Burning Questions:

Dual Dynamics of U.S. Cigarette & E-Cigarette Demand

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Disclaimer: Researcher(s)' own analyses calculated (or derived) based in part on data from Nielsen Consumer LLC and marketing databases provided through the NielsenIQ Datasets at the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business. The conclusions drawn from the NielsenIQ data are those of the researcher(s) and do not reflect the views of NielsenIQ. NielsenIQ is not responsible for, had no role in, and was not involved in analyzing and preparing the results reported herein.

Motivation

- Cigarette adult smoking rate = 11.6% (CDC 2022)
- E-cigarette adult smoking rate = 6.0% (CDC 2022)
- 35% of cigarette smokers who attempted to quit in the previous 12 months used e-cigarettes as a cessation aid (2015 Current Population Survey Tobacco Use Supplement)
  - 25% in 2019

Motivation

- E-cigarette cessation versus gateway effect
- Cigarette and e-cigarette policies simultaneously in place
- Existing work focuses on cross-sectional substitution
- Structural models versus reduced form

Research Question and Method

Research Question

1. How does smoking history drive transitions between cigarettes, e-cigarettes, and abstinence?
2. How does an e-cigarette ban impact the life cycle of cigarette use, from initiation to long-term persistence?

Method

- Study consumer adoption and switching between cigarettes and e-cigarettes
  - Emphasis on past smoking behavior
  - Original model of nicotine addiction
  - New method of addressing price endogeneity in this literature

Literature Review

- Structural models
  - Hui (2024), Allcott and Rafkin (2022), Chen and Reinhardt (2025)
- Habit formation
  - Becker and Murphy (1988), Suranovic et al. (1999), Gordon and Sun (2015)
- Negative relationship between smoking and their regulation
  - Cigarettes: Chaloupka and Saffer (1992), Bauer et al. (2005), Chaloupka et al. (2011), Seo et al. (2011), Schneider et al. (2016), Cotti et al. (2022)
  - E-cigarettes: Du et al. (2020), Jun and Kim (2021)
- Substitute goods
  - Grace et al. (2015), Stoklosa et al. (2016), Pesko et al. (2020), Saffer et al. (2020)

Background

- State and federal regulations
  - Prohibit self-service-displays: products must be kept behind the counter or in a locked box
  - Minimum age-of-purchase
  - Smoke-free-air (SFA): prohibits smoking indoors in restaurants, bars, and worksite
  - Require retail license to sell
- Excise taxes
  - E-cigarettes: Cotti et al. (2022) estimates pass-through: 0.90 - 1.01
  - Cigarettes: He et al. (2023) estimates pass-through: 1.00 - 1.10.

Background - E-cigarettes

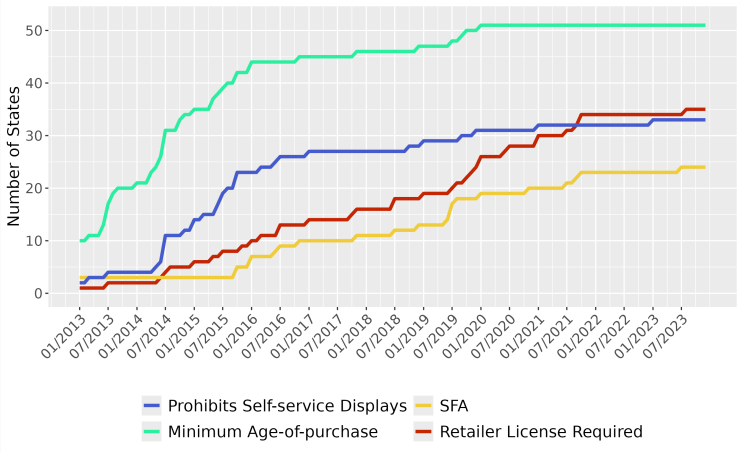


Figure 1: Number of E-Cigarette State-level Smoking Restrictions across 50 States and D.C.

