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How people pay: Evidence from grocery store data ☆

Elizabeth Klee*

Board of Governors of the Federal Reserve System, Mail Stop 59, 20th and C Streets, Washington, DC 20551, USA

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Abstract

Empirical evidence based on grocery store transaction data shows that consumer payment behavior at the point of sale is important for understanding models of money demand. There are statistically significant effects of transaction costs, opportunity costs, and product characteristics on the choice of payment instrument, which then, in turn, affect money demand. These results emphasize the overlap between the work of empirical researchers in payment choice and theoretical modelers of monetary economics and should inform both literatures.

JEL classification: E41; G20; D12

Keywords: Media of exchange; Monetary and payment economics; Consumer behavior

1. Introduction

Theoretical models of the demand for money often start from Baumol's inventory equation, where the demand for cash balances increases with the conversion cost between cash and bonds and the value of transactions, but decreases with the interest rate on bonds.[1] Subsequent models build on this framework, and show that household income determines money holdings, as well as "shopping time", or the time for a transaction. Further refinements address transactions costs to motivate results concerning cash holdings and allocation.[2] These models illustrate that transaction costs and interest rates affect money holdings, and the equilibrium use of media of exchange in an economy depends on consumers' sensitivity to these factors.

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*Tel.: +1 202 721 4501; fax: +1 202 452 2301.
E-mail address: elizabeth.klee@frb.gov
[1]Refer to Baumol (1952) and Tobin (1956).
[2]Whitesell (1989), Santomero and Seater (1996), Shy and Tarkka (2002), and Lee et al. (2005).

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A bit more recently, an empirical literature on payment choice has blossomed, in a manner mostly divorced from the theory. Most of what is known about individual consumer behavior and the payment system is based on stated preference data in household surveys.[3] These types of studies have significant advantages. They generally have good information about family income, assets and demographics, which are excellent predictors of the use and holdings of different payment instruments. Although these surveys offer insight into demographic characteristics that are correlated with use and holdings of payment instruments, these surveys lack specific information on transactions costs, which, according to the models, should critically affect payment choice at the time of the actual exchange.

This paper attempts to bridge the gap. It provides a simple framework that links payment choice to money holdings. In order to evaluate the model, this paper uses grocery store scanner data paired with census-tract level demographic information to measure the influence of transaction costs and interest rate sensitivity on payment choice. It finds that these factors are significant determinants of payment choice, and ultimately money demand.

To provide a specific preview of the results, first, the paper estimates transaction costs—measured in units of time—for different payment instruments. Cash is the fastest payment instrument overall; debit cards and credit cards take somewhat longer, while checks are on average the slowest payment instrument to use. But, the transaction costs associated with paying with exact change for cash are almost equal to using a debit card—it takes about 8 s longer to use a debit card than to use cash. In addition, the paper addresses inventory costs, and evaluates the time cost per dollar of obtaining cash back with a check or a debit card. Dollar for dollar, it is more expensive to obtain cash back with a check than a debit card.

Still, while these transaction costs can represent a fair share of the length of a transaction, in absolute terms, these costs are small. For this reason, the second part of the paper explores other factors that influence payment choice, such as opportunity costs and demongraphics. Perhaps reflecting opportunity costs, the value of the sale is a key determinant of payment choice, with cash used for lower values of sale and credit cards used for higher ones. The demographic results presented here are consistent with previous research, which shows that younger, more educated consumers are more likely to use credit and debit cards than other groups.

And finally, the paper documents a possible link between payment choice and money demand. The results show that unobserved factors that influence payment choice are correlated with unobserved factors that influence the value of the sale. Possible candidates for these unobserved factors consistent with the parameter estimates include opportunity costs, interest elasticities, and price elasticities.

Grocery store scanner data have been used extensively in other contexts, most notably to investigate price elasticities of demand for consumer products.[4] Scanner data have distinct advantages for use in studying payment behavior. First, the data are plentiful, accurate and represent actual exchange behavior, complementing existing studies using survey data. Second, everyone eats—a lot, often and locally. Grocery store expenditures represented 6.2% of personal disposable income and 16.5% of retail sales (excluding motor vehicle parts) in 2001. In addition, according to industry data, consumers shop at grocery stores an average of twice a week.[5] Moreover, evidence suggests that consumers shop locally for groceries.[6] Using census-tract information on the demographics of the local market potentially proxies well for shopper demographics.

And third, grocery stores have an interesting role in the payment and banking system. Grocery stores were one of the early adopters of debit card technology. Furthermore, grocery stores have traditionally cashed checks for customers who applied for these privileges. Indeed, many grocery stores offer banking and financial services to customers, such as in-store ATMs, bank branches, and wire and remittance services.

The paper proceeds as follows. Section 2 gives an overview of the U.S. payment system and the data used in this paper. Section 3 describes the analytical framework and the estimation procedure. Section 4 presents the results. Section 5 concludes.

[3]Refer to, for example, Boeschoten (1992), Kennickell and Kwast (1997), Carow and Staten (1999), Stavins (2001), Hayashi and Klee (2003), Mester (2003), Rysman (2007), and Zinman (2006).

[4]Refer to Chevalier et al. (2003) and Feenstra and Shapiro (2003).

[5]Refer to Food Marketing Institute (2004a, b).

[6]Refer to Kahn and McAlister (1997, pp. 94–95).

2. Overview and data description

In order to provide context for the results in this paper, this section provides a few facts about the U.S. payment system and then describes the data used in the analysis more fully.

2.1. The U.S. payment system

In general, U.S. consumers have four choices of how to pay for everyday purchases: cash, check, credit card, and debit card.[7] How people pay dictates how money flows through the plumbing of the U.S. economy. While the exact dollar value of cash transactions is unknown, the dollar value of check, credit card and debit card transactions topped more than $41 trillion in 2004.[8] Checks represent the highest share of the number and value of these payments. But, card use grew substantially over the 1990s and into the 2000s. Trends appear to imply the check share of the number of payments fell from almost 80% in 1995 to around 45% in 2004.[9] These aggregate trends accord with survey-level evidence: data from the Survey of Consumer Finances (SCF) show that debit card use increased dramatically from 1995 to 2001, from 17.6% of U.S. families to 47.0.[10]

Although all consumers arguably have access to cash, check and debit card use necessarily depend on a consumer's access to a bank account, while credit card access relies on a consumer's ability to obtain unsecured credit. Unbanked consumers tend to have lower income and lower education levels than those with bank accounts.[11] However, holding income and education constant, consumers differ according to use and holding of other payment instruments with respect to age and other characteristics, particularly for debit card use.

