

machine learning conference



Measuring Long-Term Effects using Dialed Up Experiments

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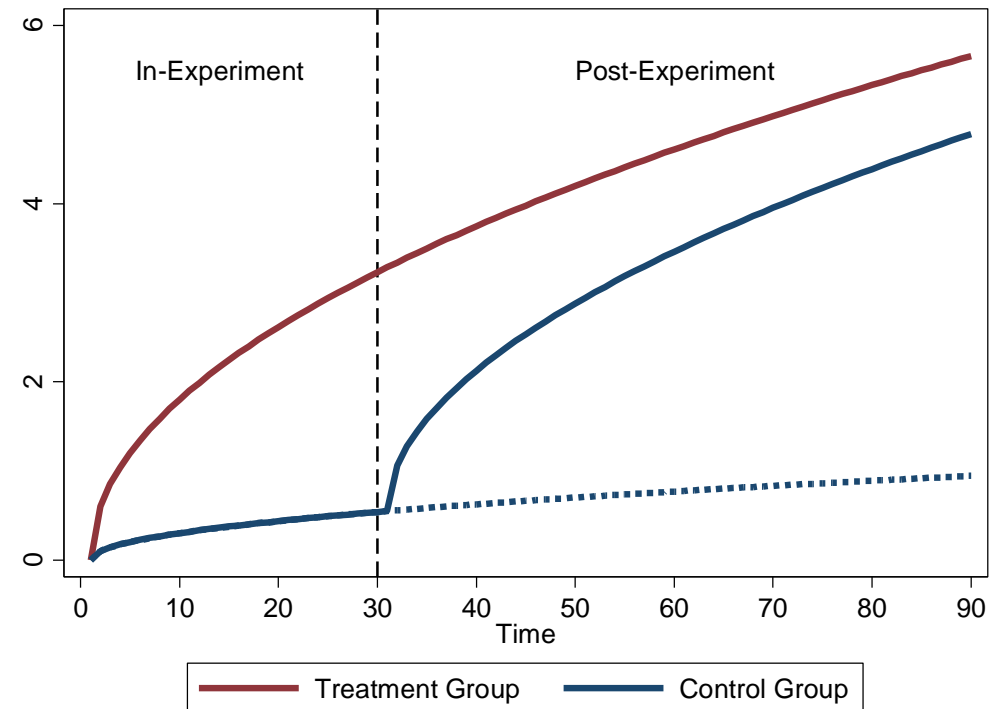
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@mgentzko
Contractor | Amazon Search

Background and Motivation

- Long-term effects of long-term exposure are a fundamental question for launch decisions
- Typically experiments at Amazon run for only a short period of time
- We develop a new method for measuring long-term effects of long-term exposure using dialed up short-term experiments
- The method allows for arbitrary treatment effect dynamics in exposure time by restricting treatment effects to be stable in calendar time
- Our end goal is to build a tool that lets experiment owners monitor treatment effects after dial-up and potentially overturn the launch decision

Identification and Estimation (Simplified Example)

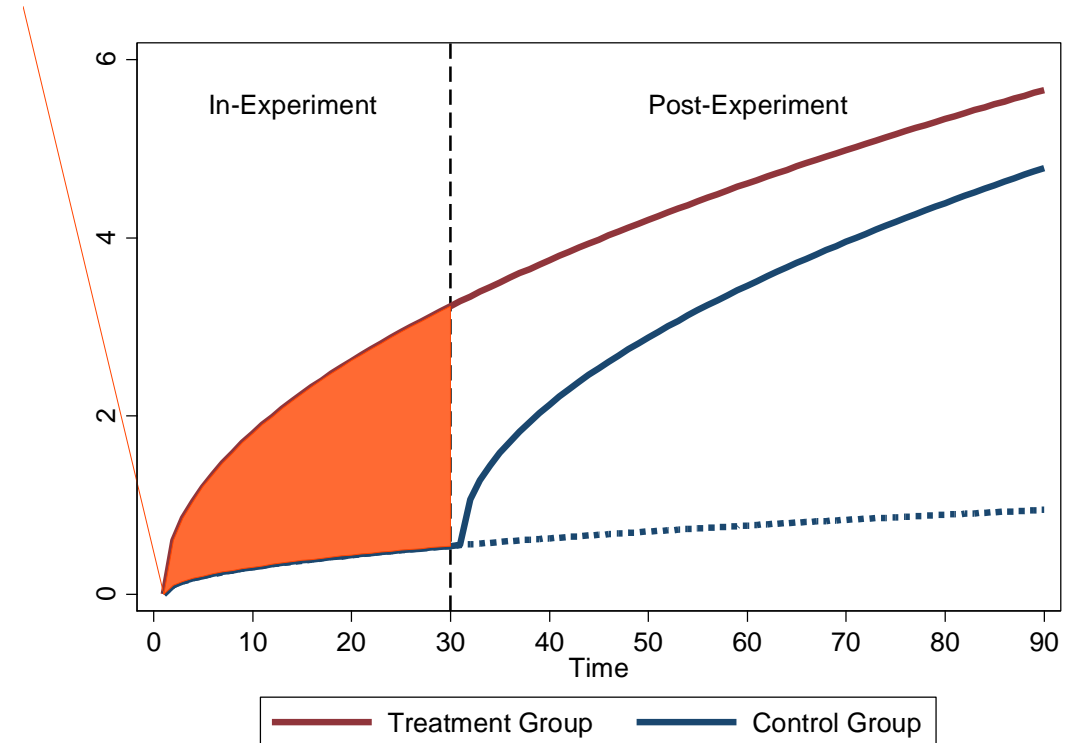
- Experiment runs during days 1-30:
 - 50% of customers assigned to $T1$
 - 50% of customers assigned to C
- Experiment dialed up to 100% on day 31
- Customers trigger their assigned experience immediately on the day of assignment
 - $T1$ triggers treatment experience on day 1
 - C triggers treatment experience on day 31
- Variation in trigger timing handled in the paper



Identification and Estimation (Simplified Example)

