Risk-Based Borrowing Limits in Credit Card Markets

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Motivation

1. Longstanding *theoretical* interest in **credit rationing** (Stiglitz & Weiss, 1981)

2. Yet, empirical & policy work focuses on **price discrimination**
   - Concern over the use of (AI-based) “risk”-based pricing
   - EU credit market **regulation** impedes lenders in individualizing **APRs**
     - Lenders must advertise an APR for a card, to be obtained by $> 50\%$ of customers
   - Extends to wider selection markets (e.g. US 2010 Affordable Care Act)

This paper: empirical model of **quantity discrimination** and its role in credit card markets alongside price discrimination

Research Questions & Answers

1. How do UK credit card lenders individualize contract features?
   - Risk-based **credit limits**
   - $\approx$90% of customers obtain exactly the card's advertised APR
2. If lenders faced no regulation or constraints in individualizing interest rates (the US case), what would happen to:
   (a) The terms of credit card contracts?
   - Individualized **interest rates** (to maximize revenues)
   - Individualized **credit limits** (to minimize default costs)

   (b) Lenders' profits and consumers' welfare?
   - **Short run profits** rise by 20–25%
   - **Consumer surplus** falls for those with most inelastic demand (**the riskiest**)

Credit Card Market Study Dataset

- **Main Data**: FCA data on 80% cards active between 2010–2015 Summary Stats

Origination Data (74mn accounts)

Card features (rates, credit limits, ...)
Demographics (income, age, ...)
Application risk score

Jan 2010
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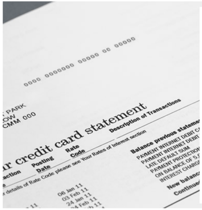
Jan 2015



Statement Data (61 months)

Balance
Interest
Transactions
Default
Costs

- **Additional Sources**: Extra Data
  - Card characteristics panel (advertised APRs)
  - Credit reference agency (matching cards to individuals)
  - Cardholder surveys

Facts About 2010 UK Credit Card Market

1. **Limits often bind**
   - Two years post-origination, approximately 40% have used 90%+ of their limit on at least one occasion
2. Limited rewards, fees, and purchase promo deals
   - EU interchange fee 0.3%, US interchange fee 2%
3. Limited dynamic adjustment of rates and limits Dynamic Adjustment
4. Most lenders offer 3–5 different card products
5. Most individuals have only **one** card Num Cards
6. Lenders construct their own risk scores Credit Scores Regulation

Credit limits are the only margin of adjustment within lender

- For each lender, perform ANOVA to calculate within- & between-card variation in card features (rewards, rates, limits)
- No within-card and minimal between-card variation in rewards, fees, promo deals, or **interest rates**
  - At main lenders, $\approx$90% of customers obtain the advertised APR
- Substantial *within-card* variation in **credit limit** at each lender, credit limits are risk-based, distributions vary across lenders

Plots Calculations CS (2000) CL Distributions Summary)

Demand Model

1. Credit card choice (Mixed logit with heterogeneous elasticities) Utility Choice Survey
   - Individual i chooses the card in choice set maximizing utility
   - Utility depends on rate & card features, *not* individual-specific credit limit
   - Choice set generated from card-level income thresholds
2. Revolving (Tobit with heterogeneous elasticities) Detail
   - Unconstrained revolving depends on rate, card features, income & **unobserved preference for revolving** ε_i^B
3. Default (Probit) Detail
   - Depends on income and **unobserved preference for default** ε_i^D
   - Does not depend on interest rate or credit limit No r No CL

Common risk component ε_i that drives unobservables in revolving (ε_i^B) and default (ε_i^D)

Supply Model

- Each month, lenders first set card-level advertised APRs r_j Rate Choice
- Then, lender sets **limits** $\bar{b}_{ij}$ and **deviation** from advertised rates z_{ij} based on income and predicted risk distribution Screen Techs
- Lender pays cost $C(z_{ij})$ for individualizing, with $C', C'' \geq 0$ and $C(0) = 0$
- For customers choosing j, (denoted $i \in I_j$) lender solves

$$\max_{z_{ij}, \bar{b}_{ij}} \sum_{i \in I_j} \Pi_{ij}(z_{ij}, \bar{b}_{ij}) - C(z_{ij})$$

subject to $z_{ij} \geq 0$ and regulatory constraint $\frac{1}{I_j} \sum_i 1(z_{ij} > 0) < \chi$

FOC: Rate FOC: CL

Main Results

1. Large variation in interest rate elasticities:
   - Lower income individuals have less elastic demand

   Card Elasticity | Revolving Elasticity

2. Intensive margin adverse selection: corr$(\varepsilon_i^B, \varepsilon_i^D) = 0.38$

3. Large variation in screening technologies and costs of individualizing rates

   Fit | 1st and 2nd Step | 3rd Step | Supply Results | Costs of Individualizing

Counterfactual

- In the data, lenders do not individualize interest rates – there are substantial costs of doing so
- In CF, lenders now solve optimization problem with the option to individualize **interest rates** and **credit limits**, subject to no restrictions, costs, or constraints Details
- **Interest rates** and **credit limits** are **individualized**, and short run profits increase by 20–25% Plots
- While interest rates vary by demand elasticity, for fixed elasticity they do not vary by risk score Elasticity Plot

Conclusion

- **Central descriptive fact**: Credit card lenders base *only* credit limits on predictions of default risk
- **Central modeling contribution**: Lenders' credit limit choices and screening technologies
- **Central messages**:
  1. Advertised interest rate requirements create non-trivial costs of individualizing interest rates for lenders Reputational Risk
  2. EU requirements favor inelastic borrowers — "risk"-based pricing arises because of the link between elasticity of demand and default risk
  3. Risk-based credit limits and interest rates are complementary tools

Backup

Literature

- Credit Availability Stiglitz and Weiss (1981); Livshits et al (2016)
- Credit Limits Agarwal, Chomsisengphet, Mahoney, and Stroebel (2017)
  - **Innovation**: estimate economic model of credit limit choices
  - **Contribution**: explain shape & scale of credit limit distributions
- Regulation in Credit Markets Nelson (2022); Cuesta and Sepulveda (2021)
  - **Innovation**: *ex-ante*, not ex-post risk-based pricing
  - **Contribution**: Understand *ex-ante* prices and regulation **in the context of risk-based credit limits**

SW Agarwal Jumps Extended Lit CL Extended Lit Risk Extended Lit Cred Cards Extended Lit Cred Card Biases

Extensions

1. **Extensive margin choice:** *"risk-based pricing enables [us] to offer cards to people who would not be offered them under a system where there was only one rate."*

   Gary Hoffman (Barclaycard CEO), 2003

   - Collect data on full credit profile and individuals without a credit card

2. **Transparency:** when interest rates are individualized, consumers might not be able to search and might not understand prices

   - Run additional counterfactuals changing transparency

Evidence of Asymmetric Information

- Conduct Chiappori & Salanie (2000) asymmetric information test

$$y_{it}^{d*} = x_{it}\beta^d + \epsilon_{it}^d \qquad y_{it}^{b*} = x_{it}\beta^b + \epsilon_{it}^b$$

  for $d =$ **default** (90 days no pay) and $b =$ **full-balance revolving**
- "Pair of probits" approach
- Correlation between ϵ_{it}^d and ϵ_{it}^b estimated at 0.15 (p<0.001), consistent with adverse selection
- **Model implication:** Need to allow for asymmetric information

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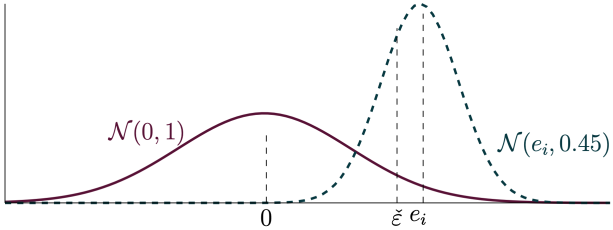
Supply Model: Screening Technology

- Provides **predicted distribution** of each customer's risk draw $\varepsilon_i \sim \mathcal{N}(0,1)$
- For lender ℓ & customer i, generates predicted distribution $\mathcal{N}(\underbrace{e_{i\ell}}_{\text{Signal}}, \underbrace{\sigma_\ell^2}_{\text{Precision}})$

