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How the ATM Affects the Way We Pay

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Abstract: Cash users withdraw money from automated teller machines (ATMs) to finance cash payments. However, most ATMs in the United States dispense only multiples of $20 bills. The paper first constructs a consumer's optimization model showing how the precise denomination of dollar bills available from ATMs affects consumers' decision whether to pay with cash or with (plastic) cards. Then, the paper uses various statistical techniques to conduct empirical analyses of consumers who choose to pay cash for transactions below a certain threshold payment amount and pay with cards for transactions exceeding that threshold.

JEL classification: D9, E42

Key words: currency denomination, automated teller machines, ATM, consumer payment choice, payment methods, point of sale

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1. Introduction

Data collected on how consumers pay in the United States reveal two important characteristics of cash payments at the point of sale: First, the use of cash declines with the payment value. Second, a large number of consumers switch from paying with cash to paying with cards for payment amounts exceeding the threshold of $20. The second observation provides the motivation for this paper. This is because most automated teller machines (ATMs) in the United States dispense only multiples of $20 bills. Therefore, paying with cash subjects buyers to what is known as the 'burden of receiving and carrying change.' The burden of change is larger for transaction values farther away from multiples of $20 where buyers exchange their $20 bills for smaller denomination coins and currency notes.

The first part of the paper constructs a consumer optimization model showing how the precise denomination of dollar bills available from ATMs affect consumers' decision whether to pay with cash or with (plastic) cards. The rest of the paper then utilizes various statistical techniques to conduct empirical analyses of consumers who choose to pay cash for transactions below a certain threshold payment amount, and pay with cards for transactions exceeding that threshold.

The analysis in this paper focuses on buyers' choice between paying with cash and paying with credit and debit cards. The latter is combined into a single payment method referred to as 'cards.' Each of the two payment methods has its own benefit and cost. The benefits from paying with cards tend to be monotonically increasing with the payment amount. This is because most credit cards provide rewards that are proportional to the payment amount (such as 1%, 1.5%, or even 2% cash back). In additional, fraud and theft prevention become more important for large amounts.

The benefit and cost of paying with cash are somewhat more complex. The benefit stems from the ability to control spending. Unlike credit cards, cash payments involve no credit. The cost is having to deal with receiving change after each cash transaction. This cost is proportional to the difference between the money in hand and the payment amount.

The complexity of analyzing the burden of receiving and handling change stems from the fact that change is composed of currency notes and metal coins. Knotek (2008, 2011) call it the "relative inconvenience of price" where inconvenience is measured by the minimum number of coins and bills needed to make a transaction. The burden of coins on buyers was analyzed in Chen, Huynh, and Shy (2019) using Canadian consumer diary data collected by the Bank of Canada. In contrast, this paper uses U.S. diary data to investigate whether the \$20 payment amount threshold (between paying cash and paying with cards) is more common than other payment amount thresholds. In this respect, using data from a discount chain, Wang and Wolman (2016) provide empirical support that individual consumers choose between cash and non-cash payments based on a threshold transaction size.

In general, cash use at the point-of-sale (POS) remains strong in most countries. A recent study by Bagnall et al. (2016) compares payment diaries from seven countries and shows that cash still dominates low-value transactions especially lower than \$25. Using payment and scanner data, Klee (2008) and Fujiki and Tanaka (2017) document that transaction value is a strong determinant of payment choice. Further studies by Schuh and Stavins (2010), Arango, Huynh, and Sabetti (2015), Bounie, François, and Waelbroeck (2016), Wakamori and Welte (2017), Shy (2018), and Chen, Huynh, and Shy (2019) confirm this finding using payment diary data.

This article is organized as follows. Section 2 constructs a simple optimization model of consumer payment choice. Section 3 describes the data and defines the variables of interest. Section 4 analyzes ATM cash withdrawals. Section 5 presents the main empirical results identifying payment amount thresholds that determine consumer payment choice. Section 6 presents results generated from data restricted to consumers who actually withdraw money from an ATM on the payment day. Section 7 concludes.

2. A simple model of consumer payment choice

Consider a consumer who has two payment instruments: cash and a payment card. The consumer goes on a shopping trip and plans on making a single purchase. Because both, cash and card, start with the letter "c", I denote a cas***h*** payment by H and a car***d*** payment by D. Let $p > 0$ be the dollar payment amount to be determined when the buyer arrives at the point of sale.

Before reaching the point of sale, the buyer withdraws cash from the nearest ATM.

ASSUMPTION 1. *The ATM dispenses dollar bills with a single denomination of* $\$m$ *(*$m > 0$*). Therefore, the consumer can withdraw only multiples of* $\$m$ *bill.*

2.1 Benefit and cost of payment methods

After observing the transaction amount at the point of sale, the buyer must decide whether to pay cash (H) or with a card (D). As discussed in the introduction, each method of payment has its own benefit and cost as formalized in the following assumptions.

ASSUMPTION 2. *The benefit of paying cash is constant, whereas the cost of paying cash increases with the amount of change the buyer must carry back from the point of sale. Formally, net benefit (benefit minus cost) from paying* $\$p$ *with cash is*

$$H(p) = h_0 - \begin{cases} h_1(m-p) & \textit{if} \quad 0 < p \leq m \\ h_1(2m-p) & \textit{if} \quad m < p \leq 2m \\ \quad \vdots & \textit{if} \quad \quad \vdots \\ h_1(nm-p) & \textit{if} \quad (n-1)m < p \leq nm, \end{cases} \tag{1}$$

where $h_0 > 0$*,* $h_1 > 0$*,* n *is a positive integer, and* nm *is the highest possible transaction value that the buyer may encounter (*$nm \geq p$*).*

Assumption 2 is illustrated by the solid upward-sloping line segments labeled $H(p)$ in figure 1. The line segments $H(p)$ show that cash payers benefit the most when the payment involves multiples of $\$m$ which are dispensed by the ATM because no change in given back. The lowest benefit from cash use are for payments slightly above $\$0$, $\$m$, $\$2m$, $\$3m$, and so on. This is because at these transaction values buyers receive almost $\$m$ in change (largest possible amount of change) given by $m - p \approx m$ or $2m - p \approx m$ and so on. Basically, smaller transactions relative to multiples of $\$m$ are less beneficial for cash users because these consumers are forced to receive and handle a large amount of change in the form of cash.

