BANK OF CANADA
BANQUE DU CANADA

30 MAY 2019

Losing contact: the impact of contactless payments on cash usage

2019 Canadian Stata Conference

Preliminary work; please do not cite.

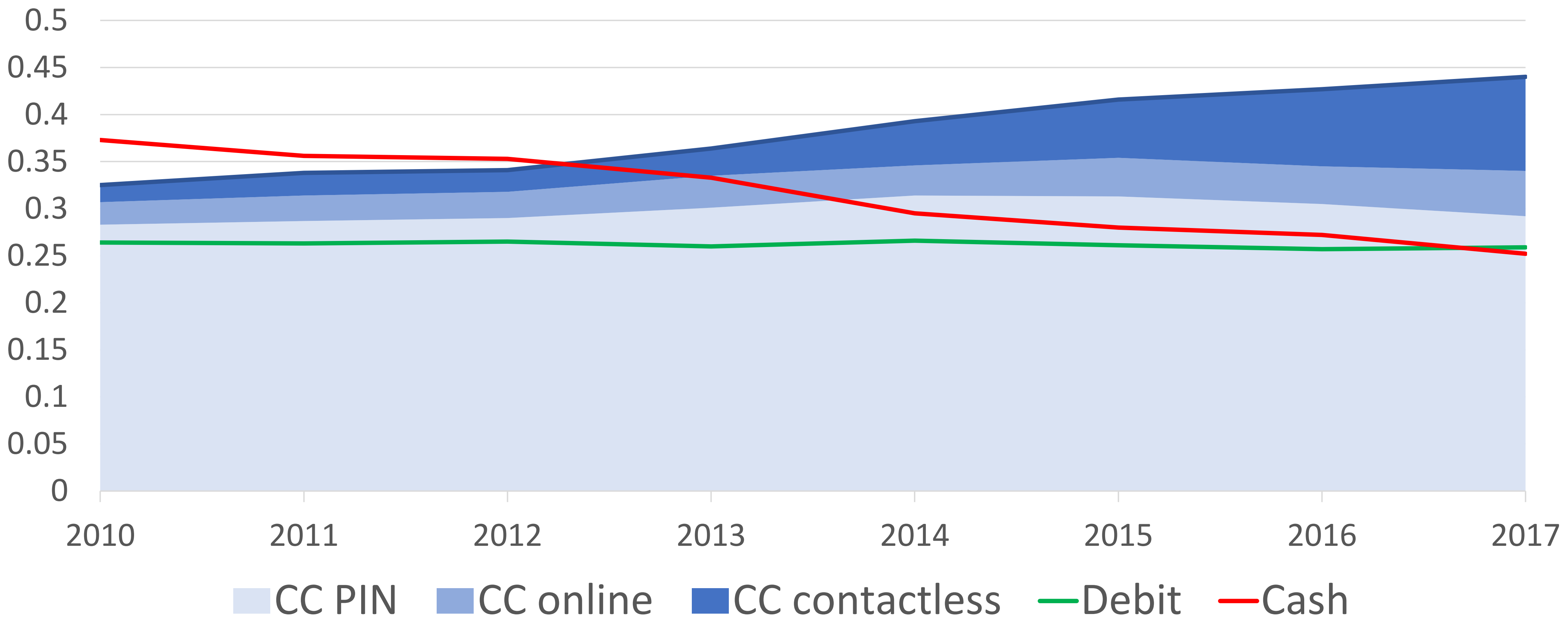
Marie-Hélène Felt

SENIOR ECONOMIST
CURRENCY DEPARTMENT

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



Previous results

Cash displaced by contactless credit card (CTC) payments?

→**Regression analysis of micro data: mixed evidence!**

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

Model

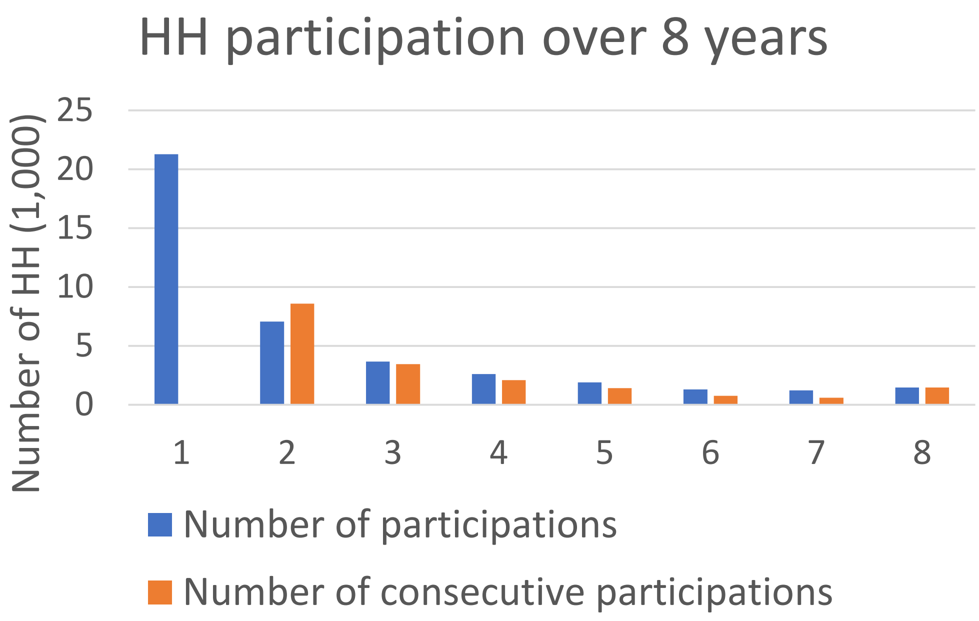
$$S_{it}^{cash} = c_i + \lambda_t + \beta CTC_{it} + X_{it}'\gamma + \varepsilon_{it}$$