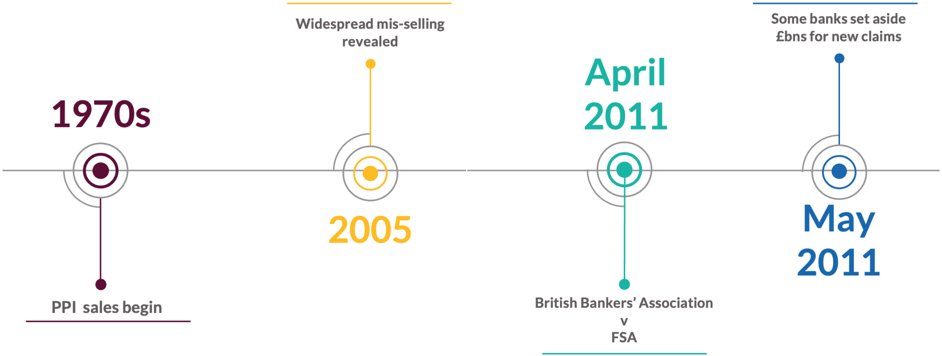


- Finite set of values of $e_{i\ell}$ and # values of $e_{i\ell}$ **differs across lenders** - explains differences in credit limit distributions
- Lender **maximises profit** taking expectation over risk distribution generated by screening technology Back

Demand Parameters

- Estimate subset of demand parameters by **maximizing likelihood** of **observed** choices of credit card, revolving, and default
- Correct for endogeneity of interest rates in demand equations
  - Lenders set higher advertized APRs for cards that are in demand because of attractive unobservables
- Address endogeneity problem using a **cost shock instrument**

Payment Protection Insurance Instrument

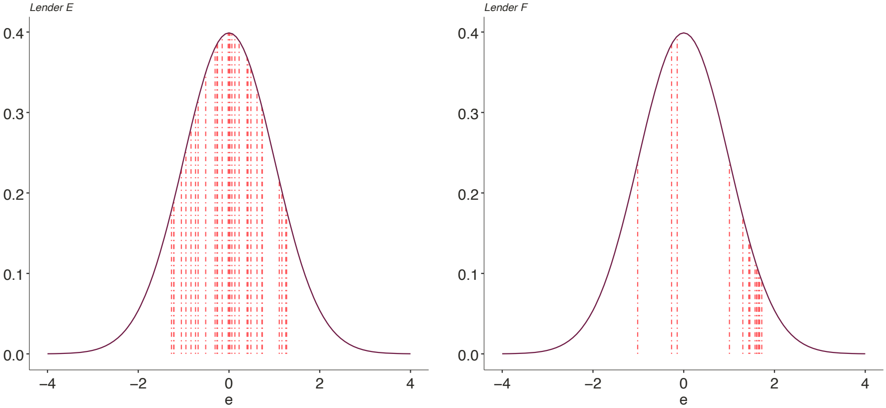


Interact "Post May 2011" with lender-FE to create instrument

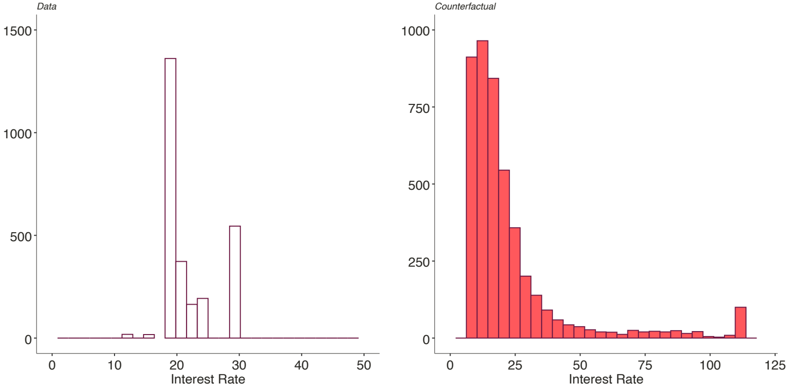
Marginal not Fixed | Validity of IV | Technical Details | BACK

Results: Supply

1. Heterogeneity in **screening technology** precision Back
2. Lenders with **precise technologies** serve ***riskier*** clientele



Interest Rates



Credit Limits Average Changes Back

Backup Data

Summary Stats: Cards at Origination

Variable	Mean	SD	10%	25%	50%	75%	90%
Credit Limit	3390.33	3144.37	300.00	1000.00	2500.00	5000.00	7700.00
Purchase APR	21.52	7.64	15.76	16.90	18.90	23.95	31.11
BT APR	20.24	5.28	15.90	17.50	18.90	20.90	30.33
Purch Promo Length	3.57	4.71	0.00	0.00	3.00	6.00	13.00
BT Promo Length	9.21	8.71	0.00	0.00	9.00	15.00	21.00
Balance Transfer	0.28	0.45					
Get Ad APR	0.83	0.37					

Back

Summary Stats: Card Characteristics

Variable	Mean	SD	10%	25%	50%	75%	90%
Annual fee	10.34	37.37	0.00	0.00	0.00	0.00	24.00
Min income	6463.20	8356.91	0.00	2.08	4000.00	7500.00	20000.00
Min CL	463.09	516.11	100.00	200.00	450.00	500.00	1000.00
Max CL	19881.44	30651.74	1000.00	3000.00	15000.00	20000.00	30000.00
Interest free	31.29	12.92	20.00	25.00	25.00	46.00	50.00
Superprime	0.02	0.15					
Prime	0.51	0.50					
Subprime	0.21	0.40					
All	0.26	0.44					

Back

Summary Stats: Card Rewards

Variable	Mean	SD
Affinity	0.25	0.43
Credit repair	0.21	0.41
Cashback	0.09	0.29
Purch protection	0.25	0.44
Contactless	0.48	0.50
Purchase rewards	0.34	0.47
Airmiles	0.07	0.26
Insurance	0.14	0.35
Priority	0.12	0.32

Back

Summary Stats: Demographics

Variable	Mean	SD	10%	25%	50%	75%	90%
Age	42.88	14.83	25.00	31.00	41.00	53.00	64.00
Net Monthly Income	2099.26	5185.72	630.00	1058.56	1604.14	2335.00	3393.00
Existing Customer	0.40	0.49					
Female	0.52	0.50					
Homeowner	0.57	0.50					
Direct Debit	0.18	0.38					
Employed	0.76	0.43					
Branch	0.32	0.46					
Online	0.53	0.50					
Post	0.12	0.32					
Telephone	0.04	0.20					

Back

Summary Stats: Statement

Variable	Mean	SD	10%	25%	50%	75%	90%
Credit Limit	4213.90	3459.56	500.00	1600.00	3500.00	5900.00	9000.00
Purchase APR (%)	16.46	8.10	0.00	15.70	17.50	18.94	29.90
Purchase Balance	611.67	1255.25	0.00	0.00	75.95	660.18	1820.31
Value Transactions	311.19	802.62	0.00	0.00	0.00	259.85	880.38
Repayment	224.69	637.35	0.00	0.00	30.02	150.00	569.40
Total Interest	8.23	20.52	0.00	0.00	0.00	6.01	26.58
Purchase Interest	6.39	17.60	0.00	0.00	0.00	3.30	20.51
# Transactions	5.13	10.15	0.00	0.00	1.00	5.00	16.00
Up-To-Date	0.94	0.23					
1 Month Overdue	0.02	0.14					
Charged Off	0.02	0.15					

Additional Data

- **Card Characteristics (61 months)**
  - **Rewards** (cashback, airmiles)
  - **Income threhsolds**
  - **Advertised APR**

- **Credit Reference Agency:** match cards to individuals

- **CCMS Survey:** Preferences

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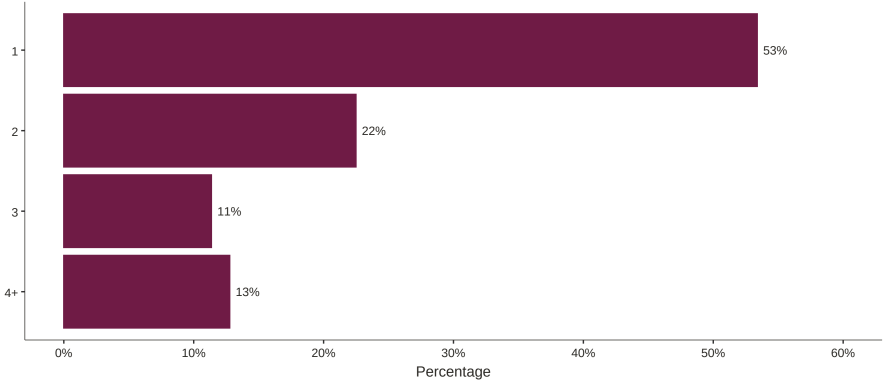
Most Individuals Have One Card

