do not have credit or debit cards. Using a random utility model, I simulate the effects on consumer welfare caused by a hypothetical complete transition to cashless stores. The simulations show that the burden from this transition on consumers with no credit or debit cards is seven times higher than the burden on consumers who have both cards. The conclusion lists policy options for alternatives to cash that may be needed before all brick-and-mortar stores become cashless.

JEL classification: D9, E42

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

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1. Introduction: The policy issue

Imagine entering a store, picking up a few items, and then exiting 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 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 requires most retail stores to accept cash. San Francisco passed a similar law in May 2019. Cashless businesses are banned in Massachusetts and more recently in New Jersey.[1]

This study focuses on the consumer side of this policy debate by investigating how banked and unbanked 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. This is 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 areas 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 waiting time between the sale and when the funds are credited to their bank account.[2]

It is important to emphasize that this paper is *not* about phasing out cash (often referred to as "cashless society"). The limited goal is to investigate how a transition to cashless stores would affect consumers in general and banked and unbanked consumers who do not have credit or debit cards in particular. This paper also abstracts from the debate on whether large denomination notes

[1] See, https://www.wsj.com/articles/philadelphia-is-first-u-s-city-to-ban-cashless-stores-11551967201, http://fortune.com/2019/04/03/cashless-stores-retail-amazon-go/, and https://www.mercurynews.com/2019/05/08/heres-why-a-cashless-society-is-not-coming-to-san-francisco/.

[2] Schmiedel, Kostova, and Ruttenberg (2012) analyze merchants' costs of accepting payment instruments in European countries and Kosse et al. (2017) in Canada. Some early cost estimates of transitioning to cashless transactions are given in Garcia-Swartz, Hahn, and Layne-Farrar (2006a,b).

should be eliminated in order to reduce crime, tax evasion, or to allow for negative interest rates, see Rogoff (2016) and counter arguments in McAndrews (2017).

The goal of this research is to identify and characterize consumers who would be affected the most by transitioning to cashless stores, and to empirically estimate the burden that may be imposed on these consumers. 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, unbanked consumers who do not have credit or debit cards would be forced to purchase prepaid cards unless some other non-cash means of payments become available without having to open an account in a commercial bank. 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.[3]

A complete transition to cashless stores would be extremely difficult in any country (if not impossible) particularly because the use of cash at the point-of-sale remains strong in most countries. Krüger and Seitz (2014), Fung, Huynh, and Stuber (2015), Arango, Huynh, and Sabetti (2015), David, Abel, and Patrick (2016), Wang and Wolman (2016), and Wakamori and Welte (2017) explore the intensity of cash use, and how cash dominates low value transactions. Studies by Bagnall et al. (2016), Bech et al. (2018), and Khiaonarong and Humphrey (2019) provide international comparisons of the intensity of cash use.

The findings on the intensity of cash use in the above literature are consistent with the survey data described in Section 2. Figure 1 shows how respondents' shares of use among the five main payment instruments vary with the payment amount for in-person purchases. 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, and to 40 percent for payment amounts between \$10 and \$20. 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

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

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. Sample statistics for Figure 1 are given in Tables 1 and 2.

This article is organized as follows. Section 2 describes the data. Section 3 characterizes banked and unbanked consumers who do not have credit or debit cards. Section 4 characterizes in-person purchases and cash users. Section 5 analyzes consumers' assessments of the benefits and cost of using each payment instrument. Section 6 uses a random utility model to simulate the burden on consumers from a hypothetical complete transition to cashless stores. Section 7 concludes with a discussion of policy options for alternatives to cash that may be needed before all brick-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 are taken from the 2017 and 2018 Survey and Diary of Consumer Payment Choice (SCPC and DCPC).[4] 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 months of October 2017 and October 2018 in a way that resembles a three-

[4]The survey and the diary are conducted in collaboration of the Federal Reserve Banks of Atlanta, Boston, Richmond, and San Francisco. 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 and O'Brien (2019). Similar surveys are conducted by the Bank of Canada, see Henry, Huynh, and Welte (2018). The data and the R-code used in this analysis are available for downloading from https://github.com/ozshy/cashless.

period overlapping generations model.[5] 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 three cost assessment variables for each of the five payment instruments, which are analyzed in section 5. I also use four binary variables "cc_adopt", "dc_adopt", "svc_adopt", and "bnk_acnt_adopt" indicating whether the respondent has a credit card, debit card, prepaid (store-value) card, and a bank account, respectively, see Table 1. Respondents who participated in both, the SCPC and the DCPC are matched via "prim_key" (2017) and "uasid" (2018) which are unique ID numbers of survey respondents.

Most of the variables are taken from the DCPC which records actual transactions. In particular, I restrict the analysis to 16,951 "in-person" (in-person $= 1$) expenditure ("type" $= 1$) payments made by 2891 unique respondents; and then further restrict to 14,076 payments made by 2706 respondents in seven merchant categories (merch $= 1$ to 7) using the five major payment methods (pi $= 1$ to 5): "cash," "check," "credit card," "debit card," and "prepaid card," see Table 2.[6] After removing a few respondents who did not report on their card adoption profile, the sample was reduced to 13,844 in-person payment observations made by 2677 respondents. Other variables used include "amnt" (dollar amount of each payment), "age," "income_hh" (household income), "hh_size" (number of persons in the household), "work," "gender," and "education."

Finally, a note about the use of sampling weights. The data contain weights for all respondents 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. In general, statistics on small subsamples or subgroups are reported without weights, because any gains in unbiasedness are likely to be outdone by increases in the variance of the estimators.[7]

[5] Jonker and Kosse (2009) compare payment diaries with different time lengths and find that shorter diaries yield more accurate information due to "survey fatigue" which leads respondents to underreport their payment activities.

[6] 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., 7. arts, entertainment and recreation.