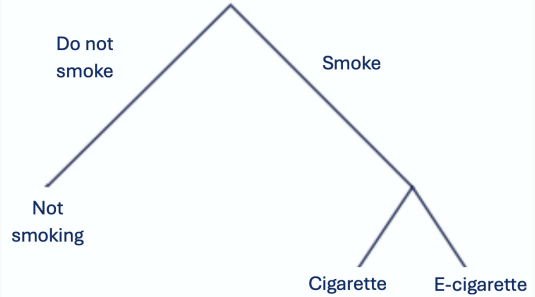
Cigarette Law Evolution

Consumer Choice - Panel Nested Logit

Each month m, agent i in U.S. state s chooses alternative $j \in \mathcal{J}$

$\mathcal{J} = \{$ representative cigarette, representative e-cigarette, not smoking $\}$

- (E-)cigarette smoking laws
- Price
- Demographics
- **Smoking history**
  - Switching costs
  - Adoption costs
  - Nicotine stock



Four Switching Costs

1. Cigarette $\rightarrow$ E-cigarette
2. E-cigarette $\rightarrow$ Cigarette
3. Cigarette $\rightarrow$ Not Smoking
4. E-cigarette $\rightarrow$ Not Smoking

Treated as a product characteristic

$$\text{Switching Cost}^{a \rightarrow b} = \begin{cases} 1 & \text{a} \neq b \\ 0 & \text{otherwise} \end{cases}$$

$a \equiv$ last period's choice $\qquad$ $b \equiv$ alternative considered this period

Two Adoption Costs

$$\text{Cigarette Adoption Cost} = \begin{cases} 1 & \text{Smoked cigarettes any of the prior two months} \\ 0 & \text{otherwise} \end{cases}$$

$$\text{E-cigarette Adoption Cost} = \begin{cases} 1 & \text{Smoked e-cigarettes any of the prior two months} \\ 0 & \text{otherwise} \end{cases}$$

Nicotine Stock N_{im}

- Data allows for detection of exactly how much nicotine is contained in (e-)cigarettes purchased: e-liquid capacity and strength, cigarette type
- Convert to approximate nicotine yield to standardize (Omaiye et al. 2019, Benowitz and Henningfield 2013)
- Ex. $n_{i,ecig} = 30\text{mg/mL} \times 2\text{mL} \times 2 \text{ units} \times .68 \text{ transfer efficiency} = 81.6 \text{ mg}$

$$N_{ijm} = (1 - \delta_j) N_{ij,m-1} + n_{ij,m-1}$$

$$\delta_j \equiv \text{alternative's depreciation rate}$$

$$N_{im} = \sum_{j \in \{cig, ecig\}} N_{ijm}$$

$$N_{i0} = 0$$

Consumer Choice - Panel Nested Logit

Agent i, located in state s in month m, derives utility U_{ijms} from purchasing alternative $j \in \mathcal{J}$, where j belongs to nest $g(j) \in \mathcal{G}$:

$$
\begin{aligned}
U_{ijms} &= V_{ijms} + \zeta_{ig(j)ms} + \lambda_{g(j)}\epsilon_{ijms} \\
V_{ijms} &= \beta^{p} p_{jms} + \mathbf{S}_i'\beta^{\mathbf{S}} \\
&\quad + \mathbf{L}_{js}'\beta_j^{\mathbf{L}} + \gamma_j^{N} N_{im} + \mathbf{D}_i'\gamma_j^{\mathbf{D}} + \gamma_j^{adc} adc_{im} + \gamma_j^{ade} ade_{im} \\
&\quad + \xi_j + \sigma_{j,s} + \alpha_{j,year}
\end{aligned}
$$

- p: prices
- **S**: vector of switching costs
- **L**: vector of state-month-alternative smoking laws
- N: nicotine stock
- **D**: vector of household demographics
- adc, ade: cigarette, e-cigarette adoption costs
- ξ, σ, α: fixed effects

