A 500,000-Person Experiment Evaluating the Impact of Geographically-Targeted, High-Payoff Vaccine Lotteries

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Abstract

Lotteries have been shown to motivate behavior change in many settings. However, the value of large-scale, geographically-targeted lotteries as a policy tool for changing the behaviors of entire populations is a matter of heated debate. In mid-2021, we implemented a pre-registered, city-wide experiment in Philadelphia to test the effects of three, high-payoff (up to $50,000) geographically-targeted lotteries designed to motivate adult residents of Philadelphia to get vaccinated against COVID-19. All Philadelphia residents ages 18 and older were eligible for inclusion in each drawing but, if selected, could not accept a prize unless they had received at least one dose of a COVID-19 vaccine. In each drawing, residents of a randomly selected “treatment” zip code received half of the 12 lottery prizes (boosting their chances of a win to 50-100x those of other Philadelphians). This experimental design makes possible a causal estimate of the impact of vastly increasing people’s odds of winning a vaccine lottery. We estimate that the first treated zip code, which drew considerable media attention, may have experienced a small bump in vaccinations compared to control zip codes: vaccinations rose by an estimated 61 per 100,000 people (an 11% increase). Pooling results from all three zip codes treated over the course of our six-week experiment, however, we do not detect any overall benefits. This unsustained effect may be because media attention waned, salience of the lottery declined, or attitudes about vaccination became increasingly entrenched over time. Further, our 95% confidence interval provides an upper bound on the overall benefits of treatment in our study of 9%. Given that lotteries of this scale cost hundreds of thousands of dollars to implement, the lack of a substantial benefit from this experiment strengthens the policy case for other, more impactful ways to encourage health behavior change.

Significance Statement

Lotteries have been shown to motivate behavior change in many settings. However, the value of large-scale, geographically-targeted lotteries as a policy tool for changing the behaviors of entire populations is a matter of heated debate. To rigorously evaluate the value of such interventions, we designed and implemented a city-wide experiment in Philadelphia. We tested the effects of three, high-payoff (up to $50,000), geographically-targeted COVID-19 vaccine lotteries in the city. In each drawing, half of the prizes were earmarked for residents of a randomly selected “treatment” zip code, significantly raising the chances that residents from that zip code would win (by 50-100x relative to other Philadelphians). Boosting residents’ odds produced an estimated increase of 61 vaccinations per 100,000 people (an 11% lift) in the two weeks leading up to our heavily-advertised first drawing. However, when pooling results from all three zip codes treated over the course of our six-week experiment, we do not detect any overall benefits. This unsustained effect may be because media attention waned, salience of the lottery declined relative to other vaccination initiatives, or attitudes about vaccination became increasingly entrenched over time. These findings strengthen the policy case for other, more impactful ways to encourage health behavior change at scale.

Main Text

Vaccination is one of the most powerful tools available for improving public health *(1)*, and motivating higher rates of vaccination is currently a major global challenge *(2)*. One tactic that has rapidly risen from obscurity to prominence as a means of promoting vaccination in the face of a global pandemic is the vaccine lottery. Between May and July 2021, at least 21 U.S. states launched vaccine lotteries in an effort to boost inoculation rates against COVID-19, most with jackpots of a hundred thousand dollars or more *(3)*.

There was good reason for this: prior research with relatively modest rewards and samples of convenience shows that lottery incentives can change people's health decisions *(4-6)*. Lottery incentives attempt to capitalize on the finding that giving people a small chance at a large payoff can be a more cost-effective persuasion tool than providing direct payments for an action. This effectiveness stems from individuals' tendency to overweight small probabilities *(7-9)*, which leads them to overvalue their long odds of winning a lottery *(10)*. Alone and in combination with other strategies, lotteries have been used to successfully motivate weight loss *(11)*, physical activity *(12-13)*, adherence to medical treatments or protocols *(14-16)*, and the completion of health surveys or assessments *(17-18)*.

However, the impact of large-scale lotteries intended to promote policy-relevant health behavior change at scale remains relatively unknown. Such lotteries have rarely been conducted prior to COVID-19, and evaluations of vaccination lotteries to date have been forced to rely on comparisons between neighboring communities whose COVID-19 policies and underlying trends in vaccination differ in many ways *(19-22)*.

In this investigation, we carried out a pre-registered, city-wide experiment in Philadelphia designed to assess the effects of three, high-payoff (up to $50,000) local lotteries to motivate adult residents to get their first-dose of a COVID-19 vaccine. Specifically, we partnered with the City of Philadelphia[1] to launch the "Philly Vax Sweepstakes" in June 2021, which gave away nearly $400,000 in cash prizes to vaccinated Philadelphia residents over a six week period when three separate drawings were held (one every two weeks). The Sweepstakes included a novel experiment: the residents of three randomly selected Philadelphia zip codes were given 50 to 100 times higher odds of winning prizes than other Philadelphians, and this feature of the lottery was highlighted in all media communications. The three "treatment" zip codes in this experiment were chosen at random from a set of 20 prioritized Philadelphia zip codes with the lowest vaccination rates (comprising 587,508 adult residents), and half of the total prizes from each lottery drawing were allocated to a given treatment zip code.

Previous research suggests that giving people up to a 100-fold increase in the chance of winning a large cash prize should be highly motivating *(23-26)*. Here, we experimentally test the value of this geographically-targeted, lottery-based approach to incentivizing vaccination.

[1] The geographic bounds of the City of Philadelphia and Philadelphia County are identical.

Methods

Sweepstakes Design and Implementation

The Philly Vax Sweepstakes consisted of a series of three, high-payoff lotteries for nearly $400,000 in total prizes. Drawings were held every two weeks between June 7 and July 19, 2021. In each of the three drawings, 12 prizes were awarded to Philadelphia adults who had received a first dose of their COVID-19 vaccine: six $1,000 prizes, four $5,000 prizes, and two $50,000 “grand prizes”.

All adult residents of Philadelphia who received at least one dose of the COVID-19 vaccine were eligible to win a prize in the Philly Vax Sweepstakes. The sweepstakes drawing pool was seeded with the names and contact information for 1,064,805 Philadelphia adults from a purchased commercial database *(27)*. In addition, to ensure they were included, residents could actively register for the sweepstakes online at phillyvaxsweeps.com or by phone. Both registration channels were managed by a professional sweepstakes vendor, Universal Promotions, Inc. By the close of the Sweepstakes, 75,356 people (6% of adult Philadelphians) had actively registered (see Figure 1 for registration volume over time and Supplemental Materials for more on how the Sweepstakes was advertised). Winners’ names were drawn from a deduplicated database.