[7] Table 2 provides a good example where 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 is larger when the sample size is restricted with respect to respondents' card adoption profile. For example, the column on the right (prepaid) shows that the difference is 2.4 minus 2.2 for the All sample, and increases to 12.1 minus 14.3 for

3. Who doesn't have a card?

This section analyzes the data described in Section 2 to identify which payment instruments were available to diary respondents who made in-person purchases from the seven merchant categories described in Footnote 6. These consumers are then grouped into card adoption (and nonadoption) profiles. Appendix A goes deeper into this grouping by regressing respondents' card adoption profiles on their demographic variables. The classification of respondents according to their bank and card adoption profiles serves as a preparation for Section 4 that investigates how the intensity of cash payments is influenced by consumers' card adoption profiles.

Table 1 is divided into columns according to respondents' possession (adoption) of credit and debit cards. The column on the right shows that 3.5 percent of the respondents (3.9 weighted) are unbanked with no credit or debit card. 72.8 percent (66.8 weighted) have both cards, 19.2 percent (19.8 weighted) do not have credit cards (but may or may not have debit cards), and 20.1 percent (18 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 2677 respondents who, during their diary days, made in-person purchases from the merchant types described in Footnote 6. For card adoption profiles in the general population see Figure 2 in Greene and Stavins (2018a).

Table 1 shows that card adoption is related to household income in the following way: The median household income of respondents who have both credit and debit cards is $67,500 and drops to $20,000 for unbanked respondents who do not have any credit or debit card.[8] The weighted average of household income is $90,103 (with both cards) and drops to $41,554 (unbanked with no cards).

Monthly values are estimated by dividing by 3 days and then multiplying by 31 days for 2017 and 2018 separately. Table 1 shows that the average monthly number of in-person payments (volume) made by unbanked respondents who do not have debit or credit cards was 27.37

unbanked respondents who do not have credit or debit cards. Note that card adoption is correlated with household income which is a component in the construction of sampling weights.

[8]Median household incomes displayed in Table 1 are multiples of $500 because in 2017 respondents reported their income brackets rather than exact values.

(28.75 weighted) which is about a half of the 54.57 (59.22 weighted) monthly number of payments made by respondents who have both cards. In dollar value, the average payment made by unbanked respondents with no cards was $23 ($20.12 weighted) which is lower than the $37.44 ($37.03 weighted) average payment value made by respondents who have both cards.

Finally, only 23 respondents (17 weighted) reported having a bank account but no credit or debit cards (the latter, is most likely by choice). These respondents are much older than the unbanked (median age 56 versus 43) and have lower household income.

4. The use of cash for in-person purchases

Section 3 and Appendix A characterized and grouped consumers according to the type of payment instruments available to them. In order to better understand the impact on consumers of a policy that allows or prohibits cashless stores, this section analyzes the use of cash for in-person purchases. Subsection 4.1 examines cash payments within each consumer group. Subsection 4.2 analyzes the distribution of individual respondents' percentage use of cash.

4.1 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. 33.1 (31.9 weighted) percent of the payments made by respondents who carry both cards were made with cash, compared with 88 (85.7 weighted) percent of cash payments made by unbanked 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 $14.96, compared with $22.06 average cash payment made by unbanked respondents who do not have debit or credit cards. This is because respondents who have both cards use cash mainly 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 five rows in Table 2 show how unbanked 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. For these respondents, 88 percent (85.7 weighted) of the payments were made with cash and 12.1 percent (14.3 weighted) were made with prepaid cards.

4.2 Percentage use of cash by individual respondents

The percentage use of cash displayed in Table 2 were constructed based on payments made by respondents with different card adoption profiles. More precisely, transactions 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 2 displays six box plots where each plot is restricted to respondents who share the same card adoption profile. The solid horizontal dividing 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 this card adoption category. For example, the second box plot focuses on respondents who carry both credit and debit cards. Within that group, half of the respondents used cash for less than 25 percent of their payments. 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 their in-person purchases. The upper edge of this box marks the upper quartile (75^{th} percentile) which is 57.1 percent. That is, three-quarters of these respondents used cash for less than 57.1 percent of their payments.

In contrast to respondents who carry both cards, the box plot on the right in Figure 2 shows that all unbanked 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 prepaid card payments made by respondents in that group, see the bottom four rows in Table 2.

The 'notches' displayed on both 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 2 reveals statistically significant differences in the medians of percentage cash use among respondents with different card adoption profiles, except for some overlap between respondents who do not have credit cards (third box plot) and respondents who do not have debit cards (fourth box plot). The third and fourth box plots show that half of the respondents who do not have credit cards and half of the respondents

who do not have debit cards used cash to pay for 60 percent and two-thirds of their in-person purchases, respectively, but the difference is not statistically significant.

Figure 3 presents a variant of Figure 2 and displays the statistics of cash use when respondents are grouped into household income categories (instead of their card adoption profiles). Clearly, the two types of grouping are correlated because credit cards are generally not approved for low-income people. Figure 3 shows half of the low-income respondents used cash for 50 percent of their payments, compared to 30.1 percent used by half of respondents with household income exceeding $100,000. The second and third box plots show that three-quarters of respondents (the upper side of each box) with household income below $50,000 use cash for all their payments (100 percent). In contrast, three-quarters of respondents with household income exceeding $100,000 use cash for only 50 percent of their in-person purchases.

5. Measuring consumer benefit and cost of payment methods

Discrete choice estimations of utility that consumers derive from a given a set of alternatives rely on known prices that consumers pay for choosing each alternative. For example, random utility models of commuters' choice among transportation modes (bus, car, subway, train, or air) are based ticket prices (fares) and travel time that passengers endure using each transportation mode.