Details

New Method: Price Endogeneity in a Nonlinear Framework

1. Estimate same nested logit model, but add market-time-level (alternative-state-month) FE
   - Drop out: laws, price, product FE, state FE, year FE
   - Overcome computational issues using minorization-maximization (Chen et al. 2022)
2. Regress step 1 estimated FE on product characteristics and instrumented price
   - Instrumented price from first stage
     - Excise taxes IV
     - F-test = 33.4
3. Bootstrap standard errors, $B = 500$

Comparison to Control Function Approach

- Control Function Approach
  - **Assumption:** Unobserved price shocks and unobserved utility shocks are linearly related (i.e. bivariate normality).
- My Approach
  - **Assumption:** All unobserved market-time-level heterogeneity (local trends, advertising, etc.) is captured by market-time-level fixed effects

Data

- Build monthly unbalanced panel, 2013 - 2023
- Nielsen Consumer Panel Data: Household purchases and demographics
  - 40,000 - 60,000 households annually
  - Households that smoke "sufficiently" frequently while observed
  - **Aggregation**: Choice defined by majority of monthly expenditure
    - $<$ 1% of households split spending between 15% and 85%
- Nielsen Retail Scanner Data: Weekly price, nicotine strength, used to construct **sales-weighted representative cigarettes and e-cigarettes**
- Manual collection and Cotti et al. (2022): e-cigarette e-liquid capacity and nicotine strength
- CDC: State smoking laws
- CDC and Cotti et al. (2024): Excise taxes

Data Construction Details

Representative E-Cigarettes

- Aggregate weekly retail data to month-state
- Representative price
  - $p_{ms} = avg.\ price\ per\ mL_{ms} \times avg.\ e\text{-}liquid\ capacity_{ms}$
- Averages constructed using e-liquid sales weights
  - Total mL sold
- Analogous formula for excise tax instrument

Pause for Questions

Summary Statistics - Duration of Smoking

Household Type	N	Pct. of Households	Pct. Months Smoking Cig.	Pct. Months Smoking Ec.
Cigarettes-only	14608	89.1	49.2	-
E-cigarettes-only	356	2.2	-	39.6
Both	1430	8.7	33.7	9.8
Total	16394			

Table 1: Amount of Time Smoking by Household Type

Summary Statistics - Period-to-period Choices

	Neither	Cigarette	E-cigarette
Neither	0.859	0.135	0.006
Cigarette	0.217	0.780	0.003
E-cigarette	0.311	0.074	0.615

Table 2: Transition Matrix

Consumer Choice Estimates - Structural Parameters

	Estimate	Δ Odds%
Real Price/Ct.	-0.017**	-1.7**
Switching Cost, cig. to not smoke	-1.201***	-69.9***
Switching Cost, ec. to not smoke	-1.187***	-69.5***
Switching Cost, cig. to ec.	-0.340***	-28.8***
Switching Cost, ec. to cig.	-0.722***	-51.4***
λ (Nested Logit Parameter)	0.624***	
δ_c	0.23†	
δ_e	0.25†	
Observations	2,474,886	
No. of Households	16,394	
Controls for Age, Race, Income, Children & HH Size	Yes	
Year FE and State FE	Yes	

Standard errors are clustered at the household-level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

† A standard error is not estimated for this parameter.