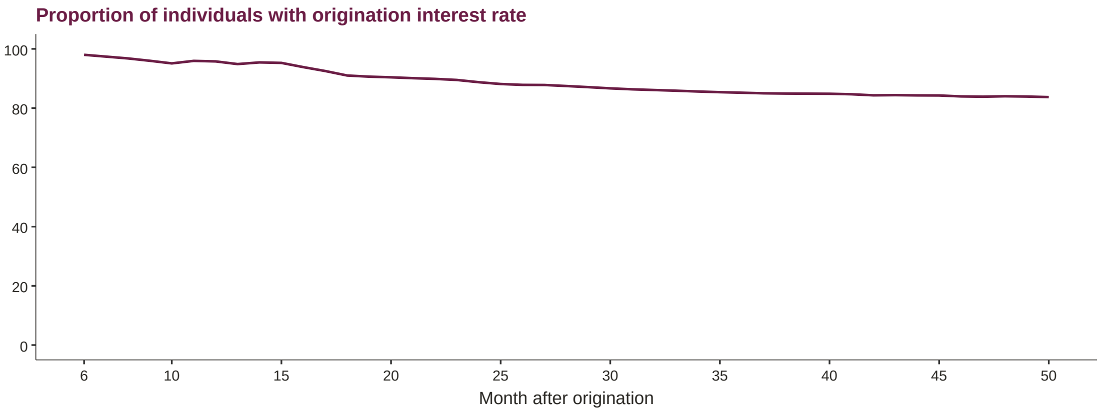
UK distribution of cards held



Source: CCMS account origination data
Conditional on holding a card
Numbers are averages over months

Back

Limited Repricing in UK Credit Card Market



Source: CCMS account origination data
Not monotone decreasing because of account closings and truncation

Back

Relevant US and UK Credit Card Regulation

1. All promotional materials and T&Cs must feature an **advertised APR**

2. At least 51% of customers each month must receive the APR advertised (or lower)

   - Prior to February 2011, threshold was 66%
   - February 2011: harmonised with EU regulation, moved to 51%
   - April 2022: Post-brexit, calls to return to 66%

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Backup Descriptive

Descriptive Plots Contents

1. C of. V and within variation in rates and credit limits Plot
2. % customers obtaining ad APR Plot
3. % customers obtaining ad APR (card level) Plot
4. Differences in credit scores Plot
5. Empirical CDFs – all lenders Plot
6. Risk-based credit limits at two lenders Plot
7. Proportion of transactors by lenders Plot

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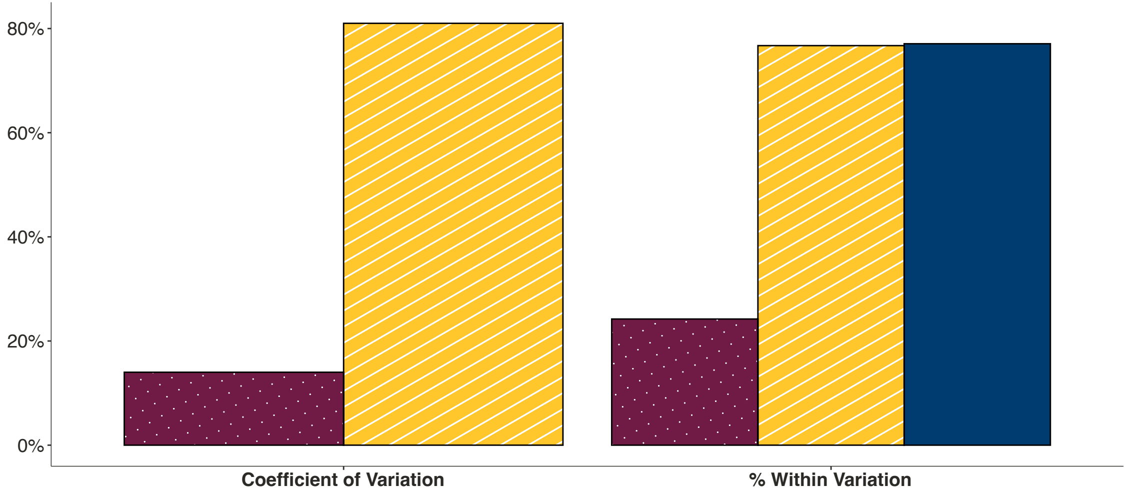
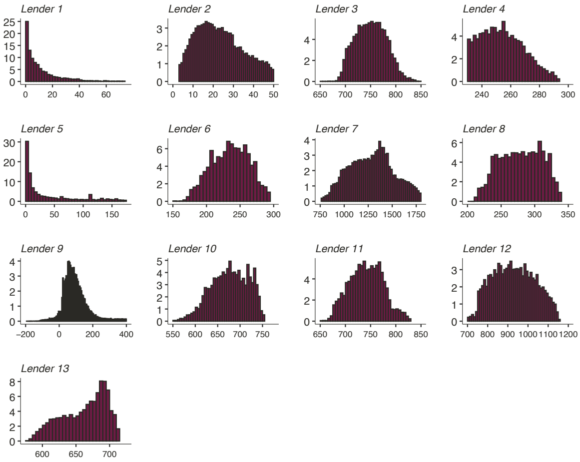
Variation in Interest Rate and Credit Limit



Histogram of Lender-Specific Credit Scores



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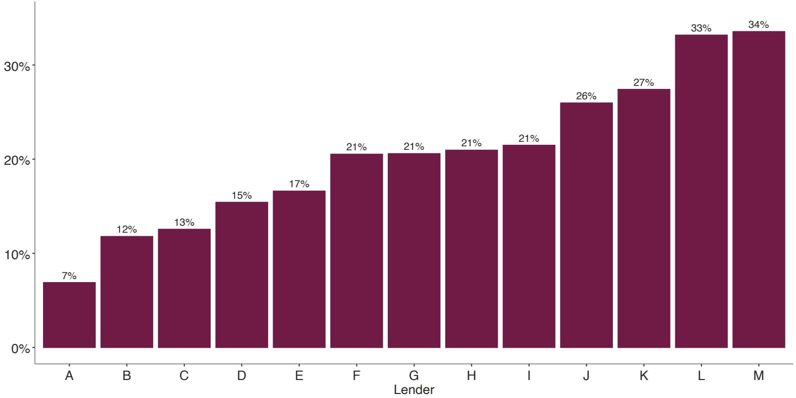
Credit Score and Observable Demographics

$$\text{Private Credit score}_{i\ell} = \alpha'\text{Income}_i + \beta'\text{Employment}_i + \gamma'\text{Month}_i + u_{i\ell}$$



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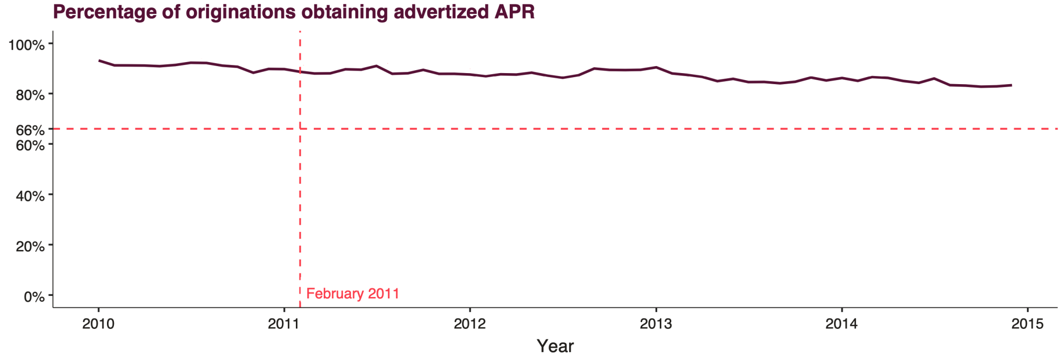
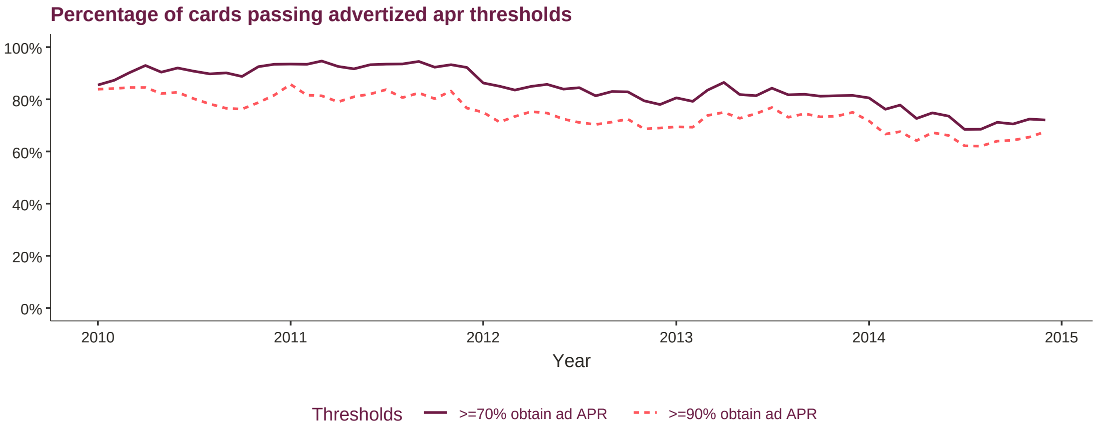
80–90% of Customers Obtain Advertized APR