Residents whose names were drawn but who had not received their first dose of the COVID-19 vaccine before the day of the drawing were ineligible to claim a prize. We reached out to each resident whose name was drawn using all available contact information.[2] If proof of first-dose vaccination could not be verified by the jurisdiction in which a resident received their shot, a new name was drawn for that prize. By design, this feature of the lottery created the potential for regret *(11-18)*.

The experimental component of the Philly Vax Sweepstakes was designed as follows: the twenty Philadelphia zip codes with the lowest per capita vaccination rates as of May 27, 2021 (11 days before the sweepstakes) *(28)* were included in the experiment, and three Philadelphia zip codes were randomly selected from this set for “treatment,” defined as vastly increased odds of winning the sweepstakes. The other seventeen zip codes from this pool became “controls”. Each “treatment zip code” was announced two weeks before the drawing in which its residents would have heightened odds of winning prizes, and residents of this zip code enjoyed 59 to 98 times higher chances of winning a prize for that drawing (depending on the zip code’s population) compared to other Philadelphians. Specifically, each resident in the first treated zip code (19126) had a 1 in 2,081 chance of winning, or 98 times the chances of residents in other parts of Philadelphia (1 in 203,542). Each resident in the second treated zip code (19133) had a 1 in 3,304 chance of winning, or 61 times the chances of residents in other parts of Philadelphia (1 in 202,307). Finally, each resident in the third treated zip code (19142) had a 1 in 3,427 chance of winning, or 59 times the chances of residents in other parts of Philadelphia (1 in 202,184). Our experiment’s design 1) allowed us to causally evaluate the impact of increasing some Philadelphians’ chances of winning and 2) targeted more lottery resources toward underserved communities.

The Philly Vax Sweepstakes officially launched on Monday, June 7, 2021, with a press conference featuring the Mayor of Philadelphia and the announcement of the first treatment zip code. Following the

Monday, June 7th announcement of the first treatment zip code, a new treatment zip code was randomly selected fortnightly and announced on the Philly Vax Sweepstakes website, with the second treatment zip code announced on Monday, June 21st and the third announced on Tuesday, July 6th (Monday, July 5th was a national holiday).

On the day the sweepstakes was announced (June 7th), it was a featured story on at least 5 local news channels *(29-33)*, and it was a front-page story in the most prominent local newspaper, the *Philadelphia Inquirer (34)*, on June 8th. Over 35 different news outlets published original stories about the Sweepstakes at some point during the six-week program (see Supplemental Materials Table S1 for the full list of news articles), which ended with the third and final drawing of winners on Monday, July 19th. Sixty-two percent of those stories were published during the first treatment period, 29% were published during the second treatment period, and 9% were published during the third treatment period.

The sweepstakes was marketed by the City of Philadelphia through twice weekly press releases, Nextdoor posts, text messages from the emergency information notification system, automated phone calls, a press conference announcing the first round winners, and a press release with quotes from the second round winners. There were also radio advertisements on Philadelphia's two largest Hip Hop and R&B stations and emails and text messages to patients about the lottery from Penn Medicine, a large, regional health system (see Supplemental Materials for more information about how and when the Sweepstakes was advertised).

Google search trends data for "Philly Vax Sweepstakes" indicates that considerably greater attention was focused on the Philly Vax Sweepstakes immediately following its launch on June 7, 2021 compared to later in the summer (see Supplemental Materials Figure S3).

Participants

The 20 zip codes included in our experiment included 587,508 adult Philadelphians and these zip codes had an average vaccination rate of 33% prior to the start of the Philly Vax Sweepstakes (i.e., as of June 6, 2021). Figure 2 shows a map of Philadelphia and its surrounding counties, highlighting the locations of our three treatment zip codes in Philadelphia – 19126, 19133, and 19142 – and our seventeen control zip codes. These treatment and control zip codes comprised the twenty Philadelphia zip codes with the lowest per capita vaccination rates as of May 27, 2021. Table 1 provides summary statistics on the demographic composition of residents of these communities as well as the percent of each population with at least one COVID-19 vaccination dose prior to the start of the Philly Vax Sweepstakes.

Data and Measures

Our primary outcome was the number of first-dose vaccinations of adults ages 18 and older in the zip code of interest each week per 100,000 people.[3] We calculated weekly vaccinations per 100,000 people by dividing the total first-dose vaccinations for adults in the geography of interest for a given week by the total adult population in that region according to the American Community Survey *(35)* and then

multiplying by 100,000. First-dose vaccinations included first doses of the Moderna and Pfizer vaccines as well as the single-dose Johnson & Johnson vaccine. The number of weekly first-dose vaccinations in each Philadelphia zip code for residents ages 18 and older was provided by the Philadelphia Department of Public Health *(36)* on August 18, 2021.

Analysis

We evaluated the impact of our geographically targeted lottery treatment using difference-in-differences analyses comparing weekly vaccinations per 100,000 adult residents over time. Specifically, to evaluate the impact of "treating" three zip codes with vastly increased odds of a prize, we compared the difference in vaccination rates between each of our treatment zip codes and our control zip codes before versus during the two-week period of the sweepstakes when a particular treatment zip code had higher odds of winning. In our Supplemental Materials, we also present an attempt to evaluate how the Philly Vax Sweepstakes affected vaccinations in Philadelphia County, overall, versus other Pennsylvania counties.

Prior to implementation, the design for the Philly Vax Sweepstakes was reviewed and approved by the institutional review boards (IRBs) of the University of Pennsylvania and the City of Philadelphia. Our study's analysis plan was also pre-registered at osf.io/gxsa4.

[2] Residents had at least 48 hours to claim their prize after being successfully contacted. If they did not, or if they could not be successfully contacted after all available means were exhausted, a new name was drawn.

[3] We focused on individuals who were 18 years old or older when calculating the vaccination rate because individuals had to be at least 18 years old to participate in the Philly Vax Sweepstakes.

Results

Effect of the Sweepstakes on Treatment Zip Codes vs. Control Zip Codes

To evaluate the impact of randomly assigning the residents of certain Philadelphia zip codes to have 50 to 100x other Philadelphians' chances of winning our vaccine lottery, we compared the difference in weekly first-dose vaccinations per 100,000 people in each of our three treatment zip codes and in each of our 17 control zip codes. We did this comparison before versus during the two weeks leading up to a drawing when treatment zip code residents had vastly elevated odds of winning (73 times higher than those residing in the control zip codes, on average). Because calculating standard errors in difference-in-differences regressions when there is a limited number of clusters poses challenges *(37)*, we begin by visualizing raw weekly vaccination data for each of the treatment zip codes during their treatment period. As shown in Figure 3, Panels A and B, there was an initial, albeit unsustained uptick in vaccinations of roughly 40% (from a pre-sweepstakes baseline of 569 per 100,000 people) in the first treatment zip code (19126) following the announcement of the Sweepstakes compared to the control zip codes. However, as shown in Figure 3, Panels C and D, the second treatment zip code (19133) did not experience any such

uptick compared to our control zip codes. Neither did the third treatment zip code (19142), as shown in Figure 3, Panels E and F.