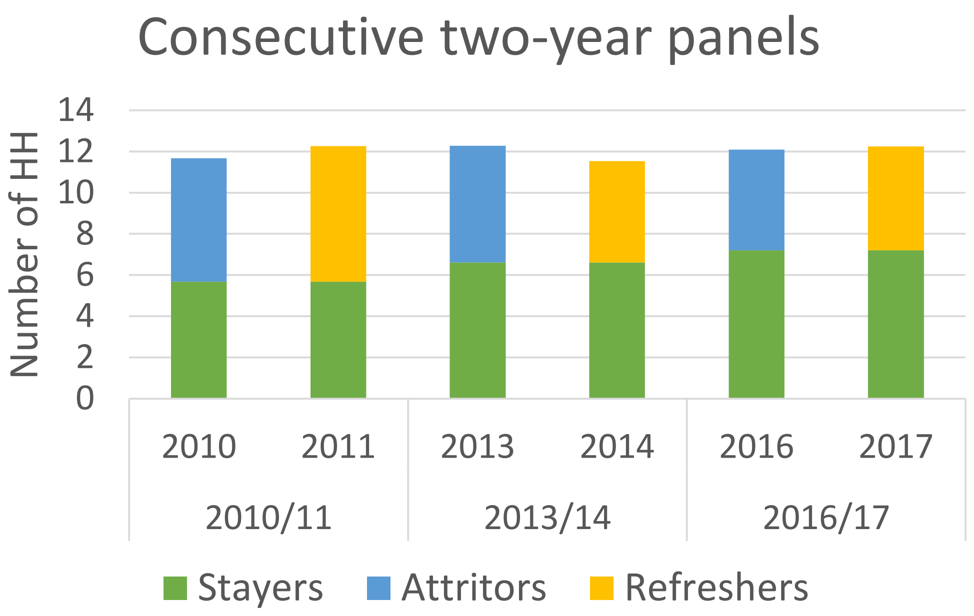
where

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

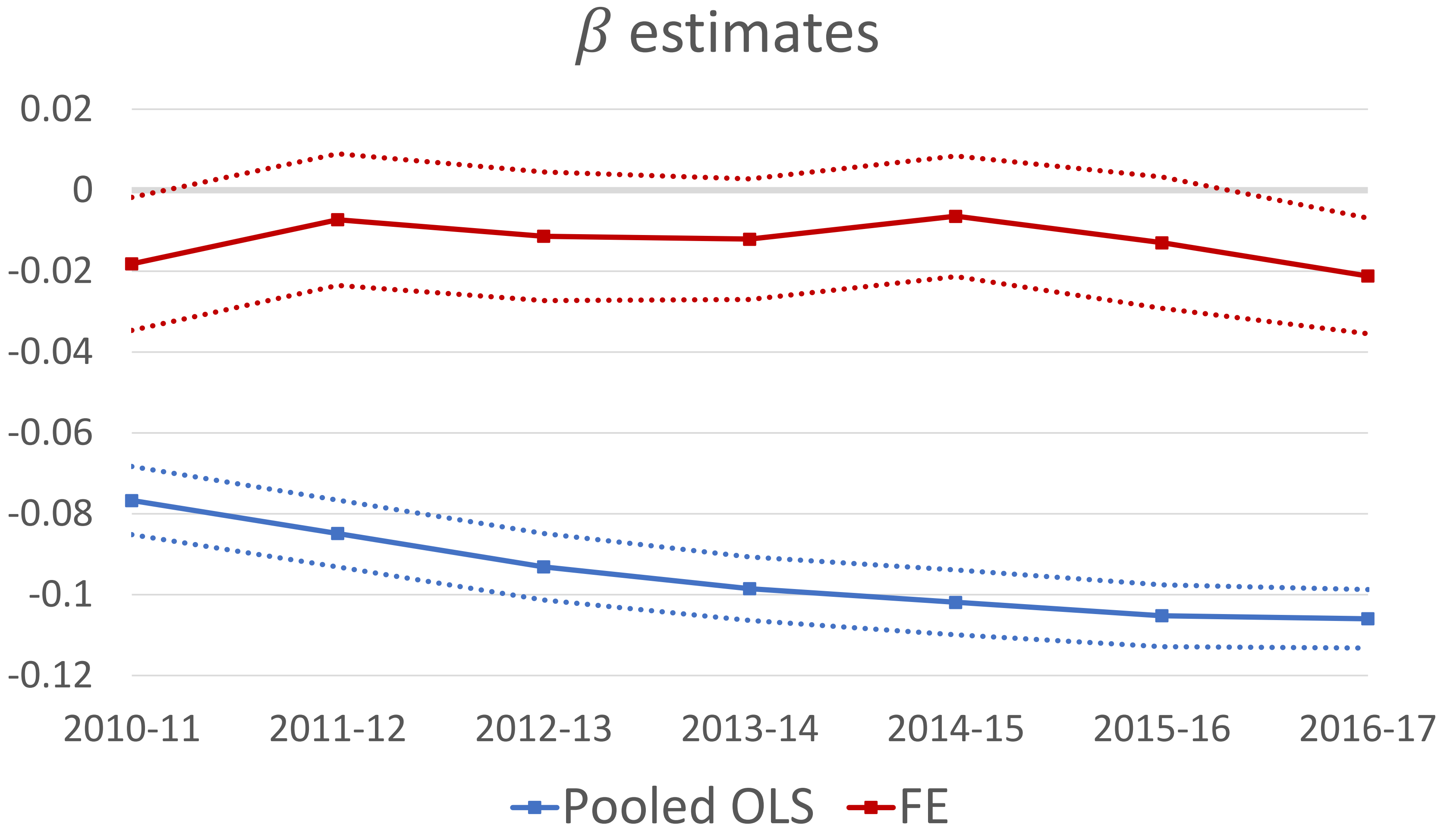
Data

- Canadian Financial Monitor
  - 40,448 households (HH)
  - 8 years: 2010-2017
  - 94,155 HH-year observations
- 7 consecutive two-years panels
  - Minimize attrition
  - Allow β and c_i to vary over time