I now proceed with the benefits buyers derive from card payments.

ASSUMPTION 3. *The benefit from paying with cards monotonically increases with the payment amount. Formally,*

$$D(p) = d_0 + d_1 p, \quad d_0 \geq 0 \quad \textit{and} \quad d_1 > 0. \tag{2}$$

Assumption 3 is illustrated by the upward-sloping dashed line labeled $D(p)$ in figure 1. Both, the intercept d_0 and the slope d_1 determine the relative positions of card benefit $D(p)$ and net cash benefit $H(p)$ for each payment amount p. As discussed in the introduction, card rewards (such as percentage cash-back or the accumulation of frequent-flyer miles) make the benefit derived from card payments increase with the payment amount p.

2.2 Payment choice decision problem

Buyers adopt a simple payment choice strategy in which there is a cutoff payment amount $\bar{p}$ (reservation price or threshold) beyond which they pay with a card instead of cash. Formally,

DEFINITION 1. *A payment choice strategy S is a unique payment amount $\bar{p}$ and a mapping from a payment amount p to the set of two choices $S : \mathbb{R}_+ \to \{H, D\}$ satisfying*

$$S(p) = \begin{cases} H \text{ (Cash)} & \text{if } p \le \bar{p} \\ D \text{ (Card)} & \text{if } p > \bar{p}. \end{cases} \tag{3}$$

Definition 1 and Figure 1 imply the following Result.

Result 1. *Let buyers' decision rule be given in Definition 1. Then, $\bar{p} = m$ if $h_0 - h_1 m \ge d_0$ and $h_0 \in [d_0 + d_1 m\,, d_0 + 2d_1 m)$. That is, under these conditions, consumers pay cash for transaction values up to (inclusive) the ATM currency denomination and pay with cards for all payment amounts exceeding it.*

Result 1 is depicted in Figure 1 showing a wide parameter range where $D(p) < H(p)$ for $p \le m$ and $D(p) > H(p)$ for $p > m$ so $\bar{p} = m$ is the cutoff payment amount beyond which buyers pay with cards.

Deviating from the conditions specified in Result 1 could lead to some extreme cases. More precisely, buyers with $d_0 \le h_0 - h_1 m$ and $d_1 = 0$ use cash for all payment amounts (cash only buyers). In the other extreme, buyers satisfying $d_0 \ge h_0 - h_1 m$ and $d_0 + d_1 m > h_0$ do not use cash at all.

To summarize, this simple model defines buyers' payment preference parameters under which the ATM currency denomination plays a key role in their strategy for deciding which payment amounts to pay for with cash and which with cards. These results call for empirical investigations of how buyers actually pay at the point of sale which is the subject of the remainder of this paper.

3. Data, variable selection, and coding

The study of consumer payment choice at the POS involves a classification of payment methods such as cash, credit cards, debit cards, prepaid cards, and paper checks. Data on "how consumers pay" are collected by consumer surveys in which consumers list all the payment instruments they have and whether and how they use them at the point of sale (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 processed 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 2016 Diary of Consumer Payment Choice (DCPC).[1] The DCPC is a diary survey in which a representative sample of U.S. consumers record all their 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 2016 in a way that resembles a three-period overlapping generations model.

The DCPC has a large number of variables describing all sorts of transactions. For the purpose of this article, I will focus only on a subset of variables which I describe below. In particular, I restrict the analysis to "in-person" and "retail" purchases (in-person = 1 and merch = 7), and to the three dominating payment methods: "cash," "credit cards," and "debit cards." These restrictions leave a total of 7067 payment observations to be analyzed.

Method of payment (Method): is our main response classification variable that takes the following values: *Cash* (2697 cash payments), *Ccard* (1780 credit card payments), *Dcard* (2590 debit card

[1] The survey was conducted by the Federal Reserve Bank of Boston and co-sponsored by the Federal Reserve Banks of Richmond and San Francisco. The data are publicly available for downloading from the Federal Reserve Bank of Atlanta Website: https://www.frbatlanta.org/banking-and-payments/consumer-payments/diary-of-consumer-payment-choice.aspx, and are summarized in Greene and Schuh (2017). Similar surveys are conducted by the Bank of Canada, see Henry, Huynh, and Shen (2015).

payments).

I now describe the list of 10 predictors, one numeric, two integer-valued, and seven categorical variables. The values that each categorical predictor can take (realize) are listed in order (levels) so that the first value is also the reference value in logistic regressions (that is, the benchmark value for which other values are compared to). The number in parentheses is the number of payments made by respondents corresponding to this category (not the number of respondents under this category).[2]

Amount: Numeric payment amount ranging from $0.25 to $5,325, with median $15.06 and mean $33.12.

Age: Integer-valued age ranging from 18 to 92, with median 51 and mean 50.4.

HH_size: Integer-valued number of people living in the payer's house ranging from 1 to 9, with median 2 and mean 2.64.

Work: *Employed* (4746 payments) and *Not_empl* (not employed, 2321 payments).

Marital: *Never_mar* (never married, 1026 payments), *Married* (4626), *Div_sep* (divorced or separated, 1109), and *Widowed* (306).

Educ: *Elem_or_less* (Elementary or less, 189 payments), *High* (high school, 3043), *Assoc_or_college* (associate or college degree, 2359), *MA+* (graduate degree, 1476).

HH_income (household annual income): $0 < 25k$ (1054 payments), $25 < 50k$ (1435), $50 < 75k$ (1483), $75 < 100k$ (1094), $100 < 125k$ (796), $125 < 200k$ (844), $200 < 500k$ (343), $> 500k$ (18).

House: *Not-own* (1675 payments), *Own* (5392).

Gender: *Male* (3265 payments), *Female* (3802).

Race: *White* (6197 payments), *Black* (368), *Asian* (135), *Other* (367).

The analysis in this article does not apply demographic sampling weights because the whole purpose of this demonstration is to analyze the effects of demographics on payment choice (among other variables).

[2]Some categorical predictors (such as *HH_income*, *Marital*, and *Educ*) were consolidated to a smaller number of categories. Four additional variables: *diary_day* (first, second, or third diary day), *time* (transaction time), *prim_key* (respondent's ID), and *cw_location* (cash withdrawal location identifies ATM cash withdrawals) are used in Sections 4 and 6 that analyze issues related to ATM withdrawals.

