Synthetic Control Analysis: Chicago PPLTT on ChatGPT Subscriptions

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1 Method

We estimate the effect of Chicago's 9% Personal Property Lease Transaction Tax (PPLTT) on ChatGPT subscriptions using synthetic control. The method constructs a weighted average of untreated ZIP3s to match Chicago on pre-treatment characteristics, then compares actual vs. synthetic outcomes post-treatment.

Matching variables:

- **Demographics (7 covariates):**
    - `pct_college`: % with bachelor's degree or higher
    - `pct_hh_100k`: % households earning $100k+
    - `pct_young`: % aged 18–34
    - `median_age`: median age
    - `median_income`: median household income
    - `pct_stem`: % in STEM occupations
    - `pct_broadband`: % with broadband internet

- **Pre-treatment outcomes (3 scalars):**
    - `pre_mean_early`: mean log(outcome) Mar–Jun 2023
    - `pre_mean_late`: mean log(outcome) Jul–Sep 2023
    - `pre_median_price`: mean of monthly median transaction price Mar–Sep 2023

Using pre-period means captures the outcome trend without overfitting to month-by-month noise. Pre-period price matching helps select donors with similar existing tax exposure.

Outcome: log(transactions in $15–$25 range) per ZIP3-month.

Implementation: Stata `synth` package (Abadie et al.).

2 Sample

- **Treated unit:** ZIP3 606 (Chicago)

- **Treatment date:** October 2023

- **Donor pool:** ~740 ZIP3s with complete panel and demographic data

- **Panel:** Constant individual panel (cardlinkids active in all 70-day windows)

- **Transaction filter:** $15–$25 (ChatGPT Plus subscription range)

- **Sample period:** March 2023 – November 2024

The $15–$25 filter captures ChatGPT Plus subscriptions ($20 + tax). Conditional on having at least one transaction in this range, the average user has 1.02 transactions per active month (1.03 in Chicago), consistent with monthly billing. However, from a user's first transaction to the end of the sample, only 0.59 of potential months have a transaction (0.57 in Chicago)—not everyone renews each period.
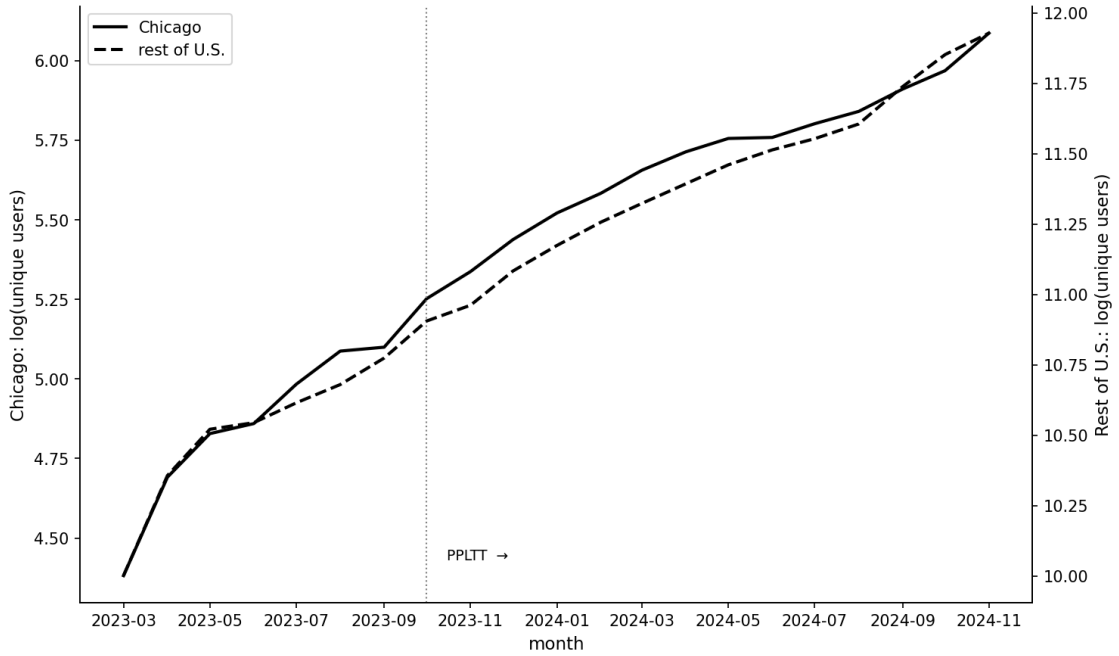

Figure 1: Raw trends: Chicago vs. rest of U.S. log(unique users). Vertical line marks October 2023 (PPLTT). Pre-trends differ, motivating synthetic control over a simple DiD.