Source: CCMS account origination data

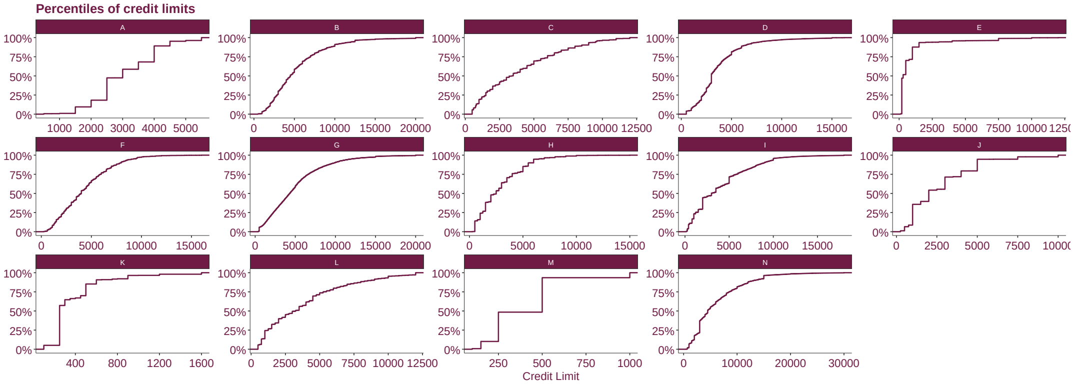
Back



Source: CCMS account origination data

Back

All Lenders' Empirical CDFs



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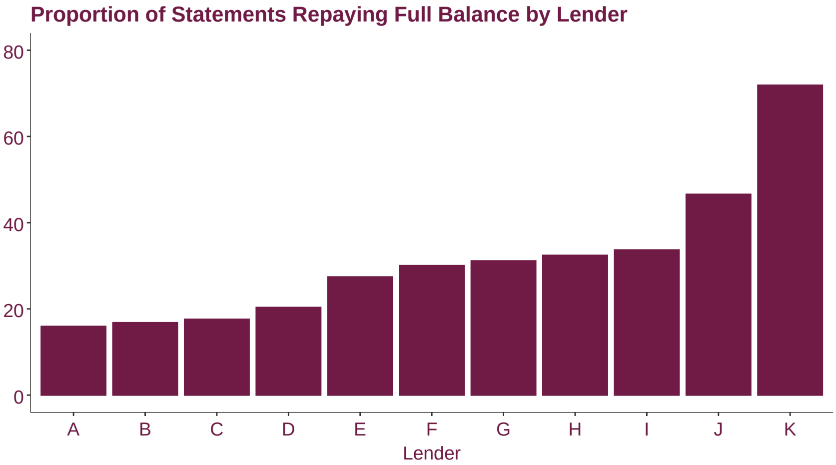
Variation in Proportion of Transactors



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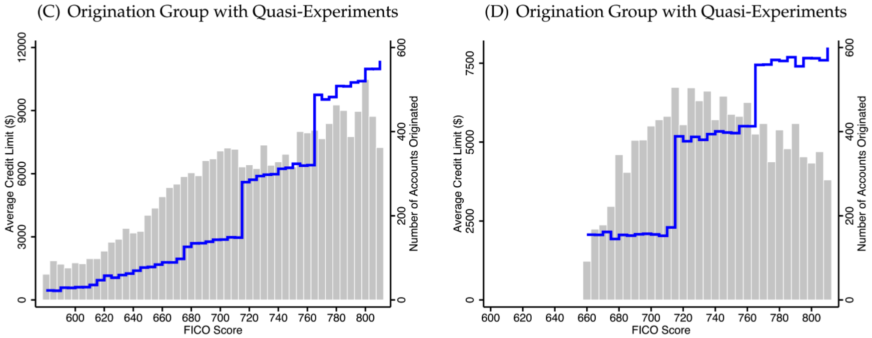
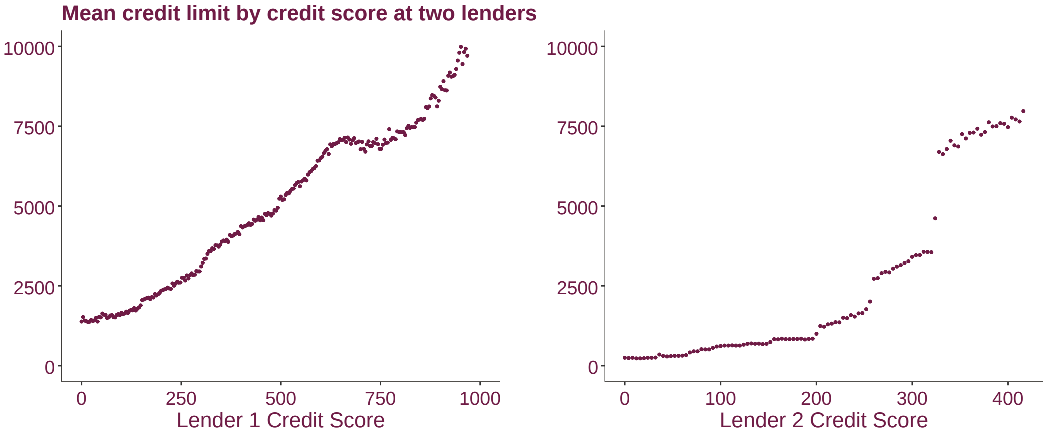
Agarwal et al (2017) Discontinuities



Source: Agarwal, Chomsisengphet, Mahoney, and Stroebel (2017)

Back Lit Back Empirics

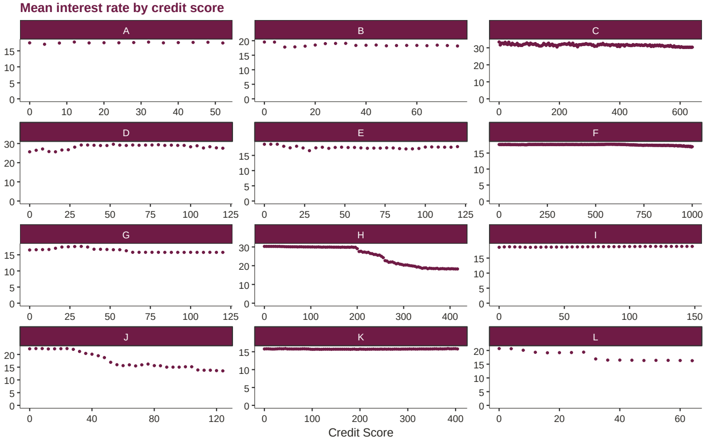
Risk-Based Credit Limits



(Similar within card)

Prices Other Lenders Agarwal Jumps Back

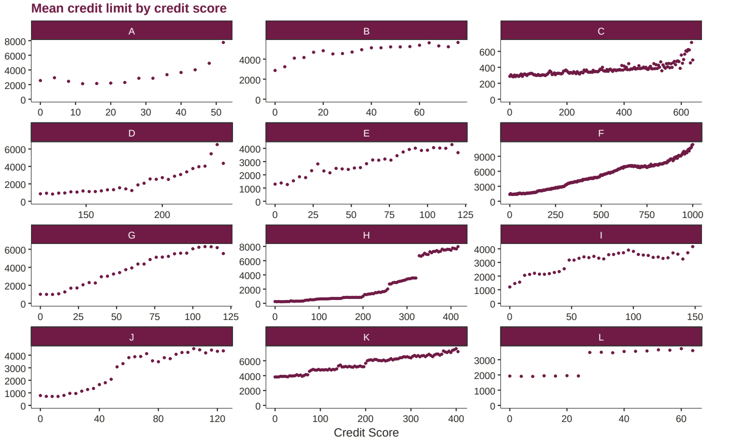
All Lenders' Pricing Schedules



Source: CCMS account origination data
For year 2012

Back

All Lenders’ Risk-Based CL



Source: CCMS account origination data
For year 2012

Back

IO of Credit Card Markets: Hot Potato

- No competition in fees, rewards, limits, purchase promos, rates
- Competition comes through balance transfer promotional deals
- Why do lenders focus on poaching existing customers relative to signing up new customers?
  1. Credit history free-riding
  2. Business stealing
  3. Avoiding negative externalities
  4. “Exploiting” behavioural biases

Sticky Back

Why are Interest Rates Sticky (and high)?