- Days 1-30: experiment running
 - $T1$ exposed to treatment
 - C not exposed to treatment
- $T1-C$ differences in average outcomes measure ATEs for 1-30 days of exposure

$$\bar{Y}_t^{T1} - \bar{Y}_t^C = ATE_t^{T1}, t = 1, \dots, 30$$

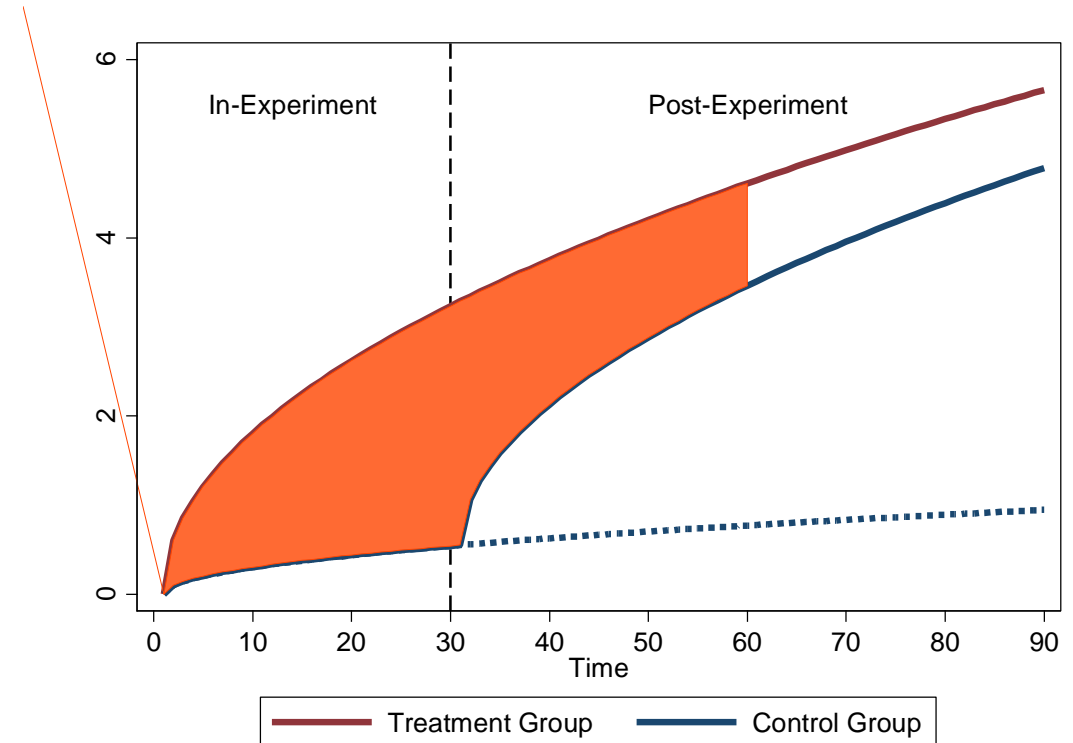


Identification and Estimation (Simplified Example)

- Days 31-60: experiment dialed up
 - $T1$ continues to be exposed to treatment
 - C starts being exposed to treatment
- $T1-C$ differences in average outcomes no longer measure ATEs for 31-60 days of exposure

$$\bar{Y}_t^{T1} - \bar{Y}_t^C = ATE_t^{T1} - ATE_{t-30}^C, t = 31, \dots, 60$$

- Need to uncover average outcomes of C had they continued to not be exposed to treatment



Identification and Estimation (Simplified Example)

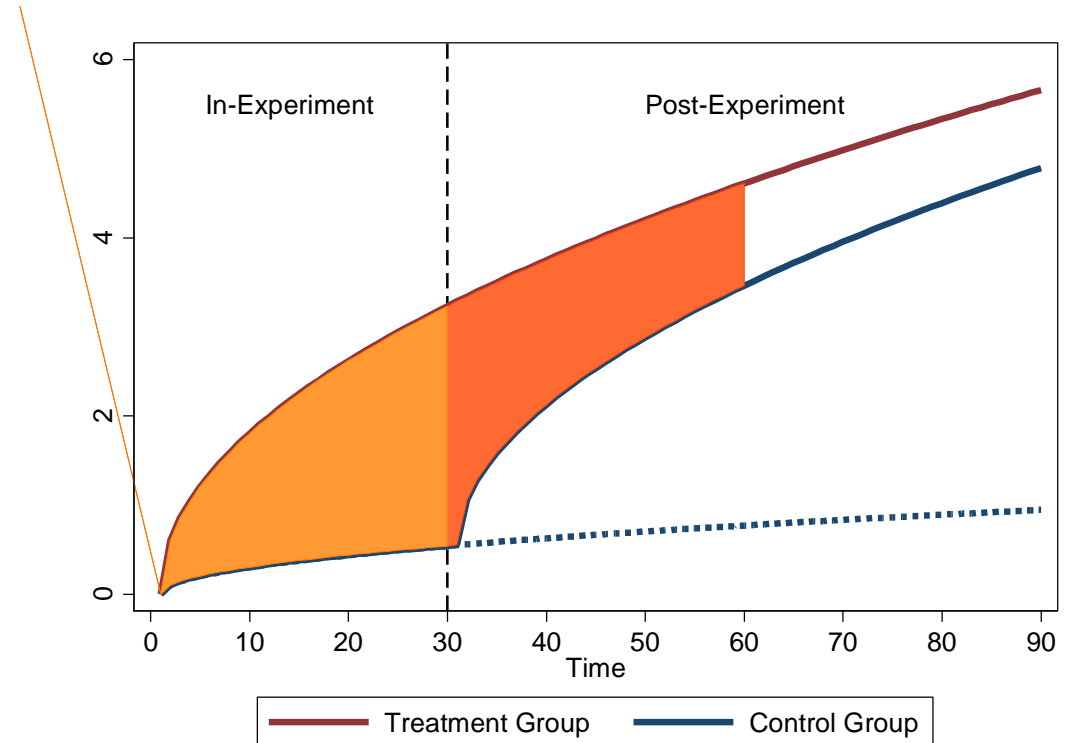
- Assume that ATEs are stable in calendar time

$$ATE_t^{T1} = ATE_t^C \text{ for all } t$$

- Correct average outcomes of C by subtracting out ATE_{t-30}

$$\bar{Y}_t^{T1} - (\bar{Y}_t^C - ATE_{t-30}^{T1}) = ATE_t^{T1}, t = 31, \dots, 60$$

