This Is What's in Your Wallet... and Here's How You Use It

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The views expressed are those of the authors and do not necessarily represent those of the Magyar Nemzeti Bank.

Overview

- **Motivation:** consumers have thicker wallets and more varieties of liquidity with which to pay
- **Literature:** theory and data have not kept pace with innovations in payments systems and liquidity
- **Theory:** we propose and estimate a dynamic optimizing model that blends monetary and payment approaches
- **Estimation:** with U.S. payment diary data; essentially continuous time longitudinal panel
- **Key results:** cash still matters a lot!
  - Cash-in-wallet, cash payment share are endogoenous
  - Shadow value of cash turns negative above $50
  - Welfare costs of inflation larger, more nuanced
  - Cash management costs are non-trivial, affect withdrawals
  - Eliminating cash or cards lowers consumer welfare a lot
- **Broader implications:** for consumption, HH finance

Payment Diary Data

- 2012 U.S. *Diary of Consumer Payment Choice*
  - Bagnall et al. (2016), Schuh (2018), Greene and Schuh (2018)
  - Consumers record all activity for 3 days in October (waves)
  - Sample restrictions
    - Card adopters only (debit and credit)
    - POS transactions only (cash, debit, credit; 2/3 of sample)
- Management of cash "on person" (pocket, purse, or wallet):
  - End-of-day cash balances, withdrawals, deposits, payments
  - Cash flow identity: $M_t = M_{t-1} + W_t - D_t + \nu_t^M$
    - If $M_{t-1} < W_t - D_t$, increase M_t by discrepancy
    - Unrecorded cash increase = less cash held elsewhere
    - End-of-day "free" withdrawal if $|\epsilon_t^M| > \$5$
  - Trimming: individuals with withdrawals above the 99th percentile ($1,100) were dropped

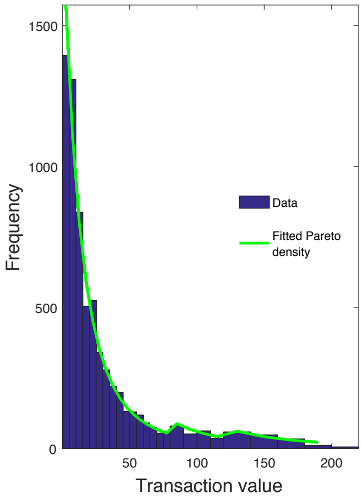
Wallet statistics

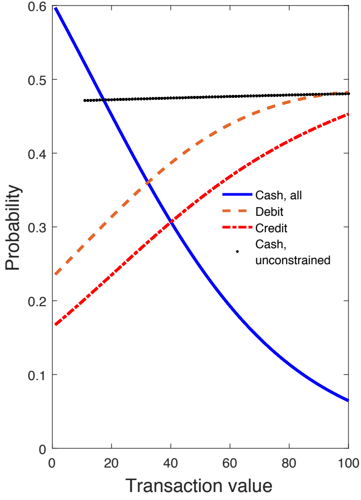
Variable	DCPC Sample	
	Full	Estimation
Adoption rates (share of respondents)		
Cash	1.00	1.00
Debit card	.78	1.00
Credit card	.69	1.00
Debit and credit card	.57	1.00
Neither debit nor credit card	.10	0.00
Payment use (share of transactions)		
Cash	.51	.44
Debit	.28	.31
Credit	.21	.24
Transactions at POS with cash, debit, credit (#)		
Total	10,822	6,707
When CIA binds	2,803	2,044
When $m < \$2$	1,206	850
Values at POS with cash, debit, credit ($)		
Median	12.60	13.41
Average	27.99	29.66
Standard deviation	66.66	73.89

NOTE: The number of respondents is 2,468 in the full DCPC sample and 1,272 in the estimation sample.

Payment choices

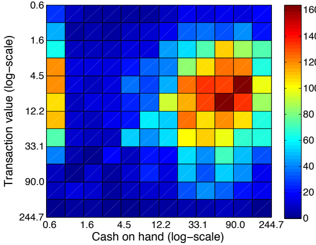
Most payments are small $ value and cash rules for these so cash-in-wallet strongly influences payment choices

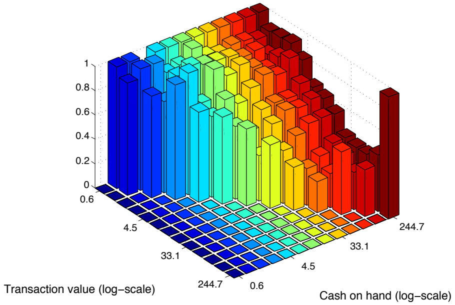




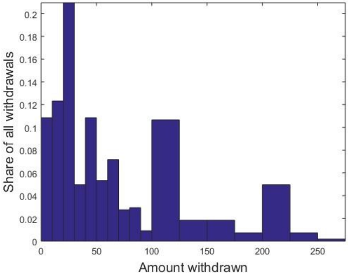
Cash holdings and transactions

LEFT: Transactions – most consumers face no CIA constraint;
RIGHT Cash shares – decline with value for all cash-on-hand