To statistically model the data visualized in Figure 3, for each of our three treatment zip codes, we estimated a separate OLS regression predicting weekly first-dose adult vaccinations per 100,000 people in that zip code and all control zip codes. Our predictor variables were zip code fixed effects, week fixed effects, and an indicator variable that took on a value of 1 for the two weeks when Philadelphians in the treatment zip code in question had higher odds of winning a prize.

The difference-in-differences literature has emphasized the importance of clustering standard errors at the geographic level *(37)*. However, these standard errors can be biased when the number of clusters is small *(38)*. In fact, our empirical approach is in some ways more akin to an event-study than a traditional difference-in-differences design given the small number of clusters. For event studies, it is common to cluster standard errors by time to account for correlations across time for the different geographic units. In an attempt to be conservative in how we estimate standard errors, we run each model three times and report the standard errors produced when clustering by week, clustering by zip code, and using simple robust standard errors, noting that the model with the largest standard errors is the most conservative. This approach has been used by other researchers *(39)*.

Table 2, Models 1 to 3 report the regression-estimated effects of the treatment on the first, second, and third treatment zip codes, relative to our 17 control zip codes. We also conducted equivalence tests, using a one-sided t-test procedure on the upper bound *(40-41)*, for each estimated treatment effect. The upper bound was based on the assumption that any increase in vaccination that cost more than $1,000 per dose might not be worthwhile (following a discussion of $1,000 payments for COVID-19 vaccination in *(42)*; see Supplemental Materials for the calculations that gave us each equivalence bound, which depended on a zip code's population). Model 1 shows that the first treatment zip code (19126) experienced an estimated increase of 61 vaccinations per 100,000 residents (or 11%) in the two weeks of the relevant treatment period (the two weeks leading up to a drawing in which residents of this treatment zip code had 98 times other Philadelphians' chances of winning a prize; most conservative 95% CI: [-67; 188], p=0.350 and least conservative 95% CI: [18;103], p=0.008). An equivalence test performed on our most conservative model allows us to reject the null that our treatment effect generates more than 250 additional vaccinations per 100,000 people, or one vaccine per $1,000 spent ($t(250)=4.501$, p=0.000).

The second treatment zip code (19133) experienced an insignificant increase of 19 vaccinations per 100,000 people in the two weeks of the relevant treatment period (the two weeks leading up to the drawing in which its residents would have 61 times other Philadelphians' chances to win; most conservative 95% CI: [-87; 125], p=0.728 and least conservative 95% CI: [-17;55], p=0.288). An equivalence test performed on our most conservative model allows us to reject the null that our treatment effect generates more than 156 additional vaccinations per 100,000 people, or one vaccine per $1,000 spent ($t(156)=3.057$, p=0.001).

Finally, the third treatment zip code (19142) experienced a decrease of 102 vaccinations per 100,000 people during its two-week treatment period (the two weeks leading up to a drawing in which residents of this treatment zip code would have 59 times other Philadelphians' chances of winning a prize; most conservative 95% CI: [-276; 73], p=0.253 and least conservative 95% CI: [-175;-28], p=0.010).[4] An equivalence test performed on our most conservative model allows us to reject the null that our treatment effect generates more than 151 additional vaccinations per 100,000 people, or one vaccine per $1,000 spent ($t$(151)=2.673, p=0.004).

Notably, the vast majority of media attention and manual registrations for the sweepstakes occurred prior to the first-round drawing. Seventy-one percent of active registrants (or 4% of adult Philadelphians) registered in the two weeks leading up to the first of the three drawings, which was the period when the sweepstakes received the most press coverage (see Supplemental Materials Table S1). The remaining 2% of Philadelphia adults who registered for the Sweepstakes did so over the remaining four weeks, as shown in Figure 1. As shown in Figure 4, Panel A, 5.59% of adult residents of the first treated zip code (19126) registered for the Philly Vax Sweeps in the two weeks leading up to the first drawing compared with 2.74% of adult residents of control zip codes (z=19.081, p<0.001), a difference of 2.85%. However, registrations from subsequent treatment zip codes were far lower, with a smaller absolute gap in registration emerging between treatment zip code residents and control zip code residents. As shown in Figure 4, Panel B, 1.17% of adult residents of the second treated zip code (19133) registered in the two weeks leading up to the second drawing compared with 0.55% in control zip codes (z=11.310, p<0.001), for a difference of 0.62%. As shown in Figure 4, Panel C, 1.75% of adult residents in the third treated zip code (19142) registered in the two weeks leading up to the third drawing compared with 0.62% in control zip codes (z=19.602, p<0.001), for a difference of 1.13%. Overall, we saw the most registrants during the treatment period in the treatment zip code in the first treatment zip code (5.59%) – a number that dwarfed registrations in the treatment zip codes during both the second (1.17%; z=23.139, p<0.001) and third treatment periods (1.74%; z=19.261, p<0.001).

In Table 2, Model 4 we present a prespecified pooled model assessing the combined effect of all three treatment periods on all three treatment zip codes. The pooled vaccination rate in treatment zip codes in the two weeks following the announcement of their elevated chances to win declined by an insignificant 4 vaccinations per 100,000 people compared to control zip codes during the same time period (most conservative 95% CI: [-99; 92], p=0.936 and least conservative 95% CI: [-79;71], p=0.924). An equivalence test performed on our most conservative model allows us to reject the null that our treatment effect generates more than 186 additional vaccinations per 100,000 people, or one vaccine per $1,000 spent ($t$(186)=3.942, p= 0.000).

[4] We tested for violations of the parallel trends assumption inherent in each of these difference-in-difference models by adding interactions between dummies for each week and an indicator for the relevant treatment zip code to a given regression model. We then examined the significance of the coefficient estimates on the pre-treatment interaction terms and conducted an F-test of their joint significance. In the first treatment zip code (19126) the coefficients on individual interaction terms and on

the joint F-test were all insignificant (all p's≥0.383), suggesting that we can't reject parallel trends leading up to the treatment period for the first treatment zip code. In the second treatment zip code (19133) the coefficients on individual interaction terms and on the joint F-test did not reach standard levels of significance (all p's≥0.081), which once again suggests that we can't reject parallel trends leading up to the treatment for the second treatment zip code. In the third selected treatment zip code (19142), the coefficient on the interaction term between the week ending on 6/13 and the treatment zip code is significant (p≤0.015) and the joint F-test also reveals significant differences in pre-treatment trends (p=0.020). This suggests we can reject parallel trends leading up to the treatment of the third treatment zip code and suggests extra caution with regards to the parallel trends assumption that is invoked when doing this difference-in-difference estimation.