4. Some statistics on ATM cash withdrawals

Diary respondents made 167 ATM cash withdrawals.[3] Dividing 167 by the total number of survey respondents yields 0.0586 ATM withdrawals per respondent over a 3 day period. In yearly terms, this means that, on average, each respondent makes about 43.41 ATM withdrawals in a year (0.835 per week). Of the 156 respondents who actually withdrew cash from an ATM during the three-day survey period, seven respondents withdrew twice and two respondents withdrew three times.

Focusing on ATM cash withdrawal dollar amounts, $10 was the lowest and $1005 was the highest amount. The median amount was $75 and the mean was $116.7. The top panel in Figure 2 displays the distribution of ATM withdrawals amounts ignoring one $600 withdrawal and one $1005 ATM withdrawal. The bottom panel in Figure 2 displays the distribution confined to withdrawals not larger than $200. Both panels show that $100 was the most frequently withdrawn amount, followed by $40, $20, $60, and $200, in this order. All these amounts are *multiples of $20* which provide the key motivation for this research.

5. Emperical results

This section utilizes visual and statistical techniques to evaluate the effect of the $20 currency denomination supplied by ATMs on consumers' decision whether to pay cash or with cards. The goal is to estimate the threshold payment values above which there are significant drops in cash payments relative to card payments.

This section conducts the analysis without restricting the data with respect to initial cash holdings or whether consumers withdraw money from an ATM just before making a payment. As it turns out, even without these restrictions, ATM currency denomination generates statistically significant payment amount thresholds that separate cash payments from card payments. Section 6, reports on estimations made using a much smaller number of observations restricted to payments made right after consumers withdrew cash from an ATM.

Using the data set described in Section 3, the vertical axis of Figure 3 displays the relative

[3] I excluded eight reported ATM withdraws on the amounts $3, $11, $18, $41, $41.93, $59, $63, $91, $103 which are unlikely to be provided by ATMs (although, these amounts may reflect some ATM fees that were billed directly to a bank account).

share of payments made with cash, credit, and debit cards. The horizontal axis measures actual payment dollar amounts in $1 intervals (total 45 intervals). The unequal spacing on the horizontal (Amount) axis reflects the relative number of transactions made at each payment amount interval. Since the number of transactions declines very rapidly towards transaction values above $45, the figure is restricted to payment amounts up to $45 dollars.

Overall, Figure 3 shows how the share of cash use declines with the transaction value. But, perhaps, the most striking observation in Figure 3 is the upward jump in the share of cash use in payment amounts between $19 and $20. Other somewhat smaller jumps in cash use are also observed in between $4 to $5, $14 to $15, $24 to $25, $29 to $30, $34 to $35, and $39 to $40.

The *top* panel of Figure 4 shows that the share of cash payments peaks at the following payment amount intervals: $0–$1 (91%), $4–$5 (64.0%), $9–$10 (55.1%), $14–$15 (39.5%), $19–$20 (50.4%), $24–$25 (30.7%), $29–$30 (33.0%), $39–$40 (32.9%), and $44–$45 (0.2%).

The *middle* panel of Figure 4 depicts the difference (jump) in the share of cash use associated with a $1 increase in the payment amount. More precisely, the middle part of Figure 4 shows a 3.1% increase in the share of cash use between $4 and $5 payment amounts, 13.6% increase between $9 and $10, 5.1% increase between $14 and $15, 21.1% increase between $19 and $20, 2.4% increase between $24 and $25, 10.5% increase between $29 and $30, 18.6% increase between $39 and $40, and 8.2% increase between $44 and $45. The middle panel also shows a 20.1% increase between $41 and $42 which cannot be explained by ATM currency denomination.

Perhaps the most striking observation in the middle panel of Figure 4 are the sharp drops in cash use in payment amounts between $20 and $21 ($-29.9\%$) and between $40 and $41 ($-29.7\%$). Both, the sharp increase in share of cash use and the sharp drop in cash use around the $20 payment amount make it clear that a large number of consumers use the $20 payment amount as a threshold above which they switch from paying cash to paying with cards. The following three subsections test this hypothesis using three statistical methods: (5.1) classification tree (5.2) logistic regression, and (5.3) de-trending with respect to payment dollar amount.

5.1 Payment method classification tree

In the context of machine learning, a classification tree displays an optimized algorithm in the form of an upside-down tree. The tree illustrates how the machine (software) splits and classifies the payment methods with the objective of minimizing a function of the number of classification errors among the predicted payment methods relative to the actually-used methods.[4]

Figure 5 displays an upside-down tree that classifies the use of the payment methods (cash, credit, and debit) according to payment amount and payers' demographic features that were described in Section 3. The classification tree displayed in Figure 5 was constructed with the *rpart* R package and pruned by setting the complexity parameter to $cp = 0.005491991$, thereby generating six splits.

Figure 5 shows that the \$10 and \$20 payment amount thresholds constitute the best predictors for cash payments. Note that the tree algorithm selects the splits on the top and on the top of the right branch according to dollar amount because this feature reduces classification errors more than a top split according to age or income (that are pushed to lower branches of the tree). The exact top splitting amount (\$10 in this sample) is determined by the error "majority rule" (or some function of it) in the sense that any other split would generate lower prediction accuracy as measured by a function of the number of prediction errors.

The second layer of branches in Figure 5 consists of splits according to age 36 and \$20 payment amount. For amounts larger than \$20, a split according to household income becomes the best predictor (in terms of reduction in classification errors). Note that on this branch, high household income may be correlated with payers' ability to obtain and use credit cards.

