Payment Choice and the Future of Currency: Insights from Two Billion Retail Transactions

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Overview

- What is the composition of in-person retail payments?
  - Rich data on non-cash payments from bank surveys
  - Cash? Mainly from small-sample consumer surveys
- We use merchant transaction data, as in Klee (2008).
  - 1 large discount chain
  - 2 billion retail transactions
  - 3 yrs, thousands of zip-code locations
- Interaction between demographic variables & transaction size important for explaining payment composition.
- Cash still dominates discount retail, but share is falling at approximately 2.5 pps per year.
1. Data: transactions, and zip-code level expl. variables.

2. Econometric model: fmlogit for shares each payment type.

3. Results for benchmark model: data aggregated by payment type to zip-code day.

4. Results for separate models by transaction size.

5. Conclusion.
Transactions data

- Discount retailer, several ’000 stores, dozens of states.
- Data covers April 1, 2010 - March 31, 2013.
- We restrict to cash, debit, credit, check.
- More than 1.75 million transactions per day.
- Median transaction size ≈ $7.
Variation across time

Fraction of Transactions by Payment Type

- Cash, left axis
- Debit, right axis
- Credit, right axis
- Check, right axis

Date range: Apr 2010 to Dec 2012
Variation across locations, March 2013

Payment Composition Across Zip Codes
Kernel Density for Fraction of Each Payment Type

- cash
- debit
- credit
- check
Transaction size variation, March 2013

Transactions concentrated below $15
Payment shares and transaction size: level and dispersion, March 2013
Explanatory variables

- Zip-code level variables, fixed across time.
  - Variables related to money demand, cost of different payment types:
    - household income, banks/branches/deposits per capita.
    - population density, robbery rate
  - Demographic variables: age, sex, race, education, housing status, family status

- State dummies, fixed across time.

- Time dummies: day-of-week, day-of-month, month-of-sample.
Distribution of Median Income Across Zip Codes

Our Sample

United States
Empirical model (fmlogit, Mullahy (2010))

- Model of $s_{i,k} = \text{share of payment type } k \text{ in zip-code day } i$.
- Shares sum to one, can be zero or one $\Rightarrow$ Fmlogit:

$$E[s_k \mid x] = G_k(x; \beta) = \frac{\exp(x \beta_k)}{\sum_{m=1}^{4} \exp(x \beta_m)}.$$

Normalize $\beta_{\text{cash}} = 0$ for identification:

$$G_k = \frac{\exp(x \beta_k)}{1 + \sum_{m=1}^{3} \exp(x \beta_m)}, \quad G_{\text{cash}} = \frac{1}{1 + \sum_{m=1}^{3} \exp(x \beta_m)}.$$

- $x$ are zip-code level explanatory vars., state/time dummies.
Background for benchmark results

- Payment shares based on all transactions for a zip-code day, 4.5 million observations.

- Include median transaction size as an explanatory variable.

- For continuous $x$ variables, report marginal effects evaluated at the mean.

- For dummies, report “discrete effects” evaluated at mean.
### Selected results: zip-code level variables (1)

<table>
<thead>
<tr>
<th></th>
<th>Cash</th>
<th>Debit</th>
<th>Credit</th>
<th>Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median transaction size</td>
<td>-0.017</td>
<td>0.012</td>
<td>0.005</td>
<td>0.001</td>
</tr>
<tr>
<td>Bank Branches per capita</td>
<td>0.243</td>
<td>-0.133</td>
<td>-0.113</td>
<td>0.003</td>
</tr>
<tr>
<td>Median household income</td>
<td>-0.048</td>
<td>0.015</td>
<td>0.042</td>
<td>-0.009</td>
</tr>
<tr>
<td>Deposits per capita</td>
<td>-0.036</td>
<td>0.035</td>
<td>0.016</td>
<td>-0.014</td>
</tr>
<tr>
<td>Banks per capita</td>
<td>-0.234</td>
<td>0.128</td>
<td>0.109</td>
<td>-0.002</td>
</tr>
<tr>
<td>Population density</td>
<td>-0.039</td>
<td>0.090</td>
<td>0.097</td>
<td>-0.148</td>
</tr>
<tr>
<td>Robbery rate</td>
<td>-0.046</td>
<td>0.063</td>
<td>-0.006</td>
<td>-0.011</td>
</tr>
</tbody>
</table>
## Selected results: zip-code level variables (2)

<table>
<thead>
<tr>
<th>Category</th>
<th>Cash</th>
<th>Debit</th>
<th>Credit</th>
<th>Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family hhlds</td>
<td>-0.093</td>
<td>0.088</td>
<td>0.013</td>
<td>-0.008</td>
</tr>
<tr>
<td>Age share: 15-34</td>
<td>-0.186</td>
<td>0.169</td>
<td>0.035</td>
<td>-0.017</td>
</tr>
<tr>
<td></td>
<td>-0.174</td>
<td>0.134</td>
<td>0.061</td>
<td>-0.022</td>
</tr>
<tr>
<td></td>
<td>0.039</td>
<td>-0.003</td>
<td>-0.014</td>
<td>-0.022</td>
</tr>
<tr>
<td></td>
<td>≥70</td>
<td>-0.034</td>
<td>-0.030</td>
<td>0.058</td>
</tr>
<tr>
<td>Education: hs</td>
<td>-0.202</td>
<td>0.137</td>
<td>0.059</td>
<td>0.006</td>
</tr>
<tr>
<td>some college</td>
<td>-0.342</td>
<td>0.246</td>
<td>0.097</td>
<td>-0.001</td>
</tr>
<tr>
<td>college</td>
<td>-0.227</td>
<td>0.140</td>
<td>0.081</td>
<td>0.006</td>
</tr>
</tbody>
</table>
## Selected results: state effects