- Limited interest rate sensitivity (Stavins, 1996)
- Biases (Ausubel, 1991)
- Collusion
- Default externalities across lenders (Parlour & Rajan, 2001)
- Adverse selection (Ausubel, 1991)
- Lack of consumer search (Galenianos & Gavazza, 2022)

Back

Backup Model

Card Utility

- Utility for revolver i from card j

$$V_{ij}^E = \alpha_i^E r_j + \beta^{E\prime} X_j^E + \xi_j^E + \nu_{ij}$$

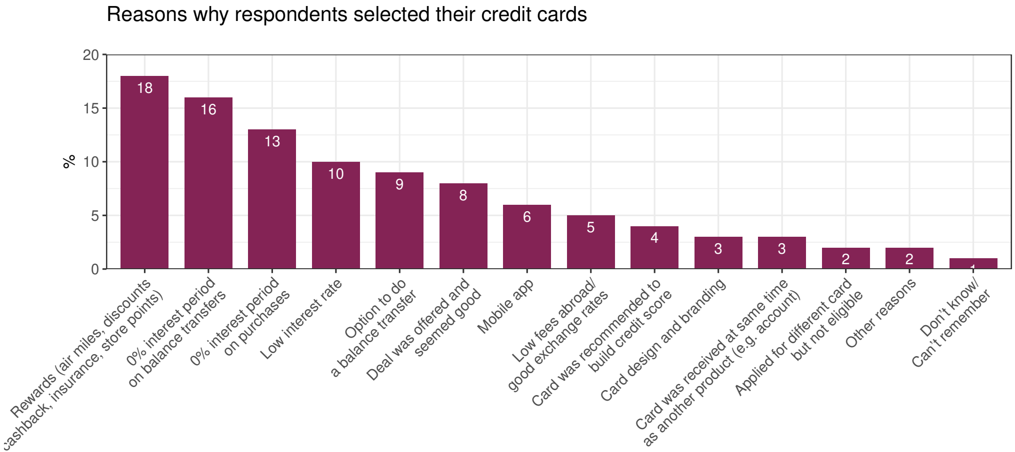
where:

  - r_j interest rate
  - X_j^E observed characteristics
  - ξ_j^E unobserved characteristics
  - ν_{ij} taste shock iid across individuals

- No individual-specific credit limits: survey evidence

Back ε^E

Why did you select this particular card?



Back

Card Choice

- Choice set: cards for which income exceeds *income threshold*
- Choose card j if
$$V_{ij}^{E} > V_{ik}^{E}$$
for all k in choice set

Back

Revolving Level

- Desired revolving balance b^*_{ij} satisfies

$$\log(b^*_{ij}) = \alpha_i^B r_j + \beta^{B'} X_j^B + \xi_j^B + \boldsymbol{\Omega^{B,cons}} \tilde{\boldsymbol{y}}_{\boldsymbol{i}} + \boldsymbol{\varepsilon_i^B}$$

  where:

  - r_j interest rate
  - X_j^B observed characteristics
  - ξ_j^B unobserved characteristics
  - $\tilde{\boldsymbol{y}}_{\boldsymbol{i}}$ Demeaned log of income
  - $\boldsymbol{\varepsilon_i^B}$ individual unobserved preference for borrowing

- Observe $b_{ij} = \min\{b^*_{ij}, \bar{b}_{ij}\}$, $\bar{b}_{ij}$ credit limit

Back

Default

- Net utility from defaulting:

$$V_i^D = \Omega^D \tilde{y}_i + \varepsilon_i^D$$

  where:

  - $\tilde{y}_i$ demeaned log income
  - ε_i^D individual unobserved preference for default

- No interest rate (Nelson, 2020; Castellanos et al 2018)

- Borrowers default if $V_i^D > 0$

Private Information Structure

- **Common component** in unobservables for borrowing & default:

$$\begin{aligned} \varepsilon_i^B &= \sigma^B \varepsilon_i \\ \varepsilon_i^D &= \sigma^D \varepsilon_i + \tilde{\varepsilon}_i^D \end{aligned}$$

- $\varepsilon_i, \tilde{\varepsilon}_i^D \sim \mathcal{N}(0,1)$

Back

Heterogeneity in Elasticities

- In the borrowing case:

$$\log(b^*_{ij}) = \alpha_i^B r_j + \beta^{B'} X_j^B + \xi_j^B + \Omega^{B,cons} \tilde{y}_i + \varepsilon_i^B$$

where

$$\alpha_i^B = \alpha^B + \Omega^{B,r} \tilde{y}_i$$

where:

  - r_j interest rate
  - X_j^B observed characteristics
  - ξ_j^B unobserved characteristics
  - $\tilde{\boldsymbol{y}}_{\boldsymbol{i}}$ Demeaned log of income
  - $\boldsymbol{\varepsilon}_{\boldsymbol{i}}^{\boldsymbol{B}}$ individual unobserved preference for borrowing

Back

Card Choice For Borrowers

- Utility for borrower i from card j

$$V_{ij}^{E} = \alpha_i^{E} r_j + \beta^{E\prime} X_j^{E} + \xi_j^{E} + \nu_{ij} + \boldsymbol{\varepsilon_i^{E}}$$

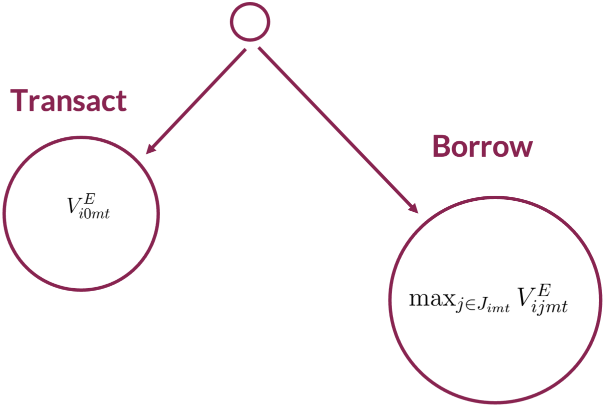
where

  - r_j interest rate
  - X_j^E observed characteristics
  - ξ_j^E unobserved characteristics
  - ν_{ij} taste shock iid across individuals
  - ε_i^E individual preference for revolving

Back

Borrowing vs Transacting

- **Transacting**: paying off your balance in full every month



Direct Debit

- 34% of customers sign up to a direct debit within 6 months of origination
- Of those signing up at origination:
  - 40% sign up to pay the full balance
  - 46% sign up to pay the minimum repayment
- Consistent with some individuals knowing whether they will transact or revolve prior to originating

Back

Outside Option: Borrowing vs Transacting

- Utility for individual i from transacting

$$V_{i0}^{E} = \delta_0 + \nu_{i0} + \Omega^{E,cons} y_i$$

  where

  - δ_0 market fixed effect
  - ν_{i0} taste shock for transacting
  - y_i log income

- Transact if $V_{i0}^{E} > \max_{j \in J_i} V_{ij}^{E}$

Back

Interpretation of Borrowing

- b^*_{ij} is average revolved balance over 18 months
- Alternative: revolved balance at 18 months

Back

No Interest Rate in Default

- Follows Cohen and Einav (2007) and Einav, Finkelstein, and Schrimpf (2010)
- **Causal Evidence:** Nelson (2022) and Castellanos, Jimenez Hernandez, Mahajan, and Seira (2018):
- **Short-run liquidity drives default, not long-run value of loan contract:** Bhutta, Dokko, and Shan (2017); Guiso, Sapienza, and Zingales (2013); Ganong and Noel (2020); Indarte (2021)

Back

No Credit Limit in Default

- Follows existing literature, e.g. Nelson (2022)
- RDD Evidence: Gibbons, Matcham, and Shaw (2022)
- Default occurs from shock to short-run liquidity, not value of loan
- OVB formula implies that estimates are lower bounds – captured by income and risk

Back

Interest Rate Model

Lender ℓ sets interest rates in Bertrand-Nash Equilibrium:

$$\max_{\boldsymbol{r}_\ell} \sum_{i \in I_{mt}} \sum_{j \in J_{i\ell}} s_{ij}^E(\boldsymbol{r}_\ell, \boldsymbol{r}_{-\ell}^*)\Pi_{ij}$$

where

- $J_{i\ell}$ set of cards i qualifies for at lender ℓ
- $\boldsymbol{r}_{-\ell}^*$ interest rates at other lenders
- s_{ij}^E probability that i chooses card j
- Π_{ij} expected profit from optimal credit limit choice

Back

Lender Problem

- Individual profit per unit credit

$$\pi_{ij} = -c_j + \left[1 - \mathbb{P}(\text{Default}_i)\right] r_j + \mathbb{P}(\text{Default}_i)(-1)$$

- Given signal $e_{i\ell}$, choose CL to maximize

$$\mathbb{E}\left[\pi_{ij} \min\{b^*_{ij}, \bar{b}_{ij}\}\right] = \int_{-\infty}^{\infty} \min\{b^*_{ij}(w_{i\ell}), \bar{b}_{ij}\} \pi_{ij} \phi_{i\ell} d w_{i\ell}$$

because $\hat{\varepsilon}_i = e_{i\ell} + w_{i\ell}$, $w_{i\ell} \sim \mathcal{N}(0, \sigma^2_\ell)$

Back

Bisecting the Expectation

- $\boldsymbol{\omega(\bar{b}_{ij})}$: value of $w_{i\ell}$ such that $\boldsymbol{\bar{b}_{ij} = b^*_{ij}(\omega)}$