Withdrawals are diverse



Location	Number	Withdrawal amount ($)		
		Average	Median	90th percentile
Bank teller	64	156	80	400
ATM	147	103	60	200
Cash back (retail store)	48	31	20	50
Cash refund (retail store)	7	30	21	75
Employer	25	104	70	200
Check cashing store	3	88	68	149
Family or friend	112	44	20	100
Other location	55	53	25	112
Beginning-of-day adjustment	112	60	26	167
Total	573	77	40	200

Most relevant literature

Blending of two largely distinct strands

1. **Monetary** – Modern cash management/BT type models (Alvarez and Lippi 2009, 2017)
   - Dynamic optimizing framework
   - Strong monetary foundations...
   - ...but counterfactual restrictions (e.g. ordering of payments)
   - Some payment choices (cash+cards)...
   - ...but no role for substitution across instruments and liquidity
2. **Payments** – Modern IO/choice models (Koulayev, Rysman, Schuh, and Stavins 2016; Wakamori and Welte 2017)
   - Rich heterogeneity of payment characteristics and choices
   - ...but weak monetary foundations (cash payments only)
   - Encompasses adoption and use of payment instruments
   - ...but essentially no other dynamic considerations

Model timing of consumer decisions

1. Make withdrawal decision *before* each POS transaction
   (i) Observe random transaction value, p
   (ii) Realize random component of cash holding cost (b)
   (iii) Decide to withdraw cash $\mathcal{I}(m^* \neq m)$ and how much $(m^* - m)$
      - If withdrawal, incur random withdrawal cost b and fixed holding costs $R \cdot m^*$
      - If no withdrawal, incur holding costs $R \cdot m$

2. Proceed to the POS for transaction
   (i) Realize random part of utilities for current transaction, $\epsilon(i)$
   (ii) Chose payment instrument, $i = \{h, c, d\}$
   (iii) Realize non-random utility, $u^i(p)$
   (iv) If cash chosen, m decreases by p

3. Move to next withdrawal opportunity (back to Step 1)

Model optimization problem

At the point-of-sale

$$\begin{aligned} V(m,p) &= \max_{i\in\{h,c,d\}} u^i(p) + \epsilon(i) + \beta E\left[W(m',p')\right] \\ u^i(p) &= \gamma_0^i + \gamma_{p\leq 10}^i \cdot \mathcal{I}(p \leq 10) + \gamma_p^i \cdot p \qquad i \in \{h,d,c\} \end{aligned}$$

Withdrawal

$$W(m,p) = \max_{m^*}\left\{-b\cdot\mathcal{I}(m^*\neq m) - R\cdot m^* + E\left[V(m^*,p)\right]\right\},$$

- $\epsilon(i)$ i.i.d Type I Extreme value shocks
- Cost of holding cash interpreted broadly (e.g. inconvenience)
- $b \sim \mathcal{U}(-b_U, -b_L)$ random withdrawal cost
  - Sometimes it is particularly inconvenient to make a withdrawal
  - Consumer knows this better than the econometrician
- Continuation values same after debit and credit $\Rightarrow$ No dynamic considerations without deposits or revolving debt

Estimation methodology

Bajari, Benkard and Levine (2007, ECTA)

- Assume observed data are the outcomes of the optimization problem described above
- Treat the diary data as an unbalanced panel
  - For respondents with fewer observations, assume we observed them for shorter time period
- Estimate $\theta = \{b_L, b_U, R, \underline{\gamma}\}$; β set to 0.995
- Follow the methodology in BBL to estimate the model
  - Extension of Hotz-Miller algorithm to models with continuous variables
  - Two-step estimator:
    1. Use reduced-form models and simulation to find continuation values in the Bellman-equation, $E[W(m,p)]$
    2. Using these value functions, find structural parameters that rationalize observed behavior in the data

Cash management costs

b_L	b_U	R	γ_0^h	$\gamma_{p\leq 10}^h$	γ_p^h	γ_0^d	$\gamma_{p\leq 10}^d$	γ_p^d
0.0003	7.99	0.0049	2.20	0.79	-0.12	.57	.51	-.0037
(0.08)	(1.57)	(0.001)	(0.43)	(0.37)	(0.03)	(0.13)	(0.22)	(0.0016)

- Avg. withdrawal cost ≈ holding cost of \$153 ($\sim \frac{\bar{\hat{b}}}{R}$).
- How big is it relative to the benefits of holding cash?
  - Benefit of having cash