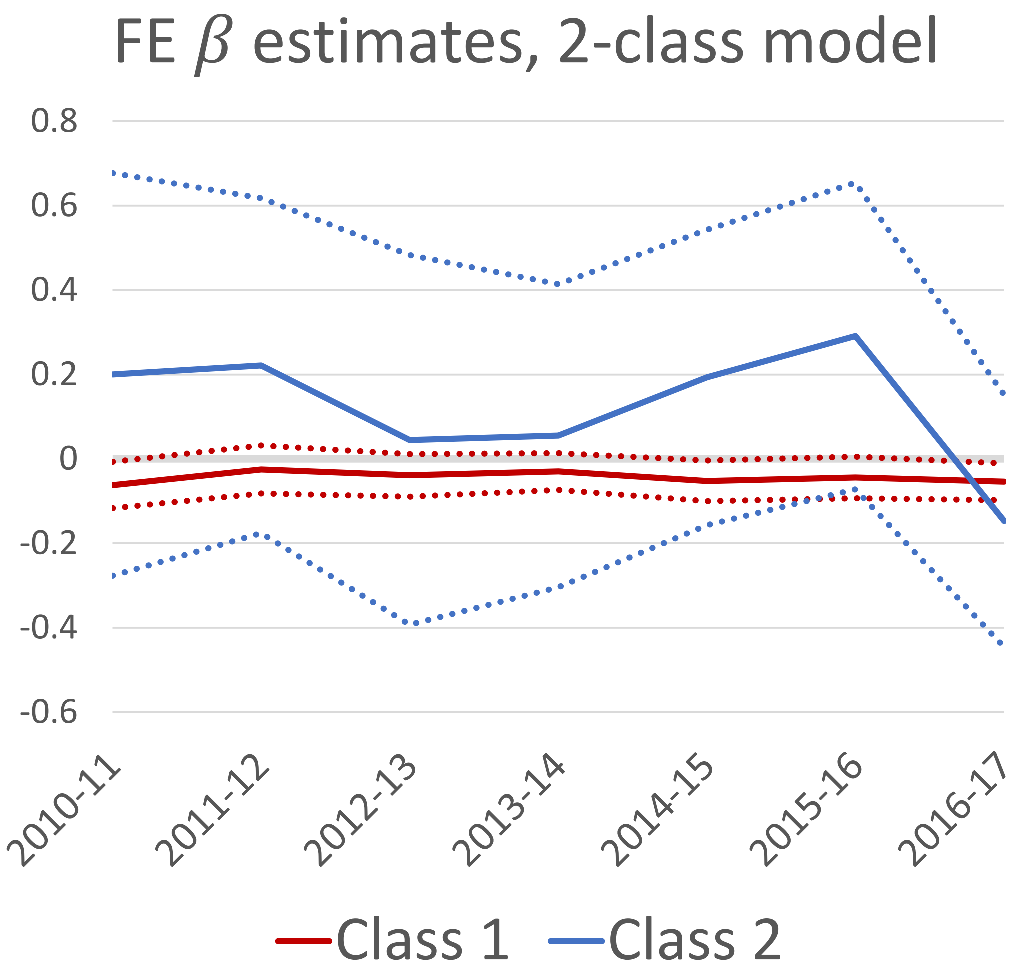


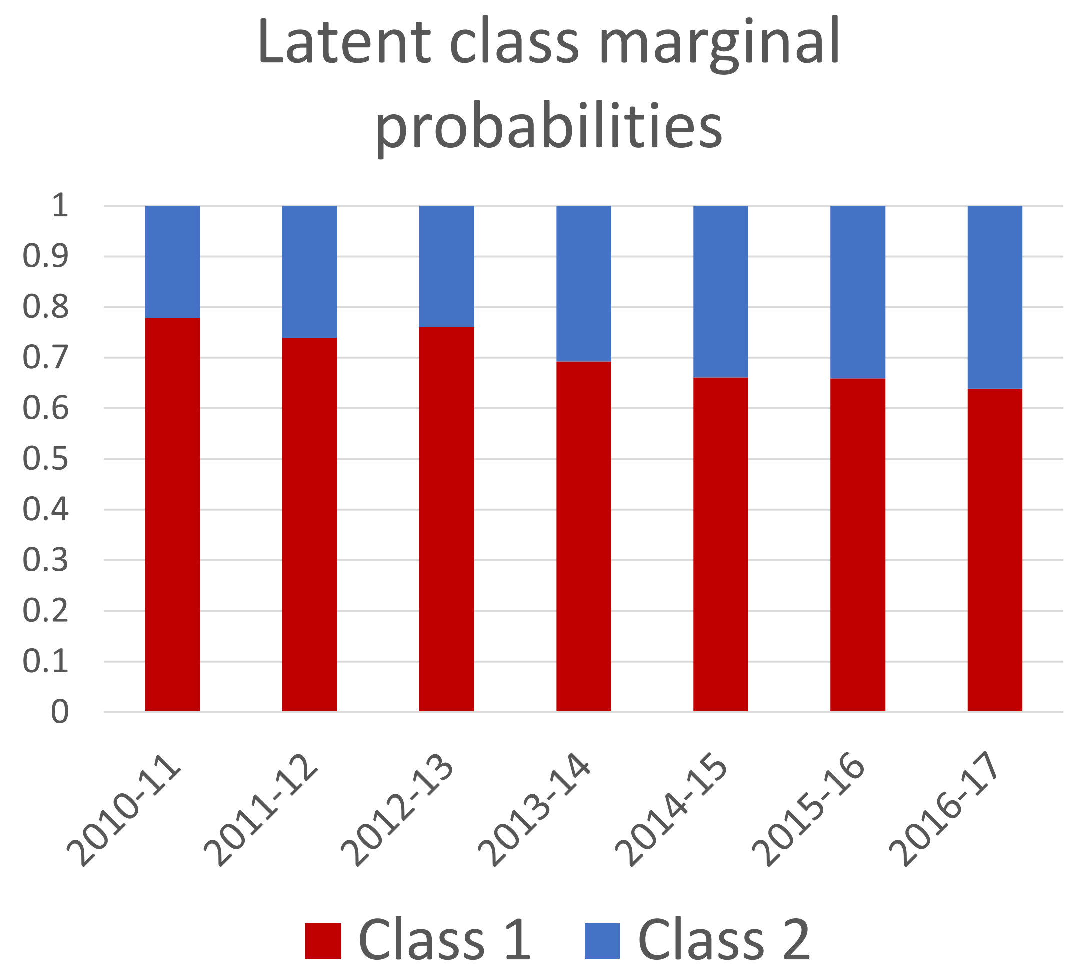


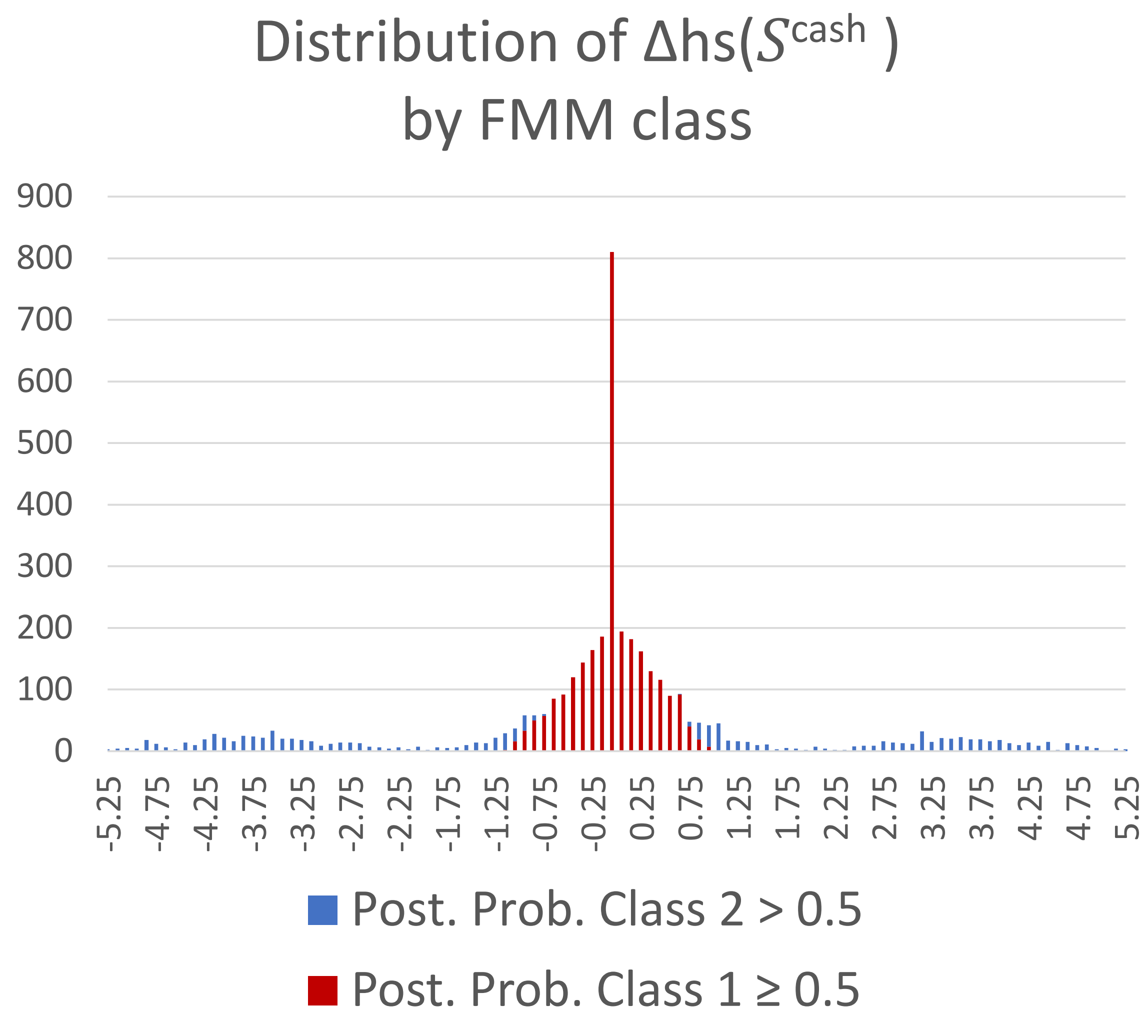
`reg` vs. `xtreg`: correcting for UH makes a difference



Exploring heterogeneity with `fmm:reg`







Notes: 2016-17 panel.

- Classes obtained with:

  `predict postpr*,classposterior`

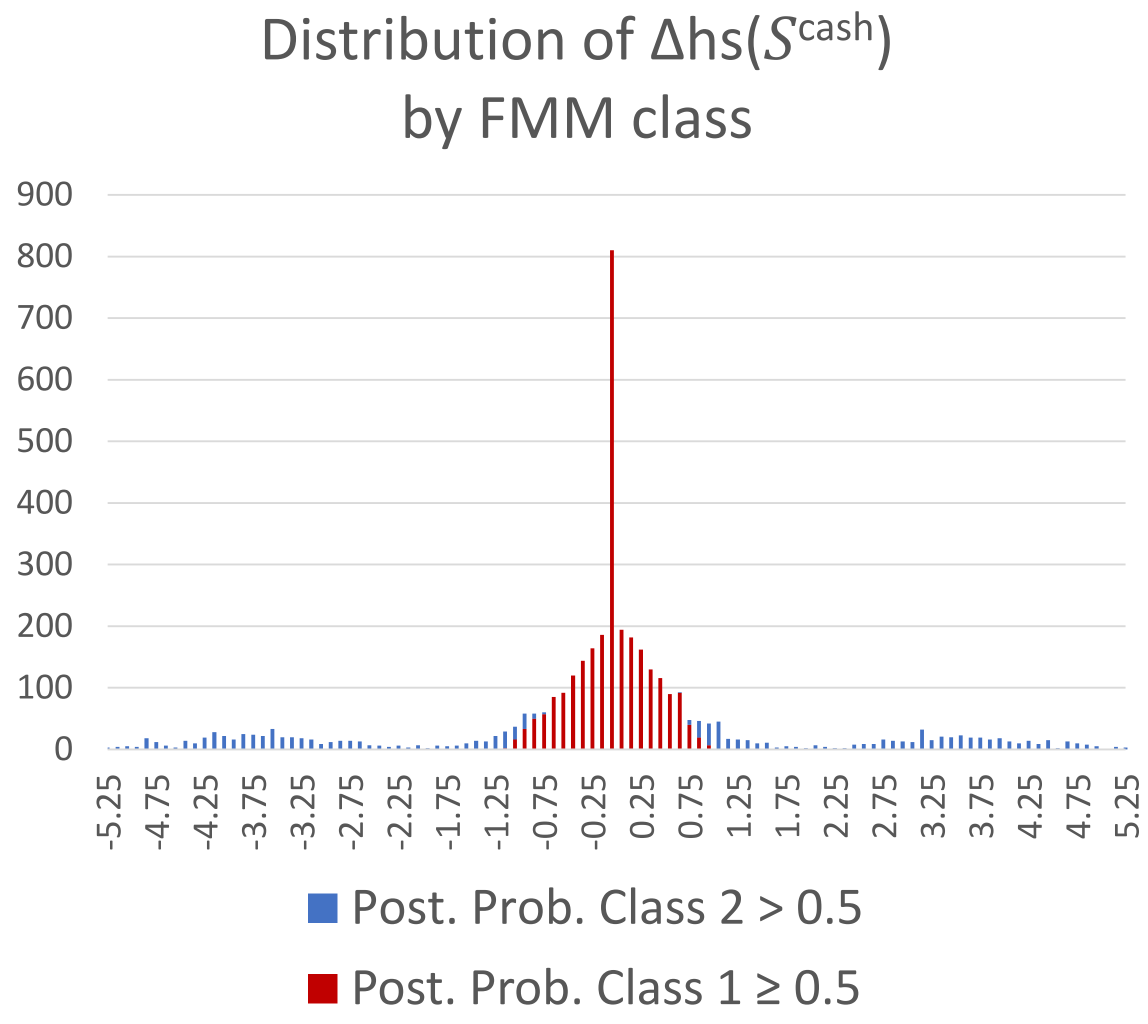
- **`hist`** $\Delta \text{hs}(S_{it}^{cash})$**`,by`** *class*
  - ➢ produces 2 subgraphs for unique values of *class*

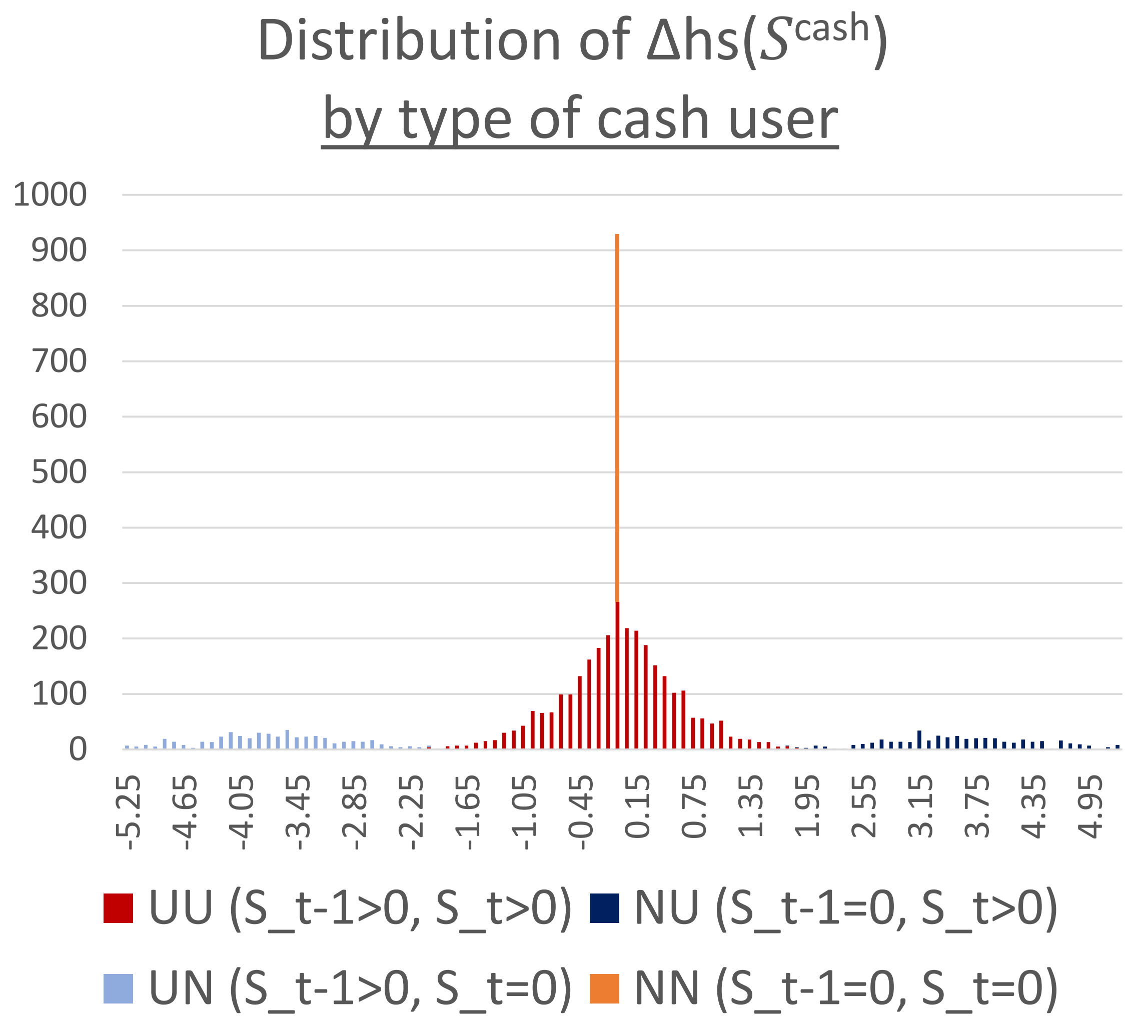
- Use **`twoway__histogram_gen`**:

  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)

Class labelling based on cash user type

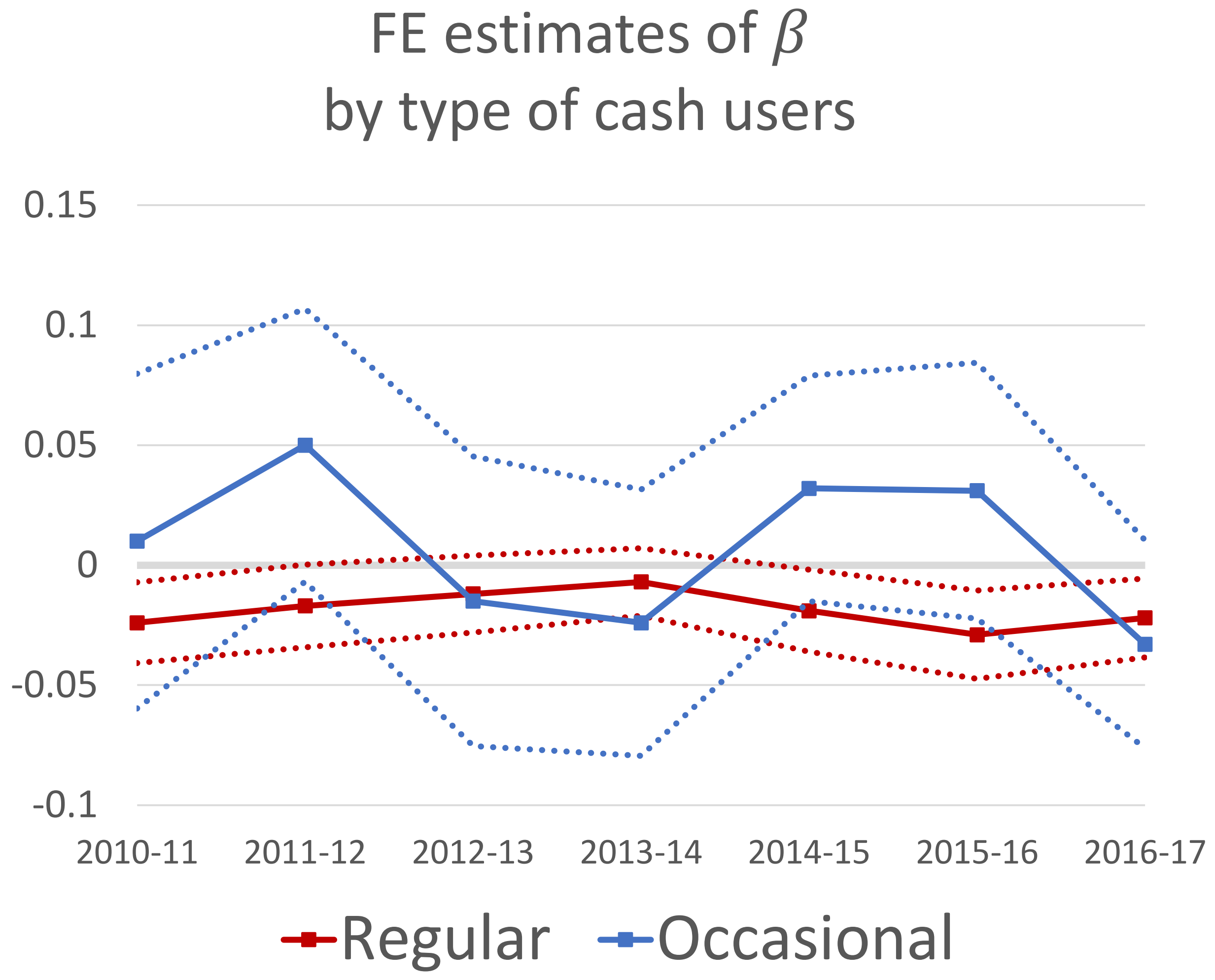




Heterogeneity that matters: types of cash users

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

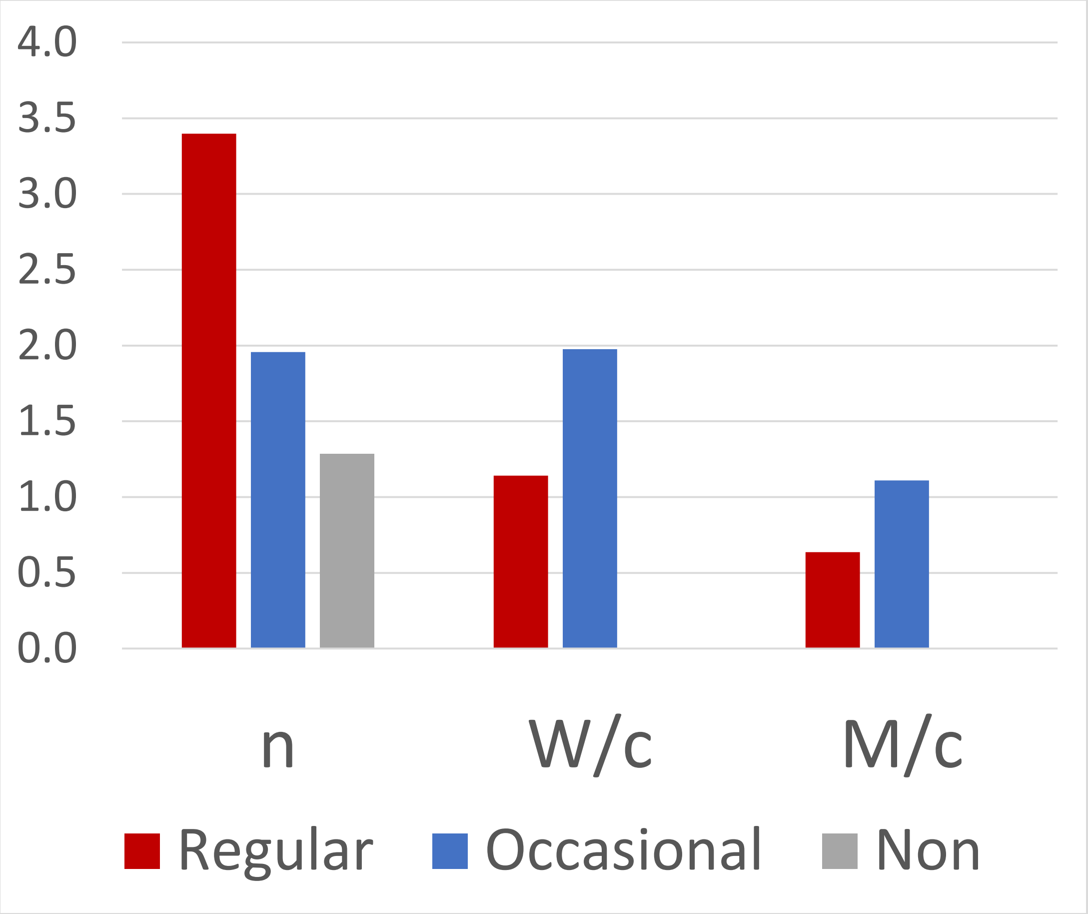
- Baumol-Tobin model predictions:
  - Withdrawal frequency:

    $n^* = \sqrt{Rc/2b}$ ↓ with b/c
  - Withdrawal size:

    $W^*/c = \sqrt{2b/Rc}$ ↑ with b/c
  - Cash holdings:

    $M^*/c = \sqrt{b/2Rc}$ ↑ 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 ($S_{it}^{cash} = 0$ vs. $S_{it}^{cash} > 0$)
  2. Amount decision = magnitude of S_{it}^{cash} when it is positive

  ➢ Extensive/intensive margin

- Fixed costs that affect the decision to "participate": cash withdrawal costs

  ➢ Instrument = banking density

Corner-solution models for panel data (1/3)

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 $S_{it-1}^{cash} S_{it}^{cash} = 1$

- ➢ Adaptation of the Exponential type II Tobit (ET2T) model (Wooldridge, 2010, p.697).
- ➢ **heckman** command after transformations.