- Allows us to continue measuring ATEs for 31-60 of exposure



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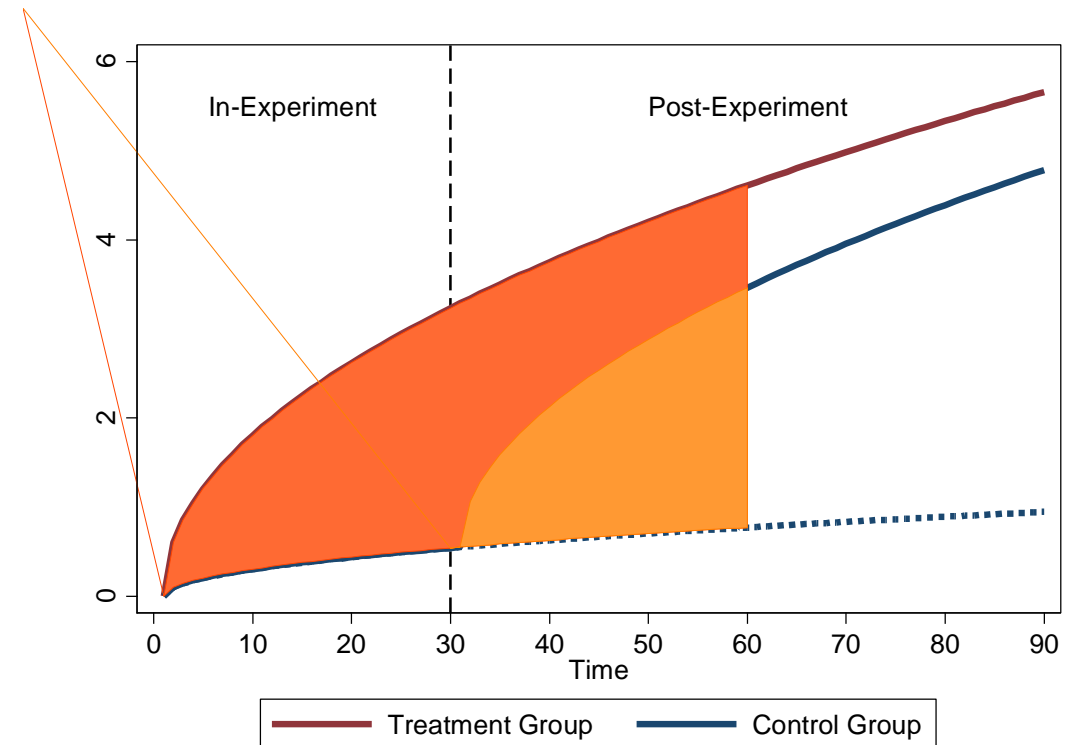
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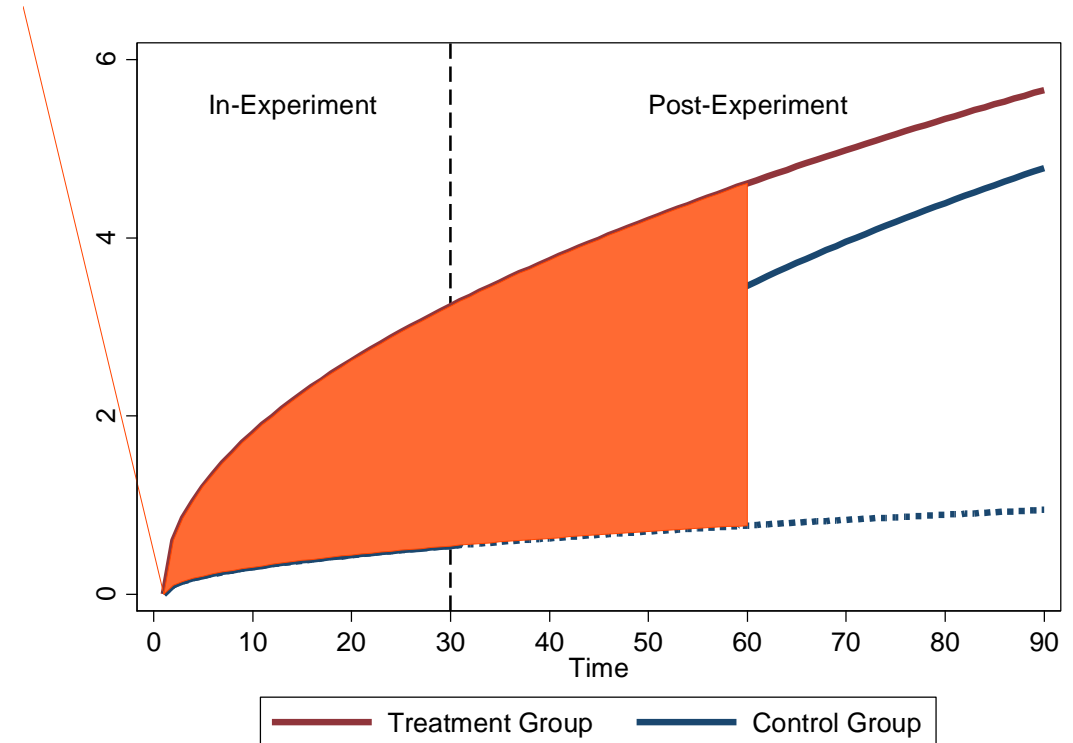
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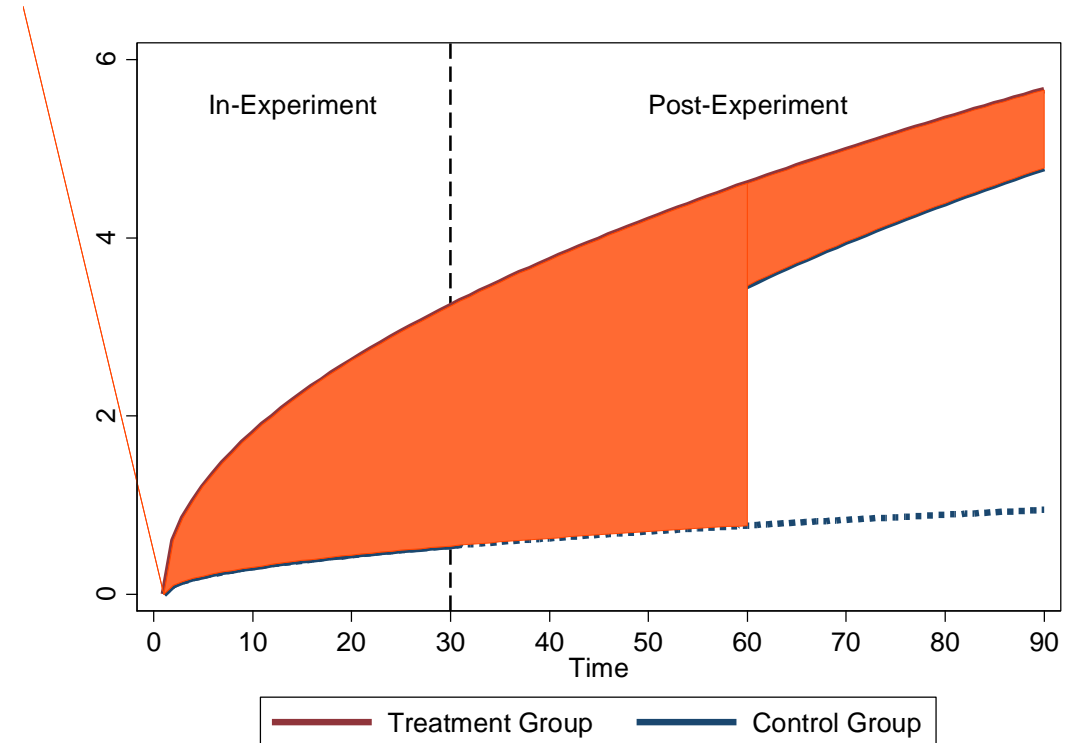
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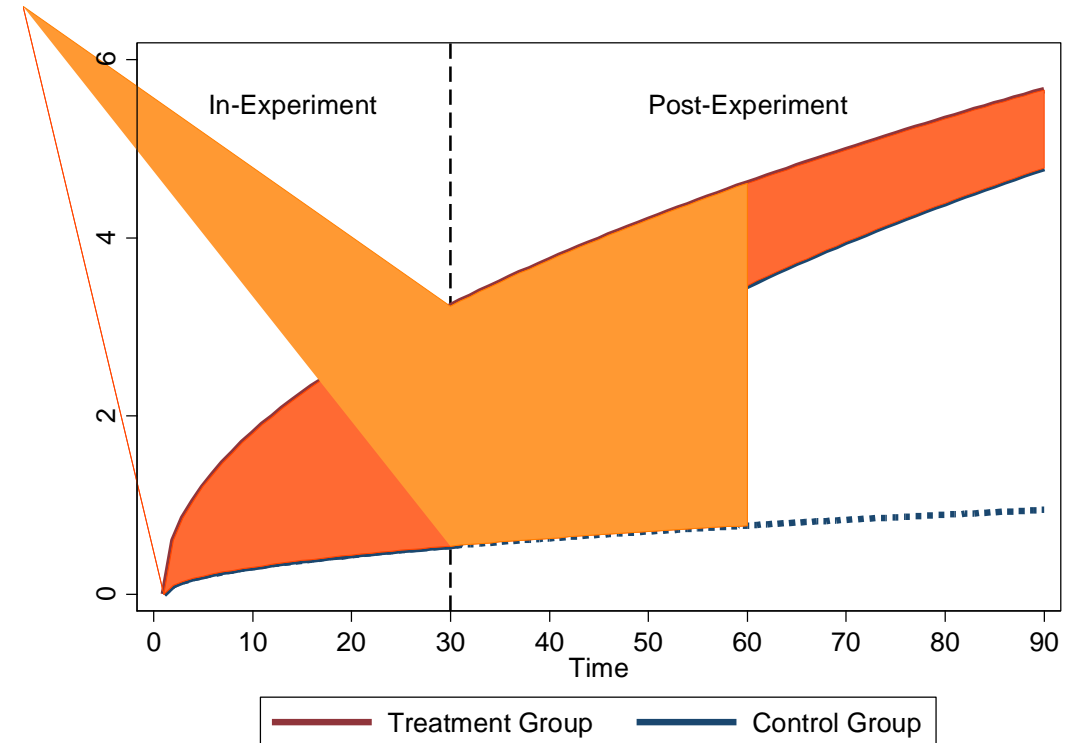
Identification and Estimation (Simplified Example)