2.2. Data description

The primary data set used in this paper is a scanner data set that contains grocery store transactions for a set of 99 retail outlets. Supplementing this data set is census-tract level statistics that contain demographic information on what is presumed to be the local market of the retail outlets.

The unit of observation is a checkout transaction, which represents one customer's total purchase at the point of sale. As the data are all from one retail chain, each transaction has exactly the same information. The data comprise over 10 million checkout transactions over a three month period, from September to November 2001. The data contain the information commonly found on most register receipts from a purchase at the grocery store. These include the identifying store number, the date of the transaction, the start time of the transaction, the end time of the transaction, the price for each item, the payment type, the amount of change received, and the number of coupons (both store coupons and manufacturer coupons). At the grocery stores in the sample, consumers can pay with six different payment types, namely cash, check, credit card, debit card, WIC, and food stamps. The first four are used generally, but the last two are associated with government food programs; thus the analysis focuses on the first four only.[12] All data were stripped of potentially identifiable information. These information items include, but are not limited to, credit card and debit card numbers, loyalty card numbers, WIC and food stamp identification numbers, and check identification numbers.

Importantly, a few caveats about the scanner data should be noted. Consumers authorize debit card transactions in two different ways. Consumers can enter a PIN, or personal identification number, or consumers can sign. If a consumer signs, it is called a "signature-based" debit card transaction, and is usually routed over the Visa and MasterCard credit card networks. There is no way to distinguish signature-based

[7]Consumers also use automated clearing house payments for mortgage, insurance and other types of recurring payments.

[8]Bank for International Settlements (BIS) (2006).

[9]For details, refer to Gerdes and Walton (2002) and Gerdes et al. (2005).

[10]The SCF surveys a cross-section of U.S. households and is conducted every three years by the Federal Reserve in conjunction with the National Opinion Research Center at the University of Chicago. For details, see Aizcorbe et al. (2003).

[11]Vermilyea and Wilcox (2002).

[12]Although food stamps and WIC are important ways that people pay for food, the programs limit recipients on the types and quantities of food to purchase. In addition, the "choice" of payment instrument does not exist in the same sort of way as it does for the other payment types. Refer to Food and Nutrition Service (2004a, b).

debit card transactions from credit card transactions in these data. Thus, the debit card results presented here are PIN debit card transactions only.

In addition, because these data were in very raw form, certain assumptions were made in order to compile the data set. To start, a significant percentage of the cash transactions had one item only. It is most likely the case that some of these transactions represented cashier error.[13] Including these in the estimation procedure could bias the results; as a result, these transactions were eliminated. Furthermore, a very small percentage of the transactions used multiple payment types. In these cases, the payment type with the highest associated dollar value associated with it is considered to be the payment type for the transaction. Finally, almost all transactions with very few items and low dollar value of sale are made with cash. In order to aid the estimation algorithm, the data are subsetted to include only those transactions where the number of items bought is greater than two and less than 60, and where the value of the sale is greater than five dollars and less than $150.[14]

The second data source used in the analysis is 2000 census-tract information from the U.S. Census and the Federal Financial Institutions Examination Council. The addresses of the retail outlets were matched with census-tract level information from the U.S. Census Bureau to proxy for demographics of the local market. The demographic information includes the median household income in a census tract,[15] the age of the head of household, the education level,[16] the percent of the census-tract population who is married, the percent of female headed households with minor children, the percent nonwhite, the percent in urban areas or urban clusters and the percent of housing units that are owner occupied.

As the first point of analysis, Table 1 presents the share of the number of transactions by payment type for the subsample used in the analysis. Cash captures the greatest share of transactions at 54%, followed by check transactions at 20%, and with credit card and debit card transactions comprising about even shares of the number of transactions, at 12% and 15%, respectively.

Continuing this data exploration, Figs. 1 and 2 display kernel density estimates of the items bought and the value of sale by tender type. Cash transactions are very concentrated at low number of items and low value of sale, with a median value of sale at about $14.20 and a median number of items bought of 6. Check transactions, by contrast, have a less concentrated distribution, fanning out a bit more by the number of items bought and the value of the sale. The median value of sale for check transactions is about $34.60 and the median number of items bought is 15. For credit cards, the median value of sale is $30.85, with a median number of items bought of 14, and for credit cards, the median value of sale is $26.35 and the median number of items bought is 10. In addition, there is a relatively greater concentration of debit card transactions at lower values of the sale and items bought, while credit card transactions appear to have a broader distribution.

Although the data are from a mid-sized grocery store chain, there is significant demographic variation. Table 1 shows summary information on the demographic characteristics, weighted by the transaction data set. The demographics of the sample range widely. The minimum median income is $20,327 and the maximum median household income is $117,690, implying that the transaction data potentially represents behavior from a wide range of income groups. In addition, there is significant variability in age and education, as well as family ethnicity and composition. Urban and rural areas are also included in the geographic coverage of the data.[17] Moreover, the demographic coverage of the grocery store chain is relatively similar to national averages.

3. Analytical framework and specification

The discussion below outlines the analytical framework and points out a few key factors that are reviewed in-depth. It then follows with the econometric specification used to evaluate the effect of these factors on payment choice and money demand.

[13]This supposition is based on the knowledge obtained through construction of the data set.

[14]Convergence was difficult with these transactions included in the sample.

[15]Household income includes the income of the householder and all other individuals 15 years old and over in the household, whether they are related to the householder or not. In most cases, the householder is the person, or one of the people, in whose name the home is owned, being bought, or rented.