Table 3a: Structural Estimates of Product Characteristics

Consumer Choice Estimates - Structural Parameters

Cigarette	Estimate	Δ Odds%	**E-cigarette**	Estimate	Δ Odds%
Cig. SFA Law	-0.063	-6.1	Cig. SFA Law	-0.024	-2.4
Ec. SFA Law	0.014	1.4	Ec. SFA Law	0.061	6.3
Cig. Retailer License	0.194***	21.4***	Cig. Retailer License	0.165	17.9
Ec. Retailer License	-0.004	-0.4	Ec. Retailer License	0.051	5.3
Ec. Min. Age of Purchase	0.006	0.6	Ec. Min. Age of Purchase	-0.018	-1.8
Ec. Prohibit Self-Service	0.023	2.3	Ec. Prohibit Self-Service	0.016	1.6
HH Nicotine Stock/300mg	0.266***	30.5***	HH Nicotine Stock/300mg	0.261***	29.9***
Smoked Cig. in last 2 months	1.518***	356.4***	Smoked Cig. in last 2 months	0.085	8.8
Smoked Ec. in last 2 months	0.044	4.5	Smoked Ec. in last 2 months	3.101***	2122.9***
Intercept	-0.642***	-47.4***	Intercept	-1.557***	-78.9***
λ (Nested Logit Parameter)			0.624***		
δ_c			0.23†		
δ_e			0.25†		
Observations			2,474,886		
No. of Households			16,394		
Controls for Age, Race, Income, Children & HH Size			Yes		
Year FE and State FE			Yes		

Standard errors are clustered at the household-level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

† A standard error is not estimated for this parameter.

Table 3b: Structural Estimates of Alternative-specific Coefficients

Simulations

- Model fit
  - All covariates evolve as they do in the data
- Baseline and Counterfactuals
  - Fix all covariates at values from $t = 1$, except for smoking history variables
  - Switching costs, nicotine stock, and adoption costs begin as if zero smoking history
- Calculate choice probabilities and simulate next period draw
- Switching costs, adoption costs, nicotine stock evolve endogeneously
  - Assumptions about how much nicotine is being consumed when c or e is simulated

Model Fit

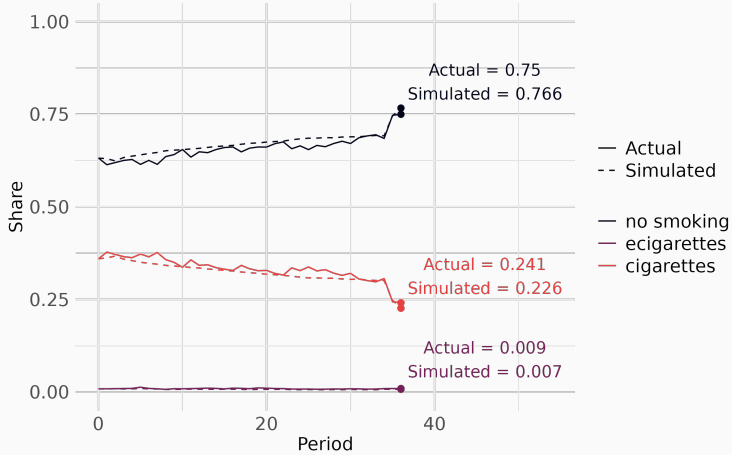


Figure 2: Simulated vs. Data Shares. Cohort: Households Observed in Nielsen 2018

No Adoption Costs Counterfactual

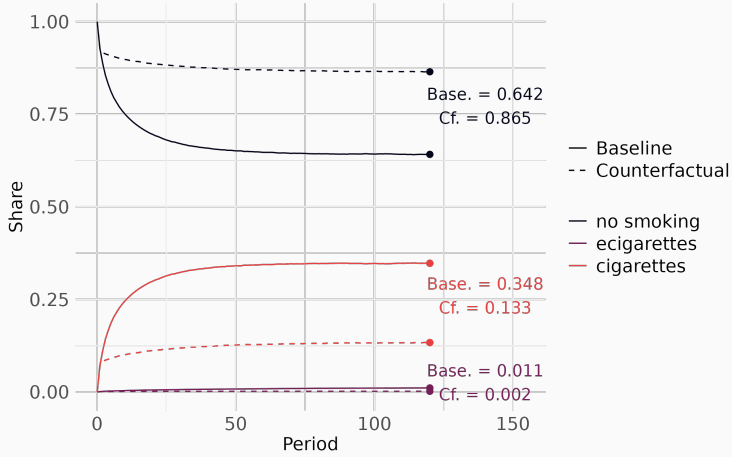


Figure 3: Adoption Costs = 0 Counterfactual. Cohort: Households Observed in Nielsen 2018