- We continue to face the same issue with $T1-C$ differences in average outcomes in days 61-90
- But we just measured the ATEs for 31-60 days of exposure using our method
- We can now correct the average outcomes of C by subtracting out these ATEs
- This allows us to continue measuring ATEs for 61-90 of exposure (and further)



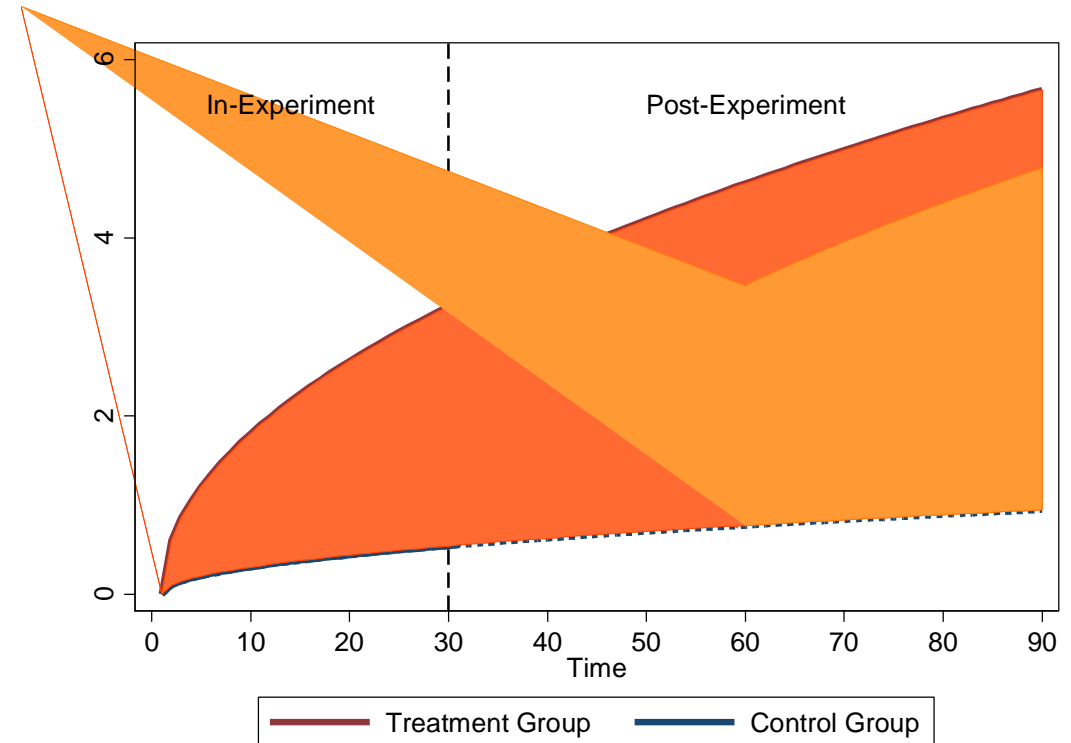
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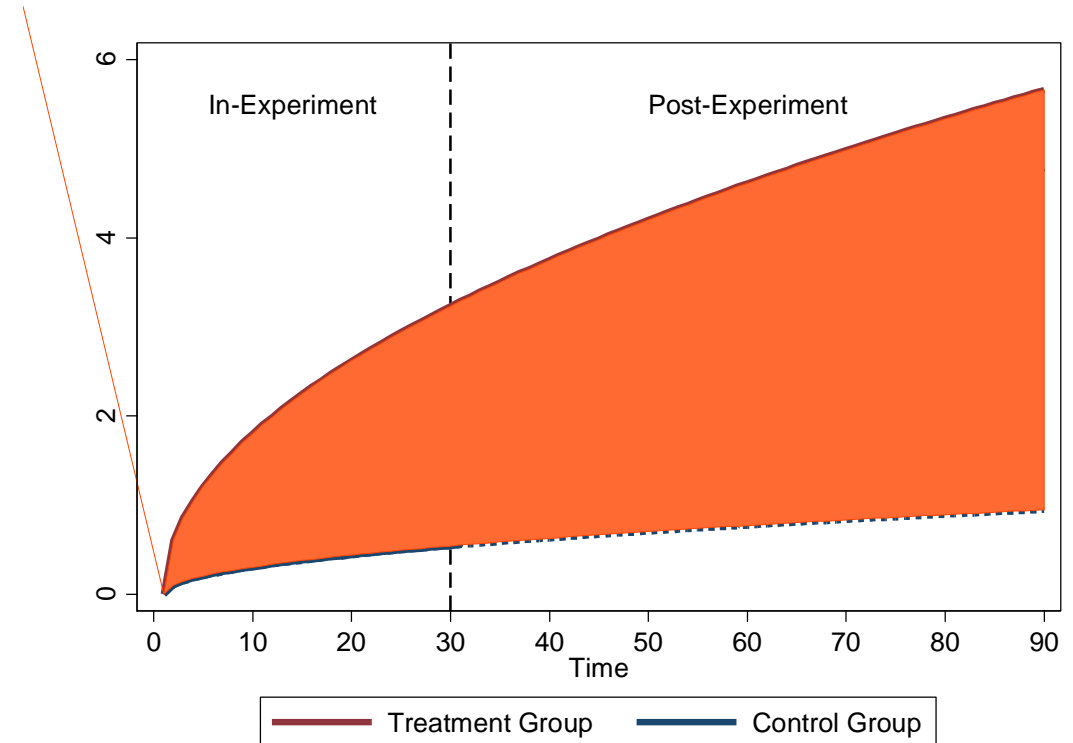
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Theoretical Contribution