Discussion

Our study presents a unique experimental evaluation of the benefits of large-scale, geographically targeted lotteries as a public policy tool to change citizens' behaviors. Overall, the findings from our experiment with a COVID-19 vaccination lottery suggest that when residents are given ~100x the chances of their neighbors in other zip codes to win up to $50,000 in prizes for getting a vaccine (roughly 1 in 2,000 odds) and when this makes the front page of the local newspaper and is featured on the local nightly news, it may generate a very small boost in vaccinations. Specifically, our first treatment zip code, which benefited from far more media coverage than subsequently announced treatment zip codes, saw an estimated 11% uptick in vaccination in the two weeks leading up to a drawing. In this zip code of 12,485 adult residents (see Table 1), our lottery produced an estimated 15 extra vaccinations over two weeks at a marginal cost of roughly $62,376 or $4,158 per vaccination (an exorbitant price-tag).[5] No other treated zip code experienced any benefits (other treatment effects were neutral to negative and equivalence tests allowed us to reject the null hypothesis that any of our treatments increased vaccinations for a price tag of $1,000 per person or less). Pooling across treated zip codes, we can tightly bound the upside of geographically-targeted vaccine lotteries across our study: the upper bound on the effect of "treating" a zip code from our most conservative 95% confidence interval is a 9% boost in vaccination rates for two weeks.[6]

This study builds on past research by experimentally evaluating a series of geographically-targeted vaccine lotteries at a uniquely large scale, encompassing over 500,000 Philadelphia residents in under-vaccinated communities (or well over 1,000 times as many participants as typical in past experiments with lotteries and health behavior change; *11-18)*. A major difference between our studies and past experimental research on lottery incentives was likely the degree to which lottery participants were aware of the incentives they faced, and our results tentatively suggest that awareness or salience may play a crucial role in the impact of lottery incentives.[7]

Our study has several limitations worth noting. First, our sample (Philadelphia residents) is not representative of the broader U.S. population, let alone the global population. Second, we cannot directly

compare how well geographically-targeted lotteries perform relative to other policy tools, nor can our results rule out the possibility that geographically-targeted lotteries with substantially larger jackpots might have had more robust, positive effects. Similarly, we cannot rule out the possibility that enhanced local marketing or coordination with community health organizations could have improved the results of our geographically-targeted lotteries or that offering lottery incentives only to those who had not yet made a vaccination decision could have increased their potency (albeit raising valid fairness concerns). We further cannot compare how well geographically-targeted lotteries would have worked earlier in the vaccine rollout, when individuals' motivations may have differed.[8] Finally, we cannot control for the potential that larger, state-wide jackpots across the nation may have created a reference point that psychologically diminished the impact of our smaller jackpot.

Though we focused on the undervaccinated in selecting our 20 treatment-eligible zip codes, we likely underestimated the reasons many had not been vaccinated and what would genuinely encourage them to be vaccinated. Our results suggest that people require more than a financial reward to be persuaded to vaccinate. Seeking input from trusted leaders in the treatment zip codes might have helped us better inform residents of these communities about the sweepstakes, understand their reluctance around vaccines, and increase vaccination rates, while contributing to efforts to mitigate the impact of the pandemic.

Despite its limitations, this pre-registered experiment gave us the opportunity to causally evaluate the benefits of concentrating rewards in undervaccinated "treatment" zip codes. To our knowledge, no other vaccine lottery has incorporated experimentation of any kind, and doing so made possible a very precise estimate of the limited effect of geographic-targeting.[9]

We found that giving residents of certain zip codes massively higher odds of winning did not meaningfully alter their vaccination decisions, and we estimate a fairly tight 9% upper bound on the benefits of such treatments. We add to a growing literature on vaccine lotteries, with implications for policymakers seeking behavior change at scale whether in the context of COVID-19 or other health-promoting activities. As the COVID-19 pandemic continues to evolve, we hope that demonstrating the limited effectiveness of our three, zip-code targeted vaccine regret lotteries will encourage policymakers to look for other, more impactful ways to encourage vaccination.

[5] The lottery produced an estimated 61 extra vaccinations per 100,000 people per week for two weeks. In a population of 12,485, that translates to 15 extra vaccinations = (12,485/100,000)*61*2. The $63,000 in lottery prizes allocated to the 1,229,325 eligible adult Philadelphians outside of the treatment zip code during the first two weeks of the Philly Vax Sweeps (see Table 1) cost an average of $0.05 per person to deploy = $63,000/1,229,325. Offering those incentives to the 12,485 Philadelphians in our treatment zip code would have cost $624 = $0.05*12,485, but instead we offered them $63,000 in prizes at a marginal cost of $62,376 or $4,158 per vaccination = $62,376/15.

[6] The 95% CI in our treatment zip codes bounds the effects between reducing weekly vaccinations by 93 per 100,000 people to increasing weekly vaccinations by 85 per 100,000 people.

[7] This might have been alleviated had actual, physical lottery tickets been handed out to all citizens.
[8] Consistent with this possibility, recent work by Rabb et al. (2021) *(43)* suggests that text reminders to get a COVID-19 vaccine may have been less potent in later stages of the vaccine rollout than they were at earlier stages *(44)*.
[9] Like other recent papers that have attempted to pinpoint the effects of vaccine lotteries without the benefit of experimental designs, we struggled to generate a reliable estimate of the overall impact of the Philly Vax Sweepstakes on Philadelphia County compared with surrounding and comparable counties, but we present pre-registered, inconclusive results from our attempts to do so in our Supplemental Materials.

Declarations

DATA AVAILABILITY

All data and analysis scripts have been deposited in the Open Science Framework (https://osf.io/gxsa4/).

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Competing Interest Statement: Dr. Kevin G. Volpp is a part owner of VAL Health, a behavioral economics consulting firm.

References

1. C. M. Rodrigues & S. A. Plotkin, Impact of vaccines; Health, economic and Social Perspectives. Frontiers in Microbiology, 11 (2020).
2. J. S. Solís Arce, et al., Covid-19 vaccine acceptance and hesitancy in low- and middle-income countries. Nature Medicine, 27(8), 1385–1394 (2021).