[16]Data on educational attainment are tabulated for the population 25 years old and over. People are classified according to the highest degree or level of school completed.

[17]1 is fully urban, and 0 is fully rural; all other compositions are between these two values.

Table 1
Summary statistics

Variable	Mean	Std. dev.	Min.	Max.
Payment choice				
Cash	0.543	0.498	0	1
Check	0.195	0.396	0	1
Credit	0.116	0.32	0	1
Debit	0.147	0.354	0	1
Items bought	12.06	10.206	3	50
Value of sale	28.79	24.89	5.01	149.99
Manufacturer coupons	0.163	1.081	0	94
Day of week				
Monday	0.138	0.345	0	1
Tuesday	0.132	0.338	0	1
Wednesday	0.136	0.343	0	1
Thursday	0.129	0.335	0	1
Friday	0.147	0.354	0	1
Saturday	0.172	0.377	0	1
Median household income	44,325.28	18,872.02	20,327	117,690
Age of head				
35–44	0.219	0.057	0.101	0.446
45–54	0.196	0.035	0.145	0.377
55–64	0.139	0.033	0.052	0.249
65–74	0.116	0.043	0.015	0.231
Education				
High school	0.248	0.08	0.076	0.386
Some college	0.328	0.071	0.166	0.567
College	0.267	0.178	0.051	0.688
Married	0.603	0.095	0.395	0.814
Female-head	0.064	0.036	0.016	0.22
Urban	0.715	0.338	0	1
Owner occupied	0.694	0.139	0.346	0.953
N	6,216,727			

3.1. Analytical framework

Most models of payment choice incorporate transaction costs. The data used enable observation of some of these costs directly. For example, the length of time for each transaction is observed. Part of this time is accounted for by handling costs, the time costs of using the payment instrument. In addition, inventory costs for cash, defined as the additional costs of obtaining cash or coins to be held by the consumer, can be constructed. Authorization costs can also be calculated.

Another issue is to characterize the effect of opportunity costs on the choice of payment instrument. In this context, opportunity costs are defined as the difference between the rate of return on an asset and a reference asset. Opportunity costs likely depend on income; higher-income households are likely to have greater opportunity costs of investment of funds. Models including Santomero and Seater (1996) stress the importance of opportunity costs as a determinant of the use of media of exchange. They claim that higher-income households are more likely to use more than one media of exchange, and in addition, are more likely to hold noncash transaction assets.[18] Therefore, a key aspect of the analysis will be to investigate the importance of income in payment choice.

Related to both inventory costs and opportunity costs, the value of the sale is a key component of theoretical models of payment choice, and is one of the major factors of the analysis.

[18]This result arises because payment choice is intrinsically connected to goods choice, and higher-income consumers tend to consume more types of goods relative to lower-income consumers.

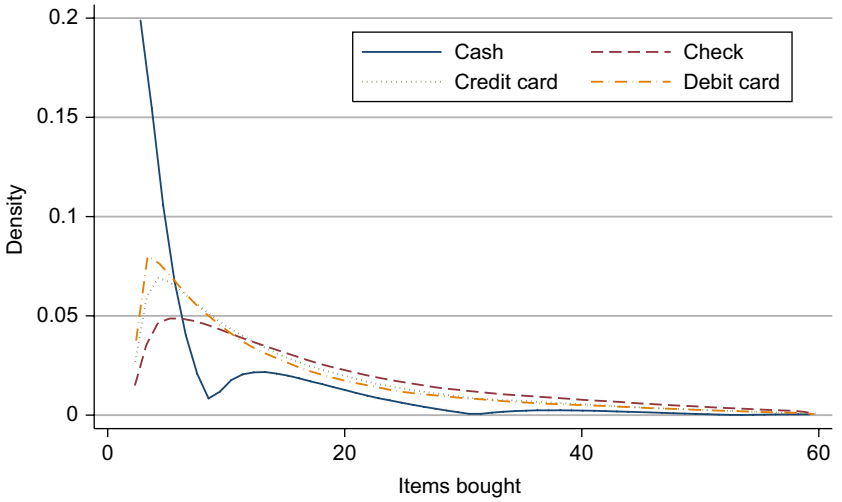

Fig. 1. Kernel density estimate of items bought distribution.

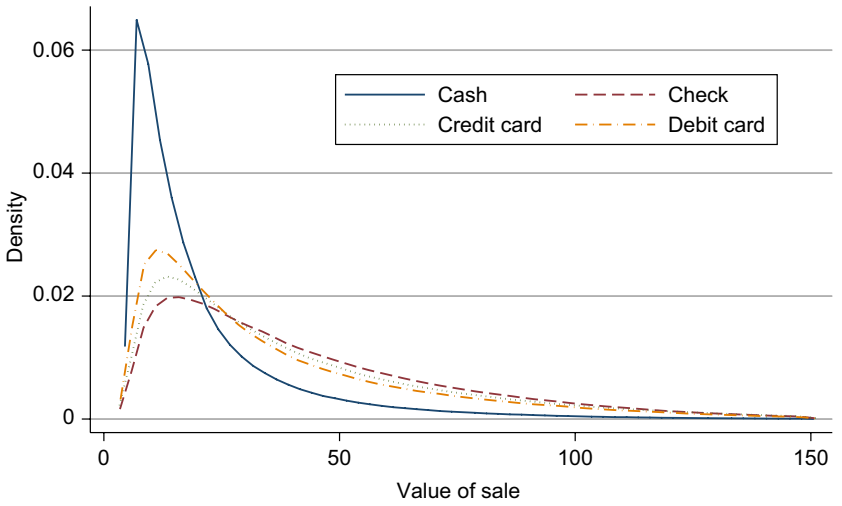

Fig. 2. Kernel density estimate of value of sale distribution.