3 Results

Table 1 reports the main synthetic control results.

Pre-treatment RMSPE (0.014) indicates good fit. The average post-treatment gap is -0.102 (≈10% reduction); the higher post-treatment RMSPE (0.125) reflects the widening gap over time visible in Figure 2.

4 Covariate Balance

Table 2 shows the covariate balance between Chicago and synthetic Chicago.

Metric	Value
Pre-treatment RMSPE (Mar–Sep 2023)	0.014
Post-treatment RMSPE (Oct 2023–Nov 2024)	0.125
RMSPE ratio (post/pre)	8.96
Average post-treatment gap	-0.102
Implied effect	-10%

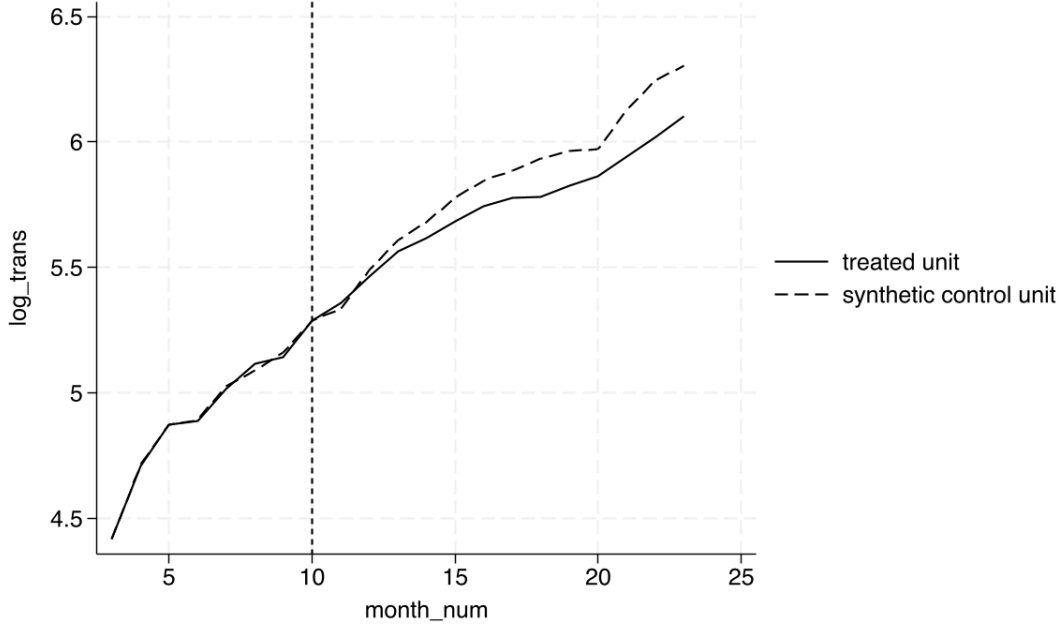Table 1: Synthetic control results for Chicago (ZIP3 606).

Figure 2: Chicago vs. synthetic control. Vertical line marks October 2023 (tax implementation). Output from Stata `synth` command.

5 Donor Weights

Table 3 shows the ZIP3s receiving positive weight in the synthetic control.

Figure 3 compares Chicago to the top donors over time.

6 Interpretation

The Chicago PPLTT reduced the number of unique ChatGPT Plus subscribers by approximately 10% relative to the synthetic counterfactual. This is the extensive margin effect—fewer distinct cardholders making subscription-priced transactions.

At a $20 subscription price, a 9% tax is $1.80/month. A 10% reduction in subscribers implies a demand elasticity on the order of -1, though this is rough given the level shift rather than continuous price variation.

Variable	Chicago	Synthetic
% college	41.0%	40.9%
% HH income >$100k	35.1%	35.0%
% ages 18–34	9.8%	9.9%
Median age	35.88	35.92
Median income	$74k	$74k
% STEM	43.1%	43.2%
% broadband	85.2%	85.3%
Log Transactions (Mar–Jun)	4.72	4.72
Log Transactions (Jul–Sep)	5.09	5.09
Median price (pre)	$20.11	$20.12

Table 2: Covariate balance for synthetic control.