5.2 Logistic regression discontinuity design

Using the transaction data described in Section 3, define a binary variable "Cash" to take the value of 1 for cash payments and 0 for card payments. Using 25 payment amount thresholds, the

[4] The classification tree algorithm is designed and tuned using cross validation. The cross validation procedure partitions the training data into k folds, where the algorithm is constructed using $k - 1$ folds of data and tested on the retained k's fold on which the classification errors are measured. The process repeats itself k times, each with a different retained k's fold. The k error measurements are then averaged to produce the final tree algorithm. The advantage of this method is that all observations are used for both training and validation.

estimated model takes the form of[5]

$$
\begin{aligned}
\text{Cash} = \text{Amount} + \sum_{j=1}^{25} \delta_j I\{\text{Amount} > j\} + \alpha_W \text{Work} + \alpha_S \text{HH\_size} \\
+ \alpha_I \text{HH\_income} + \alpha_H \text{House} + \alpha_A \text{Age} + \alpha_G \text{Gender} + \alpha_E \text{Educ} + \epsilon.
\end{aligned} \tag{4}
$$

For all $j = 1, \ldots, 25$ reflecting \$1 increments, I is the indicator function which takes a value $I = 1$ if the payment amount is strictly greater than j and $I = 0$ otherwise, and δ_j are the corresponding dummy variables. The α coefficients correspond to demographic variables described in Section 3.

Table 1 displays the estimated marginal effects and their confidence intervals. The table shows that the largest drops in cash use occur at the \$1 and \$20 thresholds where the probability of paying cash drops by over 27 percent. The marginal effect at the \$1 threshold most likely reflects the transition from payments made with coins (below \$1) to paper currency (above \$1). For the purpose of this investigation, the important threshold is \$20 which corresponds to the denomination of bills dispensed by most ATMs in the United States. Disregarding the \$1 threshold, \$20 is the only threshold which shows a drop of over 27 percent in the probability of cash use. Figure 6 shows that this drop in the probability of cash use stands out when the marginal effects and the corresponding confidence intervals are drawn as functions of the payment amount thresholds.

Finally, I also estimated a simplified version of the logit model (4) by using a single threshold $I\{\text{Amount} > 20\}$ instead of 25 thresholds. The marginal effect at this threshold is -0.3006 (compared to -0.272 in the full model) and is statistically significant at the 0.001 level.

5.3 De-trending according to payment amount

The regression marginal effects displayed in Table 1 and Figure 6 show drops in the probability of cash use between the payment amounts: \$5 and \$6, \$10 and \$11, \$15 and \$16, \$20 and \$21, \$25 and \$26, and so on. The middle panel in Figure 4 also shows that the drop between the payment amounts \$20 and \$21 is larger than drops around the other thresholds. Moreover, the marginal effects depicted in Figure 6 show that the 95-percent confidence intervals around the marginal effects at the \$5 and \$15 payment amounts include zeros which make them not statistically signif-

[5] A similar model was estimated in Chen, Huynh, and Shy (2019) using the 2013 Canadian diary data.

icant. These observations support the claim that the $20 ATM currency denomination has a strong effect on consumer payment choice.

To further strengthen the claim that the $20 ATM denomination has a significant effect on consumer payment choice, this subsection takes a different approach by separating the negative relationship between the share of cash use and payment amount (the downward trend) displayed in both, Figure 3 and the top panel in Figure 4, from the local jumps and drops around the threshold payment amounts. Note that for very low payment amounts, such as below $5, this downward trend is also consistent with observation that some merchants refuse to get paid with cards for low-value transactions due to high credit card processing costs.

To separate the downward trend of cash use from the local jumps and drops, the analysis in this subsection 'de-trends' the share of cash use with respect to payment dollar amount. The bottom panel in Figure 4 depicts the share of cash use for each payment amount after it is subtracted from the regression line depicted on the top panel of Figure 4. This procedure 'de-trends' the negative effect of dollar amount on the share of cash use and shows the jumps and drops in cash use relative to the trend in shares of cash use. The bottom panel shows that the de-trended share of cash use is by far the highest for payment values between $19 and $20. This finding provides another strong support for the major hypothesis of this paper in which ATM currency denomination does has a strong effect on consumer payment choice.

6. Other explorations into the data

The results obtained so far are general in the sense that they were derived from the entire data set regardless of how much cash respondents held in their wallet when they entered the store, and without taking into consideration whether the consumer withdrew cash from an ATM on the same day when a payment was made.

As shown in Section 4, the diary data set contains information about 167 ATM cash withdrawals. Since respondents also recorded the time and date of each payment and cash withdrawal, I was able to analyze two subsets of the in-person retail purchases data:

(i) Cash and card payments that took place during the same day that the respondent withdrew cash from an ATM. With this restriction, the number of payment observations was reduced from 7067 to 177.

(ii) The first payment following an ATM withdrawal on the same day. That further reduced the number of payment observations to 91.

The first restricted data set with 177 payments resulted in a significant increase in the share of cash payments from 38 to 62 percent, and reduced credit and debit card payments to 15 percent and 23 percent, respectively. Repeating the same analysis as for the full data set generated very different results. More precisely, reproducing the equivalent chart to Figure 4 (not shown) reveals that with the reduced data set there are many payment amounts where all respondents paid with cash. These findings lead me to conclude that consumers who frequently withdraw cash from ATMs are heavy cash uses who use cash for most payment amounts below $45.

The second restricted data set with only 91 transaction observations shows a 63 percent share of cash, 16 percent credit, and 21 percent debit card. Therefore, it would be too ambitious to try and draw general conclusions about payment threshold amounts from such small data sets.

The takeaway from the above analysis of the two restricted data subsets is that ATM currency denomination affects payment choice of all consumers even in days when consumers do not withdraw cash from an ATM. Saying it differently, we can think of the $20 ATM currency denomination as influencing payment choice of consumers who rarely withdraw cash from an ATM in the same way (if not more) than consumers who frequently withdraw cash from ATMs.

7. Conclusion

This research shows that the availability of bills with specific currency denomination has a major effect on consumer payment choice. Beyond availabiilty of bills from ATMs, this research also hints on some policy implications for how optimal currency should be designed to minimize the burden of change. In fact, in the literature, there have been several attempts to compute the optimal currency according to the "principle of least effort," as discussed in Telser (1995), Van Hove (2001) and reference therein as well as in Shallit (2003) for the case of optimal coin denomination.

However, this literature does not take into consideration that even if central banks issue the effort-minimizing currency denominations, consumers may not be able to obtain all available currency denominations if ATMs provide only one type of currency ($20 bills in the United States). This distortion has been the focus of this paper.

Finally, the hypothesis analyzed in this paper is experimental in nature. It calls for randomized testing by providing buyers with different currency denominations and record their threshold payment amounts below which they pay only cash. One can think of field experiments where buyers who receive only $5, or $10, or even $50 dollar bills from the ATM. Obviously, such experiments are extremely costly to perform.