Although the opportunity cost of a particular payment instrument for an individual consumer is unobservable, there are known differences. Cash earns no return, and thus has a relatively large opportunity cost. Checks and debit cards theoretically have the same opportunity cost, as they both draw funds from checking accounts. There could be, however, a difference between checks and debit cards in terms of float. Checks may take a longer time to clear than debit cards—a few days versus a few seconds. This float wedge will cause the opportunity costs of checks and debit cards to differ.[19]

Manufacturer coupon use can offer insight into both price sensitivity and time sensitivity. People who seek discounts may systematically choose payment instruments with lower-opportunity costs. On the other hand, because consumers must cut coupons out of the newspaper before coming to the store, sensitivities of payment choice to the number of manufacturer coupons may lend insight either into time sensitivity as well.[20]

[19]In many cases, however, this difference is more apparent than real, if the check is converted into an electronic payment at the point of sale. Still, it should be mentioned as a factor possibly affecting consumer choices.

[20]As a final note, credit card borrowing costs are not observed, which probably have some effect on payment choice.

And finally, previous empirical research shows that consumer characteristics are correlated with payment choice. To this end, census-tract level aggregates of age, education, marital status, urban or rural status, and homeownership are also included as factors that affect payment choice.

3.2. Specification

Three different models are estimated in the econometric work that follows. First, some share of the transaction costs for using the payment instrument can be quantified by the length of time for the transaction, as

$$t_{ijk} = \alpha_{ik} + x_i\gamma_1 + m_i\gamma_2 + \varepsilon_{ijk}, \tag{1}$$

where t_{ijk} is the length of time for transaction i by consumer j with payment instrument k, α_{ik} is a dummy variable that equals 1 if the payment instrument was used in the transaction, x_i is a vector of transaction characteristics, which includes the number of items bought, m_i is a vector of payment characteristics, including the number of coins paid and received as change, and the amount of cash back, and ε_{ijk} is an error term. γ_1 and γ_2 are vectors of parameters to be estimated.

Second, a multinomial discrete choice model for payment choice is estimated. The probability of choosing payment instrument k for transaction i is specified as

$$P_{ik} = x_i\beta_1 + d_j\beta_2 + \varepsilon_{ijk}, \tag{2}$$

where d_j represent consumer characteristics (measured at an aggregate census-tract level). β_1 and β_2 are vectors of parameters to be estimated. Because many consumer and transaction characteristics are invariant across payment types, separate coefficients are estimated for each.

Third, the costs of the transaction, the payment instrument choice, and expenditure can be linked using a selection framework introduced by Dubin and McFadden (1984). Theory suggests that consumers choose asset allocation and payment instruments jointly. Prescott (1987) shows that in a world with two types of payment instruments (currency and bank drafts), equilibrium expenditures and equilibrium money holdings are intrinsically connected to the costs of using these two payment instruments. Although the data in this study contain no information on the individual consumers, one could still test some parts of the hypothesis. In particular, using the framework developed by Dubin and McFadden (1984), it is possible to evaluate whether unobserved factors correlated with the value of the sale are correlated with unobserved factors that affect payment choice, by each type of transaction asset used. If there is unobserved correlation, it could be consistent with consumers choosing jointly the type of payment instrument to use, the level of expenditure, and the allocation of money holdings.

Using the Dubin–McFadden specification, the conditional expenditure function for each tender type can be written as

$$M_{ki} = x_i\beta_1 + \sum_{j\neq k}\gamma_j\left(\frac{P_j\log(P_{ji})}{1-P_{ji}} + \log(P_{ki})\right), \tag{3}$$

where M_k is the value of the sale and P_k is the probability of using the payment instrument estimated from the stage above. The summation term is a Heckman-style selection term allows us to infer whether there is sample selection in our observations of expenditure using a particular payment instrument. Evidence of sample selection could be consistent with consumers jointly determining expenditure and payment choice. Possible unobserved factors contributing to the sample selection could include opportunity costs.

4. Results

4.1. Calculating transaction costs

Transactions costs are addressed first, divided into three components: handling costs, inventory costs, and authorization and verification costs.

Table 2
Transaction costs

Variable	Ring time			
	(1)	(2)	(3)	(4)
Check	67.313*(0.064)	35.816*(0.053)	70.902*(0.065)	34.427*(0.053)
Credit	36.851*(0.075)	15.040*(0.057)	50.126*(0.067)	14.963*(0.057)
Debit	28.533*(0.063)	10.296*(0.048)	45.377*(0.059)	9.293*(0.050)
Items bought		4.592*(0.007)	4.579*(0.007)	4.615*(0.007)
(Items bought)^2		−0.026*(0.000)	−0.025*(0.000)	−0.026*(0.000)
Manufacturer coupons		4.638*(0.028)	4.605*(0.028)	4.645*(0.028)
Cash back, check				0.768*(0.008)
Cash back, debit				0.264*(0.004)
Cash			32.249*(0.060)	
Exact cash			8.434*(0.096)	
Tendered				
Quarters			5.461*(0.043)	
Dimes			4.692*(0.062)	
Nickels			3.867*(0.094)	
Pennies			1.704*(0.025)	
Received				
Quarters			−0.435*(0.020)	
Dimes			−0.046(0.031)	
Nickels			−0.178*(0.044)	
Pennies			−0.069*(0.015)	
Constant	73.380*(0.027)	35.001*(0.039)		34.830*(0.038)
R-squared	0.190	0.538	0.869	0.540
Observations	6,191,160	6,191,160	6,191,160	6,191,160

Robust standard errors in parentheses.
*Significant at 1%.

4.1.1. Handling costs

In order to get a baseline understanding of the relationship between payment instruments and time costs, Table 2 presents regression results from a specification with the length of time of the transaction as the dependent variable, with dummy variables for each payment instrument as independent variables (cash is the omitted payment instrument).

Without conditioning on other variables, as shown in the first column, transactions with checks are almost 70 s longer than transaction with cash. By contrast to some theoretical work,[21] other payment types also seem to have higher time costs than cash: credit card transactions are 15 s longer than cash transactions, while debit card transactions are 10 s longer. The specification in column (2) controls for other factors that affect the length of a transaction. Differentials according to the number of items bought are not surprising: on average, each item adds 4.5 s to the transaction. The negative coefficient on the number of items squared seems to imply that some economies of scale can be achieved with respect to the number of items, revealing fixed costs for transactions. Other factors that likely affect time costs are controlled in this specification as well. Manufacturer coupons are costly in terms of time, about 4 s on average for an extra coupon.