In contrast, researchers who study consumer payment choice are unable to figure out the exact price or cost of paying with each payment instrument. There are two reasons for that: First, it is very hard to separate variable from fixed costs associated with adopting and using a particular payment instrument. For example, the cost of paying cash is heavily influenced by ATM fees and their nearest location. Similarly, the cost of paying with prepaid cards depends heavily on the cost of reloading funds onto the cards. Second, some costs of payment instruments vary among consumers. In other words, the cost of using a particular payment method tends to be consumer specific. Consumer cost of paying with credit cards depends on whether the consumer is a borrower or a convenience user (who may also earn cash back). The cost of using debit cards depends on checking account maintenance fees charged by the card issuing bank.[9]

[9]For payment instruments' cost studies see: Schmiedel, Kostova, and Ruttenberg (2012), Krüger and Seitz (2014), Kosse et al. (2017), and references therein. Hayashi and Keeton (2012) and Shampine (2012) compare several payment

For this reason, following Koulayev et al. (2016), Huynh et al. (2020) and Shy (2020), the analysis in this article uses respondent-specific assessments of each payment instrument to identify consumer-specific cost and benefit derived from using each payment instrument.[10] The analysis uses three assessments: cost, security, and convenience. Note that respondents' assessments are ratings (as opposed to rankings) so each assessment can take any number between 1 to 5 independently of the assessment numbers assigned to other payment instruments.

The welfare simulations in the next section assume that consumers' payment choice is influenced by consumers' assessments of cost, security, and convenience of each payment method. In order to test whether consumers' assessments of the different payment instruments affect their payment choice, Table 3 displays the distribution of respondents' three ratings (cost, security, and convenience) with respect to the payment instruments that they actually used for each of their in-person purchase.

Table 3 shows that 77.35 percent (56.96+20.39) of in-person purchases were paid with the payment instruments respondents rate as the least costly. Similarly, 90.24 percent (25.56+64.68) purchases were paid for with the payment method respondents view as the most convenient. For security ratings, only 51.4 percent (30.3+21.1) purchases were paid for with the payment method respondents view as the most secure. Therefore, at least with respect to cost and convenience, Table 3 establishes close correlation between respondents' subjective ratings of payment methods and the payment method that they actually use for their in-person purchases.

The welfare simulations in the next section use median assessment ratings as independent variables in order to mitigate potential endogeneity issues that may arise in the random utility regression analysis. Table 4 displays respondents' median assessments of the five main payment methods. The medians are weighted by the sample's population weights. Table 4 shows that cash is viewed as the least costly payment method and credit cards as the most costly. Credit

cost studies and highlight the need for developing standards for cost estimation to facilitate comparisons across time and countries.

[10] Klee (2008) uses transaction time (ring time) in a multinomial logit payment choice model using scanner data from grocery stores where transaction time can be measured. Borzekowski and Kiser (2008) use three attributes: checkout time, whether the payment instrument is electronic, and whether it draws funds from a liquid account. Ching and Hayashi (2010) regress on 11 consumer-perceived attributes of each payment method. Arango, Huynh, and Sabetti (2015) regress on an index that combines perceptions of costs, acceptance, record keeping, ease of use, and risk of financial loss.

cards are considered to be more secured than other payment methods. Credit and debit cards are considered to be the most convenient.

6. Transitioning to cashless stores: Consumer welfare simulations

This section simulates changes in consumer welfare by constructing a random utility model to estimate the effects of a hypothetical complete transition to cashless stores. It should be emphasized that the terms *consumer welfare*, *utility*, and *consumer surplus* all refer to the net gain (benefit minus cost) that consumers derive from *paying* using a particular payment instrument. Here, the use of these three terms is substantially different from the widespread use of these terms to measure the benefits derived from *consuming* products or services that consumers purchase.

The welfare simulations are based on existing payment instruments: cash, checks, debit cards, credit cards, and prepaid cards. Therefore, these estimations do not take into consideration that a transition to cashless stores may be supported by an emergence of new payment instruments which are discussed in the conclusion of this article.

As already discussed in Section 5, there are no recent objective data on U.S. consumer cost, security, convenience, or other attributes associated with using the different payment methods. Therefore, the simulations in this section rely on respondent-specific assessments of each payment instrument. The advantage of this procedure is that it looks at cost and benefits from consumers' perspectives. However, one drawback of using assessments is the possibility of encountering endogeneity problems.

In order to mitigate potential endogeneity problems, instead of using individual-specific assessments as independent variables, the simulations below use the weighted medians of cost, security, and convenience assessments as independent variables. This procedure assumes that the population weighted median values capture the "objective" cost and benefit values. It is important to emphasize that the scale of each assessment rating (1 to 5) has no effect on the estimated changes in consumer surplus associated with a complete transition to cashless stores. More precisely, the exact same changes occur even if we double the assessment ratings to range from 2 to 10 (instead of 1 to 5) or any other linear transformation of these assessment ratings.

6.1 Simulating the burden using a random utility model

Each respondent recorded several payments for in-person purchases that were made during the assigned diary days. Most respondents used more than one payment instrument to pay for their purchases. This section estimates consumers' utility derived from each in-person payment using the population weighted medians of cost, security, and convenience assessments of payment methods.

Consumers choose among five payment instruments $i = 1, 2, 3, 4, 5$, where 1 denotes cash, 2 denotes check, 3 denotes credit card, 4 denotes debit card, and 5 denotes prepaid card. In a random utility model, the utility derived by respondent n from paying with payment instrument i for transaction t is defined by

$$U_{n,i,t} = V_{i,} + \epsilon_{n,i,t}, \quad \text{where} \tag{1}$$

$$V_i = \beta_C \, \text{cost}_i + \beta_S \, \text{security}_i + \beta_E \, \text{convenience}_i. \tag{2}$$

$\epsilon_{n,i,t}$ is the random component of the utility (1) which is assumed to be distributed Type I Extreme Value. The independent variables cost_i, security_i, and convenience_i are the population weighted medians of cost, security, and convenience assessments of each payment method $i = 1, 2, 3, 4, 5$.