Corner-solution models for panel data (2/3)

Model 2:

1. Multinomial "participation": $type_{it} \in \{regular, occasional, non\}$
2. Amount equation estimated in FD,

   when $S_{it-1}^{cash} S_{it}^{cash} = 1 \; \Leftrightarrow type_{it} = regular$

- "Selection bias correction based on the multinomial logit model", survey by Bourguignon, Fournier and Gurgand (2004)
- **selmlog** package available here:

http://www.parisschoolofeconomics.com/gurgand-marc/selmlog/selmlog13.html

Corner-solution models for panel data (2/2)

Model 3:

1. Binary participation with FE:

$$d_{it} = 1[c_i^1 + \lambda_t^1 + \beta_1 CTC_{it} + X_{it}'\delta_t + Z_{it}'\xi_t + v_{it} > 0]$$

2. Amount equation with FE

$$S_{it}^* = c_i^2 + \lambda_t^2 + \beta_2 CTC_{it} + X_{it}'\gamma + \varepsilon_{it}$$

- "Estimating Panel Data Models in the Presence of Endogeneity and Selection" by Semykina and Wooldridge (JoE, 2010)
- **`Do-files`** available here:

  http://myweb.fsu.edu/asemykina/

Corner-solution models: partial effects

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

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

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

- ➢ β_2 does not itself provide partial effects of CTC on any conditional mean involving S_{it}^{cash}
- ➢ **Focusing on estimates of $\boldsymbol{\beta_2}$ is inappropriate**
- ➢ Different from the sample selection context!

Corner-solution models: partial effects

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

$$S_{it}^{cash} = 1[\beta_1 CTC_{it} + X'_{it}\delta + Z'_{it}\xi + v_{it} > 0]\exp(\beta_2 CTC_{it} + X'_{it}\gamma + \varepsilon_{it})$$

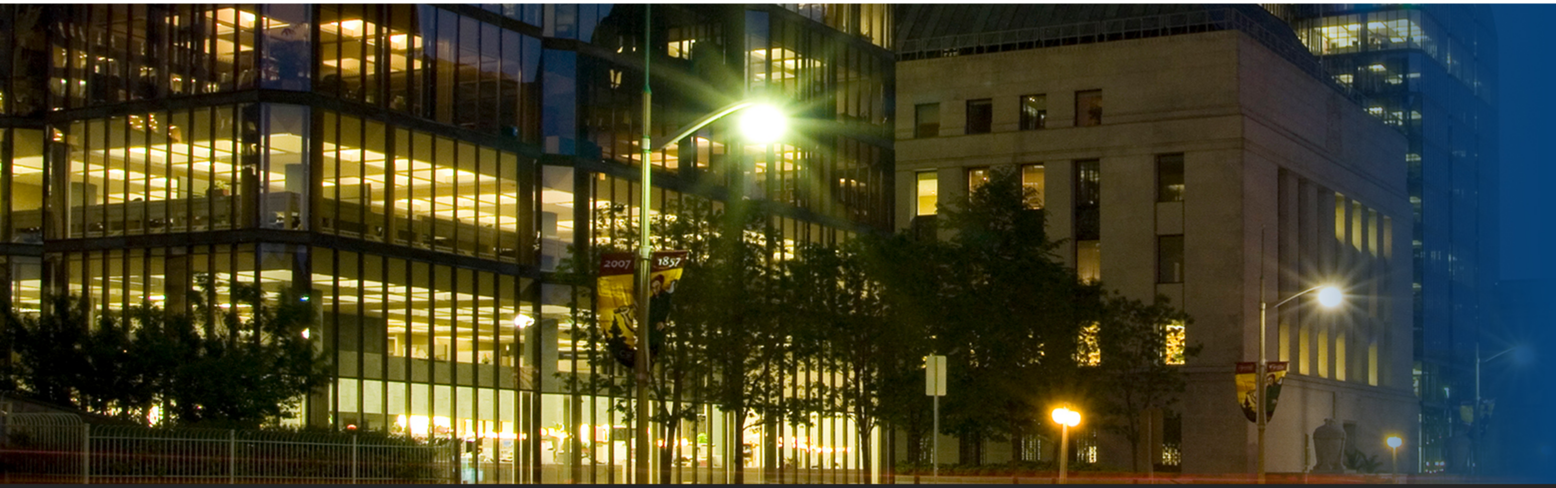
$$\mathrm{E}(\ln S_{it}^{cash}|S_{it}^{cash} > 0) = \beta_2 CTC_{it} + X'_{it}\gamma + \rho\sigma\lambda(\beta_1 CTC_{it} + X'_{it}\delta + Z'_{it}\xi)$$

➢ β_2 does not itself provide partial effects of CTC on any conditional mean involving S_{it}^{cash}

➢ **Focusing on estimates of $\boldsymbol{\beta_2}$ is inappropriate**

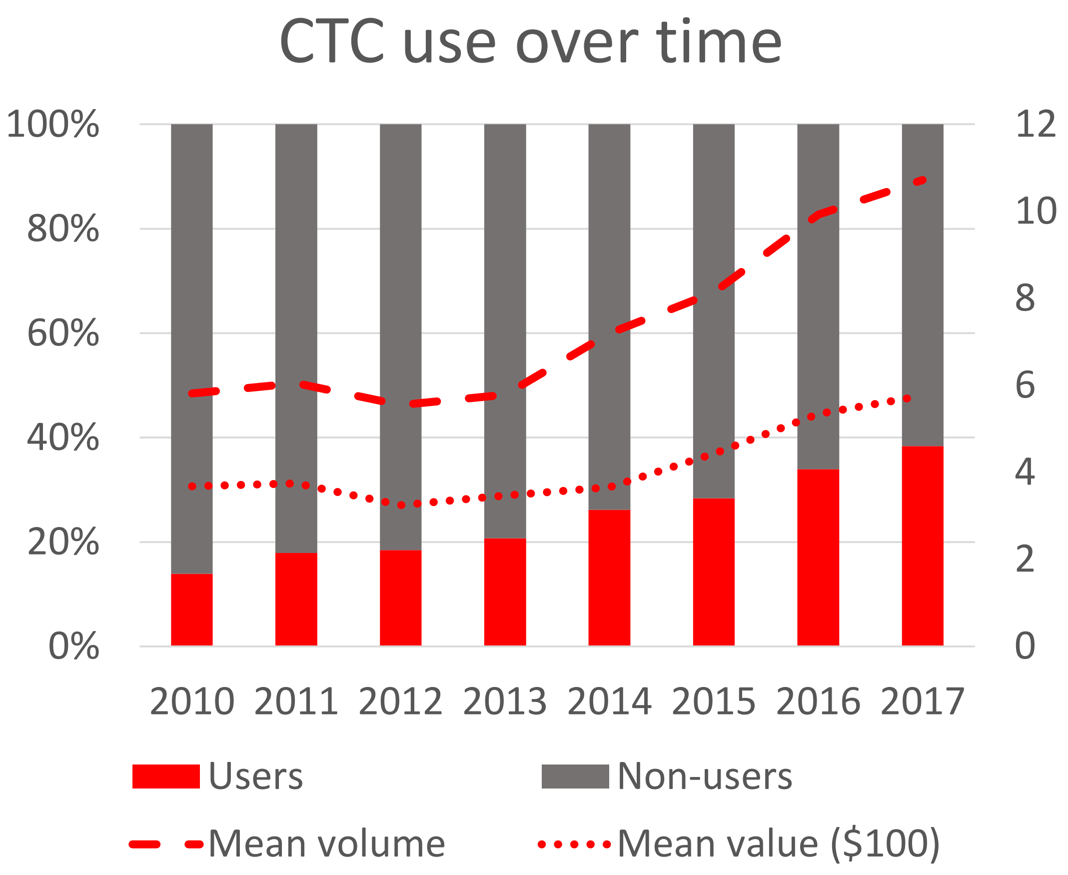
➢ Different from the sample selection context!