4.1.2. Inventory costs

Columns (3) and (4) of Table 2 investigates the inventory costs of cash, expressed in units of time. Column (3) specifically addresses coin costs. Although the data contain no information on the number of coins tendered or received as change for cash transactions, these values are imputed by constructing a hypothetical number of coins consistent with the tender amount and the change received. This specification does not include a constant term, but rather, a dummy variable for cash. The coefficient on the cash dummy

[21] Refer to Shy and Tarkka (2002).

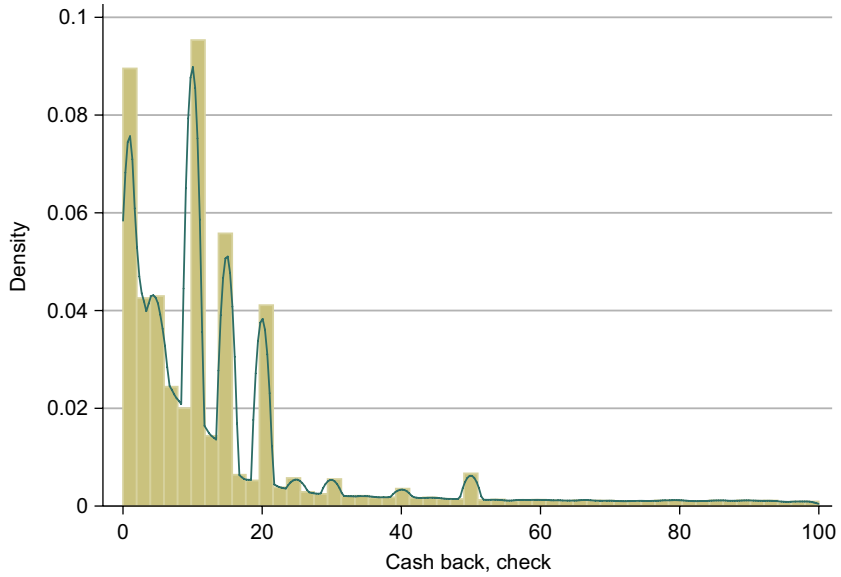

Fig. 3. Kernel density estimate of cash back distribution, check.

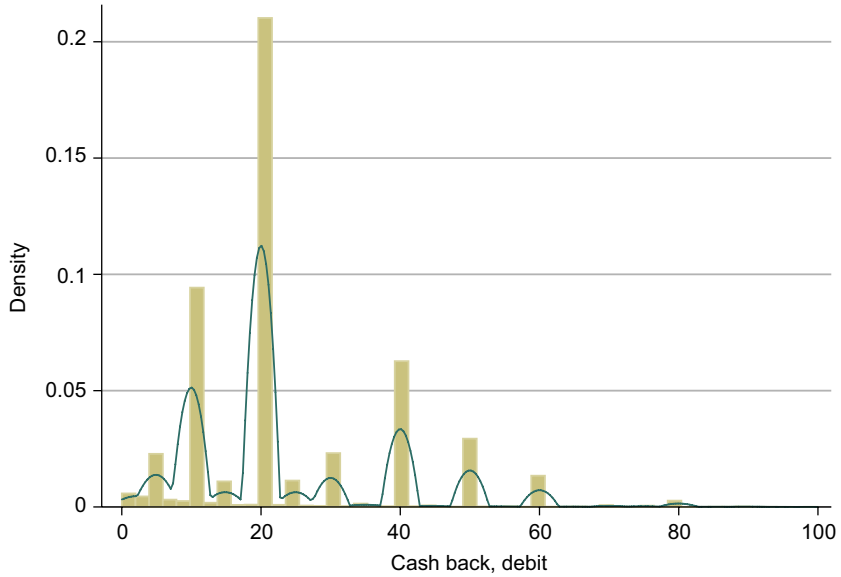

Fig. 4. Kernel density estimate of cash back distribution, debit card.

corresponds to a cash transaction with no change handling. The exact cash dummy corresponds to a transaction where the customer chose to tender exact change; this action adds about 8.5 s on average to the transaction time. The results indicate some asymmetry between tendering coins and receiving coins as change. While tendering each coin adds considerable time to the transaction, receiving coins as change saves a little time. Interestingly, pennies save almost no time (less than $\frac{1}{10}$th of a second), which could be why many retailers have discontinued returning pennies as change.

A sizable fraction of check and debit card transactions are associated with cash back: 12% and 15%, respectively. Column (4) presents information of the time costs of obtaining cash back, expressed in units of time. Cash back costs about 0.77 s per dollar with a check, versus 0.21 s per dollar with a debit card. Thus, it is more expensive in terms of time to obtain cash back with a check than with a debit card. On average, cash

Table 3
Authorization and verification costs

Payment type	Predicted time	Less cash = authorization and verification time
Cash	86.4	0
Check	121.9	35.5
Credit	101.5	15.1
Debit	95.8	9.4

back values with debit cards are higher—about $23 on average for debit cards versus about $14.50 for checks. But, minimizing other costs come into play with a check. Figs. 3 and 4 show this well. Interestingly, there is a lower share of cash back values in round dollar lots for checks than for debit cards. Of course, there are likely restrictions on the dollar values of cash back for debit cards, and such restrictions likely do not similarly exist for checks. Still, the dichotomy likely represents consumers rounding checkbook entries to whole dollar amounts in order to minimize on bookkeeping costs. This result provides evidence that consumers minimize costs when using payment instruments, and points to the need to think about these costs in equilibrium.

4.1.3. Authorization and verification costs

A subset of payment instrument handling costs are likely authorization and verification costs. Theoretical work by Whitesell (1989) suggests that authorization and verification costs of payment instruments, which are fixed costs of using these payment instruments, can affect equilibrium use by incenting consumers to use substitutes. Both check and credit card transactions require signatures. Debit card transactions require a PIN, and cash transactions require no authorization. Verification costs for card payments usually involve a "ping" on a database of collected profiles of payment records.