3. H. Thirumurthy, K. L. Milkman, K. Volpp, A. Buttenheim, & D. G. Pope, Association between Statewide Financial Incentive Programs and COVID-19 Vaccination Rates (2021). Available at SSRN: https://ssrn.com/abstract=3912786
4. K.G. Volpp, D.A. Asch, R. Galvin, & R. Loewenstein, Redesigning employee health incentives–lessons from behavioral economics. The New England journal of medicine 365(5), 388–390 (2011).
5. G. Loewenstein, D.A. Asch, K.G. Volpp, Behavioral economics holds potential to deliver better results for patients, insurers, and employers. Health Aff (Millwood) 32(7), 1244-50 (2013).
6. J. B. Kessler & C.Y. Zhang, Behavioral economics and health. Paper for Oxford Textbook of Public Health (2014).
7. C.R. Sunstein, Probability neglect: Emotions, worst cases, and law. The Yale Law Journal 112(1), 61-107 (2002).
8. C. Ungemach, N. Chater, & N. Stewart, Are probabilities overweighted or underweighted when rare outcomes are experienced (rarely)?. Psychological Science 20(4), 473-479 (2009).
9. R. Hau, T.J. Pleskac, & R. Hertwig, Decisions from experience and statistical probabilities: Why they trigger different choices than a priori probabilities. Journal of Behavioral Decision Making 23(1), 48-68 (2010)
10. D. Kahneman, & A. Tversky, Prospect Theory: An Analysis of Decision under Risk. Econometrica 47(2), 263-291 (1979).
11. K. G. Volpp, et al. Financial incentive–based approaches for weight loss: a randomized trial. JAMA, 300(22), 2631-2637 (2008).
12. M. S. Patel, et al., A randomized trial of social comparison feedback and financial incentives to increase physical activity. American Journal of Health Promotion 30(6), 416-424 (2016).
13. M. S. Patel, et al., A randomized, controlled trial of lottery-based financial incentives to increase physical activity among overweight and obese adults. American Journal of Health Promotion 32(7), 1568-1575 (2018).
14. S. E. Kimmel, et al. Randomized trial of lottery-based incentives to improve warfarin adherence. American heart journal 16(2), 268-274 (2012).
15. D. A. Asch, et al. Effect of financial incentives to physicians, patients, or both on lipid levels: a randomized clinical trial. JAMA 314(18), 1926-1935 (2015).
16. S. A. Husain, et al. Behavioral economics implementation: regret lottery improves mHealth patient study adherence. Contemporary clinical trials communications 15, 100387 (2019).
17. E. Haisley, K.G. Volpp, T. Pellathy, & G. Loewenstein, The impact of alternative incentive schemes on completion of health risk assessments. American Journal of Health Promotion 26(3), 184-188 (2012).
18. K. H. Chaiyachati, et al. Improving longitudinal survey participation among internal medicine residents: incorporating behavioral economic techniques and avoiding Friday or Saturday invitations. Journal of general internal medicine 34(6), 823-824 (2019).

19. D. Dave, A. I. Friedson, & B. Hansen, Association Between Statewide COVID-19 Lottery Announcements and Vaccinations, JAMA, 326(8), 766-767 (2021).
20. M. E. Brehm, P. A. Brehm, & M. Saavedra, The Ohio Vaccine Lottery and Starting Vaccination Rates. Technical Report, 345 (2021).
21. D. Lang, L. Esbenshade, & R. Willer, Did Ohio's Vaccine Lottery Increase Vaccination Rates? A Pre-Registered, Synthetic Control Study (2021).
22. A.J. Walkey, A. Law, & N. A. Bosch, Lottery-Based Incentive in Ohio and COVID-19 Vaccination Rates. JAMA (2021).
23. D. Prelec, The Probability Weighting Function. Econometrica 66(3), 497-527 (1998).
24. J. Lewis & J. P. Simmons, Prospective Outcome Bias: Incurring (Unnecessary) Costs to Achieve Outcomes That Are Already Likely. Journal of Experimental Psychology: General (2019).
25. R. Gonzalez & G. Wu, On the Shape of the Probability Weighting Function. Cognitive Psychology 38(1), 129-166 (1999).
26. P. Slovic & S. Lichtenstein, Relative importance of probabilities and payoffs in risk taking. Journal of Experimental Psychology 78(3), 1-18 (1968).
27. Databases, Sales Leads, Email Services, Mailing Lists, Data Analytics & Enhancement. DatabaseUSA, https://databaseusa.com/ (2021).
28. COVID-19 Vaccinations. OpenDataPhilly, www.opendataphilly.org/dataset/covid-vaccinations (2021).
29. D. Stamm, Philly to Give $50,000 in Cash to Residents in COVID 'Vax Sweepstakes', NBC 10 Philadelphia, https://www.nbcphiladelphia.com/news/coronavirus/philly-giving-away-multiple-50000-cash-prizes-in-vax-sweepstakes/2839533/ (2021).
30. S. Wilson, Philly Vax Sweepstakes: City giving vaccinated residents a chance to win up to $50K. FOX 29 Philadelphia, https://www.fox29.com/news/philadelphia-announces-50000-sweepstakes-for-covid-19-vaccinations (2021).
31. Philadelphia offers prizes up to $50,000 as incentive for residents to get COVID vaccine. 6ABC, https://6abc.com/10757437/ (2021).
32. 36 Fully Vaccinated Philadelphians To Win Up To $50,000 Through New Philly Vax Sweepstakes Program. CBS Philadelphia, https://philadelphia.cbslocal.com/2021/06/07/philly-covid-19-vaccine-program-sweepstakes/ (2021).
33. Philadelphia to give away big bucks in vaccine sweepstakes. PHL17, https://phl17.com/phl17-news/philadelphia-to-giveaway-big-bucks-in-vaccine-sweepstakes/ (2021).
34. L. McCrystal, Philadelphia residents could now win as much as $50,000 for getting the COVID-19 vaccine, The Philadelphia Inquirer, https://www.inquirer.com/health/coronavirus/vaccine-sweepstakes-cash-drawing-prize-philadelphia-covid-20210607.html (2021).
35. American Community Survey (ACS). United States Census Bureau, https://www.census.gov/programs-surveys/acs (2019).

36. Data | Department of Public Health. City of Philadelphia, https://www.phila.gov/departments/department-of-public-health/data/ (2021).
37. M. Bertrand, D. Esther, & M. Sendhil, How Much Should We Trust Differences-in-Differences Estimates? Quarterly Journal of Economics 119(1), 249-275 (2004).
38. S. Cunningham, Causal Inference: The Mixtape (Yale University Press, New Haven, CT, 2021), pp. 424.
39. D. Arindrajit, K. Ethan, & N. Suresh, Coups, Corporations, and Classified Information, The Quarterly Journal of Economics 126(3), 1375–1409 (2011).
40. H.I. Patel, & G.D. Gupta, A Problem of Equivalence in Clinical Trials, Biometrical Journal 26(5), 471-474 (1984).
41. D. Lakens, Equivalence Tests: A Practical Primer for t Tests, Correlations, and Meta-Analyses, Social Psychological and Personality Science 8(4), 355-362 (2017).
42. E.A. Largent, F.G. Miller. Problems With Paying People to Be Vaccinated Against COVID-19. JAMA, 325(6), 534–535 (2021)
43. N. Rabb, et al. Text messages do not increase COVID-19 vaccination four weeks after universal eligibility. Available at: https://osf.io/cg3nt/ (2021).
44. H. Dai, et al. Behavioral Nudges Increase COVID-19 Vaccinations. Nature (2021).