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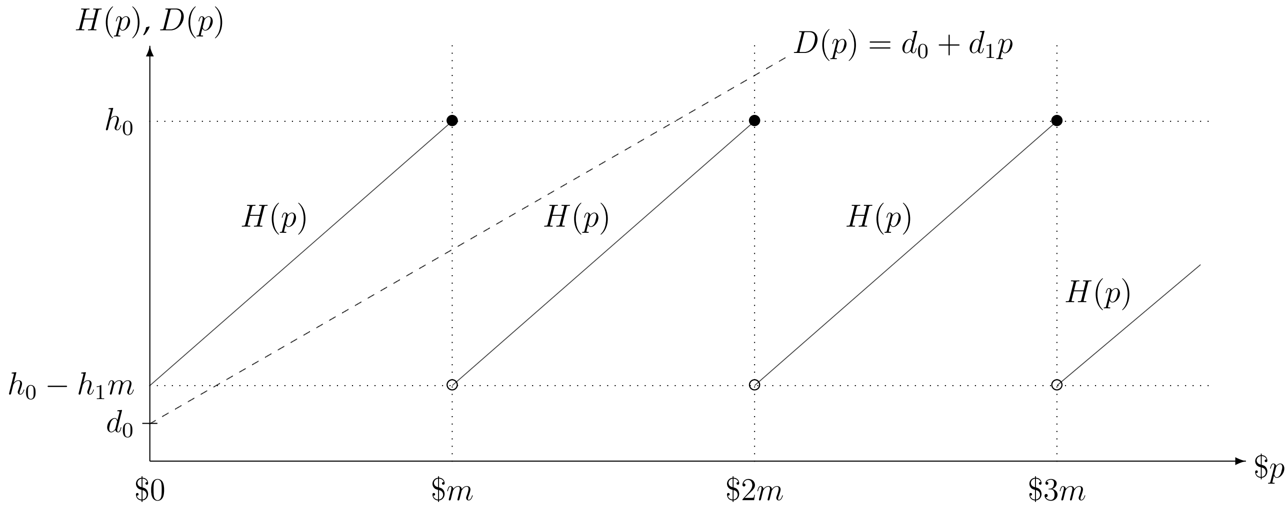

Figure 1: Net benefit from paying cash (solid upward-sloping line segments labeled $H(p)$) and net benefit from paying with cards (upward-sloping dashed line labeled $D(p)$).
Note: The figure assumes that ATMs provide only bills of \$m (\$20 as an example), and that buyers have no other forms of cash, except for cash obtained from an ATM.

	dF/dx	Std.Err.	Sig.	Conf. Interval	
Amount	-0.000	0.000	.	-0.001	0.000
I(Amount > 1)TRUE	-0.277	0.090	**	-0.454	-0.101
I(Amount > 2)TRUE	-0.065	0.049		-0.160	0.031
I(Amount > 3)TRUE	-0.119	0.047	*	-0.211	-0.027
I(Amount > 4)TRUE	0.019	0.039		-0.057	0.096
I(Amount > 5)TRUE	-0.056	0.040		-0.134	0.021
I(Amount > 6)TRUE	-0.095	0.041	*	-0.176	-0.015
I(Amount > 7)TRUE	0.020	0.042		-0.063	0.102
I(Amount > 8)TRUE	-0.085	0.047	.	-0.177	0.006
I(Amount > 9)TRUE	0.115	0.038	**	0.040	0.190
I(Amount > 10)TRUE	-0.140	0.044	**	-0.228	-0.053
I(Amount > 11)TRUE	0.004	0.050		-0.095	0.102
I(Amount > 12)TRUE	-0.053	0.055		-0.161	0.055
I(Amount > 13)TRUE	0.009	0.057		-0.103	0.121
I(Amount > 14)TRUE	0.028	0.053		-0.076	0.132
I(Amount > 15)TRUE	-0.037	0.059		-0.152	0.078
I(Amount > 16)TRUE	-0.095	0.067		-0.226	0.036
I(Amount > 17)TRUE	0.052	0.067		-0.078	0.183
I(Amount > 18)TRUE	-0.021	0.069		-0.156	0.114
I(Amount > 19)TRUE	0.194	0.060	**	0.077	0.311
I(Amount > 20)TRUE	-0.272	0.052	***	-0.373	-0.170
I(Amount > 21)TRUE	0.002	0.074		-0.142	0.147
I(Amount > 22)TRUE	0.031	0.077		-0.119	0.181
I(Amount > 23)TRUE	0.070	0.080		-0.087	0.226
I(Amount > 24)TRUE	0.001	0.071		-0.139	0.141
I(Amount > 25)TRUE	-0.166	0.043	***	-0.250	-0.083
WorkNot_empl	-0.014	0.016		-0.045	0.017
HH_size	0.011	0.006	.	-0.001	0.023
HH_income25<50k	-0.067	0.020	***	-0.107	-0.027
HH_income50<75k	-0.137	0.020	***	-0.176	-0.098
HH_income75<100k	-0.116	0.022	***	-0.158	-0.073
HH_income100<125k	-0.054	0.026	*	-0.105	-0.004
HH_income125<200k	-0.129	0.024	***	-0.176	-0.083
HH_income200<500k	-0.106	0.031	***	-0.167	-0.045
HH_income>500k	-0.290	0.063	***	-0.414	-0.167
HouseOwn	0.009	0.017		-0.025	0.043
Age	0.006	0.001	***	0.005	0.008
GenderFemale	-0.005	0.014		-0.032	0.022
MaritalMarried	-0.030	0.022		-0.073	0.014
MaritalDiv_sep	0.007	0.025		-0.042	0.055
MaritalWidowed	-0.155	0.027	***	-0.209	-0.101
EducHigh	-0.195	0.037	***	-0.267	-0.123
EducAssoc_or_college	-0.254	0.033	***	-0.319	-0.189
EducMA+	-0.299	0.026	***	-0.351	-0.247
RaceBlack	0.140	0.032	***	0.078	0.202
RaceAsian	-0.112	0.044	*	-0.198	-0.026
RaceOther	0.037	0.030		-0.021	0.095

Table 1: Cash use logistic regression marginal effects. *Note*: Sig. codes: *** 0.001, ** 0.01, * 0.05, . 0.1,