<table>
<thead>
<tr>
<th></th>
<th>Cash</th>
<th>Debit</th>
<th>Credit</th>
<th>Check</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Top States</strong></td>
<td>NJ</td>
<td>AZ</td>
<td>MN</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td>NY</td>
<td>ID</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td></td>
<td>MI</td>
<td>NV</td>
<td>SD</td>
<td>MN</td>
</tr>
<tr>
<td></td>
<td>VT</td>
<td>NM</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td></td>
<td>DE</td>
<td>FL</td>
<td>OH</td>
<td>CO</td>
</tr>
<tr>
<td><strong>Bottom States</strong></td>
<td>FL</td>
<td>MD</td>
<td>IA</td>
<td>NH</td>
</tr>
<tr>
<td></td>
<td>TX</td>
<td>NY</td>
<td>AR</td>
<td>NY</td>
</tr>
<tr>
<td></td>
<td>NM</td>
<td>ND</td>
<td>NV</td>
<td>AZ</td>
</tr>
<tr>
<td></td>
<td>ID</td>
<td>SD</td>
<td>MS</td>
<td>DE</td>
</tr>
<tr>
<td></td>
<td>AZ</td>
<td>MN</td>
<td>NJ</td>
<td>NJ</td>
</tr>
</tbody>
</table>
Selected results: time effects (day-of-week)

Day of Week Dummies (marginal effects)

- Mon: cash, debit, credit, check
- Tues: cash, debit, credit, check
- Weds: cash, debit, credit, check
- Thurs: cash, debit, credit, check
- Fri: cash, debit, credit, check
- Sat: cash, debit, credit, check
- Sun: cash, debit, credit, check

Graph showing the marginal effects of day of the week on transaction time.
Selected results: time effects (day-of-month)

Day of Month Dummies (marginal effects)
Selected results: time effects (month-of-sample)

Month of Sample Dummies (marginal effects)

- cash
- debit
- credit
- check

(grey lines demarcate 12 mos. from April through March)
Separate models by transaction size

- Relationship between payment shares and explanatory variables may vary with transaction size.
- Benchmark case is highly restrictive:
  - Transaction size can only shift constant, not coeffs. on $X$
  - Effect on levels limited to median transaction size in zip-code day
- Alternative: aggregate to zip-code day separately for $1-$2, $2-$3 etc.
  - Transaction size can affect coefficients as well as constants
  - Trans. size can matter within, not just across zip-code days
Formal Motivation

- fmlogit model implies

\[
\frac{S_k}{S_M} = \exp(c + X\beta_k) \Rightarrow \ln \frac{S_k}{S_M} = c + X\beta_k.
\]

- If allow \( c \) but not \( \beta_k \) to vary with transaction size \( (v) \), then

\[
\ln \frac{S_k(v)}{S_M(v)} = c(v) + X\beta_k
\]

and

\[
\frac{\partial E(\ln \frac{S_k}{S_M})}{\partial v} = c'(v) \quad \text{and} \quad \frac{\partial \text{Var}(\ln \frac{S_k}{S_M})}{\partial v} = 0.
\]

- Variation in level of payment shares must come from intercept, and dispersion in payment shares must be constant across \( v \)!
Description, and Summary of Results

- Same explanatory variables, except omit transaction size.
- Similar number of observations to benchmark. Number of underlying transactions between 11 and 199 million.
- Results:
  - Marginal effects amplify with transaction size
  - Allowing coefficients to vary across transaction size is important for explaining variation in *levels* of shares, as well as *dispersion*
Amplification of marginal effects
Day of week effects

Day of Week Marginal Effects, by Value of Sale

solid = cash, dashed = debit

- $1 to $2
- $5 to $6
- $10 to $11
- $25 to $30
- $40 to $45

Mon Tues Weds Thurs Fri Sat Sun
Day of month effects

Day of Month Marginal Effects, by Value of Sale
solid = cash, dashed = credit

0 5 10 15 20 25 30
−0.04 −0.02 0.00 0.02

$1 to $2
$5 to $6
$10 to $11
$25 to $30
$40 to $45
Month of sample effects

Month of Sample Marginal Effects, by Value of Sale

- solid = cash, dashed = debit
Predicted payment shares and transaction size: level and dispersion, March 2013
Shifts in the predicted payments mix

Predicted Payment Mix by Sale Value

Sale Amount ($)

Cash
Debit
Credit
Check
March 2013
April 2010
Projecting the future of cash

Forecasts for cash fractions, by transaction size

- March 2013
- 2015, demographics only
- 2015, demographics and time effect
- 2020, demographics only
- 2020, demographic and time effect
Conclusions

- Analyze payments at a discount retailer: 3 years, thousands of locations ⇒ 2 billion transactions.

- Features of data:
  - Payment mix varies across time and locations
  - Payment mix varies with size of transaction
  - Cross-sectional dispersion increases with transaction size

- Estimates from FMLOGIT model of payment mix:
  - Support generalized inventory-theoretic demand for cash, with multiple means of payment
  - Account for both level and dispersion of payment choice across transaction sizes with coefficients that vary across transaction size
  - Project cash share declining 2.5pp per year