Tables

Table 1. Population Summary Statistics for Philadelphia County and for Zip Codes of Interest.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	First Doses per 100k People Week of 5/31-6/6/2021	**Percent with At Least One Dose as of 5/27/2021**	**No. of 18+ Residents**	**% White**	**% Black**	**% Asian**	**% Hispanic**	**% Over Age 65**	**Median Household Income**
Philadelphia County	1,419	64%	1,241,810	34%	40%	8%	15%	14%	$47,474
Treatment Zip Code #1 (19126)	569	40%	12,485	6%	81%	3%	5%	18%	$44,006
Treatment Zip Code #2 (19133)	1,165	30%	19,824	3%	35%	1%	58%	9%	$20,353
Treatment Zip Code #3 (19142)	1,065	30%	20,565	6%	82%	8%	2%	9%	$33,265
All 3 Treatment Zip Codes	985	33%	52,874	5%	64%	4%	24%	11%	$32,541
All 17 Control Zip Codes	877	34%	534,634	21%	51%	5%	20%	13%	$39,913
All 20 Zip Codes Eligible for Treatment	886	33%	587,508	20%	52%	5%	20%	12%	$38,808

Note. Zip code-level first dose data was provided by the Philadelphia Department of Public Health as of June 6, 2021 *(36)*; and Zip code-level "at least one dose" data was downloaded from OpenDataPhilly on May 27, 2021 *(28)*. ZIP code-level first dose vaccination data pertains to the 18 and over population. The Zip code level "at least one dose" vaccination data reflects the total population. Columns 3-9 and all population data come from the 2019 American Community Survey *(35)*. Columns 4-8 reflect the percentages of each respective variable relative to the total population. Column 9 presents the median

household income for each unique geography, and the average of those medians where geographies are pooled.

Table 2. Regression-estimated Impact of Being Selected as a Treatment Zip Code in the Philly Vax Sweepstakes on Weekly First-Dose COVID-19 Vaccinations per 100,000 People.

	Model 1			Model 2			Model 3			Model 4		
Clustered Standard Errors by…	Zip	Week	N/A	Zip	Week	N/A	Zip	Week	NA	Zip	Week	N/A
Treatment Zip Code #1 During Treatment (19126)		61										
	(20)**	(38)	(65)									
Treatment Zip Code #2 During Treatment (19133)					19							
				(17)	(48)	(54)						
Treatment Zip Code #3 During Treatment (19142)								-102				
							(35)**	(66)	(89)			
Treatment Zip Codes During Treatment (Pooled)											-4	
										(40)	(45)	(45)
Treatment Zip Evaluated		19126			19133			19142			3 Zips Pooled	
No. of clusters	18	15	0	18	15	0	18	15	0	20	15	0
Observations		270			270			270			300	
R-squared		0.93			0.93			0.93			0.93	

Note. This table reports a series of difference-in-differences models relying on ordinary least squares regressions to predict a zip code's weekly first-dose COVID-19 vaccinations per 100,000 for adult residents. The predictor variables in each regression include zip code fixed effects, week fixed effects, an indicator that takes on a value of 1 when a treatment zip code of interest was eligible for rewards and 0 otherwise, and an indicator that takes on a value of 1 in the weeks after a treatment zip code of interest was eligible for rewards and 0 otherwise. Standard errors have been estimated clustered by zip code (first), clustered by week (second) and robustly without clustering (third) for all four models and are reported in parentheses. +p<0.10; *p<0.05; **p<0.01; ***p<0.001.

Figures

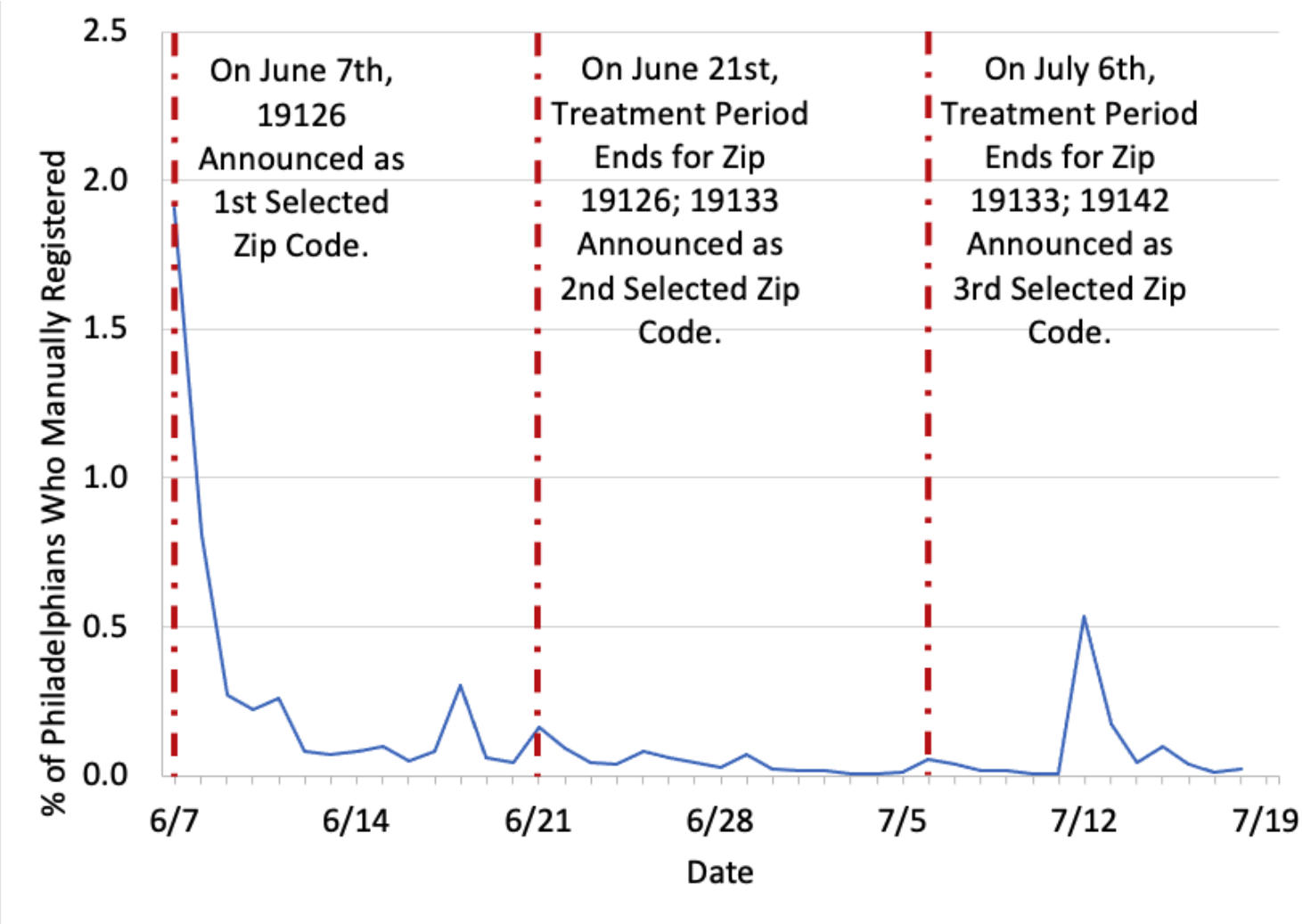

Figure 1

Daily manual registrations for the Philly Vax Sweepstakes at phillyvaxsweeps.com as a function of the total city population over the six weeks following its launch (on June 7, 2021) and up until (and including) the day before the final drawing (on July 19, 2021).