- Objective becomes

$$\int_{-\infty}^{\boldsymbol{\omega}} b^*_{ij}(w_{i\ell})\pi_{ij}\phi_{i\ell}dw_{i\ell} + \boldsymbol{\bar{b}_{ij}} \int_{\boldsymbol{\omega}}^{\infty} \pi_{ij}\phi_{i\ell}dw_{i\ell}$$

- FOC

$$\int_{\boldsymbol{\omega}}^{\infty} \pi_{ij}\phi_{i\ell}dw_{i\ell} = 0$$

Back

Backup Estimation

1st Step: Conditional Simulated MLE

- Contribution to log-likelihood: $\mathcal{L}_i^E + \mathcal{L}_i^{BD}$
- Contribution by borrowing & default $\mathcal{L}_i^{BD}$ has four terms:

$$\text{Interior/Corner revolving} \times \text{Default/No default}$$

- Simulated MLE, because of:
  1. Correlation between unobservables
  2. Truncation in borrowing
- Estimate separately market-by-market: 84 sets of estimates

Back

1st Step: Conditional Simulated MLE

- Mixed logit for card choice with GEV taste shocks
- $\mathcal{L}_i^E = \sum_j 1(\text{i chooses j}) \log(s_{ij}^E)$

$$s_{ij}^E = \frac{\exp(\bar{V}_{ij}^E)}{\sum\limits_{k \in J_i} \exp(\bar{V}_{ik}^E)}$$

- $\bar{V}_{ij}^E$ is the utility of card j for individual i (net of taste shock)
- Total log-likelihood is sum of contributions $\sum_i \mathcal{L}_i^E + \mathcal{L}_i^{BD}$

Demand Estimation: MLE

- **Main challenge**: correlated interest rates r_j and unobserved card features ξ_j
- **Intermediate step**: estimate fixed effects (card-market averages)

$$\underbrace{V_{ij}^E}_{\text{Card Utility}} = \underbrace{\delta_j}_{\text{Fixed Effect}} + u_{ij}$$

- 1st step estimates fixed effects and correlation between unobservables
- Fixed effect subsumes rate and unobserved card features

Back

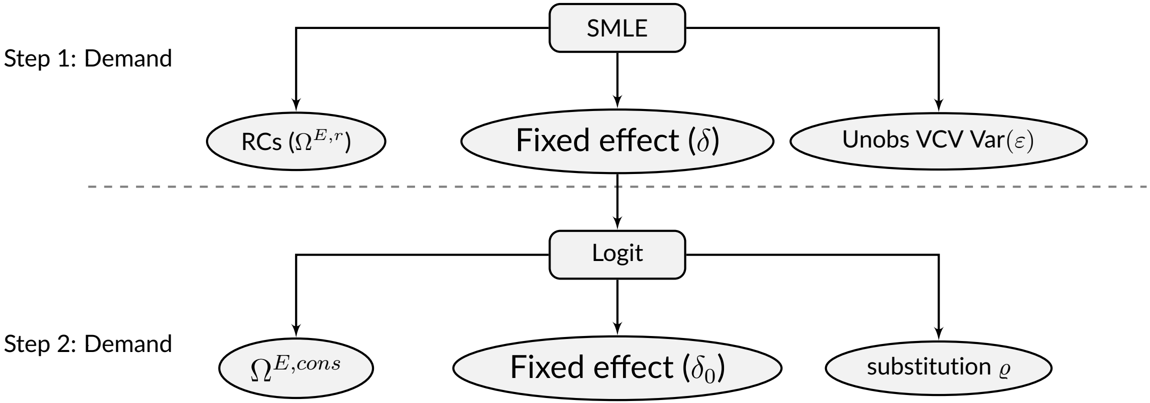
Demand Estimation

$$\delta_j = \eta + \alpha \boldsymbol{r_j} + \beta' X_j + \boldsymbol{\xi_j}$$

- Interest rate r_j potentially correlated with unobservables ξ_j
- Replace fixed effects δ_j with first step estimates
- Deal with endogeneity using instruments

Back

Estimation Steps 1 and 2: Demand



2nd Step: Borrowing vs Transacting

- Utility for individual i from transacting in channel m and month t

$$V_{i0}^{E} = \delta_0 + \nu_{i0} + \Omega^{E,cons} y_i$$

- Binary choice log likelihood for transacting vs borrowing

$$\mathcal{L}^{tr} = \sum_i \textbf{tr}_i \log(s_{i0}^{E}) + (1 - \textbf{tr}_i) \log(1 - s_{i0}^{E})$$

  where

  - tr a dummy for transacting
  - s_{i0}^{E} probability that i transacts

- Higher-income individuals less likely to transact Back

2nd Step: Borrowing vs Transacting

- Probability that i transacts

$$s_{i0}^{E} = \frac{\exp\left(\bar{V}_{i0}\right)}{\exp\left(\bar{V}_{i0}\right) + \exp\left(\varrho F_i\right)}$$

- Inclusive value

$$F_i = \log \sum_{k \in J_i} \exp\left(\bar{U}_{ik}^{E}\right)$$

- Scaled indirect utility

$$\bar{U} = \frac{\bar{V}_{ij}^{E}}{\varrho}$$

Back

PPI Affects Funding Cost

- Big repayment implies less cash/assets/resources:
  - Worse financial position
  - More susceptible to financial difficulties
  - Increased probability not able to repay debts
  - Hence higher rate on any money they borrow to fund credit card loans
- Breaking PPI rules is a signal of bad business practice & poor governance
  - Bank not being run well
  - Potential red flag to lend to
- Potential downgrade in credit rating, too Back

Payment Protection Insurance Instrument

- Validity assumption: the only way that court case loss affects individuals' borrowing is through impact on rates

- Other factors:
  - No other events around May 2011 that would affect unobservables driving borrowing and card choice
  - No changes to other variables: credit limits, rewards etc.
  - No obvious heterogeneous damages to lenders' reputation

Back

Backup Estimates

Demand Estimates 1/2

Variable	Interpretation	Parameter	SE
η^D	Default Constant	-1.90	0.02
Ω^D	Default-Income Gradient	-0.15	0.02
σ^D	S.D. in Default Unobservables	0.48	0.02
$\Omega^{B,\text{cons}}$	Revolving-Income Gradient	0.24	0.02
$\Omega^{B,r}$	Income Gradient for Revolving Elasticity	-1.16	0.02
σ^B	S.D. in Revolving Unobservable	3.70	0.06
Corr$(\varepsilon^B, \varepsilon^D)$	Correlation in Unobservables	0.38	0.02
$\Omega^{E,r}$	Income Gradient for Card-Choice Elasticity	-0.22	0.00
$\Omega^{E,\text{cons}}$	Transacting-Income Gradient	-0.11	0.01
ϱ	Transact/Revolve Substitution Parameter	0.29	0.00

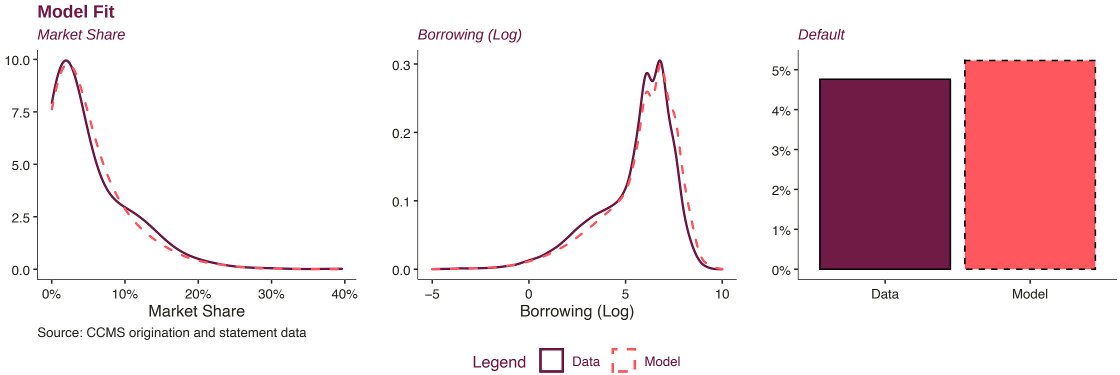
Back

Demand Estimates: 2/2

	(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent Variable	δ^B	δ^B		δ^E	δ^E	δ^E	δ^E	δ^E	δ^E	δ^E
Price Sensitivity (α)	2.626	-1.489		1.083	-1.277	-0.934	-1.238	-3.264	-0.901	-2.825
	(0.369)	(1.71)	(0.269)	(0.804)	(0.831)	(0.793)	(0.904)	(0.815)	(0.834)	
Airmiles (β_{airmiles})						0.121			0.124	0.266
						(0.048)			(0.049)	(0.042)
Cashback (β_{cashback})							0.059		0.072	-0.026
							(0.069)		(0.070)	(0.056)
Contactless ($\beta_{\text{contactless}}$)								0.178		0.270
								(0.035)		(0.075)
Estimation	OLS	IV		OLS	IV	IV	IV	IV	IV	IV
First-stage F	-	22.870		-	21.912	20.562	22.416	19.540	21.508	20.007
Wu-Hausman	-	30.120		-	13.410	4.653	9.196	32.177	4.699	22.316