ZIP3	Area	Weight
900	39.0%	Los Angeles, CA
303	26.2%	Atlanta, GA
588	7.9%	Rapid City, SD
288	7.6%	Asheville, NC
701	5.8%	Unknown
865	4.9%	Flagstaff, AZ
830	4.1%	Wyoming
828	2.2%	Unknown
803	1.8%	Columbia, SC

Table 3: Top donor ZIP3s for synthetic Chicago.

6.1 Identification Caveat: Manhattan Placebo

Running the synthetic control procedure on ZIP3 100 (Manhattan) as a placebo reveals a similar pattern: treated unit falls below its synthetic control post-treatment. New York State has taxed SaaS at approximately 8.5% continuously—there was no new tax in October 2023. Yet Manhattan exhibits a similar divergence pattern, placing it toward the high end of the placebo distribution.

Update (Jan 2026): A systematic scan of median transaction prices across all ZIP3s (March 2023 vs. November 2024) reveals Manhattan shows a +2.6% price increase—second only to Chicago's +5.7% (Figure 6). This price increase is consistent with OpenAI beginning to collect New York sales tax during the sample period, which would mean Manhattan is not a valid placebo. If so, Manhattan should be excluded from the donor pool (not yet implemented).

Three alternative explanations for big-city divergence:

1. **Big-city saturation**: Large cities may have adopted ChatGPT earlier and faster, saturating by late 2023.

2. **ChatGPT Enterprise**: OpenAI launched ChatGPT Enterprise in August 2023. If big-city employers began paying for employee subscriptions, those users would stop appearing in Consumer Edge data (personal credit card transactions).

3. **Synthetic construction**: No weighted combination of smaller areas can replicate big-city
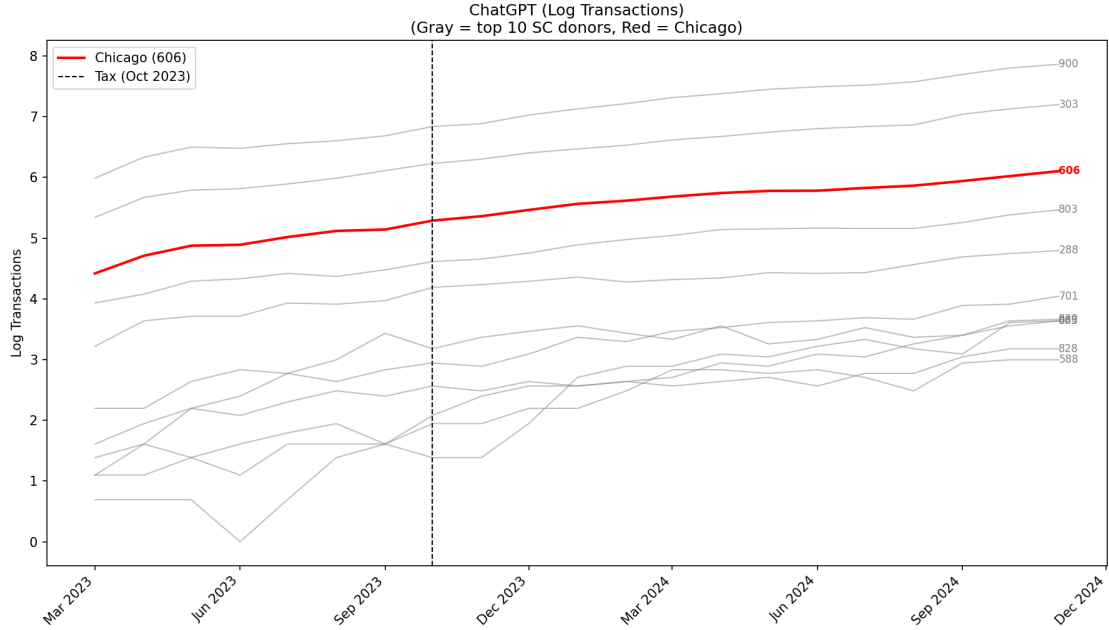
Figure 3: Log unique users: Chicago vs. top donor ZIP3s.

dynamics. Chicago tracks Manhattan because both face the same urban-specific shocks.