These authorization and verification costs are calculated at the mean values for the independent variables included in column (4) of Table 2, assuming zero cash back for check and debit card transactions. They are calculated as the time differences between using cash and using the respective payment instrument and presented in Table 3. Authorization costs are about 36 s with checks, 15 s with credit cards, and 9 s with PIN debit cards. These calculations suggest that the time differential between signing and entering a PIN is about 6 s, which further suggests that it takes a full 30 s to fill out the payee and amount information on a check.

4.2. Inventory behavior, interest elasticity, and demographic characteristics

The next step is to evaluate consumer choices, addressing inventory behavior, and interest and price elasticity, which are key variables in theoretical models of payment choice.

Table 4 shows results from estimating a multinomial logit model of the choice of payment instrument.[22] The coefficient estimates are expressed in terms of marginal effects.[23] The columns are labeled according to the outcome chosen by the consumer.

4.2.1. Inventory behavior

Two types of inventory considerations are evaluated in the specification: value of the sale and day of the week. The results show that as the value of the sale increases, consumers are more likely to use checks and credit cards and less likely to use cash and debit cards. Evaluated at the mean value of sale of about $29, the marginal effects indicate that a $10 increase in the value of the sale marks down the probability of using cash

[22]The multinomial logit model exhibits restrictive substitution patterns between choices, which limits its use as a gauge of substitutability for different payment instruments at the point of sale. Its advantage is its computational tractability; with the large data sets used in this paper, it is certainly an advantage.

[23]For continuous variables, the marginal effects are calculated at the means of the independent variables in the case of continuous variables. For dummy variables, the marginal effects are calculated as the average difference between the probability of using the payment instrument of the dummy variable set to one and set to zero.

Table 4
Consumer choice

Variable	Marginal effects			
	(1) Cash	(2) Check	(3) Credit	(4) Debit
Items bought	−0.024*(0.000)	0.018*(0.000)	0.003*(0.000)	0.002*(0.000)
(Items bought)^2	0.001*(0.000)	−0.000*(0.000)	−0.000*(0.000)	−0.000*(0.000)
Value of sale	−0.008*(0.000)	0.003*(0.000)	0.003*(0.000)	0.003*(0.000)
Manufacturer coupons	−0.014*(0.000)	0.006*(0.000)	0.006*(0.000)	0.002*(0.000)
Day of week				
Monday	−0.016*(0.001)	0.024*(0.001)	0.005*(0.000)	−0.013*(0.001)
Tuesday	−0.029*(0.001)	0.037*(0.001)	0.006*(0.000)	−0.014*(0.001)
Wednesday	−0.030*(0.001)	0.041*(0.001)	0.004*(0.000)	−0.015*(0.001)
Thursday	−0.017*(0.001)	0.038*(0.000)	0.000 (0.000)	−0.021*(0.001)
Friday	0.022*(0.001)	0.011*(0.001)	−0.006*(0.000)	−0.027*(0.001)
Saturday	0.012*(0.001)	0.012*(0.001)	−0.006*(0.000)	−0.017*(0.000)
Median household income	−0.004*(0.000)	−0.009*(0.000)	−0.005*(0.000)	0.018*(0.000)
Age				
35–44	0.281*(0.009)	0.029*(0.007)	−0.074*(0.005)	−0.236*(0.006)
45–54	0.300*(0.010)	0.260*(0.008)	−0.181*(0.005)	−0.378*(0.006)
55–64	−0.269*(0.011)	−0.484*(0.008)	0.495*(0.006)	0.258*(0.008)
65–74	1.080*(0.011)	0.332*(0.008)	−0.554*(0.006)	−0.858*(0.008)
Education				
High school	−0.309*(0.009)	−0.018*(0.007)	0.077*(0.006)	0.249*(0.007)
Some college	−0.514*(0.004)	−0.065*(0.003)	0.207*(0.002)	0.372*(0.003)
College	−0.474*(0.005)	−0.170*(0.004)	0.393*(0.003)	0.251*(0.004)
Married	−0.466*(0.006)	0.115*(0.004)	0.249*(0.004)	0.102*(0.004)
Female-headed household	0.341*(0.011)	−0.595*(0.008)	0.075*(0.007)	0.180*(0.008)
Urban	−0.068*(0.001)	0.039*(0.001)	0.000 (0.001)	0.030*(0.001)
Owner-occupied	0.055*(0.003)	0.084*(0.003)	−0.098*(0.002)	−0.042*(0.002)
Pseudo R-squared	0.117			
Observations	6,204,845			

Robust standard errors in parentheses.
*Significant at 1%.

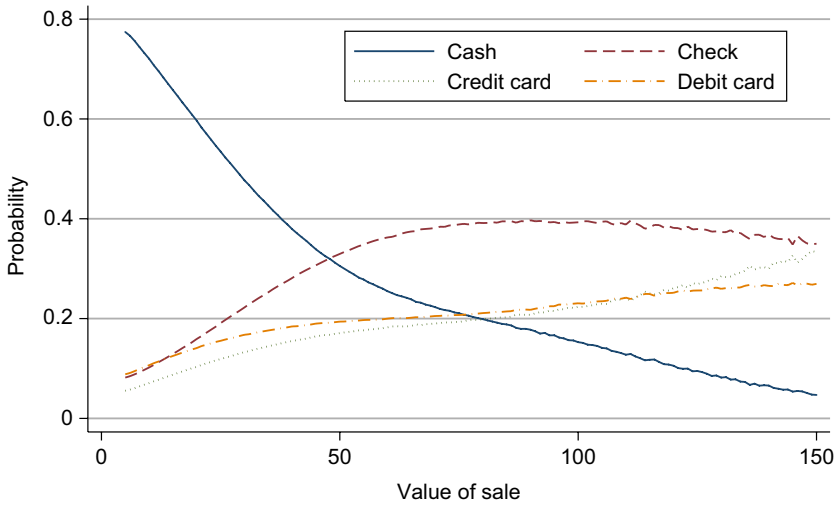

Fig. 5. Predicted probabilities.

about 8 percentage points, consistent with economic theory that suggests lower incidence of cash use at higher-dollar values of sale. At the same time, the probability of using a check, credit card, or debit card increase about 3 percentage points each, indicating relatively similar changes in the probability of use at average values of sale.