Back

Fit

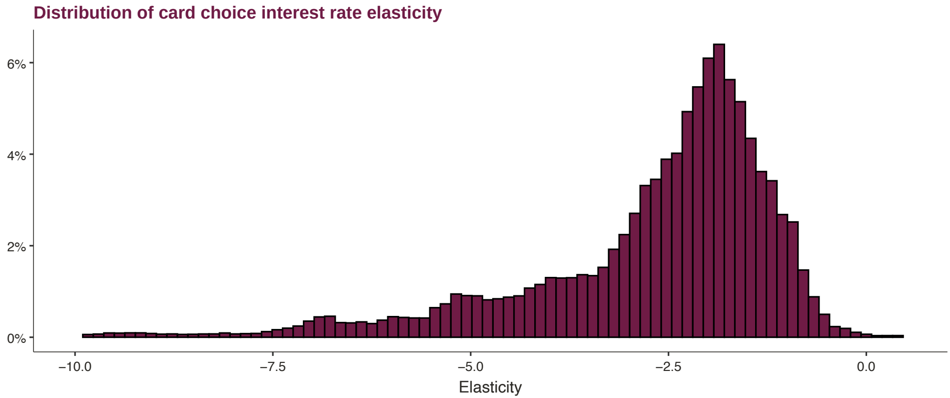


Source: CCMS origination and statement data

Source: CCMS origination and statement data

Back

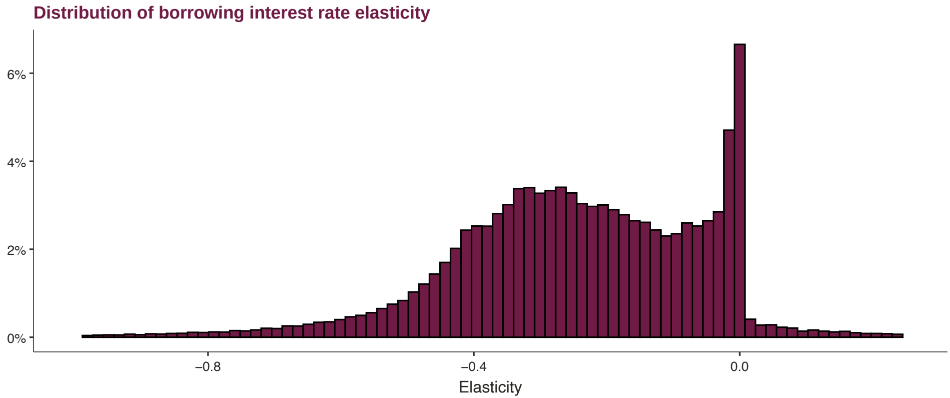
Card Choice Elasticities



Source: CCMS origination and statement data

Back

Borrowing Elasticities



Source: CCMS origination and statement data

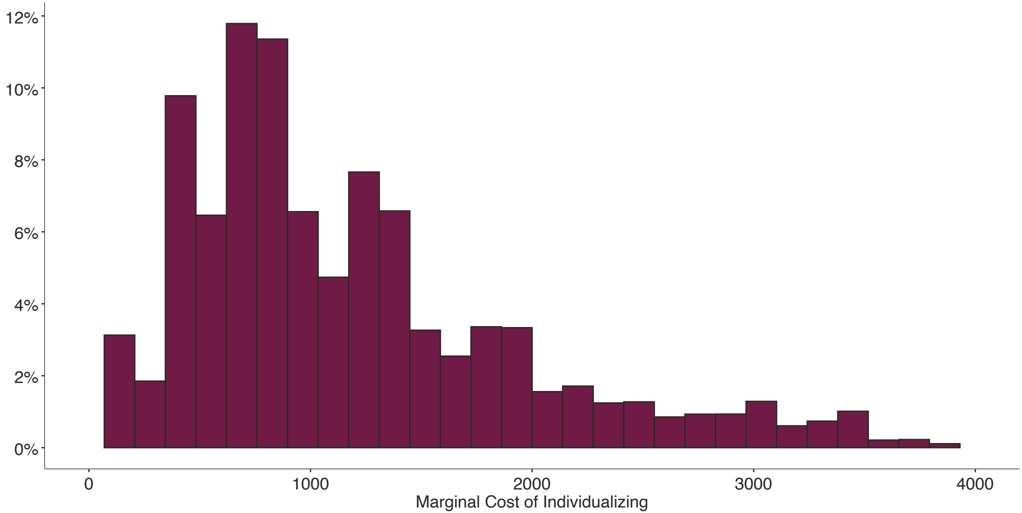
Back

Heterogeneity in Precision

Variable	Mean	SD	10%	25%	50%	75%	90%
σ_ℓ	0.196	0.333	0.002	0.004	0.004	0.198	0.704

Back

Results: Costs of Individualizing



Back

Backup Counterfactuals

Unconstrained Interest Rates

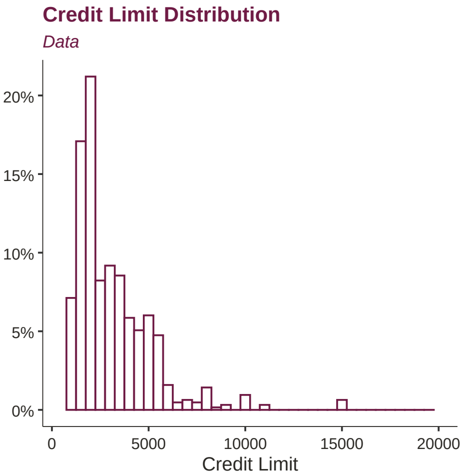
- Lender can freely set individualized interest rates $r_{i\ell}$ & credit limits $\bar{b}_{i\ell}$

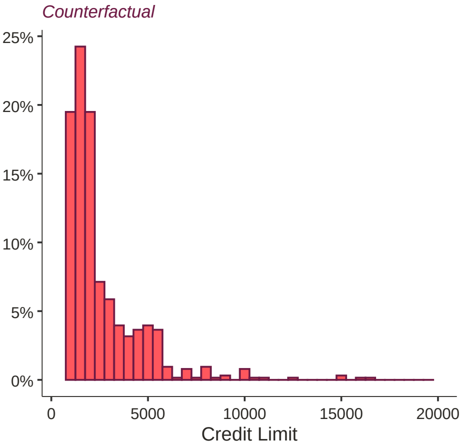
$$\max_{\boldsymbol{r}_{i\ell}, \bar{\boldsymbol{b}}_{i\ell}} \sum_j \underbrace{s^E_{ij}(\boldsymbol{r}_{i\ell}, \boldsymbol{r}^*_{-i\ell})}_{\text{3rd degree PD}} \underbrace{\mathbb{E}\left[\min\{b^*_{ij}, \bar{b}_{ij}\}\pi_{ij}\right]}_{\text{Managing default risk}}$$

- where:
  - $\boldsymbol{r}^*_{-i\ell}$ interest rates for i at other lenders
  - s^E_{ij} probability that i chooses card j
  - b^*_{ij} desired borrowing
  - $\bar{b}_{ij}$ credit limit
  - π_{ij} profit per unit credit

Profit per unit credit Back

Credit Limits





Back

Counterfactual: Averages

- Interest rates increase on average by 10% (1.9 p.p.)
- Credit limits decrease on average by 15%
  Interest rate $\nearrow \longrightarrow$ Customer using entire credit limit riskier $\longrightarrow$ Lower CL
- Analogous with downward sloping supply of Einav et al (2011)

Back

Alternative Explanations

- Setup/computational costs:
  - There are fixed costs of setting up, designing, and implementing risk-based interest rates. If these costs exceed the benefits of using risk-based pricing on 49% of customers, it is optimal not to individualize interest rates at all
- Consumer preferences
  - If consumers choose their card based on advertised APRs and not because of credit limits, individualizing credit limits may be optimal
- Reputational risk of discrimination
  - If risk scores correlate with protected characteristics, risk-based pricing could be misconstrued as discrimination Back

Backup Literature

Stiglitz Weiss (1981)

- *Credit rationing* – don't raise market interest rates to market clearing
    - **Adverse Selection:** riskier borrowers higher WTP
    - **Moral Hazard:** Higher rates induce default
- Small exclusion from borrowers
- **Departure:** Infer default risk through risk scores, not interest rates
- **Departure:** Use credit limits to mitigate downside risk from a certain interest rate

Back

Further Literature on Credit Limits

- **Effect of credit limit on borrowing:** Gross and Souleles (2002a,b)
- **Randomizing credit limit shocks:** Aydin (2022)
- **Ex-post variation in credit limits:** Fulford (2015)