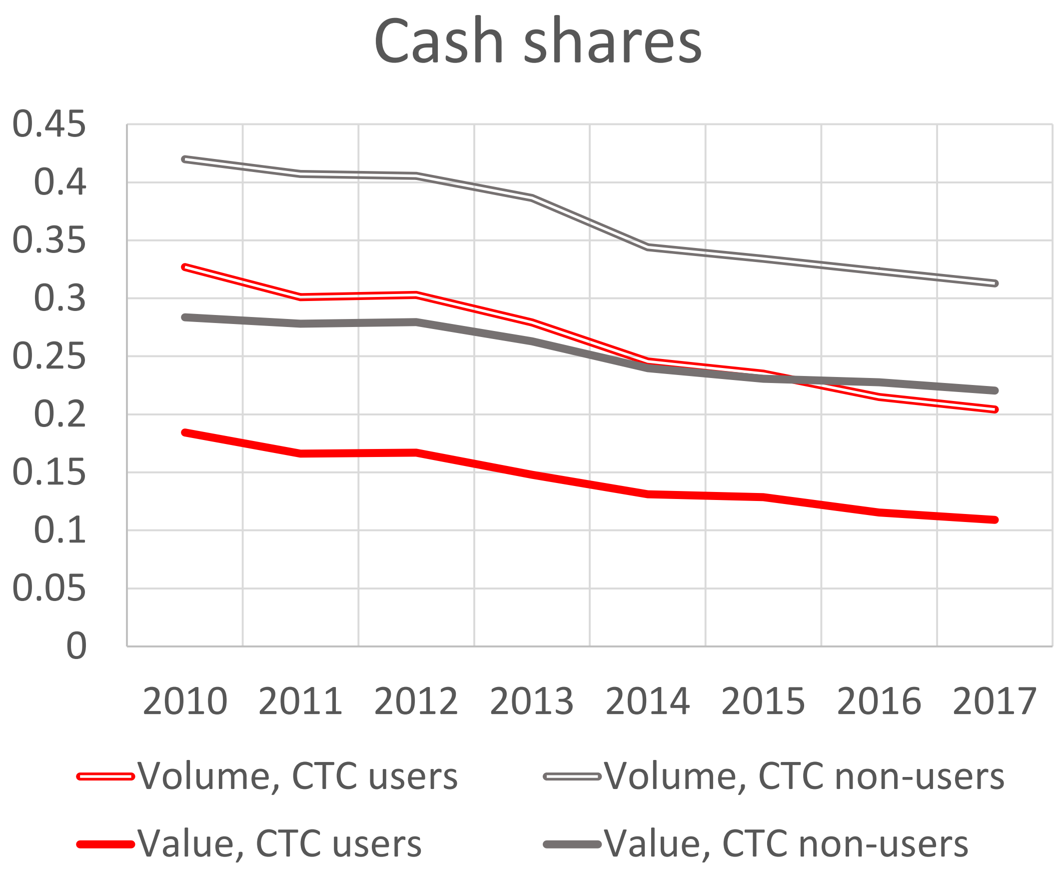
➔ *New*: “Estimation methods in the presence of corner solutions”, Sánchez-Peñalver, in the current issue of the Stata Journal !


2007
1857

Additional material

CTC and cash use

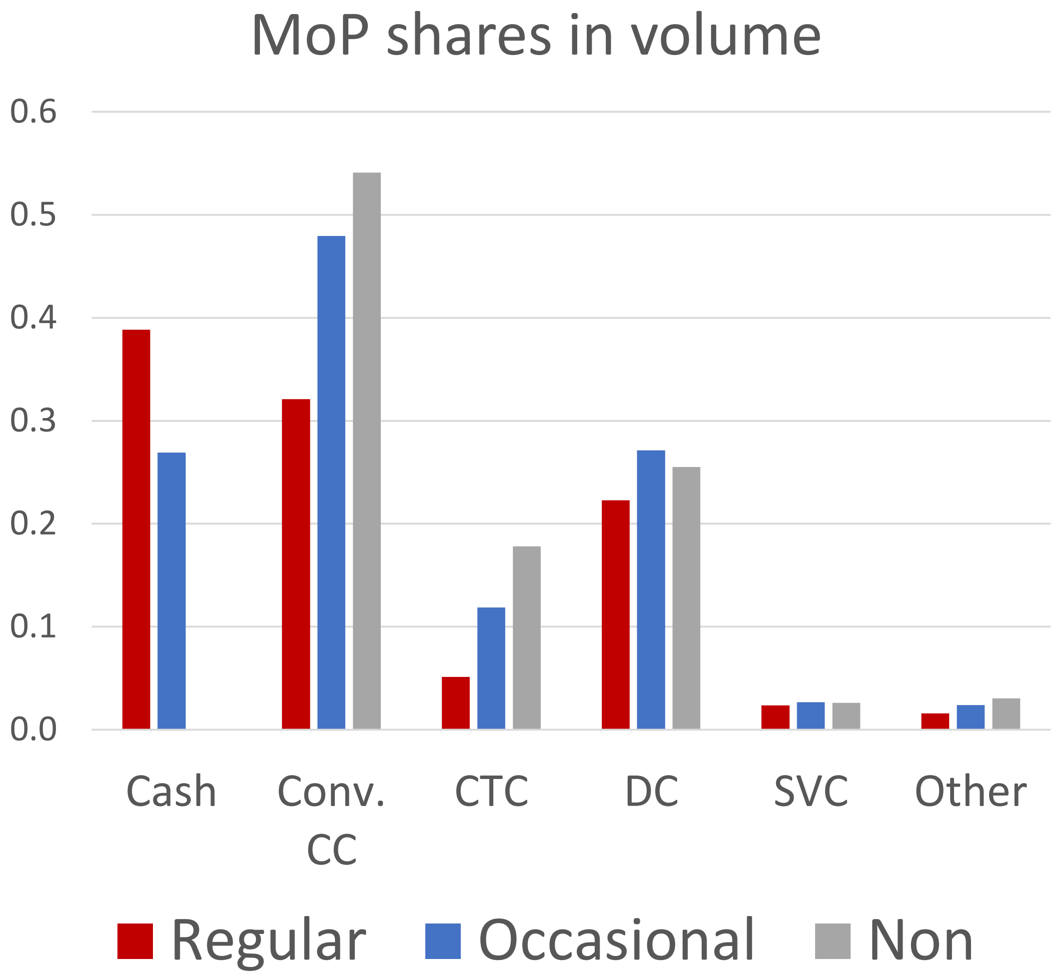


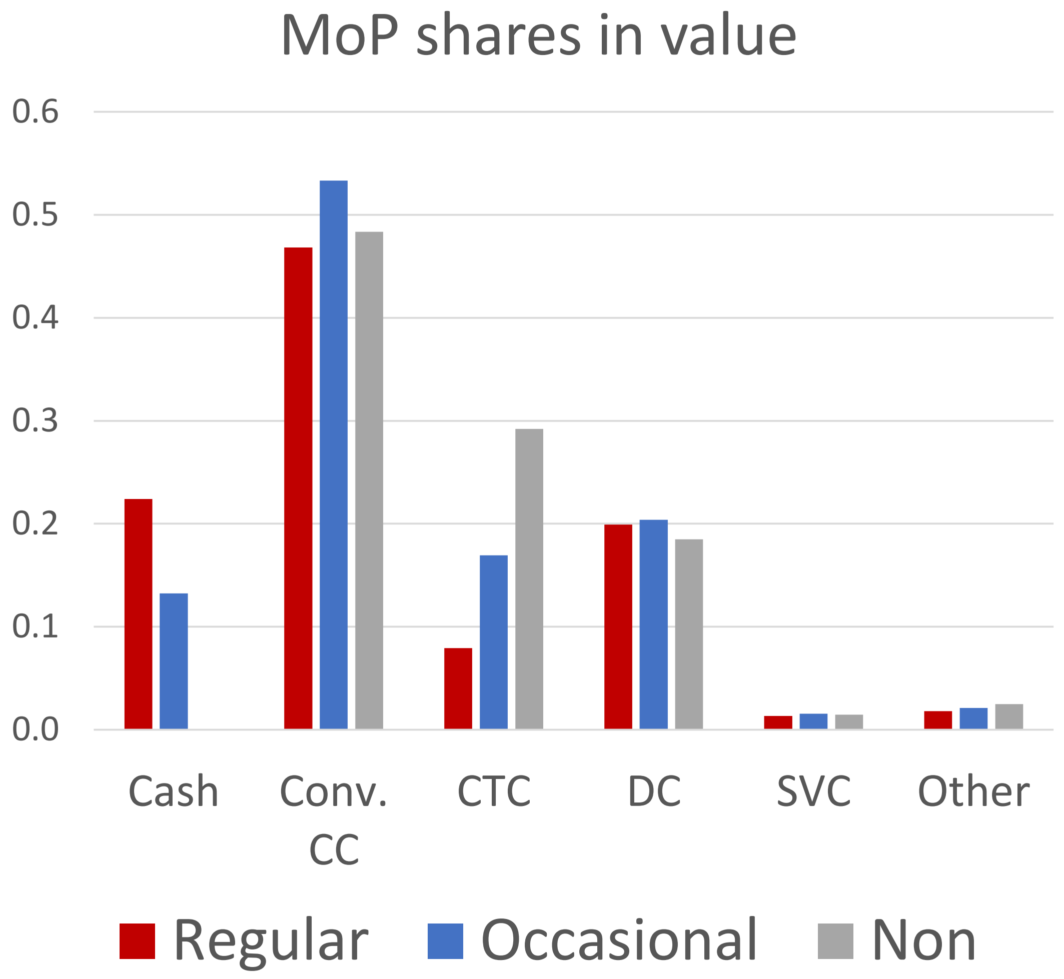


Exploring heterogeneity: finite mixture model

- Transform S_{it}^{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: β negative, small s.e.
  - Class 2: β positive, large s.e.

