Losing contact: the impact of contactless payments on cash usage

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*Preliminary work; please do not cite.*

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Context

• Bank of Canada issues Canadian bank notes
  • Monitor and understand the demand for cash
• Retail payment innovations reshaping the payment landscape.
Aggregate shares in volume

- CC PIN
- CC online
- CC contactless
- Debit
- Cash
Previous results

Cash displaced by contactless credit card (CTC) payments?

→Regression analysis of micro data: mixed evidence!

- Cross-sectional data (2009): Use of CTC $\rightarrow$ ↓ cash share
- Panel data (2010-2012): When correct for unobserved heterogeneity (UH), find no significant effect of CTC on cash use.
Model

\[ S_{it}^{\text{cash}} = c_i + \lambda_t + \beta CT C_{it} + X_{it}' \gamma + \varepsilon_{it} \]

where

- \( S_{it}^{\text{cash}} \) is the share of the total number purchases made with cash
- \( c_i \) captures unobserved heterogeneity (UH)
- \( \lambda_t \) accounts for aggregate time effects
- \( CT C_{it} \): binary variable indicating CTC use in the past month (by \( i \) in year \( t \))
- \( \beta \) is the parameter of main interest
Data

- Canadian Financial Monitor
  - 40,448 households (HH)
  - 8 years: 2010-2017
  - 94,155 HH-year observations

- 7 consecutive two-years panels
  - Minimize attrition
  - Allow $\beta$ and $c_i$ to vary over time

HH participation over 8 years

Consecutive two-year panels
reg vs. xtreg: correcting for UH makes a difference

\[ \beta \] estimates

-0.12  -0.1  -0.08  -0.06  -0.04  -0.02  0  0.02


-0.12  -0.1  -0.08  -0.06  -0.04  -0.02  0  0.02

Pooled OLS  FE
Exploring heterogeneity with `fmm reg`

**FE $\beta$ estimates, 2-class model**

**Latent class marginal probabilities**
Distribution of $\Delta h_s(S_{\text{cash}})$ by FMM class

- Classes obtained with:
  predict postpr*, classposterior

- hist $\Delta h_s(S_{it}^{\text{cash}})$, by class
  - produces 2 subgraphs for unique values of class

- Use twoway__histogram_gen:
  twoway__histogram_gen diffhsCR if class2==0, gen(freq_class1 x1) freq width(0.1) start(-5.3)
  twoway__histogram_gen diffhsCR if class2==1, gen(freq_class2 x2) freq width(0.1) start(-5.3)

Notes: 2016-17 panel.
Class labelling based on cash user type

Distribution of $\Delta h_s(S^{\text{cash}})$
by FMM class

- Post. Prob. Class 2 > 0.5
- Post. Prob. Class 1 ≥ 0.5

Distribution of $\Delta h_s(S^{\text{cash}})$
by type of cash user

- UU ($S_{t-1}>0$, $S_t>0$)
- NU ($S_{t-1}=0$, $S_t>0$)
- UN ($S_{t-1}>0$, $S_t=0$)
- NN ($S_{t-1}=0$, $S_t=0$)
Heterogeneity that matters: types of cash users

Types in 2-year panels:

• Used some cash in the past week both in year $t-1$ and $t$
  ➢ Regular cash users

• Did not use cash in the past week in year $t-1$ or $t$
  ➢ Occasional cash users

• Did not use cash in the past week both in year $t-1$ and $t$
  ➢ Cash non-users
Cash user types: different withdrawal costs

• Baumol-Tobin model predictions:
  • Withdrawal frequency:
    \[ n^* = \sqrt{Rc/2b} \quad \downarrow \text{with } b/c \]
  • Withdrawal size:
    \[ W^*/c = \sqrt{2b/Rc} \quad \uparrow \text{with } b/c \]
  • Cash holdings:
    \[ M^*/c = \sqrt{b/2Rc} \quad \uparrow \text{with } b/c \]

where:
- \( c \) is cash consumption
- \( b \) is the withdrawal cost
Selection and corner solution models

• Allow separate mechanisms to determine:
  1. “Adoption” decision = whether to obtain cash.
  2. Usage = whether/how much to use cash given that cash was obtained.

• But “adoption” not observed; only observe usage.