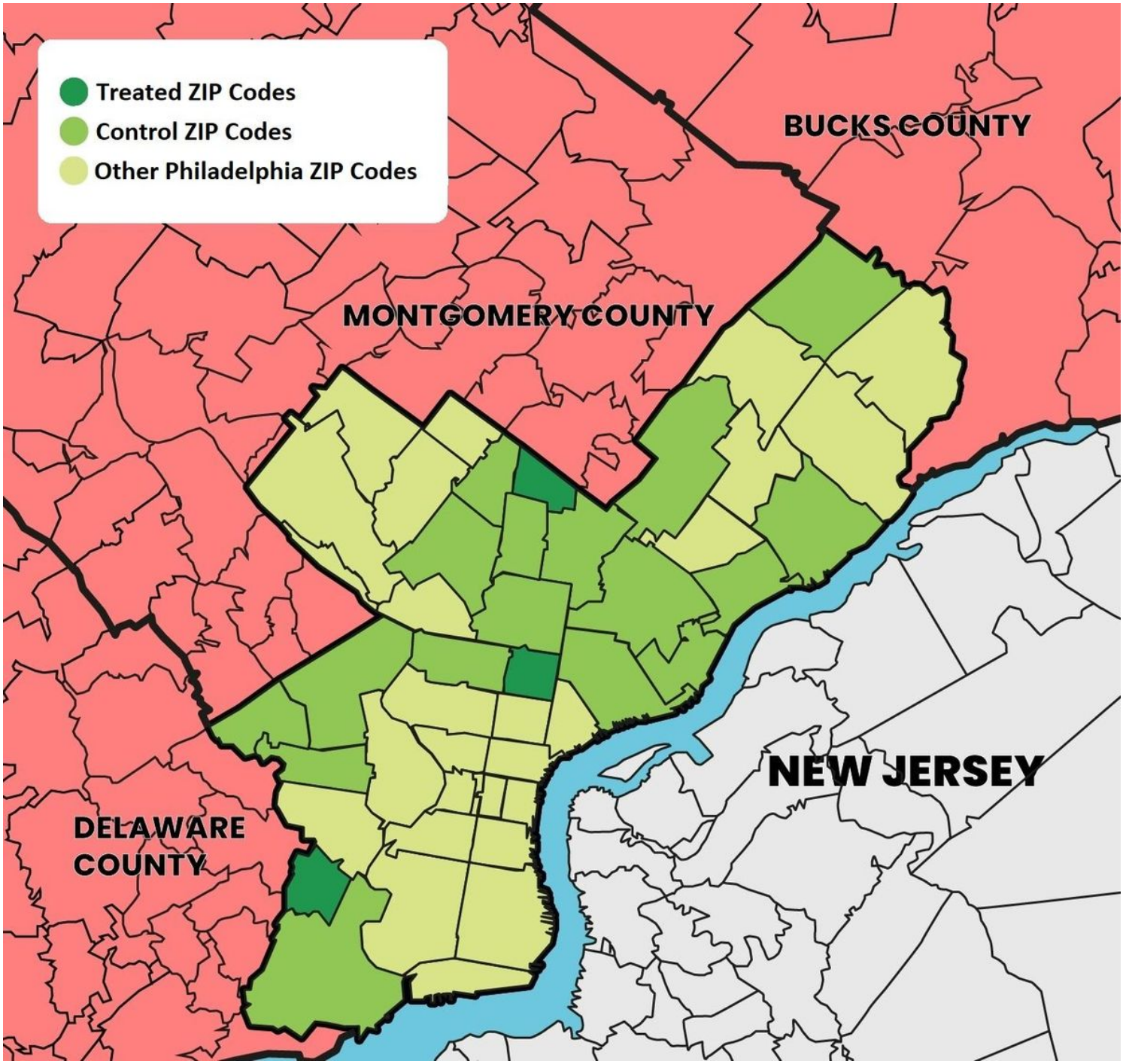

Figure 2

Map of Philadelphia County (where the Philly Vax Sweepstakes occurred). Treatment zip codes within Philadelphia are shown in dark green, control zip codes are shown in medium green, and all other Philadelphia zip codes are shown in light green.