- We show theoretical results for our estimator (closed form and simulation)
- Our estimation technique is unbiased for the correct long-term effect under a key assumption
 - It allows any pattern in outcome unrelated to treatment (e.g., seasonality)
 - Treatment effects can follow any function in terms of duration of exposure

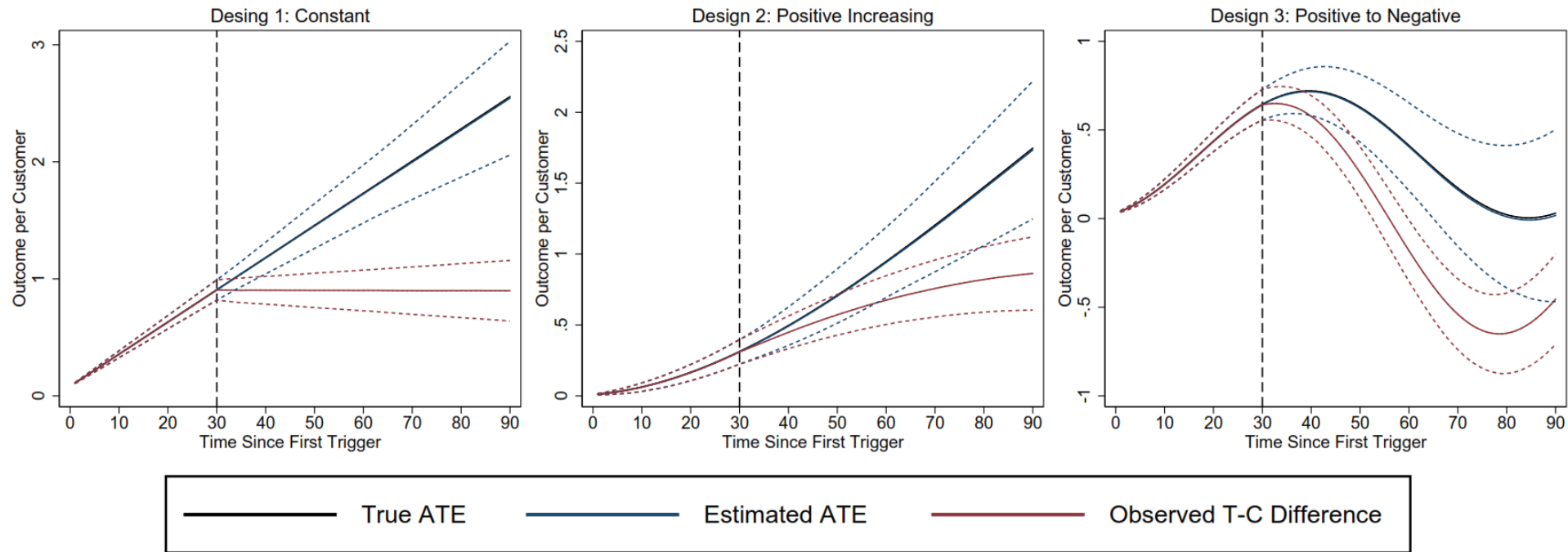
Key Assumption: time-stable causal effects

- **Assumption:** causal effects are the same for the time period of A/B start and dial-up for a similar population
- Violated if there are un-modeled seasonality or trends in effects
- We need this assumption to use A/B tests anyway
- Experiments always look forward: we learn an effect today to predict the impact of changing a policy tomorrow
- We only need to perform better than the baseline approach (simple T/C difference for all periods)

Types of Effects

- Constant effect
- Effect that grows over time
- Effect smaller over time (“novelty effect”)
- Treatment displaces spend over time (e.g., “Pull forward” effect)

Types of Effects: Monte Carlo Simulation



Note: Dashed lines represent simulation-based 95% confidence intervals

Example: Sponsored Products Weblab (Control)

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Health & Personal Care

vitamin c serum

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Hello, Sign in
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Try
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List

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Cart

Shop by Department

Your Amazon.com Today's Deals Gift Cards Sell Help

Health & Personal Care Best Sellers New Arrivals Baby & Child Care Vitamins & Diet Supplements Sports Nutrition Household Supplies Health Care Personal Care Sexual Wellness Sales & Special Offers

1-24 of 5,444 results for Health & Personal Care : "vitamin c serum" Sort by Relevance

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Health & Personal Care

Oils & Serums (2,104)

Facial Skin Care Products (3,674)

Exfoliators (33)

Complexes (17)

Fluids (73)

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Avg. Customer Review

★★★★★ & Up (1,836)

★★★★☆ & Up (2,012)

★★★☆☆ & Up (2,048)

★★☆☆☆ & Up (2,075)

Skin Type

Dry

Oily

Normal

Combination



Vitamins from real, organic, non-GMO whole foods
Shop now▶

Related Searches: vitamin, vitamin c, vitamins.