6.2 Price Pass-Through Evidence

While quantity effects face identification challenges, price pass-through is cleaner. Chicago's median transaction price jumps from \$20.11 to \$21.03 exactly at October 2023, while Manhattan (existing tax) shows no discrete jump. This confirms the tax is being passed through to Chicago consumers.

6.3 Placebo Check: ZIP3 077 (New Jersey Shore)

ZIP3 077 (Long Branch / Red Bank, NJ) produces an RMSPE ratio of 6.90, exceeding Chicago's 8.96. However, the direction differs: 077's post-treatment gap is *positive* (+0.115), meaning actual usage *exceeded* the synthetic control. Chicago's gap is negative (−0.118), meaning actual usage *fell below* the synthetic control.

Figure ?? shows flat median prices for 077 throughout the sample—no discrete tax-induced jump. The high RMSPE ratio reflects idiosyncratic positive shocks (perhaps local growth or demographic shifts), not a tax effect.

This pattern does not threaten our causal interpretation: 077's divergence is in the opposite direction from Chicago's. A true confounder would need to produce *negative* gaps in untreated areas around October 2023.

6.4 Placebo Inference

Figure 4 shows the spaghetti plot of placebo gaps for all ZIP3s with pre-treatment RMSPE within 2× of Chicago's. Chicago (solid black) diverges visibly below the placebo distribution post-treatment.
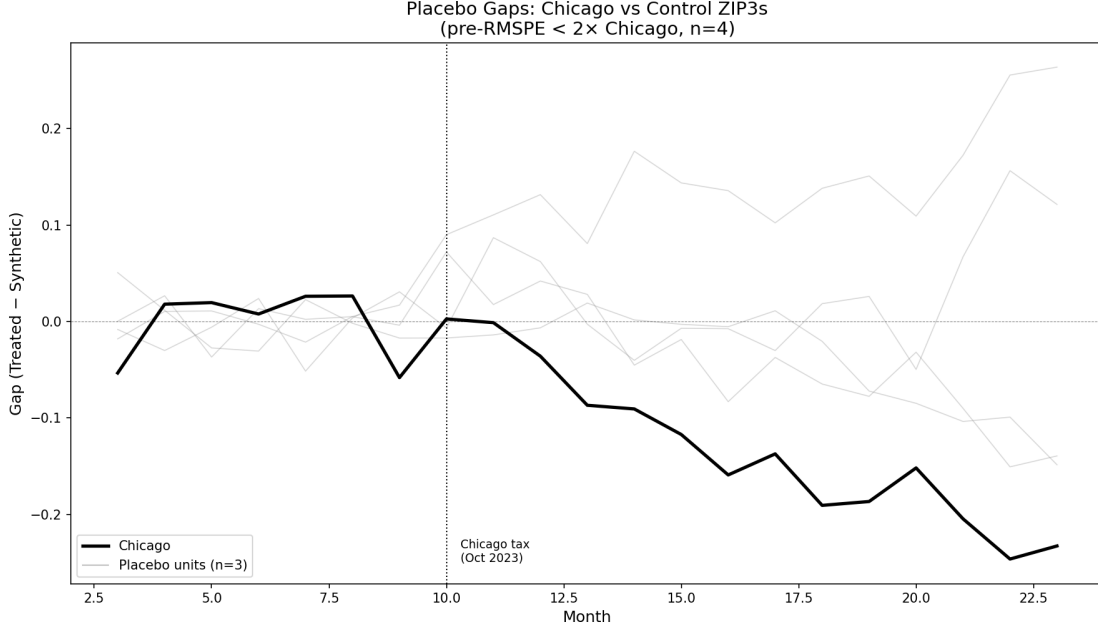
Figure 4: Placebo gaps for ZIP3s with pre-RMSPE $\leq 2\times$ Chicago's. Chicago is the solid black line; placebo units in gray.

Figure 5 shows the distribution of gap ratios (post-treatment gap / pre-treatment RMSPE) across placebo units.

6.5 Methodological Limitations

Compared to Abadie, Diamond, and Hainmueller's (2010) California smoking study, our setting raises concerns about overfitting. Abadie et al. use 38 control states and match on 6 covariates plus 3 pre-period outcome levels (cigarette sales in 1975, 1980, and 1988), drawing from a 19-year pre-treatment period (1970–1988). Their covariates—ln(GDP per capita), percent aged 15–24, retail cigarette price, and beer consumption—are chosen with clear theoretical justification for predicting cigarette demand.