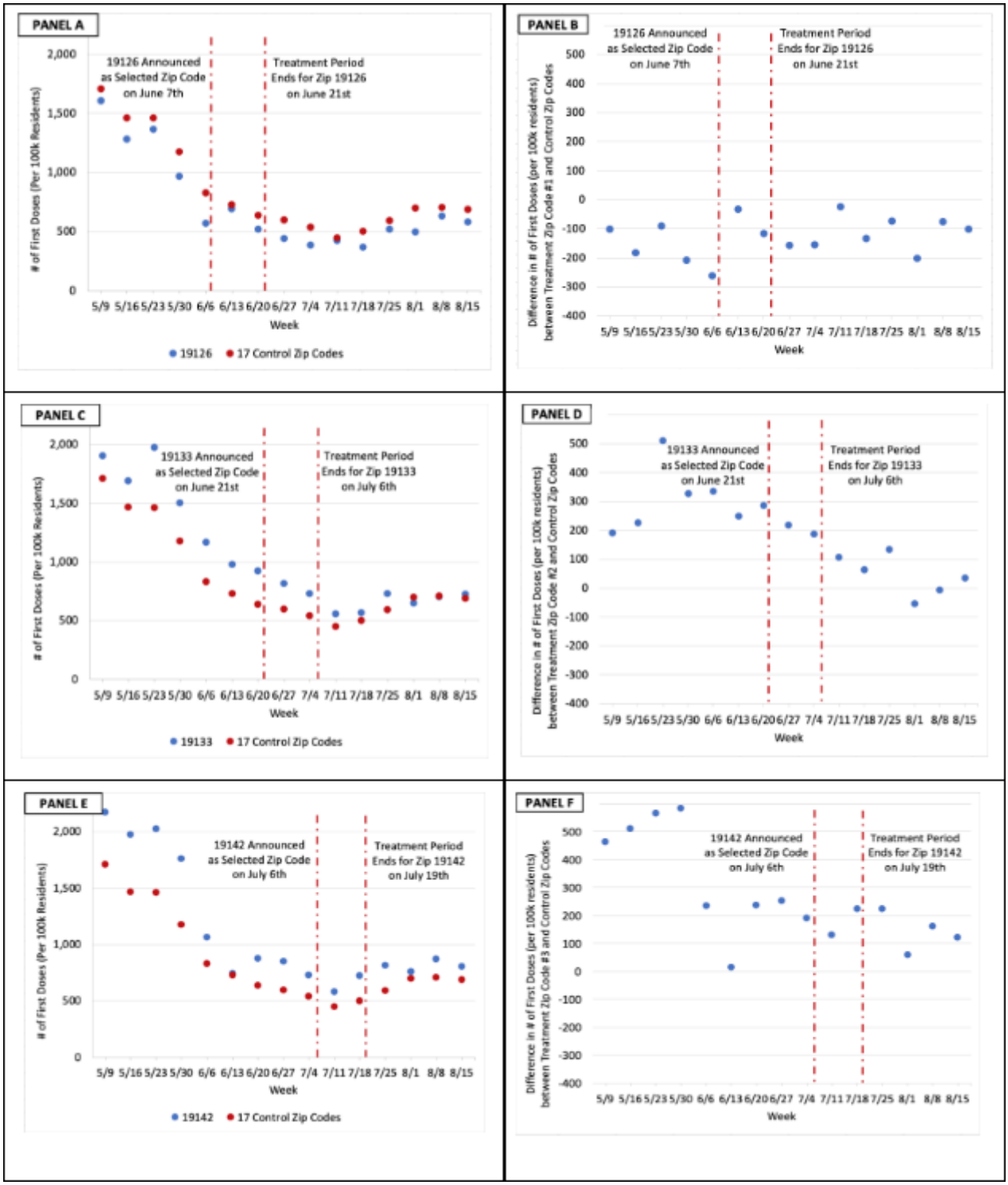

Figure 3

Panels on the left present the weekly number of first-dose vaccinations per 100,000 adult Philadelphians in each of the treated zip codes (19126 in Panel A, 19133 in Panel C, and 19142 in Panel E) versus the pooled 17 control zip codes. Panels on the right present the difference in the number of weekly first-dose vaccinations per 100,000 adult Philadelphians between treated and control zip codes (19126 in Panel B, 19133 in Panel D, and 19142 in Panel F).

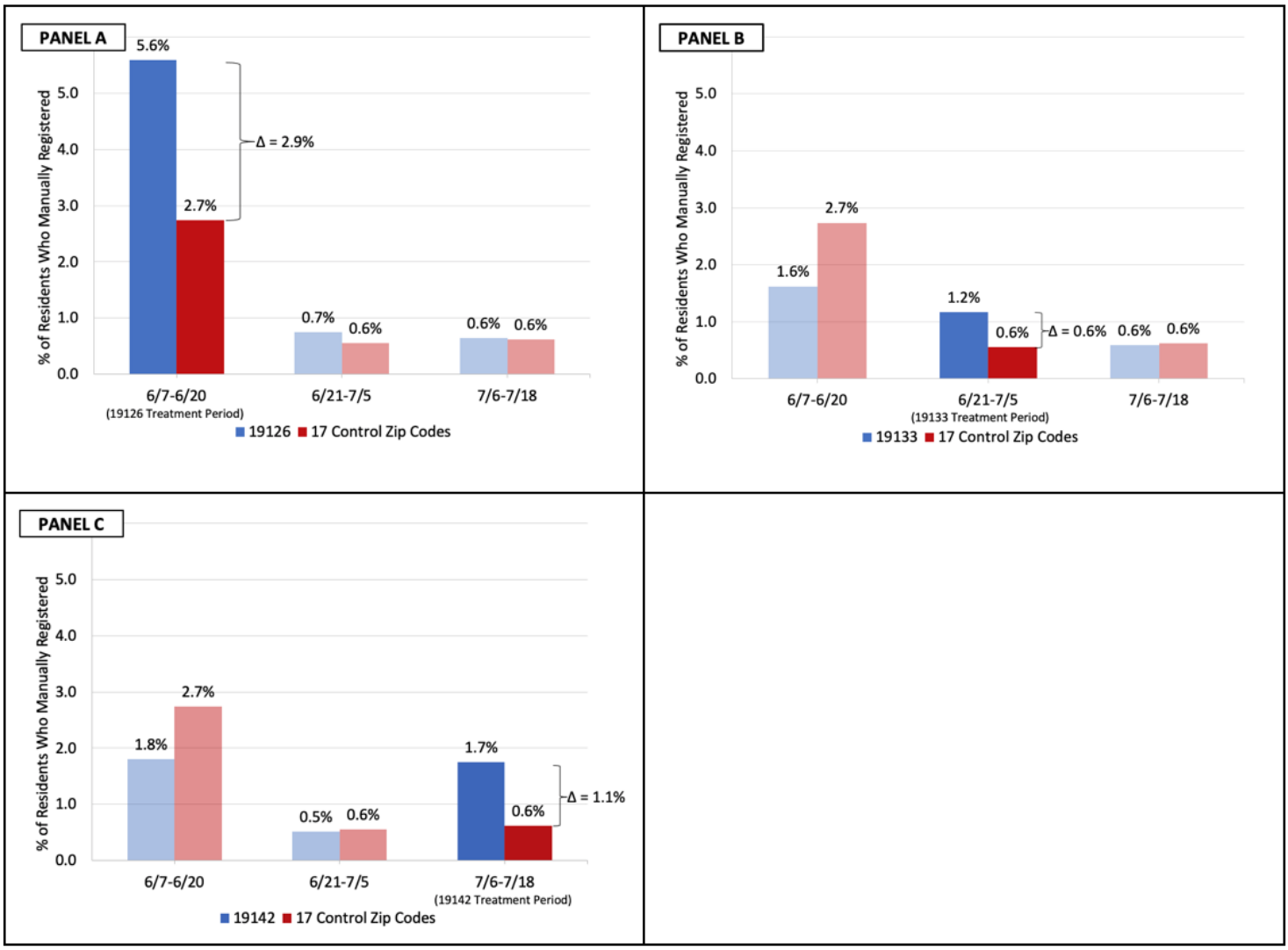

Figure 4

The pooled percentage of manual registrations for the Philly Vax Sweepstakes at phillyvaxsweeps.com as a function of the total city population for each treated zip code (19126 in Panel A, 19133 in Panel B, and 19142 in Panel C) and for control zip codes during each of the three treatment periods, highlighting the relevant treatment period for each treated zip code.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementalMaterials.docx