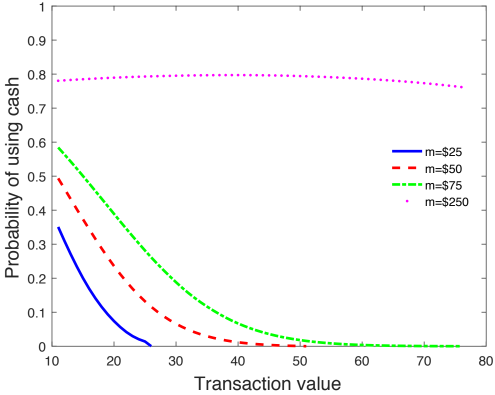
$$\Delta E[u(p)] = \log\left[\sum_{i=\{h,d,c\}} u^i(p)\right] - \log\left[\sum_{i=\{d,c\}} u^i(p)\right]$$

  - Almost two median-size transactions required to recoup avg. withdrawal cost

$$\frac{\bar{\hat{b}}}{\Delta E[u(p=13.41)]} = 1.82$$

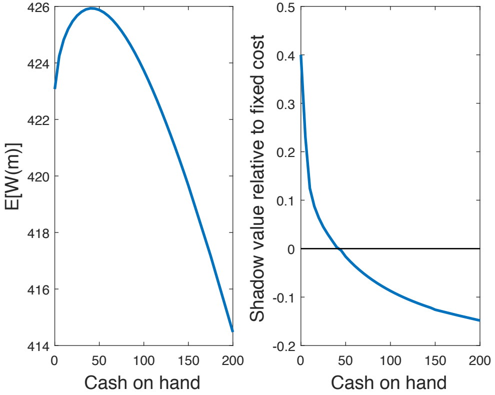
Cash holdings and simulated cash payments

Probabilities of choosing cash are quite sensitive to cash holdings; with $250, cash choice is uncorrelated with transaction values



Continuation and shadow values

The continuation value is maximized around $50 and the shadow value of extra cash turns negative at large holding amounts

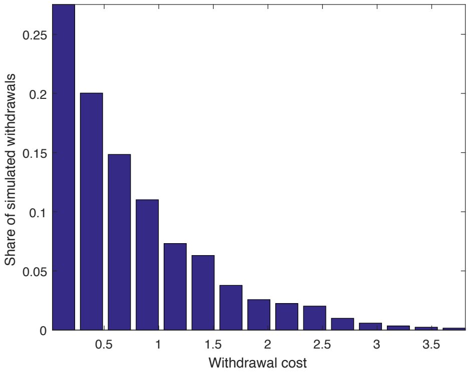


Cash holding costs

Holding-cost elasticity of demand for cash is −.85, more negative than basic Baumol-Tobin model (−.50); cash share also responds.

R	Cash holdings before transaction	Cash holdings before withdrawal	Withdrawal amount	Withdrawal prob.	Cash use share	Cash costs	Payment utility
.0025	36.59	15.57	43.94	.049	.35	26.5	465.5
.0030	33.36	14.01	40.48	.051	.34	28.7	464.1
.0035	30.76	13.21	37.25	.053	.33	30.4	462.7
.0040	28.31	11.28	36.22	.052	.33	31.8	461.1
.0045	26.50	11.03	33.23	.055	.32	33.2	459.9
.0049	25.49	10.68	31.90	.056	.32	34.6	459.0
.0055	23.58	9.69	29.71	.058	.31	35.9	457.4
.0060	22.71	9.43	28.77	.058	.31	37.2	456.5
.0065	21.33	8.65	27.68	.058	.30	37.6	454.5
.0070	20.04	8.23	26.14	.059	.30	38.2	453.0
.0075	19.47	7.79	25.77	.059	.30	39.5	452.4

Withdrawal costs



	Cash holdings before		Withdrawal		Cash use	Cash	Payment
b_L	transaction	withdrawal	amount	prob.	share	costs	utility
.0003	25.49	10.68	31.90	.056	.32	34.6	459.0
1	26.49	6.49	43.56	.038	.31	41.3	457.2
2	27.73	5.12	50.66	.031	.30	46.3	456.0
4	29.04	3.56	60.71	.023	.28	53.2	453.1

Counterfactual simulations of instrument availability

Eliminating any payment instrument reduces consumer welfare considerably, especially cash; eliminating both cards is worst

	Cash holdings before		Withdrawal		Cash use	Cash	Payment
Model	transaction	withdrawal	amount	prob.	share	costs	utility
Full	25.49	10.68	31.9	.056	.32	16.6	459.0
No cash	0	0	0	0	0	0	336.1
No debit	36.52	15.42	45.3	.072	.47	52.0	357.8
No credit	29.60	12.66	36.8	.063	.37	40.8	401.3
No cards	123.95	55.42	162.1	.177	1.00	219.4	-76.7

Summary

Conclusions:

- Cash management and payment choices are jointly determined
- Cash holdings have first-order effect on payment choice
- Cash use is moderately influenced by cash management costs

Future research directions:

- Allow for different withdrawal methods
  - Parameterize b_k and R
- Add stocks and flows for demand deposits and revolving credit/debt
- Build better model of consumer transaction choices
- Include bill payments
- Model merchant acceptance of cards