Counterfactuals

	Cigarette Share	E-cigarette Share	Non-smoking Share
Baseline Shares	0.348	0.011	0.642
Change			
Adoption costs = 0	-0.215	-0.009	0.223
N = 0	-0.165	-0.009	0.173
Switching costs = 0	-0.110	-0.006	0.115

Table 4: Changes in Product Shares Under Counterfactuals Relative to Baseline

E-cigarette Ban Counterfactual

- 65.3% of e-cigarette choice in baseline $\rightarrow$ not smoking in counterfactual
- 34.7% of e-cigarette choice in baseline $\rightarrow$ cigarette in counterfactual

E-cigarette Ban Counterfactual

Banning e-cigarettes → modest increase in cigarette smoking...

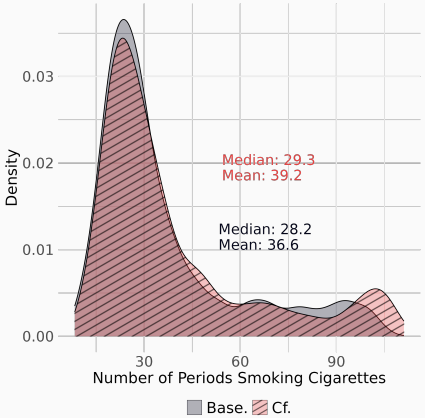


Figure 4: Distribution of Number of Periods Households Smoke Cigarettes ($T = 120$)

E-cigarette Ban Counterfactual

... but disproportionately harms tails

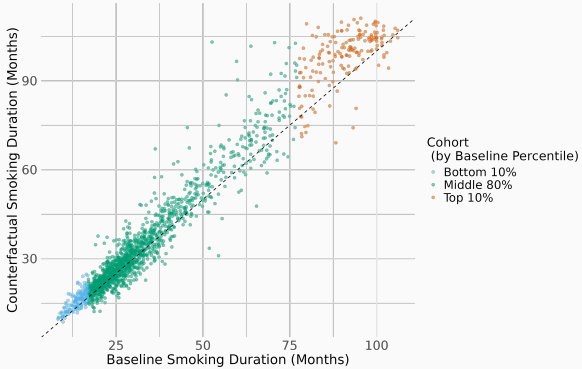
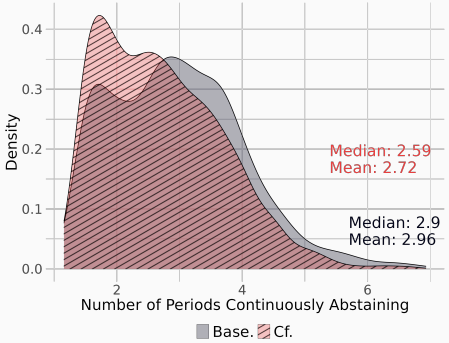


Figure 5: Number of Periods Households Smoke Cigarettes ($T = 120$)

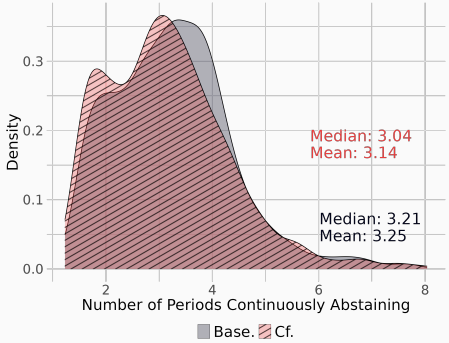
Distributions Across Cohorts

E-cigarette Ban Counterfactual

Banning e-cigarettes → shorter abstinence durations



(a) Abstaining from **Cigarettes or E-cigarettes**



(b) Abstaining from **Cigarettes**

Figure 6: Distribution of Continuous Abstinence Streaks ($T = 120$)