Back

Further Literature on Risk Signals

- **Profit increases following risk scoring adoption:** Einav, Jenkins and Levin (2012,2013); Paravisini and Schoar (2015)

- **Credit scores' predictive, *statistical* quality:** Lessmann, Baesens, Seow, and Thomas (2015); Albanesi and Vamossy (2019); Fuster, Goldsmith-Pinkham, Ramadorai, and Walther (2022)

- **The economic content of risk scores:** Einav, Finkelstein, Kluender, and Schrimpf (2016)

Back

Further Literature on Credit Cards

- Surveys and market studies: FCA (2015); CFPB (2021); Knight (2010); Agarwal and Zhang (2015); Evans and Schmalensee (2005)
- Other features:
  - **Search:** Galenianos and Gavazza (2022); Stango (2002); Stango and Zinman (2015); Nosal and Drozd (2011); Calem and Mester (1995)
  - **Promo deals:** Drozd and Kowalik (2019)
  - **Learning:** Agarwal, Driscoll, Gabaix, and Laibson (2008)
  - **Minimum Repayments:** Druedahl and Jørgensen (2018)
  - **Information frictions**: Ausubel (1999); Karlan and Zinman (2009)
  - **Interchange**: Wang (2023)

Back

Further Literature on Credit Card Biases

- **Time inconsistency and present bias:** Ausubel and Shui (2005); Ausubel (1991, 1999); Laibson, Repetto, and Tobacman (2000); Meier and Sprenger (2010); Kuchler and Pagel (2021)
- **Self-control and naivete:** (Heidhues and Koszegi (2010)
- **Anchoring:** Keys and Wang (2019); Stewart (2009)
- **Exponential growth bias:** Stango and Zinman (2009); Adams, Guttman-Kenney, Hayes, Hunt, Laibson, and Stewart (2022)
- **Over-optimism:** Exler, Livshits, MacGee, and Tertilt (2021); Yang, Markoczy, and Qi (2007)
- **Repayment heuristics:** Gathergood, Mahoney, Stewart, and Weber (2019)

Back

EU Regulation and Timing

For each credit card product:

1. All promotional materials and T&Cs must feature an advertised APR
2. At least 51% of customers each month must receive the APR advertised (or lower)

Cannot discover personal interest rate or credit limit until after applied for the card, and costly to apply for a card

Classic Credit Card ›

Improve or start building your credit rating.

Eligibility criteria apply. Credit is subject to status.

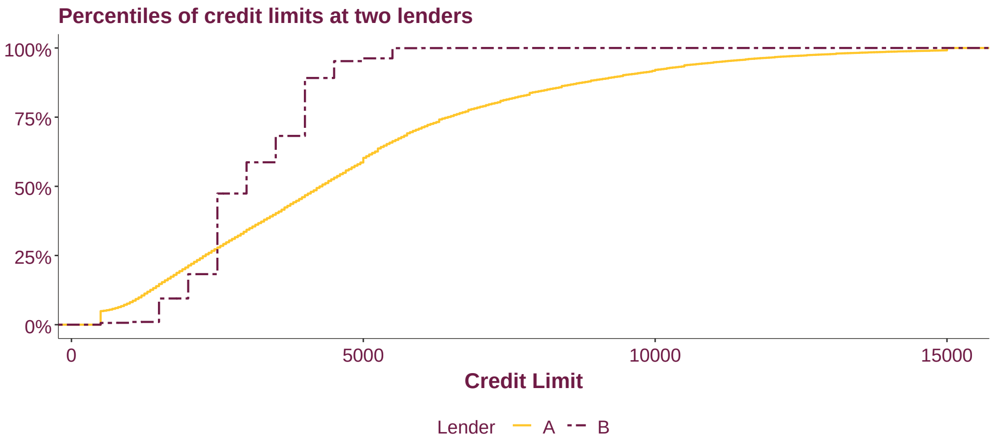
Representative example
Purchase rate: **29.9% p.a. (variable)**
Representative: **29.9% APR (variable)**

Extra Details Back

Lenders Construct Their Own Credit Scores

- Numerical scales and shapes
- Relationship to observed demographics
  - Regress lender's risk score on observed demographics (income, age, etc.)
  - R^2 ranges from 7% to 34% (mean across lenders = 21%)
- 87% of total variation in credit scores at a lender is **within card**: customers not sorted onto cards by credit score
- **Model implication**: Need lender-specific risk scores Back

Heterogeneity in Lenders' Credit Limit Distributions



- **Model implication**: Need lender-specific risk-based credit limit distributions Back

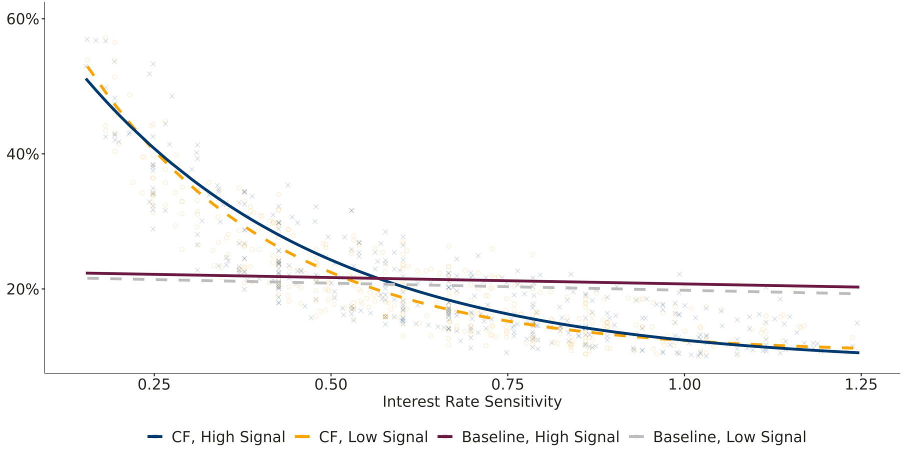
Summary of Descriptive Findings

1. How do credit card lenders individualize contract features?
   - **Risk-based credit limits**
   - Smooth distribution of limits for some lenders; more discrete for others
   - Interest rates not risk-based & APR regulatory constraint does not bind

Next step: quantify economic costs/benefits of individualizing interest rates

- Use a model

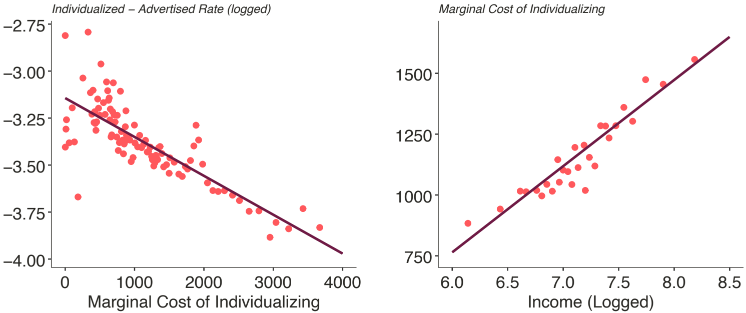
Rates by Elasticity



No difference in interest rate-elasticity gradient for risky and safe signals Back

Results: Costs of Individualizing

1. 5pp above advertised $\Longrightarrow$ \$110 per-customer cost on average
2. Important caveat: distribution is a lower bound
3. Substantial variation in κ across borrowers Distribution Back
4. Variation by characteristics:



Implications

- Data shows that lenders don't individualize interest rates, yet sizeable **profit increases** available from tailoring interest rates when no costs/regulation of interest rate tailoring exist
- Shows the importance of costs of interest rate tailoring
- These could be:
    1. **Reputational risk and reputational costs**
    2. Fixed costs of implementation
    3. Legal consequences
    4. Inability to profit maximize (behavioral)

Other Explanations Back

Optimality Condition for Individualized Rate

- Regulatory constraint is not binding at any lender, so ignore. Implies
$$\frac{\partial \Pi_{ij}}{\partial z_{ij}} = \frac{\partial C_{ij}}{\partial z_{ij}} - \lambda_{ij}$$
λ_{ij} is the Lagrange multiplier on $z_{ij} \geq 0$
- For $z_{ij} > 0$, $\lambda_{ij} = 0$ and we have that marginal costs of individualizing equal marginal profits from individualizing
- Estimation: Specify $C = \kappa_{ij} z_{ij}$ and estimate marginal costs of individualizing interest rates, κ_{ij}, by calculating LHS derivative

Optimality Condition for Credit Limit

$$\mathbb{E}(\pi_{ij} | b^*_{ij} \geq \bar{b}_{ij}) = 0$$

Zero expected profit per unit revolved, over those who would revolve entire credit limit

- **Not** a zero profit condition: positive expected profit on "infra-marginal" revolvers (those not using entire CL)
- Gives equation linking signals, precision, and credit limits
- Estimation: **minimize RSS** of left-hand side to estimate **signals** e_ℓ and **precision** σ_ℓ

Back