Alina Skin Care Enhanced Vitamin C Serum and Moisturizer with Hyaluronic Acid and Green & White Tea Extracts
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\$26.95

\$90.00

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More Buying Choices

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FREE Shipping on orders over \$35

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Alice Nouveau Super C 25% Serum with Hyaluronic Acid + Vitamin C-effective Anti Wrinkle, Age Defying-serum - Protect...
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Vitamin C Serum 1oz Pump Action Bottle with 25% Vitamin C Plus Hyaluronic Acid & Ferulic Acid with Additional...
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BEST Botanical 20% Vitamin C + ...
\$10.99 \$64.99



Anti-Aging Skin Serum - Le Fair Wri...
\$28.77 \$89.99 Prime
★★★★☆ (161)



BIG - 2 oz Vitamin C Serum (20%) ...
\$17.95 Prime
★★★★☆ (30)



Vitamin C Serum

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Example: Sponsored Products Weblab (Treatment)

amazon **Try Prime** Health & Personal Care **vitamin c serum**

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 Facial Skin Care Products (3,675)
 Exfoliators (33)
 Complexes (17)
 Fluids (73)
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 C-Complex Vitamin Supplements (37)
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 Treatments & Masks (706)
 Vitamins & Dietary Supplements (251)
 + See more

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 Eligible for Free Shipping
 Free Shipping by Amazon
 Avg. Customer Review
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 ★★★★★ & Up (2,010)
 ★★★★★ & Up (2,046)
 ★★★★★ & Up (2,073)
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 Oily
 Normal
 Combination

Vitamins from real, organic, non-GMO whole foods
 Shop now

Related Searches: vitamin, vitamin c, vitamins.

Sponsored

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 by Majestic Pure
 \$14.20
 Save more with monthly Subscribe & Save deliveries.
 Misc.
 \$14.95 ~~\$49.95~~
 Get it by **Monday, Aug 10**
 FREE Shipping on orders over \$35
 ★★★★★ 873

Sponsored

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 by Le Fair
 Misc.
 \$28.77 ~~\$89.99~~
 Get it by **Monday, Aug 10**
 FREE Shipping on orders over \$35
 ★★★★★ 161

Sponsored

 BEST Hyaluronic Acid Serum For Your Face. Our Anti Wrinkle Facial Skin Care Brings Deep Hydration, Boost Collagen...
 by Pure Body Naturals
 Misc.
 \$14.95 ~~\$69.99~~
 Get it by **Monday, Aug 10**
 FREE Shipping on orders over \$35
 ★★★★★ 129

Sponsored

 Snowberry - Intensive Renewal Nat...
 \$121.00
 ★★★★★ (2)

Sponsored

 THE BEST Organic 20% Vitamin C ...
 \$11.95
 ★★★★★ (321)

Sponsored

 Dr Kadir Tropical Fruit Serum, 1-Flu...
 \$33.42 ~~\$59.95~~

Sponsored

 Alina Skin Care Enhanced Vitamin C Serum and Moisturizer with Hyaluronic Acid and Green & White Tea Extract

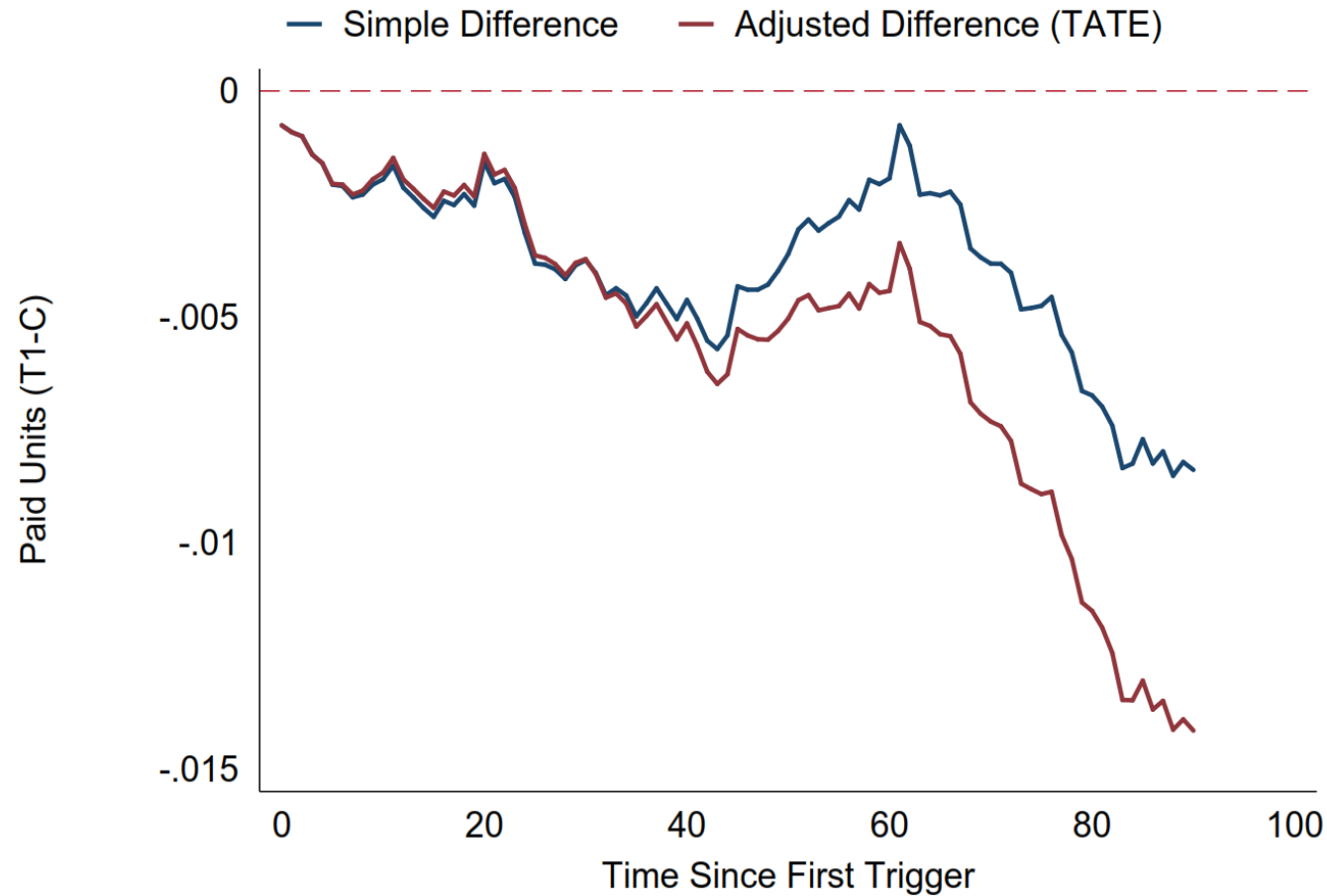
Sponsored

 Alice Nouveau Super C 25% Serum with Hyaluronic Acid + Vitamin C Effective Anti Wrinkle, Age Defying serum, Protect