In order to investigate this phenomenon a bit more closely, Fig. 5 plots the predicted probabilities of using each payment instrument for ranges of the value of the sale. Inspection of Fig. 5 reveals that the probabilities of using a cash far exceed the probabilities of using one of the other three payment types at the lower end of the distribution, credit cards and debit cards dominate in the middle part of the range, and checks take over at the higher-dollar values. While checks and debit cards arguably have the same costs of funds (as they both draw on checkable deposits), the probabilities of using these payment instruments at different values of sale behave quite differently. At ranges of the value of the sale well below \$50, the probability of using a debit card far exceeds the probability of using a check, by about 2 to 1. The predicted probabilities are roughly equal for these two payment instruments at \$50, however.

The interplay of the credit card and debit card probabilities is interesting. At relatively low dollar values of sale, the probability of using a credit card is higher than the probability of using a debit card, suggesting credit use by lower-income households. In the middle of the range for the value of sale, debit card use dominates credit card use. However, these probabilities again reverse at higher-dollar values of sale, suggesting higher-income households are sensitive to the opportunity cost of funds for purchases.

Turning to another aspect of inventory considerations, the day of the week coefficients indicate that consumers are significantly less likely to use cash on Mondays, Tuesdays, Wednesdays and Thursdays, and significantly more likely to use cash on Fridays and Saturdays, relative to Sunday. The probability of using cash on Friday is on average 2.5 percentage points higher than on Sunday. In contrast, the probability of observing a check payment is lower on Sunday than on any other day of the week. Patterns with respect to credit card use are less prominent, but all of the day coefficients are significant and negative in the debit card equation, suggesting that the probability of using a debit card is highest on Sunday, the omitted day of the week.

Economic theory suggests that payment choice could be tied to the timing of income receipt. The results are consistent with a scenario where people who are paid in cash are more likely to be paid on Fridays. These people then have a higher inventory of cash than what is optimal, and as a result bring down their balances by using cash for transactions.[24] Debit card use may increase on the weekends in order to get cash back when banks are closed. However, inspection of the data shows that the percentage of debit card transactions with cash back is actually lower on the weekends than during the week. More likely the higher incidence points to the demographics of shoppers on the weekend versus during the week.[25] The marginal derivatives indicate that overall, the probabilities of choosing a particular payment instrument change between roughly one and four percentage points according to the day of the week, with the largest swings seen in checks and debit cards.

4.2.2. Income and price elasticities

Income and price elasticities may also drive payment choices. Looking at the coefficient on the median household income in the census tract, the probability of using checks and credit cards decreases as income increases; however, the probability of using debit cards increases. The magnitude of these effects is not great: for a \$10,000 increase in income from the mean income, the probability of using a debit card is about 2 percentage points higher. But, the magnitude of this effect may be tempered by the collinearity of income and education; in the census-tract data the correlation between these two factors is approximately 0.84. Thus, part of the income effect likely is captured by the education effect.

Prices associated with different payment instruments are not directly observed.[26] However, it is possible to investigate the sensitivity of payment choice to factors that may be correlated with prices by investigating

[24]However, a counterveiling hypothesis (which is perhaps just as interesting) suggests that the types of items bought on Fridays and Saturdays—beer and cigarettes in particular—are more likely to be purchased with cash than with other forms of payment.

[25]Analysis by the Food Marketing Institute (2004a, b) shows that older consumers shop during the week, while employed, younger consumers shop on the weekends.

[26]Refer to Borzekowski et al. (forthcoming) for an investigation of debit card fee sensitivity.

coupon use. As shown in the table, the number of manufacturer coupons is negatively correlated with cash use, but positively correlated with check, credit card, and debit card use. Consumers may be more less likely to use coupons when paying with cash when they are just "running to the store" for a few items, regardless of whether it is on sale. On the other hand, the results also potentially indicate that check writers and credit card users are more price sensitive than people who use other forms of payment evaluated at the mean values. Consumers using checks or credit cards may be attempting to choose payment instruments with perceived delayed settlement rather than instruments with perceived instant settlement, allowing for some "float" between consumption and payment. While in practice this difference may be more apparent than real, it is interesting to note the overall price sensitivity evident in the data. The magnitude of the coefficient for debit card use is about $\frac{1}{3}$ of that for check and for credit cards, suggesting a smaller effect.

4.2.3. Demographic characteristics

As noted above, previous research using stated preference and survey data indicates that income, age and demographics are significantly correlated with payment use. In order to test whether these factors are also evident in this sample of scanner data, the analysis includes the demographics of the local market in the specification for payment choice.

The age statistics overall indicate that the probabilities of using different payment types are correlated with age. The older age groups are significantly more likely to use cash or check relative to the baseline head of household age, under 35. In contrast, the age statistics show that the age profile with respect to credit card use is nonlinear. Relative to the lowest age group, a higher proportion of families with a household head between 35 and 44 is correlated with a lower probability of using a credit card, while a higher proportion of families with a household head between 55 and 64 is correlated with a higher probability. In general, age is negatively correlated and education is positively correlated with debit card use. These results roughly agree with those found in survey data, and thus offer some evidence of preferences for payments that differ according to age.

Turning to the education results, higher education implies that the consumer is on average less likely to use cash or check, and more likely to use credit cards. As mentioned above, the collinearity of education and income may point to why education has a significant positive coefficient, while income has a significant negative coefficient. After controlling for education, the residual effect of income on credit card use is negative. Cash-strapped, less wealthy households may be forced to buy groceries on credit, which would be indicated by a negative coefficient in the estimation results.

The married coefficients indicate that census tracts with a higher percentage of married households are less likely to use cash and more likely to use the other three payment types. Census tracts with a higher percentage of households with a female head and children under 18 are more likely to use cash or debit cards.