The coefficients β_C, β_S, and β_E and their standard errors estimated from the regression model (2) are given in the estimated equation[11]

$$V_i = \underset{(0.0709)}{-2.7728} \, \text{cost}_i + \underset{(0.0752)}{2.5274} \, \text{security}_i + \underset{(0.0708)}{2.8489} \, \text{convenience}_i. \tag{3}$$

For this estimation, I removed all 224 check payment observations and also removed check (payment instrument $i = 2$) from the consumers' choice set. There are two reasons for that: First, check payments constituted only 1.8 percent of all payments made for in-person purchases. Second, check is unlikely to serve as a substitute for cash after stores become cashless. Credit, debit, and prepaid cards are closer substitutes for cash than checks.

The estimation is based on 10,083 payment observations made by 1,921 respondents who have credit and debit cards. Only this group of respondents were able to choose from the entire set of

[11] The estimation used the `mlogit` R-package. All three coefficients are statistically significant at the 0.1 percent level.

payment methods. Therefore, regressing on this group is needed in order to obtain good estimates of the three coefficients β_C, β_S, and β_E in the regression model (2).

The estimated equation (3) shows that utility of paying declines with the cost of the payment instrument, $\beta_C < 0$. In addition, $\beta_S > 0$ and $\beta_E > 0$ imply the utility of paying increases with the security and convenience of the payment instrument.

6.2 Change in per-payment consumer surplus: Simulation results

Following Train (2009) (chapter 3, page 56), the *per-payment* and *per-consumer* rate of change in consumer surplus resulting from a hypothetical complete transition to cashless stores (elimination of payment instrument $i = 1$ as a payment choice) is computed by

$$\frac{\Delta CS}{CS} = \frac{\mathrm{E}(CS)_{3\mathrm{PI}} - \mathrm{E}(CS)_{4\mathrm{PI}}}{\mathrm{E}(CS)_{4\mathrm{PI}}} = \frac{\ln\left(\sum_{i=3,4,5} e^{V_i}\right) - \ln\left(\sum_{i=1,3,4,5} e^{V_i}\right)}{\ln\left(\sum_{i=1,3,4,5} e^{V_i}\right)}, \tag{4}$$

where V_i are computed by substituting the estimated regression coefficients from (3) into (2) and evaluating V_i at the median cost, security, and convenience assessment levels given in Table 4. Subscript 4PI indicates the surplus with four payment instruments (cash, credit, debit, and prepaid card) before cash (payment instrument $i = 1$) is eliminated. Subscript 3PI indicates consumer surplus after stores become cashless.

Note that equation (4) applies to respondents who carry all four payment instruments before and three payment instruments after stores become cashless. Therefore, the welfare simulations of consumers with no credit cards will slightly modify equation (4) to simulate consumers who can choose to pay with instruments $i = 1, 4, 5$ before cash is eliminated and $i = 4, 5$ after cash is eliminated. The last simulation will modify equation (4) to simulate consumers with no credit or debit cards who can choose to pay with instruments $i = 1, 5$ before cash is eliminated and only $i = 5$ after cash is eliminated.

Two issues are worth noting about (4). First, individuals' marginal utility of income (which we do not know) are omitted from (4) because each marginal utility cancels out when expressed as a

rate change (instead of just a difference in consumer surplus). Second, the formulation (4) relies on the assumption that the estimated utilities of payment instruments V_i for $i = 3, 4, 5$ do not change after payment choice $i = 1$ is eliminated. This assumption implies that the assessments of cash attributes (cost, security, and convenience) are independent of the assessments of non-cash payment instruments. This assumption is reasonable because respondents' assessments are ratings (not rankings) so each assessment can take any number between 1 to 5 independently of the numbers assigned to other payment instruments. From a technical perspective, (4) relies on the Property of Independence of Irrelevant Alternatives (IIA) in which adding or subtracting choice alternatives have no effects on the utility derived from other choice alternatives.

Expression (4) provides the formula for computing the rate of change (drop) in consumer surplus resulting from a hypothetical complete transition to cashless stores. The column labeled $\%\Delta CS$ in Table 5 displays the drop rates in the per-payment consumer surplus. The results show that the simulated utility drop rate of consumers who carry both credit and debit card is 2.36 percent. For consumers with debit cards but no credit cards, the simulated drop rate is 3.71 percent. This rate increases to 17.42 percent for consumers who do not have credit or debit cards.[12]

How should the above findings on the drop rates in consumer surplus be interpreted? Note that because assessments are not measured in dollar value and because we cannot estimate the marginal utility of income, the simulated drop rates $\%\Delta CS$ in Table 5 cannot be used to infer the loss of consumer welfare relative to variables such as total consumer expenditure or the GDP in order to obtain estimates of the absolute magnitudes of these losses. Therefore, the results are limited for comparing welfare losses among the different consumer groups, but not relative to their total consumption.

In view of the above discussion, the column $\%\Delta CS_{\text{relative}}$ measures the *relative burden* on consumers with no debit cards by dividing the simulated drop rate in their consumer surplus by the simulated drop rate of consumers who possess both cards. This division implies that the burden on consumers with no credit cards is $3.71/2.36 \approx 1.6$ times higher than the burden on consumers

[12]Incidentally, using an entirely different method which involves estimations of consumer demand, Alvarez and Argente (2019) experiment with a ban on paying cash for Uber rides in Mexico. They find that consumers, who either sometimes or exclusively use cash, suffer an average loss of approximately 50 percent of the expenditure on trips paid in cash before cash was banned .

who possess both cards. Similarly, the burden on consumers with no credit or debit cards is $17.42/2.36 \approx 7.4$ times higher than for consumers who possess both cards.

7. Conclusion: Policy options for alternatives to cash

This article identifies the type of consumer who would be affected the most from a transition to cashless stores. The analysis proceeds with estimations of a random utility model in order to compute the expected burden on cash users from a hypothetical complete transition to cashless stores. The model defines the utility of paying with each payment instrument as a linear function of three median attributes of each instrument: cost, security, and convenience. These attributes are reported by survey respondents and are matched with the payment choices reported in their diaries. It should be emphasized that the effects of these three attributes on payment choice have also been recorded in other surveys. For example, a survey by the Bank of Canada also found that "consumers still rate cash as an easy-to-use, low cost, secure, and widely accepted payment method," see Henry, Huynh, and Welte (2018).