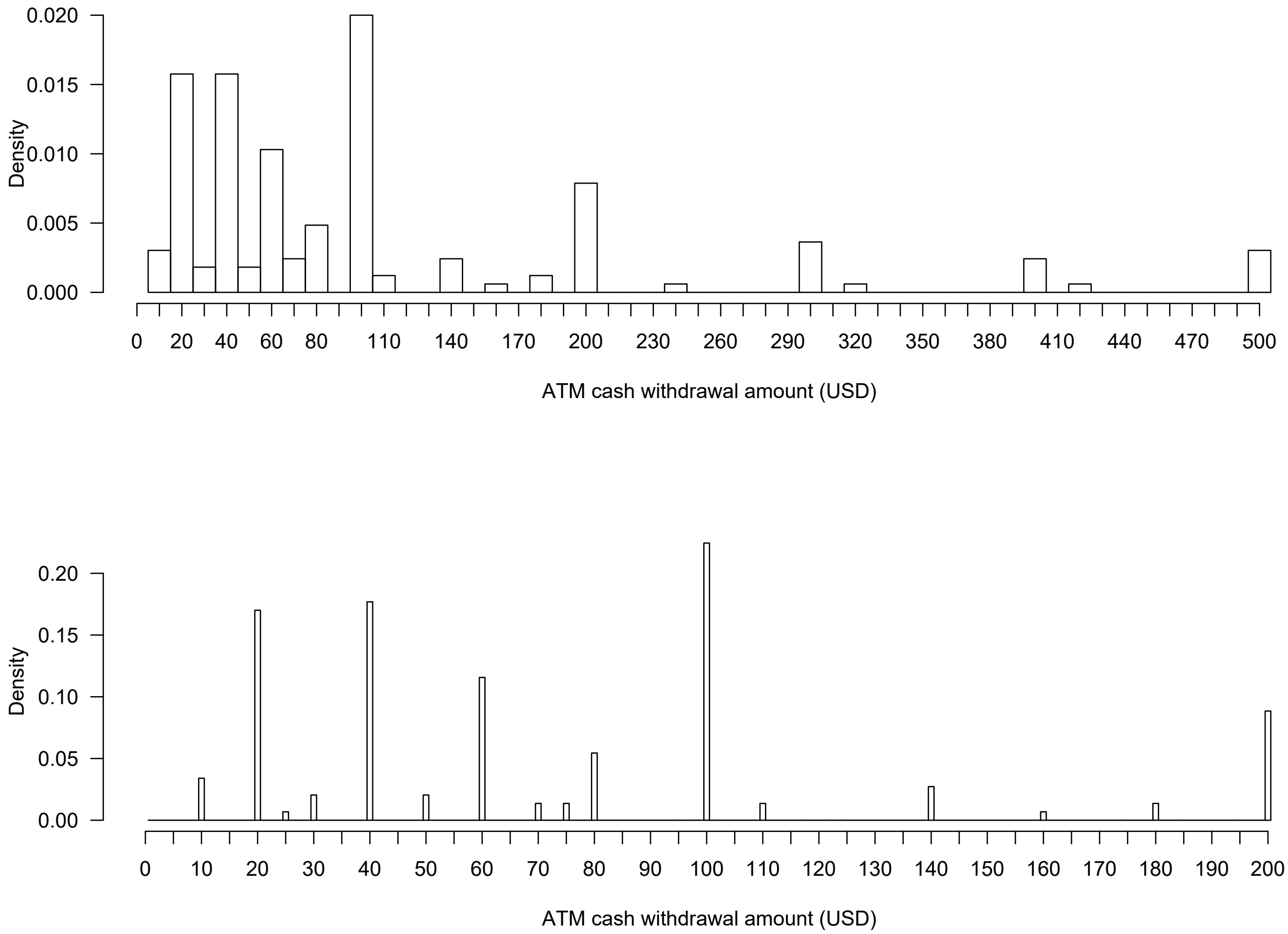

Figure 2: Density of ATM cash withdrawals. *Top*: Withdrawals limited to $500. *Bottom*: Withdrawals limited to $200.