We match on 10 covariates (7 demographics plus 3 pre-period outcome summaries) using only 7 pre-treatment months. Our donor pool contains ~740 ZIP3s, or 184 in the top-quartile restriction used for placebo inference. With fewer pre-periods and more potential donors relative to covariates, synthetic control has greater scope to find spurious matches.

Two specific concerns:

1. **Covariate selection**: Our demographic covariates (college attainment, income, broadband access, STEM employment) were chosen based on intuitions about ChatGPT adoption, not prior empirical validation. Abadie et al.'s covariates have established relationships to cigarette consumption.

2. **Pre-period length**: Collapsing 7 months into two averages (early/late) provides less information about outcome dynamics than matching on multiple years of pre-treatment data. Idiosyncratic shocks in our short pre-period may not average out.
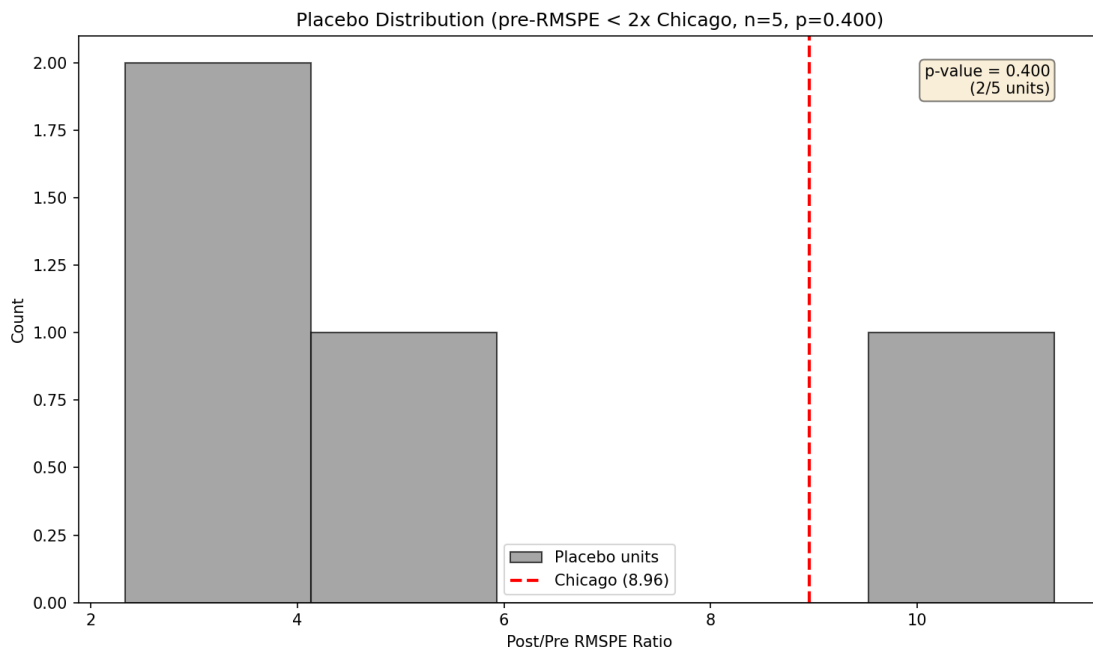
Figure 5: Distribution of gap ratios among placebo units (2× threshold). Chicago's gap ratio marked by vertical line.

7 Technical Notes

- **Constant panel:** Restricted to cardlinkids active in all 70-day windows throughout the sample period.

- **Demographics source:** ACS 5-year 2022 estimates, aggregated from ZCTA to ZIP3 using population weights.

- **Pre-period price matching:** Matching on pre-period median price helps select donors with similar existing tax exposure.