The policy options discussed below have two related goals: First, to facilitate the integration of consumers who do not have access to debit and credit card into the non-cash digital payment system.[13] Second, to introduce cash users to some innovative options that currently not available to U.S. consumers. The policy options include:

(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 accounts maintain 100-percent reserves in order to eliminate any risk.

(b) Advocates for a nationwide public banking option believe there should be a single institution that offers everyone access to a basic transactional account. This public bank would specialize in financial services addressing the unique needs of excluded and vulnerable populations, see

[13] Bostic et al. (2020) explore a policy option that instead of focusing on helping unbanked people become banked in order to enhance financial inclusion, a faster and more effective approach could be giving cash users access to digital payment vehicles that do not necessarily depend on traditional bank accounts.

a discussion in Bostic et al. (2020). Baradaran (2015) advocates reenlisting the U.S. Post Office in its historic function of providing bank services.

(c) Fung and Halaburda (2016), BIS (2018, 2020), and Khiaonarong and Humphrey (2019) analyze Central Bank Digital Currency (CBDC) that could replace currency notes and coins for the general public and may be issued directly to consumers. At the implementation stage, policy makers and regulators will need to specify whether and how consumers will be able to access and use CBDC for their daily transactions.

Unlike the U.S., some countries have managed to achieve some ubiquity in the use of non-cash 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.[14] 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. The exception is M-Pesa which relies on local kiosks that convert cash to mobile money and vice versa without the use of bank accounts.

Finally, a complete analysis of a transition to cashless stores must also estimate its effect on merchants who pay fees for processing card payments. Hayashi and Ruiz (2020) show that credit card interchange fees in the United States are significantly higher than in Europe and several other countries. Therefore, transitioning from cash payments to card payments would increase the total amount of fees paid by merchants to the card-issuing banks.

Appendix A Card adoption and consumer demographics

The regressions in this appendix estimate demographic effects on 2677 respondents' card adoption profiles. Each column in Table 6 lists the average marginal effects estimated from five discrete

[14] See, https://web.wechat.com, https://intl.alipay.com, and https://www.safaricom.co.ke/personal/m-pesa in Kenya. 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.

choice logistic regressions using the following model:

$$\text{Adoption profile} = \overbrace{\beta_A \text{Age} + \beta_I \log(1 + \text{HH Income}) + \beta_S \text{HH Size}}^{\text{numerical variables}} + \underbrace{\beta_W \text{Work} + \beta_M \text{Marital} + \beta_E \text{Education} + \beta_G \text{Gender}}_{\text{categorical variables}}. \tag{A.1}$$

In each regression (corresponding to each of the five adoption profiles), the dependent variable "Adoption" takes a value 1 if a respondent meets a certain card adoption (or nonadoption) profile, and 0 if not. The five adoption profiles correspond to the five columns in Table 6. The first is the adoption of both credit and debit cards. The remaining four profiles are nonadoptions profiles: no credit card, no debit card, and neither credit nor debit (banked and unbanked). The average marginal effects listed on the top three rows correspond to the numerical variables whereas the bottom seven rows correspond to marginal effects of the categorical variables.

Comparing the column on the left side with the column on the right side in Table 6 reveals that household income is positively related to the adoption of both cards and negatively related to not having a bank account and not having cards. These marginal effects are statistically significant. The use of log of income (instead of just income) is needed to avoid complete separation for the two "None" regressions. I added $1 to each respondent's yearly income because out of the 2677 respondents, 18 respondents reported having no income. Older age slightly increases the probability that a respondent owns both types of card and slightly reduces the probability that the respondent is unbanked with no cards.

Looking at some categorical variables in Table 6, college education and higher are positively related to the adoption of both cards, and negatively related to being unbaked. Relative to respondents who have only high school education or less, some college education increases the probability of having both cards by 9.2 percent, and a graduate degree by 11.8 percent. These marginal effects are statistically significant. Relative to female respondents, male respondents are 5.8 percent less likely to own both cards.

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Variable	All	CC_DC	No_CC	No_DC	None_B	None_UB
Number of respondents	2677	1948	515	538	23	94
% of total	100.0	72.8	19.2	20.1	0.9	3.5
Number of respondents (w)	2677	1787	531	483	17	105
% of total (w)	100.0	66.8	19.8	18.0	0.6	3.9
Number of payments	13844	10288	1741	2127	56	249
% of total	100.0	74.3	12.6	15.4	0.4	1.8
Number of payments (w)	13844	10244	1920	2021	39	293
% of total (w)	100.0	74.0	13.9	14.6	0.3	2.1
Monthly payments per respondent	53.44	54.57	34.93	40.85	25.16	27.37
Monthly payments per respondent (w)	53.44	59.22	37.41	43.23	23.24	28.75
Monthly value $ per respondent	1949	2043	1023	1478	887	630
Average payment $ value	36.47	37.44	29.30	36.17	35.25	23.00
Monthly value $ per respondent (w)	1953	2012	1088	1551	678	648
Average payment $ value (w)	36.55	37.03	28.24	39.97	38.64	20.12
Average HH income	79866	88827	39720	73780	23205	31588
Average HH income (w)	82315	90103	50064	74271	24550	41554
Median HH income	67500	67500	27500	55000	18000	20000
Average age	52	52	45	56	55	44
Average age (w)	49	48	46	54	48	48
Median age	53	53	45	58	56	43

Table 1: Payments for in-person purchases and respondents' adoption of credit cards, debit cards, and bank accounts.

Notes: All is entire sample, CC_DC have both credit and debit cards, No_CC do not have credit cards, No_DC do not have debit cards, None_B and None_UB are banked and unbanked, respectively who do not have debit or credit cards. (w) refers to weighted data to fit the U.S. adult population.
Source: Author's computations from the 2017 and 2018 Diary of Consumer Payment Choice.