• Corner solution model:
  1. “Participation” decision = whether to use cash \( S_{it}^{\text{cash}} = 0 \) vs. \( S_{it}^{\text{cash}} > 0 \)
  2. Amount decision = magnitude of \( S_{it}^{\text{cash}} \) when it is positive
     ➢ Extensive/intensive margin

• Fixed costs that affect the decision to “participate”: cash withdrawal costs
  ➢ Instrument = banking density
Model 1:

1. Binary participation: \( S_{it}^{cash} = 0 \) vs. \( S_{it}^{cash} > 0 \)

2. Amount equation estimated in first-difference after log transformation, when \( S_{it}^{cash} S_{it}^{cash} = 1 \)


- `heckman` command after transformations.
Model 2:

1. Multinomial “participation”: $type_{it} \in \{\text{regular, occasional, non}\}$

2. Amount equation estimated in FD,

   when $S_{it-1}^{\text{cash}} S_{it}^{\text{cash}} = 1 \iff type_{it} = \text{regular}$

“Selection bias correction based on the multinomial logit model”, survey by Bourguignon, Fournier and Gurgand (2004)

selmlog package available here:
Corner-solution models for panel data (2/2)

Model 3:

1. Binary participation with FE:
   \[ d_{it} = 1[c_i^1 + \lambda_t^1 + \beta_1 CT C_{it} + X'_{it} \delta_t + Z'_{it} \xi_t + \nu_{it} > 0] \]

2. Amount equation with FE
   \[ S^*_{it} = c_i^2 + \lambda_t^2 + \beta_2 CT C_{it} + X'_{it} \gamma + \varepsilon_{it} \]


Do-files available here:

http://myweb.fsu.edu/asemykina/
Corner-solution models: partial effects

- \( E(y|x) = P(y > 0|x)E(y|x, y > 0) \)
- For the ET2T model in level:

\[
S_{it}^{\text{cash}} = 1\left[ \beta_1 CTC_{it} + X_{it}'\delta + Z_{it}'\xi + v_{it} > 0 \right] \exp(\beta_2 CTC_{it} + X_{it}'\gamma + \varepsilon_{it})
\]

\[
E(\ln S_{it}^{\text{cash}}|S_{it}^{\text{cash}} > 0) = \beta_2 CTC_{it} + X_{it}'\gamma + \rho \sigma \lambda (\beta_1 CTC_{it} + X_{it}'\delta + Z_{it}'\xi)
\]

\( \beta_2 \) does not itself provide partial effects of \( CTC \) on any conditional mean involving \( S_{it}^{\text{cash}} \)

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- Focusing on estimates of \( \beta_2 \) is inappropriate
- Different from the sample selection context!
Corner-solution models: partial effects

• \( E(y|x) = P(y > 0|x)E(y|x, y > 0) \)

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S_{it}^{cash} = 1 \left[ \beta_1 CTC_{it} + X_{it}' \delta + Z_{it}' \xi + v_{it} > 0 \right] \exp(\beta_2 CTC_{it} + X_{it}' \gamma + \epsilon_{it})
\]

\[
E(\ln S_{it}^{cash} | S_{it}^{cash} > 0) = \beta_2 CTC_{it} + X_{it}' \gamma + \rho \sigma \lambda (\beta_1 CTC_{it} + X_{it}' \delta + Z_{it}' \xi)
\]

\(\beta_2\) does not itself provide partial effects of \( CTC \) on any conditional mean involving \( S_{it}^{cash}\)

\(\beta_2\) focusing on estimates of \(\beta_2\) is inappropriate

Different from the sample selection context!

*New*: “Estimation methods in the presence of corner solutions”, Sánchez-Peñalver, in the current issue of the Stata Journal!
Additional material
CTC and cash use

CTC use over time

Cash shares
Exploring heterogeneity: finite mixture model

• Transform $S_{it}^{\text{cash}}$ using inverse hyperbolic sine, then FD
• Finite mixture of linear FD regression model
• Use AIC/BIC criteria to select optimal number of classes
  ➢ 2 classes (in each two-year panel)
• Classes must be labelled:
  • Class 1: $\beta$ negative, small s.e.
  • Class 2: $\beta$ positive, large s.e.
Cash-user types: methods of payments used

MoP shares in volume

MoP shares in value

Regular | Occasional | Non

Cash | Conv. CC | CTC | DC | SVC | Other

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### Cash user types: demographics and preferences