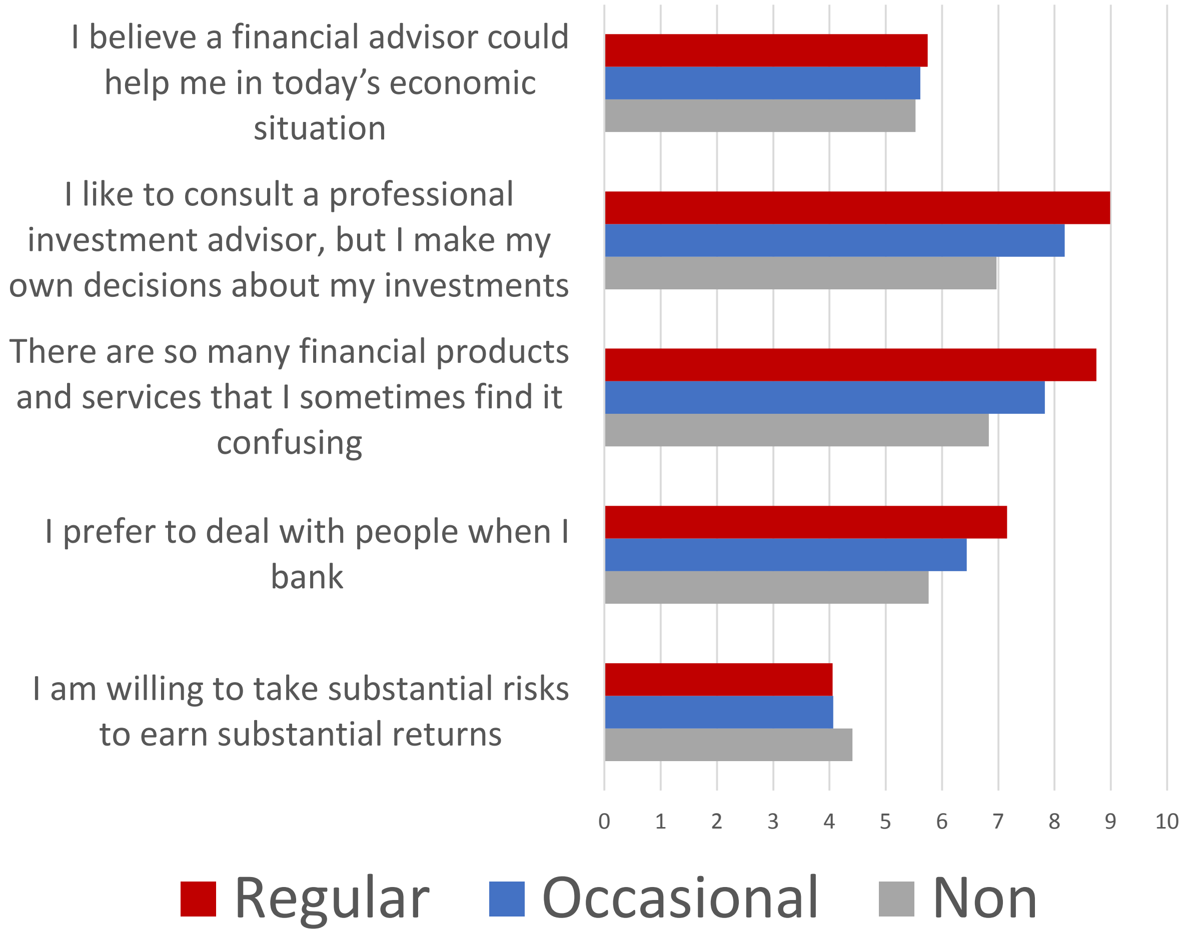
Cash-user types: methods of payments used



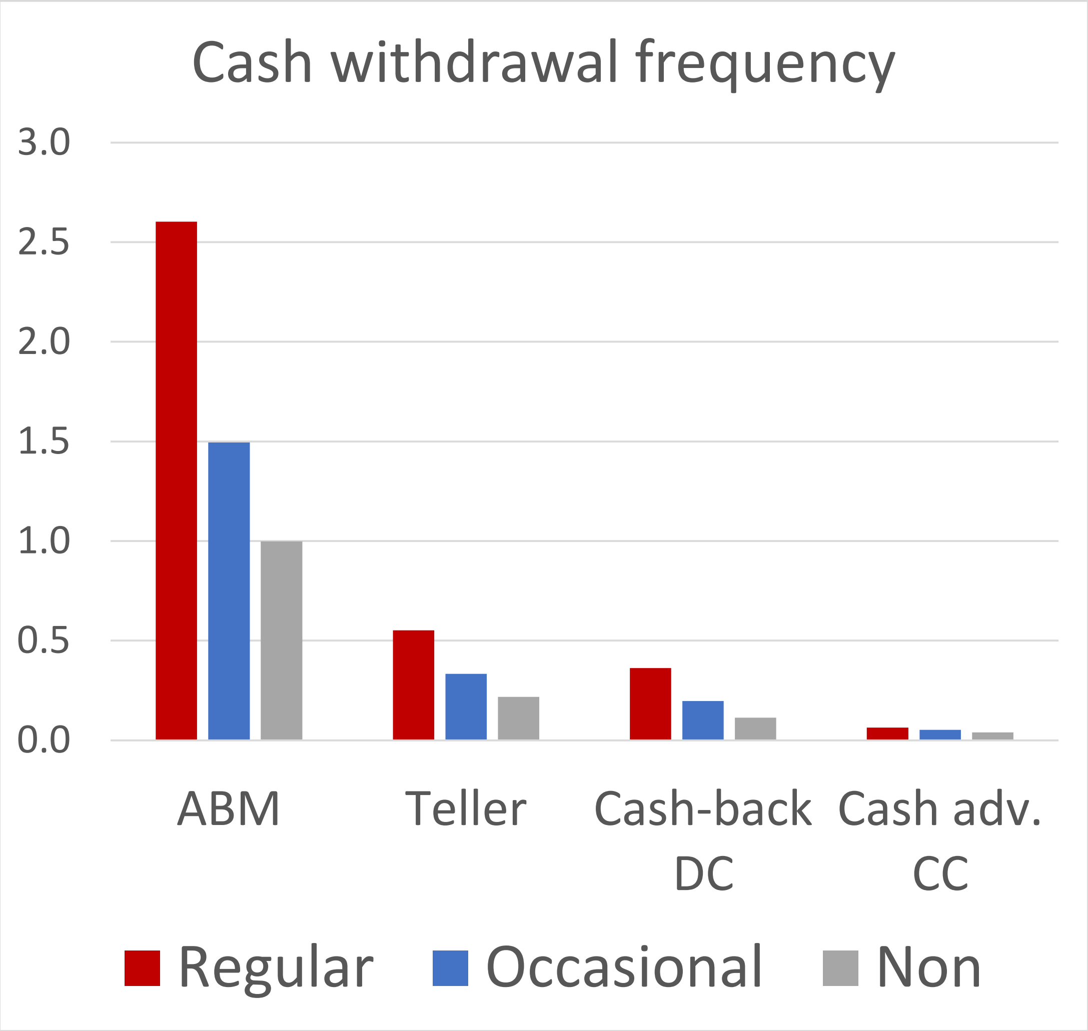


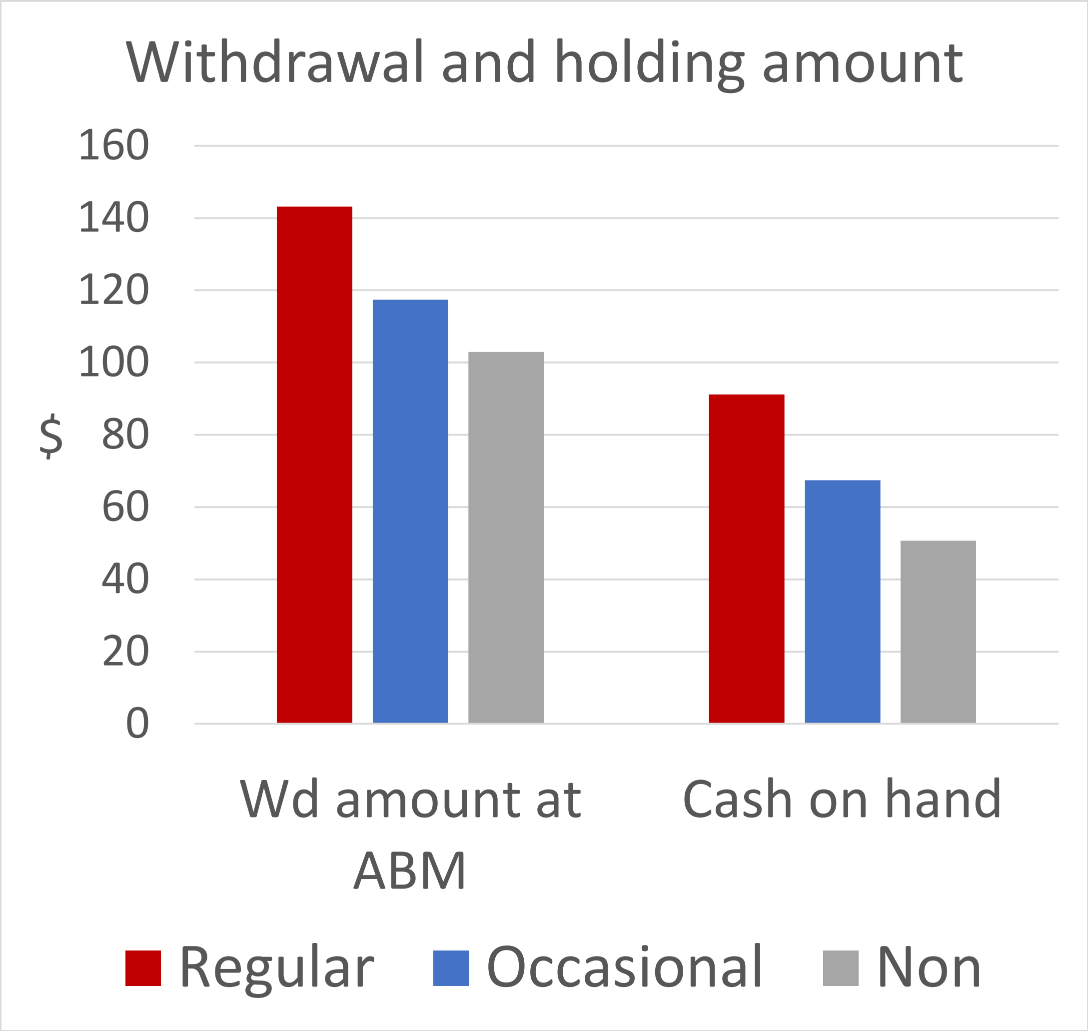
Cash user types: demographics and preferences