Subsample	Variable	Cash	Check	Credit	Debit	Prepaid
All	Number of payments	5139	244	3740	4392	329
	%	37.1	1.8	27.0	31.7	2.4
	% (w)	36.1	1.6	27.3	32.8	2.2
	Monthly number per respondent	19.84	0.94	14.44	16.95	1.27
	Average payment $ value	17.93	197.63	49.08	39.29	25.36
CC_DC	Number of payments	3404	161	2861	3651	211
	%	33.1	1.6	27.8	35.5	2.0
	% (w)	31.9	1.4	28.9	35.9	1.8
	Monthly number per respondent	18.06	0.85	15.18	19.37	1.12
	Average payment $ value	14.96	247.72	50.16	40.08	21.69
No_CC	Number of payments	901	21	0	741	78
	%	51.8	1.2	0.0	42.6	4.5
	% (w)	49.9	1.0	0.0	44.6	4.5
	Monthly number per respondent	18.08	0.42	0.00	14.87	1.57
	Average payment $ value	23.03	63.61	0.00	35.37	34.68
No_DC	Number of payments	1106	65	879	0	77
	%	52.0	3.1	41.3	0.0	3.6
	% (w)	52.7	3.1	40.3	0.0	3.9
	Monthly number per respondent	21.24	1.25	16.88	0.00	1.48
	Average payment $ value	24.81	111.72	45.57	0.00	28.33
None_B	Number of payments	46	3	0	0	7
	%	82.1	5.4	0.0	0.0	12.5
	% (w)	89.3	4.0	0.0	0.0	6.7
	Monthly number per respondent	20.67	1.35	0.00	0.00	3.14
	Average payment $ value	32.45	86.77	0.00	0.00	31.61
None_UB	Number of payments	219	0	0	0	30
	%	88.0	0.0	0.0	0.0	12.1
	% (w)	85.7	0.0	0.0	0.0	14.3
	Monthly number per respondent	24.07	0.00	0.00	0.00	3.30
	Average payment $ value	22.06	0.00	0.00	0.00	29.91

Table 2: Number of payments and average dollar value per respondent for in-person purchases sorted by payment instrument and respondents' adoption of credit cards, debit cards, and bank accounts.

Notes: All is entire sample, CC_DC have both credit and debit cards, No_CC do not have credit cards, No_DC do not have debit cards, None_B and None_UB are banked and unbanked, respectively who do not have debit or credit cards. (w) refers to weighted data to fit the U.S. adult population.
Source: Author's computations from the 2017 and 2018 Survey and Diary of Consumer Payment Choice.

Assessment\ rating	1	2	3	4	5
Cost	56.96	20.39	15.26	5.82	1.57
Security	16.53	19.56	12.51	30.3	21.1
Convenience	1.83	2.98	5.01	25.56	64.68

Table 3: Distribution of respondents' assessments of the payment instruments that they actually used for their in-person purchases.

Note: Each row sums up to 100 percent.
Source: Author's computations from the 2017 and 2018 Survey and Diary of Consumer Payment Choice.

Assessment	Cash	Check	Credit	Debit	Prepaid
Cost	1	2	3	2	2
Security	3	3	4	3	3
Convenience	4	3	5	5	4

Table 4: Respondents' population weighted median assessments by payment method.

Source: Author's computations from the 2017 and 2018 Survey and Diary of Consumer Payment Choice.

Sample	Payments	Respondents	CS_{cash}	CS_{cashless}	$\%\Delta CS$	$\%\Delta CS_{\text{relative}}$
Credit and debit	10,083	1,921	17.30	16.89	-2.36	1.0
Debit only	1,284	382	16.97	16.34	-3.71	1.6
No credit/debit	248	93	16.27	13.43	-17.42	7.4

Table 5: Simulated percentage drop in per-payment consumer surplus (CS) from a hypothetical complete transition to cashless stores (simulated using a random utility model).

Note: Simulations are based on 10,083 payments made by 1,921 respondents who have both cards.
Source: Author's computations from the 2017 and 2018 Survey and Diary of Consumer Payment Choice.

Variable	Credit and debit		No credit card		No debit card		None banked		None unbanked	
age	0.00175	*	-0.00547	***	0.00309	***	0.00016		-0.00107	***
log(1 + income)	0.03577	***	-0.03110	***	-0.00905		-0.00103		-0.00637	***
hh_size	-0.01056		0.00089		0.01176		0.00038		0.00204	
worknot_employed	-0.10322	***	0.05438	***	0.05720	**	-0.00062		0.02459	**
maritalnot_married	-0.06512	**	0.08091	***	0.00069		0.00607		0.02271	**
educSome_college	0.09224	**	-0.07704	***	-0.03145		0.00314		-0.02004	*
educAssoc_degree	0.16545	***	-0.17692	***	-0.04133	**	-0.00941	***	-0.05101	***
educBA_degree	0.05239		-0.06249		-0.01470		-0.00780	***	-0.03853	***
educMA_or_higher	0.11869	*	-0.17907	***	0.01263		-0.00785	***	-0.03873	***
gendermale	-0.05808	**	0.02332		0.03053	*	-0.00425		0.00128	

Table 6: Average marginal demographic effects of five consumer card adoption profile regressions.

Notes: The top three variables are numeric, the other nine are categorical. (***), (**), and (*) correspond to the 99.9, 99, 95, and 90 percent confidence levels, respectively.
Source: Author's computations from the 2017 and 2018 Diary of Consumer Payment Choice.