Note: "Continuously Abstaining" measured as the length of a streak of no smoking within the simulation

E-cigarette Ban Counterfactual

Banning e-cigarettes → start smoking cigarettes earlier

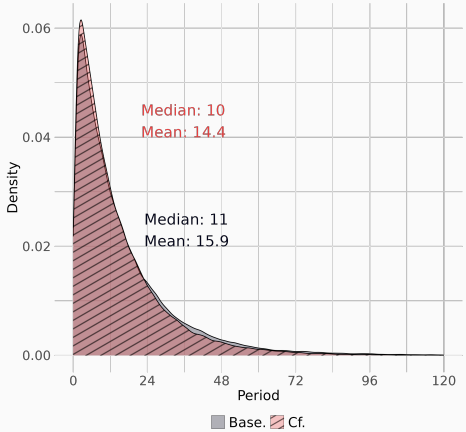


Figure 7: Distribution of First Period that Household Smokes Cigarettes ($T = 120$)

Summary of Findings

- No evidence of switching being driven by adoption costs, however, nicotine stock and switching costs may capture this
- Adoption costs play largest role in choice to smoke, followed by nicotine levels, and switching costs
- E-cigarette ban leads to
  - Overall modest increase in cigarette smoking, however, larger jumps in the tails
  - Shorter abstinence durations
  - Earlier cigarette initiation
- Important to think about targeted policy

Moving Forward

- Event study
- Sensitivity checks: single-person households, adoption costs month duration
- Capture changing heterogeneity of e-cigarette landscape with number of brands or products available

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Background - Cigarettes

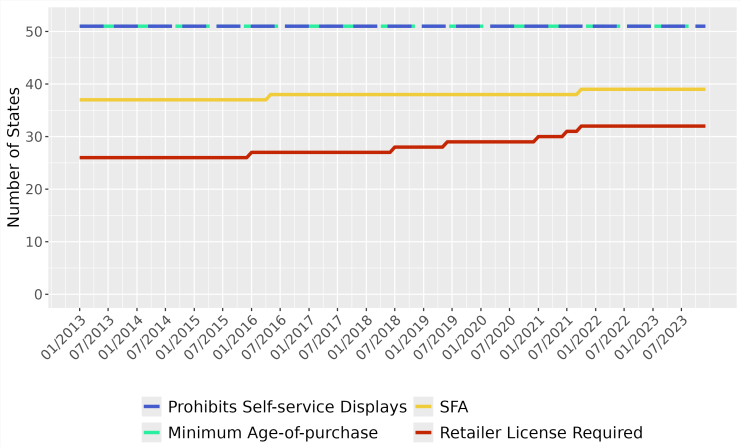

Figure A1: Number of Cigarette State-level Smoking Restrictions across 50 States and D.C.