The McFadden pseudo R-squared statistic indicates that a fair amount of the variation in the dependent variable is explained by the chosen set of independent factors.

4.3. Equilibrium use of payment instruments and money holdings

The final set of exercises focuses on understanding the equilibrium use of payment instruments and the potential correlation with money holdings. These are key aspects to understanding consumer payment choice and ultimately money demand. To this end, Table 5 displays the results.

Not surprisingly, the number of items bought is statistically significant. In addition, the relative magnitudes of the coefficients across subsamples suggest that, on average, items bought using credit cards are more expensive than items bought using cash. Day of the week is also significant: the largest grocery bills are seen on Friday, Saturday, and Sunday (the omitted category).

Median household income is interesting: higher income is associated with lower values of sale for cash transactions, not a significant factor in the value of sale of check transactions and higher values of sale for credit and debit card transactions. While it is likely true that higher-income households spend more on groceries than lower-income households, these higher-income households probably substitute credit cards or debit cards for cash at higher values of sale. Manufacturer coupon use is clearly associated with lower values of sale.

Table 5
Sample selection based on payment instrument

Variable	(1) Cash	(2) Check	(3) Credit	(4) Debit
Items bought	1.76** (0.005)	1.937** (0.006)	2.295** (0.003)	2.175** (0.010)
Day of week				
Monday	−0.742** (0.019)	−0.917** (0.051)	−0.615** (0.063)	−0.735** (0.050)
Tuesday	−0.86** (0.022)	−0.911** (0.055)	−0.244** (0.063)	−0.516** (0.056)
Wednesday	−0.687** (0.023)	−0.828** (0.053)	0.205** (0.065)	−0.096 (0.059)
Thursday	−0.436** (0.023)	−0.653** (0.056)	0.303** (0.066)	0.150** (0.053)
Friday	0.572** (0.020)	0.387** (0.050)	1.643** (0.067)	1.598** (0.051)
Saturday	0.614** (0.019)	0.925** (0.051)	1.666** (0.063)	1.735** (0.044)
Median household income	−0.028** (0.001)	−0.003 (0.002)	0.010** (0.001)	0.008** (0.001)
Manufacturer coupons	−0.961** (0.013)	−1.012** (0.012)	−1.370** (0.016)	−1.207** (0.019)
Selection terms				
Cash		9.452** (0.172)	−5.777** (0.226)	5.059** (0.446)
Check	−0.492** (0.206)		0.922** (0.226)	5.266** (0.421)
Credit	−6.095** (0.162)	−16.653** (0.375)		−11.484** (0.252)
Debit	1.614** (0.205)	6.138** (0.358)	9.182** (0.317)	
Constant	2.169** (0.032)	9.897** (0.381)	13.137** (0.205)	3.993** (0.232)
Observations	3,374,309	1,204,150	716,467	909,919

Bootstrap standard errors in parentheses.
**Significant at 5% level.

Generally, the significant coefficients on the selection terms suggest that unobserved factors associated with payment choice are correlated with unobserved factors that affect the value of sale, and by extension, money demand. A few general themes appear. Turning to the cash results in column (1), unobserved factors that are correlated with a high predicted probability of choosing credit are associated with lower values of sale, while unobserved factors associated with a high probability of debit card use are associated with higher values of sale. The credit card use coefficient is consistent with lower-income households buying less expensive items than other households; they are also perhaps more likely to buy these goods on credit in order to smooth consumption. Family-level data from the 2001 Survey of Consumer show that lower-income households are more likely to borrow on credit cards, while upper-income households are more likely to be convenience users of credit cards, or users who pay off the balance each month in full. The negative coefficient on the cash selection term in column (3) is also consistent with this hypothesis. The debit card coefficient is consistent with a preference towards using liquid transaction assets more generally. The small magnitude (and thus the relatively low economic significance) of the check coefficient suggests that other factors unique to check likely dominate the liquid asset effect.

The check results are a bit trickier to interpret. The selection term for cash suggests that transactions with high predicted probabilities of using cash are associated with higher values of check transactions. It could be the case that consumers who are likely to use cash use checks only when the value of sale crosses a certain threshold. This behavior is consistent with consumers who have low inventory costs for cash and do not choose based on the opportunity costs of holding cash. The credit selection term is consistent with liquidity constraints for lower-income households: those who are likely to purchase groceries on credit spend less on transactions made with checks. The debit card selection term is consistent with substitution of checks for debit cards on transactions that are more time-consuming or higher-value transactions.

Turning to the credit card results, the debit selection term in column (3) and the credit selection term in (4) both suggest that consumers substitute credit cards and debit cards based on the value of sale: credit cards are used for more expensive transactions, and debit cards are used for less expensive ones. The positive coefficient on the check selection term in column (3) reflects inventory costs. Consumers with high probabilities of using checks spend more on average when using a credit card, in order not to deplete checking account balances.

Finally, the positive coefficient on the cash term in the debit card results also suggests inventory control by consumers, that is, substitution of deposit account balances for currency when transaction size hits a

threshold. Checks are generally associated with higher-dollar value transactions than debit cards; transactions with high predicted values of check use have a higher value of sale than other debit card transactions.

5. Conclusion

The contributions of this paper are the systematic investigation of factors that influence payment choice at the point of sale and their implication for widely used economic theories of money demand. The results show that consumer choices are based on opportunity costs and interest elasticities, but also crucially on transaction and other handling costs. Models that incorporate all these factors likely paint a more complete picture of money demand.

Moreover, the paper provides some evidence that consumer choose payment instruments in conjunction with their asset allocation: there exists some correlation in the choice of using payment instruments from the same account, and there exists correlated unobserved factors that affect both payment choices and spending. These empirical results are roughly in line with theory and intuition.

The empirical literature on payment instruments is generally divorced from the theoretical literature on payments, transactions, and money demand. This paper attempts to bridge the gap by presenting empirical regularities on the possible connection between payment instrument choice and money demand. These results should help empirical researchers and theoretical modelers understand the overlap of their work.

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