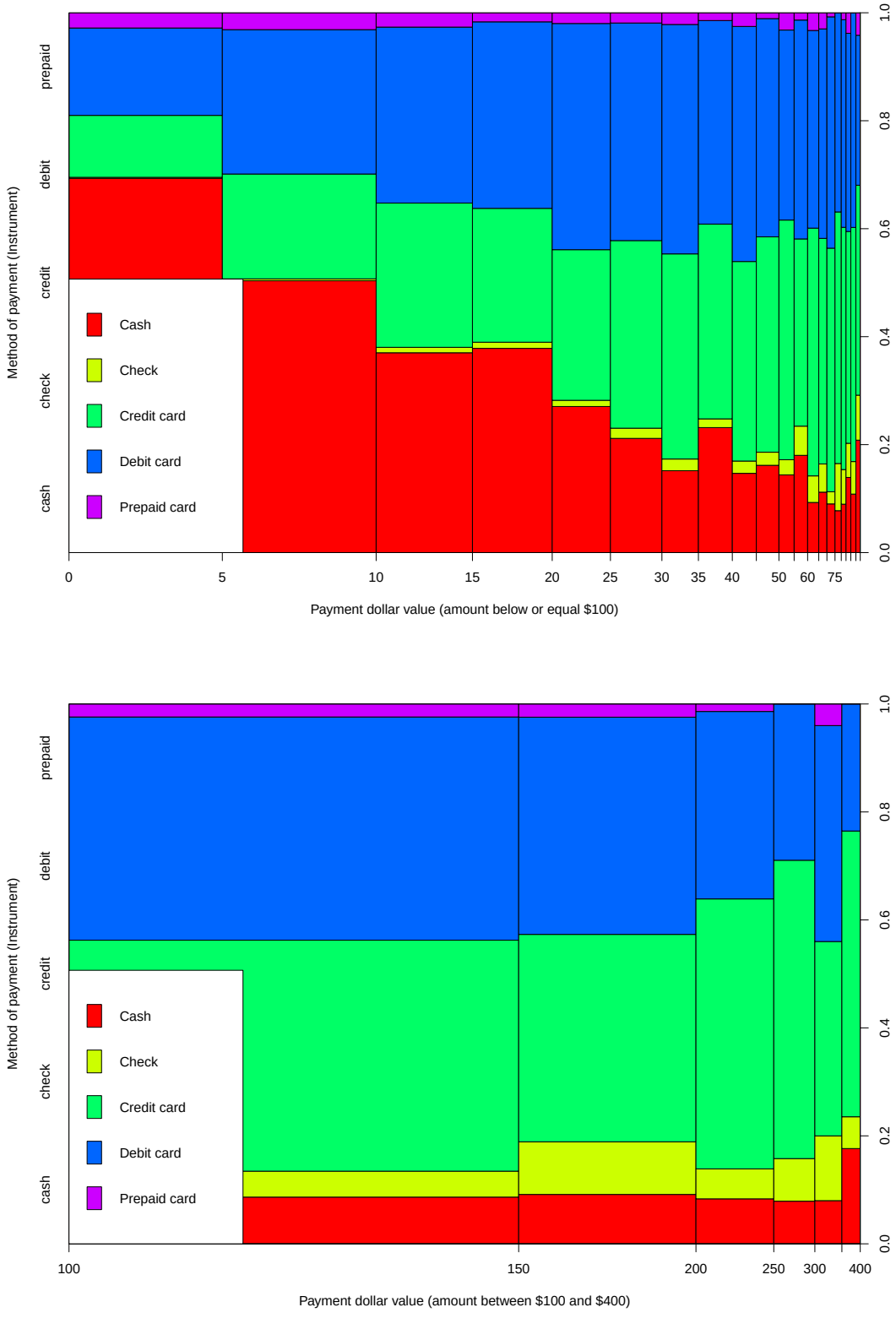

Figure 1: Respondents' use of payment instruments for in-person purchases by dollar amount.

Notes: *Top*: 13,038 payments not exceeding $100 made by 2,634 respondents. *Bottom*: 765 payments between $100 and $400 made by 583 respondents. Unequal spacing reflects relative number of transactions within the amount range.
Source: Author's computations from the 2017 and 2018 Diary of Consumer Payment Choice.