A Tax Detection Scan

B ZIP3 Reference

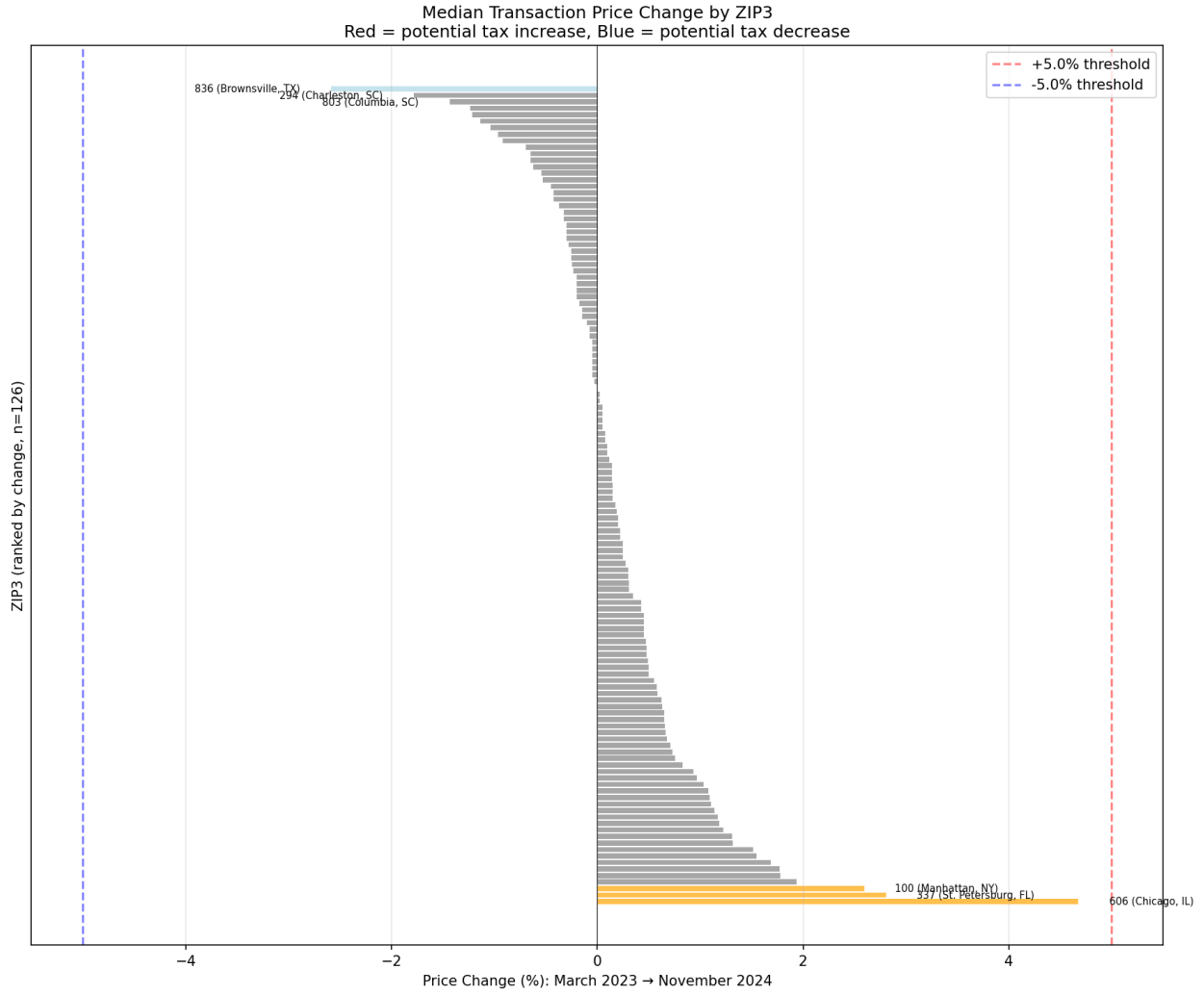For reference, key ZIP3 codes mentioned in this analysis:

Figure 6: Median transaction price change by ZIP3 (March 2023 to November 2024). Chicago (606) is the only ZIP3 exceeding the 5% threshold. Manhattan (100) shows $+2.6\%$, suggesting possible tax collection starting mid-sample. Full results in `zip3_price_changes.csv`.

ZIP3	Area
606	Chicago, IL (treated)
100	Manhattan, NY
077	Long Branch / Red Bank, NJ
069	Garden City / Long Island, NY
094	San Mateo / Silicon Valley, CA
174	Binghamton, NY
900	Los Angeles, CA
277	Raleigh, NC
303	Atlanta, GA

Table 4: ZIP3 codes referenced in this document.