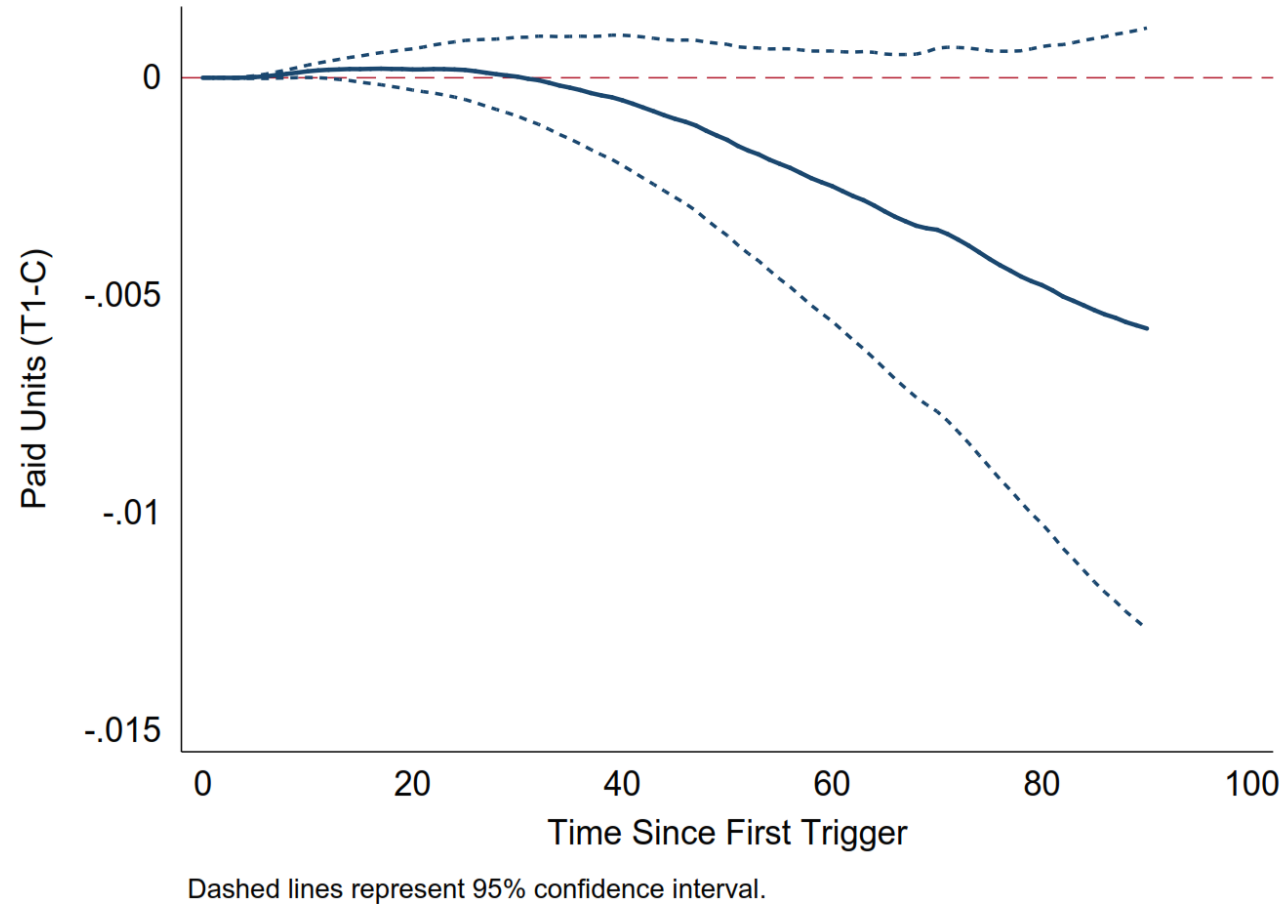
Sponsored

 Vitamin C Serum 1oz Pump Action Bottle with 25% Vitamin C Plus Hyaluronic Acid & Ferulic Acid with Additional

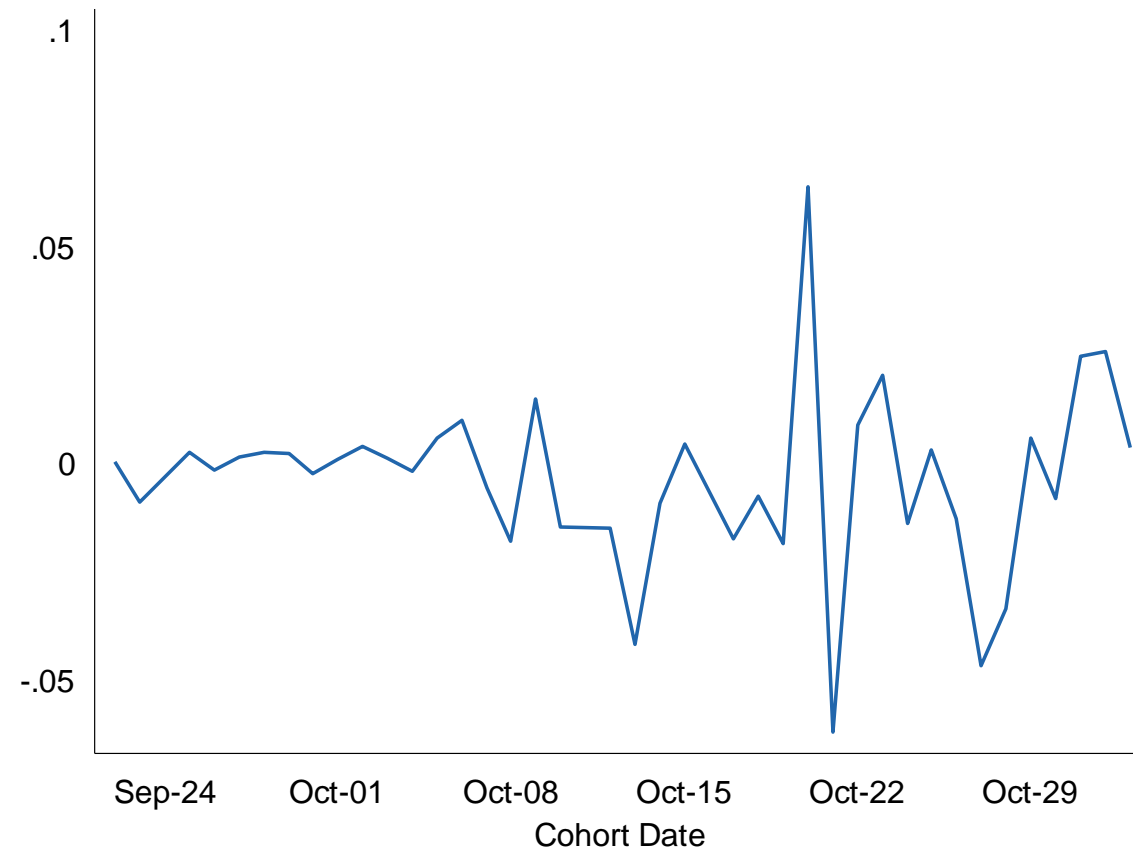
Estimates of Long-Term Cumulative Effect