<table>
<thead>
<tr>
<th></th>
<th>Regular</th>
<th>Occasional</th>
<th>Non</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age: 18-35</strong></td>
<td>18</td>
<td>21</td>
<td>20</td>
</tr>
<tr>
<td><strong>35-55</strong></td>
<td>36</td>
<td>39</td>
<td>44</td>
</tr>
<tr>
<td><strong>55+</strong></td>
<td>46</td>
<td>39</td>
<td>36</td>
</tr>
<tr>
<td><strong>High school</strong></td>
<td>20</td>
<td>18</td>
<td>14</td>
</tr>
<tr>
<td><strong>College</strong></td>
<td>40</td>
<td>39</td>
<td>41</td>
</tr>
<tr>
<td><strong>University</strong></td>
<td>39</td>
<td>44</td>
<td>45</td>
</tr>
<tr>
<td><strong>Born in Canada</strong></td>
<td>85</td>
<td>83</td>
<td>80</td>
</tr>
<tr>
<td><strong>Income: &lt;25</strong></td>
<td>12</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td><strong>25-44</strong></td>
<td>20</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td><strong>45-59</strong></td>
<td>21</td>
<td>22</td>
<td>21</td>
</tr>
<tr>
<td><strong>70+</strong></td>
<td>47</td>
<td>48</td>
<td>51</td>
</tr>
<tr>
<td><strong>No internet</strong></td>
<td>5</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>City size: &lt;10K</strong></td>
<td>17</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td><strong>10 - 100K</strong></td>
<td>15</td>
<td>14</td>
<td>11</td>
</tr>
<tr>
<td><strong>&gt;100K</strong></td>
<td>68</td>
<td>71</td>
<td>75</td>
</tr>
<tr>
<td><strong>Revolv on CC</strong></td>
<td>30</td>
<td>27</td>
<td>21</td>
</tr>
<tr>
<td><strong>Reward on CC</strong></td>
<td>67</td>
<td>73</td>
<td>75</td>
</tr>
</tbody>
</table>

- **I believe a financial advisor could help me in today’s economic situation**
- **I like to consult a professional investment advisor, but I make my own decisions about my investments**
- **There are so many financial products and services that I sometimes find it confusing**
- **I prefer to deal with people when I bank**
- **I am willing to take substantial risks to earn substantial returns**
Cash user types: cash handling

Cash withdrawal frequency

Withdrawal and holding amount
Two-part model in level

\[ S_{it}^{\text{cash}} = d_{it} S_{it}^*; \ S_{it}^* \text{ is observed only if } d_{it} = 1 \]

(1a) \[ d_{it} = 1[\beta_1 CTC_{it} + X_{it}' \delta + Z_{it}' \xi + v_{it} > 0] \]

(2a) \[ \ln S_{it}^* = \beta_2 CTC_{it} + X_{it}' \gamma + \epsilon_{it} \]

➤ Exponential type II Tobit (ET2T) model (Wooldridge, 2010, p.697)

➤ Estimation: Heckman two-step procedure.
   ➤ Reject independence of (1) and (2)
   ➤ Bank branch density measure positively impact \( \Pr(d_{it} = 1) \)

➤ Problem: don’t correct for UH in (1a) or (2a).
Two-part model with panel data (1/2)

\[
\Delta S_{it}^{\text{cash}} = d_{i(t-1)} d_{it} \Delta S_{it}^* + (1 - d_{i(t-1)}) d_{it} S_{it}^* - d_{i(t-1)}(1 - d_{it}) S_{i(t-1)}^*
\]

\[\Delta S_{it}^* \text{ is observed only if } d_{i(t-1)} d_{it} = 1\]

(1b) \[d_{i(t-1)} d_{it} = 1[CTC'_{i(t-1)t} \beta_{1t} + X'_{i(t-1)t} \delta_t + Z'_{i(t-1)t} \xi_t + u_{i(t-1)t} > 0]\]

(2b) \[\Delta \ln S_{it}^* = \beta_{2t} \Delta CTC_{it} + \Delta X'_{it} \gamma + \Delta \varepsilon_{it}\]

• Binary participation decision:
  • \(d_{i(t-1)} d_{it} = 1 \text{ if } \text{type}_{it} = \text{regular}\)
  • \(d_{i(t-1)} d_{it} = 0 \text{ if } \text{type}_{it} \in \{\text{occasional, non}\}\)

- Estimation: Heckman two-step procedure
- Problem: control for UH in (2b) only
Two-part model with panel data (1/2)

\[ \Delta S_{it}^{\text{cash}} = d_{i(t-1)}d_{it}\Delta S_{it}^* + (1 - d_{i(t-1)})d_{it}S_{it}^* - d_{i(t-1)}(1 - d_{it})S_{i(t-1)}^* \]

\( \Delta S_{it}^* \) is observed only if \( d_{i(t-1)}d_{it} = 1 \)