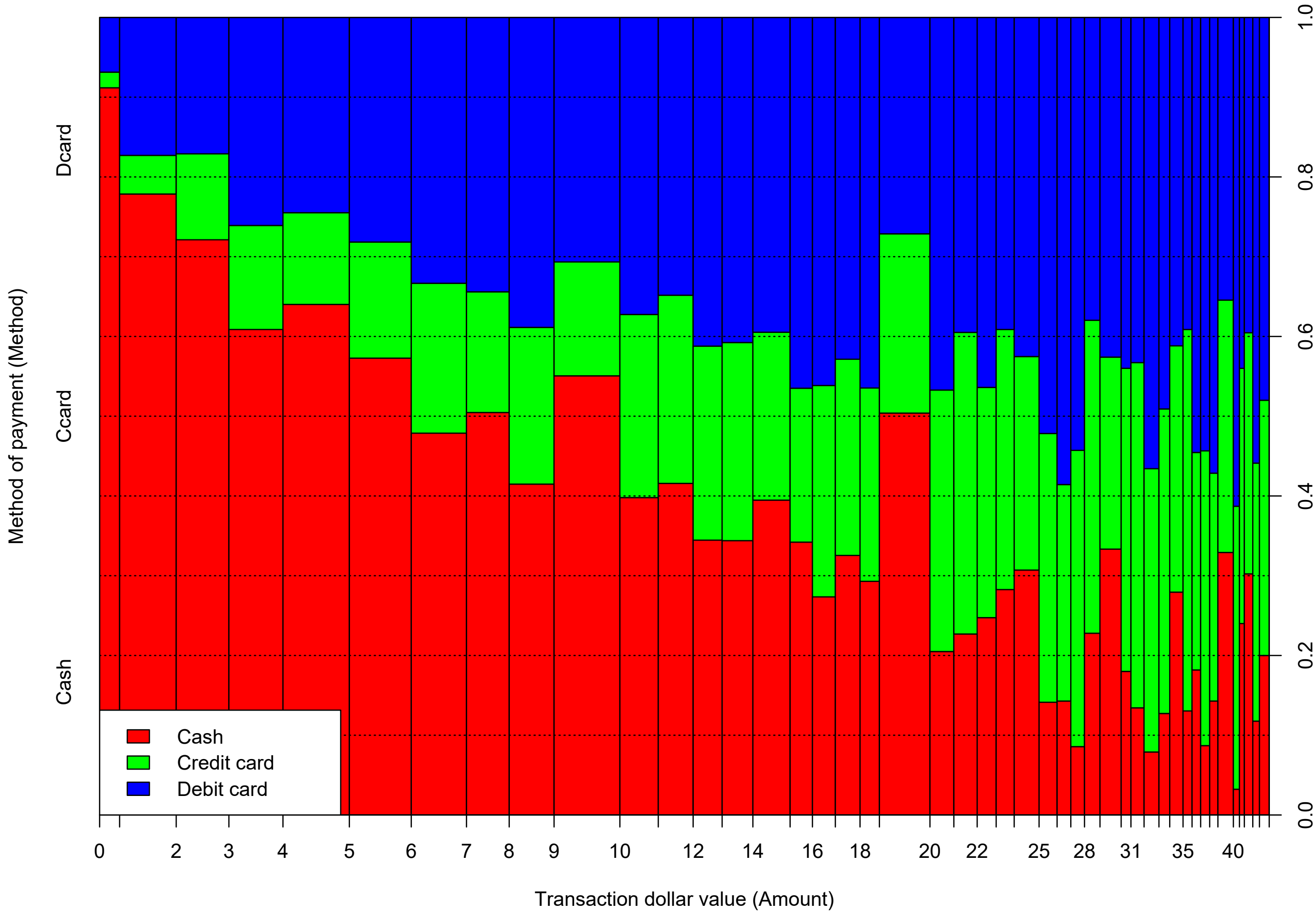

Figure 3: Share of use of cash, credit, and debit cards by each payment dollar amount up to $45.
Note: Unequal spacing between each $1 reflect relative number of payments at this amount.

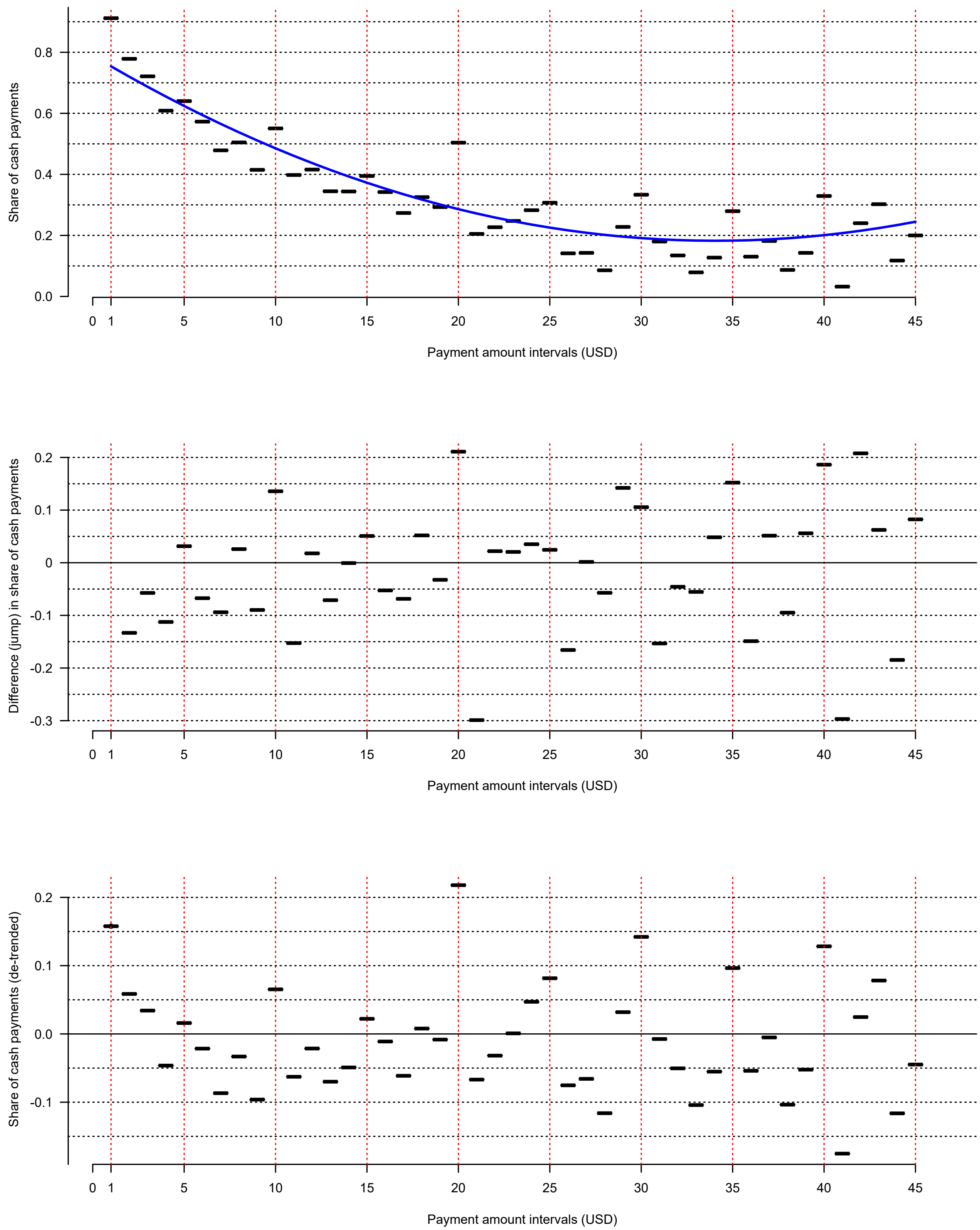

Figure 4: *Top*: Shares of cash use by payment dollar amount up to $45 and regression curve. *Middle*: Differences (jumps and drops) in share of cash use between two consecutive payment amounts. *Bottom*: Share of cash use de-trended around the regression curve.