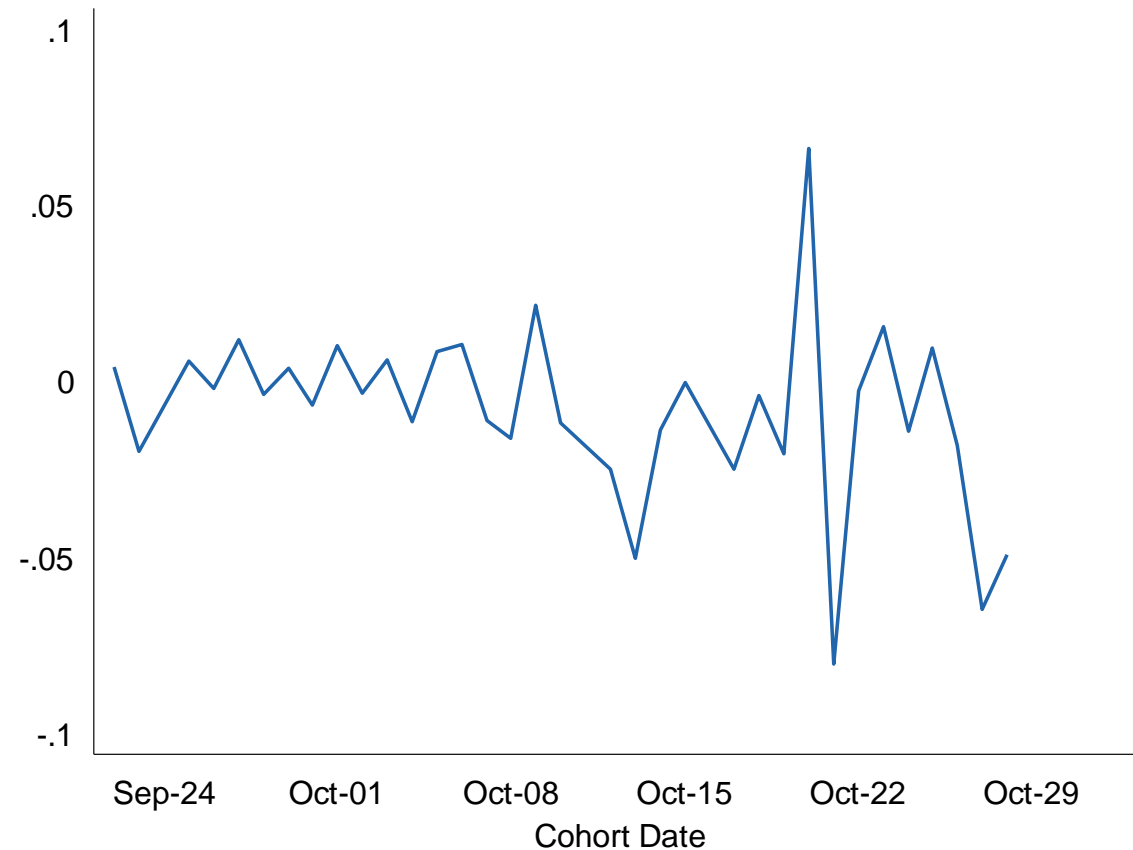
Difference between estimates of cumulative effect (Simple Difference - Adjusted Difference)



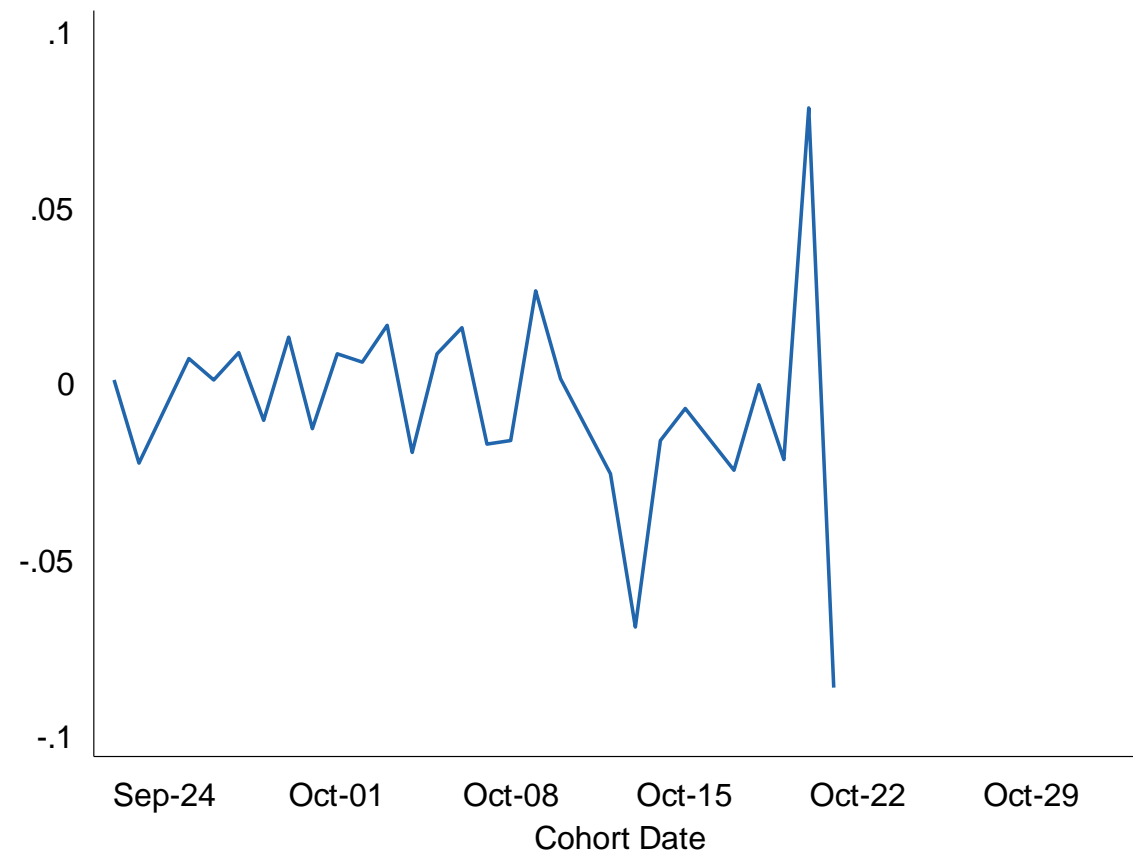
Validation: time constant effects assumption (1-Day Effects)



Validation: time constant effects assumption (7-Day Effects)



Validation: time constant effects assumption (14-Day Effects)



Future Work

- Improve estimation strategy to reduce variance
- Reduce noise using high-quality ML estimators
- Re-analyze more Weblabs
- Use long-term holdouts to validate
- Build as monitoring metric into APT/Weblab