(1b) \( d_{i(t-1)}d_{it} = 1[CTC'_{i(t-1)t}\beta_{1t} + X'_{i(t-1)t}\delta_t + Z'_{i(t-1)t}\xi_t + v_{i(t-1)t} > 0] \)

(2b) \[ \Delta \ln S_{it}^* = \beta_{2t} \Delta CTC_{it} + \Delta X'_{it}\gamma + \Delta \epsilon_{it} \]

- Binary participation decision:
  - \( d_{i(t-1)}d_{it} = 1 \) if \( \text{type}_{it} = \text{regular} \)
  - \( d_{i(t-1)}d_{it} = 0 \) if \( \text{type}_{it} \in \{\text{occasional, non}\} \)

- Alternative:
  - \( \text{type}_{it} \in \{\text{regular, occasional, non}\} \)

- Estimation: Heckman two-step procedure
- Problem: control for UH in (2b) only
- Estimation: Dubin & McFadden (1984); Bourguignon et al. (2007)
Two-part model with panel data (2/2)

\[ S_{it}^{cash} = d_{it} S_{it}^*; \quad S_{it}^* \text{ is observed only if } d_{it} = 1 \]

(1c) \[ d_{it} = 1 \left[ c_i^1 + \lambda_t^1 + \beta_1 CTC_{it} + X'_{it} \delta_t + Z'_{it} \xi_t + v_{it} > 0 \right] \]

(2c) \[ S_{it}^* = c_i^2 + \lambda_t^2 + \beta_2 CTC_{it} + X'_{it} \gamma + \epsilon_{it} \]


- Control for UH in (1c) and (2c)!
Two-part model: estimation results for $\beta_2$

<table>
<thead>
<tr>
<th>Year</th>
<th>ET2T-binary</th>
<th>ET2T-multinomial</th>
<th>S&amp;W</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010-11</td>
<td>-0.05</td>
<td>-0.15</td>
<td>-0.2</td>
</tr>
<tr>
<td>2011-12</td>
<td>-0.05</td>
<td>-0.15</td>
<td>-0.2</td>
</tr>
<tr>
<td>2012-13</td>
<td>-0.05</td>
<td>-0.15</td>
<td>-0.2</td>
</tr>
<tr>
<td>2013-14</td>
<td>-0.1</td>
<td>-0.2</td>
<td>-0.25</td>
</tr>
<tr>
<td>2014-15</td>
<td>-0.05</td>
<td>-0.15</td>
<td>-0.2</td>
</tr>
<tr>
<td>2015-16</td>
<td>-0.05</td>
<td>-0.15</td>
<td>-0.2</td>
</tr>
<tr>
<td>2016-17</td>
<td>-0.05</td>
<td>-0.15</td>
<td>-0.2</td>
</tr>
</tbody>
</table>
Summary

• Correcting for UH in cash ratio regressions matters.
• Different cash-user types in two-year panels have different cash ratio regression functions, with different responses to CTC use.
• Attempt to reconcile the 3 regression functions in a two-part model/corner solution framework.

Work in progress:

➢ Compute marginal effects
➢ Compare intensive and extensive margins
Additional material

Types of CTC users
Pooled OLS vs. FE: Correcting for UH makes a difference

• Pooled OLS uses variation over both time and HH... but inconsistent if the FE model is appropriate.

• FD/FE/within estimator uses variation over time only:

\[ \Delta S_{it}^{cash} = \lambda + \beta \Delta CTC_{it} + \Delta X_{it}' \gamma + \Delta \varepsilon_{it} \]

where \( \Delta CTC_{it} = CTC_{it} - CTC_{i(t-1)} \) takes the values \{-1,0,1\}.

• New-users: \( CTC_{i(t-1)} = 0, CTC_{it} = 1 \)
• Always-users: \( CTC_{i(t-1)} = 1, CTC_{it} = 1 \)
• Never-users: \( CTC_{i(t-1)} = 0, CTC_{it} = 0 \)
• Stop-users: \( CTC_{i(t-1)} = 1, CTC_{it} = 0 \)
Exploring heterogeneity: different types of CTC users

Types of CTC users

- Always-user
- New-user
- Stop-user
- Never-user

More flexible specification:

$$\Delta S_{it}^{cash} = \beta_a I_{it}^{always} + \beta_n I_{it}^{new} + \beta_s I_{it}^{stop} + \lambda + \Delta X_{it}' \gamma + \Delta \varepsilon_{it}$$