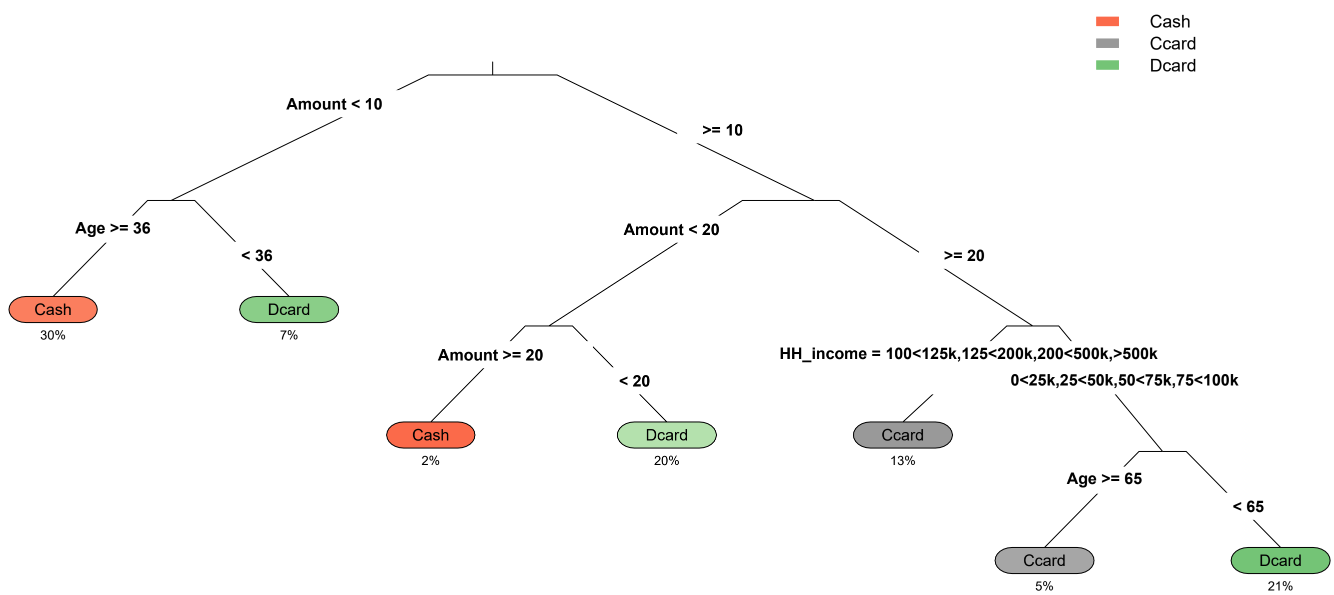

Figure 5: Payment method classification tree.

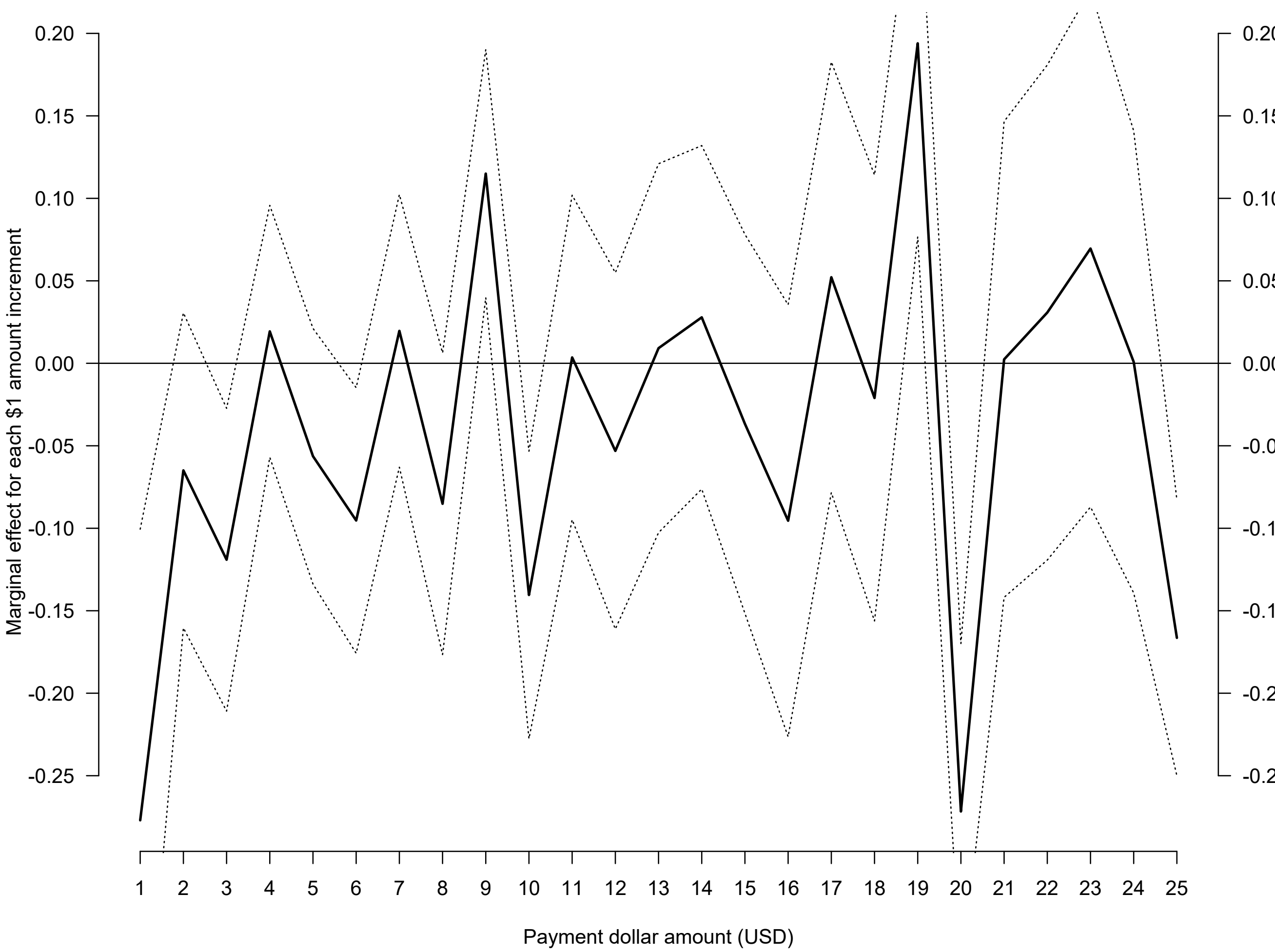

Figure 6: Marginal effects and 95-percent confidence intervals at each payment amount threshold.