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



Cash user types: cash handling





Two-part model in level

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

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

(2a) $\ln S_{it}^{*} = \beta_2 CTC_{it} + X_{it}'\gamma + \varepsilon_{it}$

- 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)

$$\Delta S_{it}^{cash} = d_{i(t-1)} d_{it} \Delta S_{it}^{*} + \left(1 - d_{i(t-1)}\right) d_{it} S_{it}^{*} - d_{i(t-1)} (1 - d_{it})\, S_{i(t-1)}^{*}$$

ΔS_{it}^{*} is observed only if $d_{i(t-1)} d_{it} = 1$

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

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

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

➢ Estimation: Heckman two-step procedure

➢ Problem: control for UH in (2b) only

Two-part model with panel data (1/2)

$$\Delta S_{it}^{cash} = d_{i(t-1)} d_{it} \Delta S_{it}^{*} + \left(1 - d_{i(t-1)}\right) d_{it} S_{it}^{*} - d_{i(t-1)} (1 - d_{it})\, S_{i(t-1)}^{*}$$

ΔS_{it}^{*} is observed only if $d_{i(t-1)} d_{it} = 1$

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

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

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

➢ Estimation: Heckman two-step procedure

➢ Problem: control for UH in (2b) only

- Alternative:

$type_{it} \in \{regular, occasional, non\}$

➢ Estimation: Dubin & McFadden (1984); Bourguignon et al. (2007)

Two-part model with panel data (2/2)

$S_{it}^{cash} = d_{it}S_{it}^{*}$; S_{it}^{*} is observed only if $d_{it} = 1$

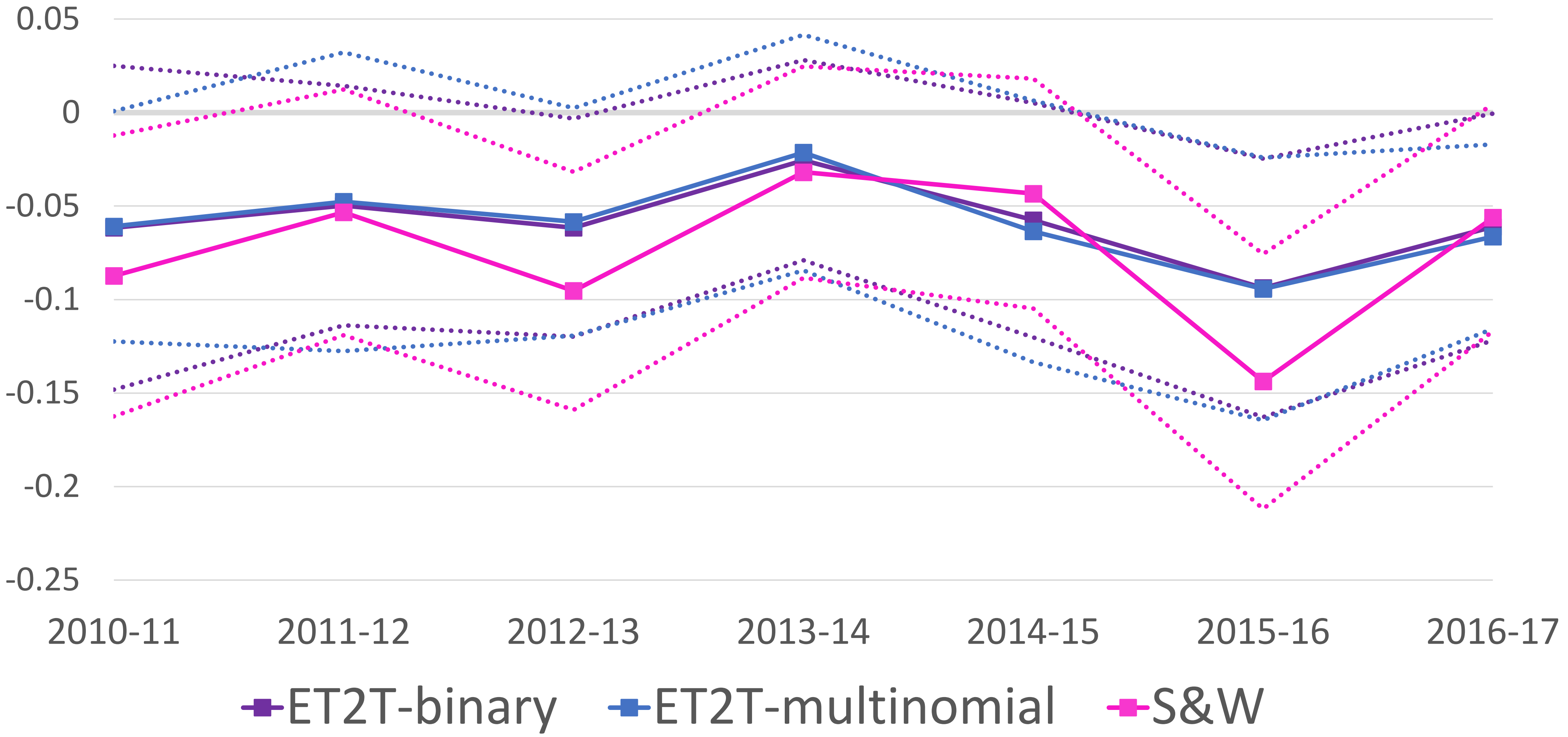
(1c) $d_{it} = 1[\boldsymbol{c_i^1} + \lambda_t^1 + \beta_1 CTC_{it} + X_{it}'\delta_t + Z_{it}'\xi_t + \upsilon_{it} > 0]$

(2c) $S_{it}^{*} = \boldsymbol{c_i^2} + \lambda_t^2 + \beta_2 CTC_{it} + X_{it}'\gamma + \varepsilon_{it}$

- Estimation: Wooldridge (1995), Semykina and Wooldridge (2010); correlated random effect.

- **Control for UH in (1c) and (2c)!**

Two-part model: estimation results for β_2



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.

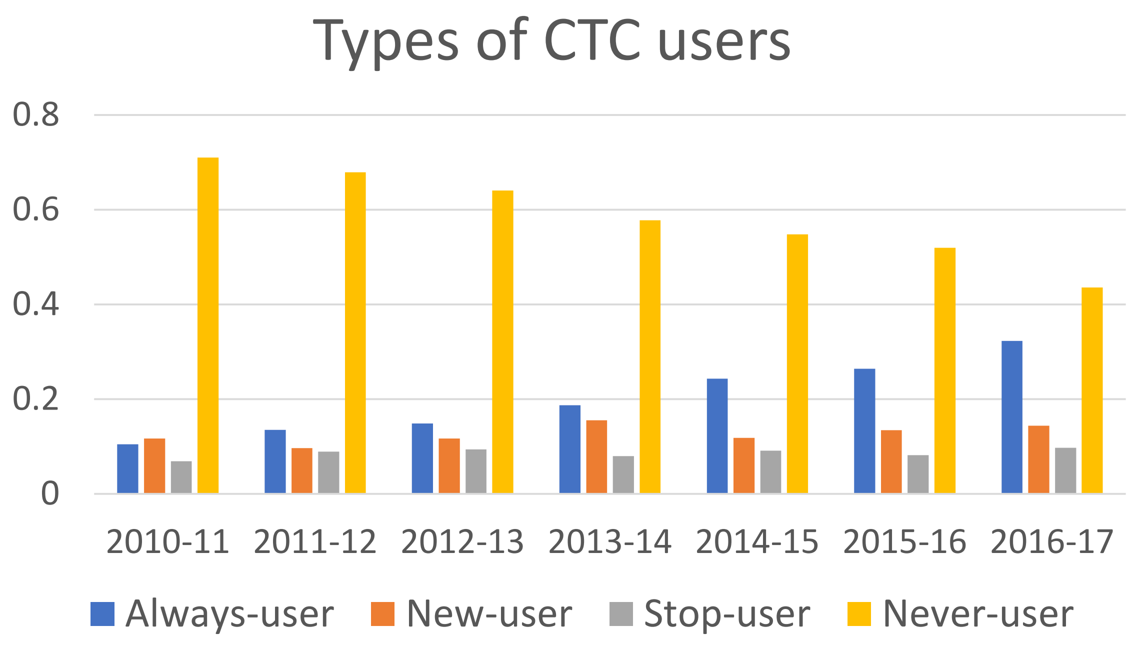
- FD/FE/within estimator uses variation over time only:

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

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



- More flexible specification:

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