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Nicotine Stock N_{im}

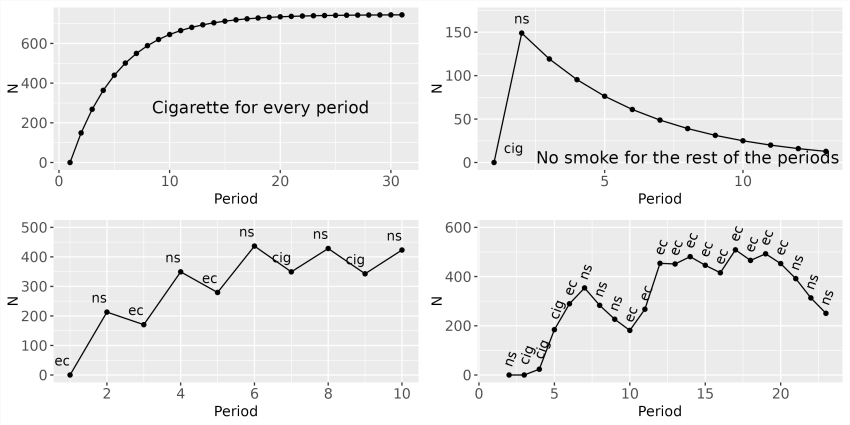

Figure A2: N_{im} evolution examples

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Panel Nested Logit Details

- Unobserved component $\epsilon_{ijms} \sim T1EV$
- The nest-level unobservable $\zeta_{ig(j)ms}$ introduces correlation between alternatives within the same nest, and it is distributed such that $\zeta_{ig(j)ms} + \lambda_{g(j)}\epsilon_{ijms} \sim T1EV$
- The scale parameters $0 < \lambda_{g(j)} \leq 1$ govern substitution patterns within nests, relaxing the IIA assumption relative to standard logit

The probability of consumer i choosing alternative j at time m is therefore

$$\mathcal{P}_{ijms} = \underbrace{\frac{\exp\left(\frac{V_{ijms}}{\lambda_{g(j)}}\right)}{\sum_{k\in\mathcal{J}_{g(j)}} \exp\left(\frac{V_{ikms}}{\lambda_{g(j)}}\right)}}_{\Pr(\text{choose } j|\text{ nest } g(j) \text{ chosen})} \cdot \underbrace{\frac{\left[\sum_{k\in\mathcal{J}_{g(j)}} \exp\left(\frac{V_{ikms}}{\lambda_{g(j)}}\right)\right]^{\lambda_{g(j)}}}{\sum_{g'\in\mathcal{G}} \left[\sum_{k\in\mathcal{J}_{g'}} \exp\left(\frac{V_{ikms}}{\lambda_{g'}}\right)\right]^{\lambda_{g'}}}}_{\Pr(\text{choose nest } g(j))}$$

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Data Aggregation and Sample Selection

Sample Construction:

- **Regular Smokers**: Exclude households with < 4 purchase dates
- **Geographic Consistency**: Exclude households purchasing in > 1 state (6.5% of sample) to mitigate cross-border shopping concerns

Discrete Choice Assumption:

- Households are assigned the alternative (j) with the highest monthly spend
- **Validation**: Less than 1% of households split spending nearly equally (defined as 15% - 85% of total monthly nicotine spend)
- Suggests concurrent smoking in close proportion is extremely rare

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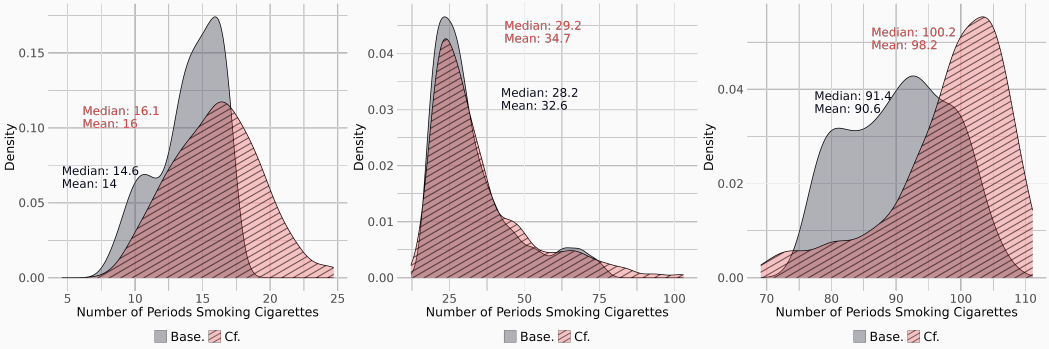
E-cigarette Ban Counterfactual

... but disproportionately harms tails



(a) Bottom 10% **(b)** Middle 80% **(c)** Top 10%

Figure A3: Distribution of Number of Periods Households Smoke Cigarettes ($T = 120$)

Baseline restricted to respective deciles. Counterfactual tracked for the same household cohorts

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