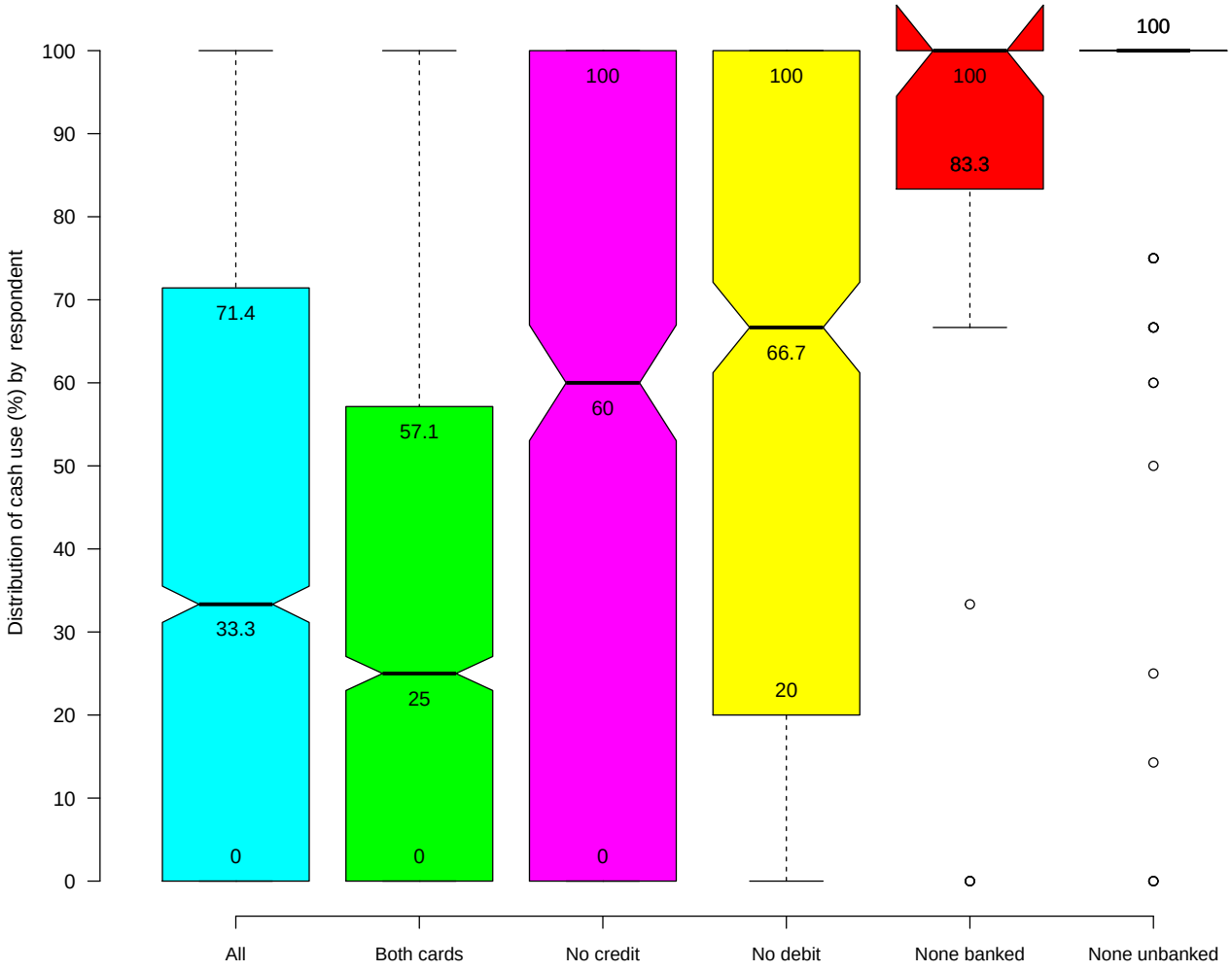

Figure 2: Distributions of percentage cash use for in-person purchases by individual respondents according to their card adoption profile.

Note: The three percentages in each box correspond to the lower quartile (25th percentile), median (50th percentile), and upper quartile (75th percentile), respectively.
Source: Author's computations from the 2017 and 2018 Survey and Diary of Consumer Payment Choice.

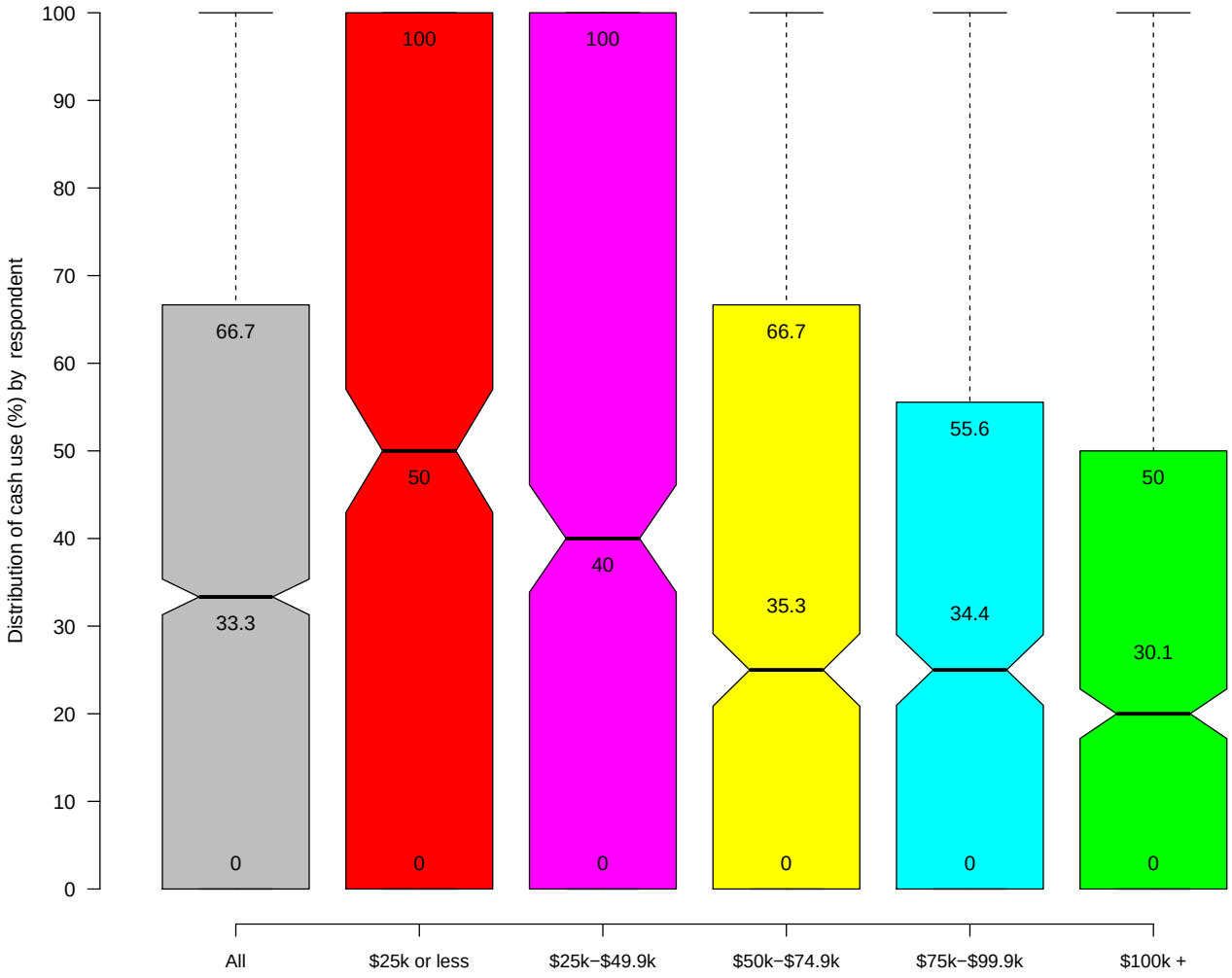

Figure 3: Distributions of percentage cash use for in-person purchases by household income groups.

Note: The three percentages in each box correspond to the lower quartile (25th percentile), median (50th percentile), and upper quartile (75th percentile), respectively.
Source: Author's computations from the 2017 and 2018 Diary of Consumer Payment Choice.