The Ohio Vaccine Lottery and Starting Vaccination Rates

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Abstract

We find that Ohio’s “Vax-a-Million” lottery increased first dose Covid-19 vaccinations by between 50,000 and 100,000, with most of the additional doses occurring during the first two weeks of the six-week lottery. We use county-level data and two empirical approaches to provide causal estimates of the lottery in Ohio. First, a difference-in-differences design compares vaccination rates in border counties in Ohio and Indiana before and after the announcement. Second, we use a pooled synthetic control method to construct a counterfactual for each of Ohio’s counties using control counties in Indiana, Michigan, and Pennsylvania. The synthetic control analysis reveals larger increases in vaccination rates in more populous counties. Our estimates imply that Ohio paid about $75 per additional starting dose during this period.

JEL codes: I12, I18, H75

Keywords: Vaccine lottery, Covid-19 vaccination, Vax-a-Million, event study, synthetic control method

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I kept hemming and hawing about it, and I work all the time, and when the Vax-a-Million thing started I immediately went down there and got it. It pushed me over the edge.

- Jonathan Carlyle, Vax-a-Million winner, The Cincinnati Enquirer

1 Introduction

The three primary Covid-19 vaccines in the United States have been shown to be effective at preventing Covid-19 infections, hospitalizations, and deaths. Paid for by the Federal Government, the vaccine is free of charge to all people living in the United States. The Centers for Disease Control and Prevention (CDC) currently recommends that everyone 12 and older receive a vaccination. While the exact herd immunity threshold for Covid-19 is unknown, models predict that we need at least 70 percent of the population to be vaccinated in order for the incidence of infection to decline (Randolph and Barreiro, 2020). Clinical trials demonstrate safety and efficacy and the vaccine is freely available, yet vaccination coverage remains below this threshold. As of June 23, 2021, less than 54 percent of the US population has received at least one vaccine dose, with large variation across geography and demographics (Centers for Disease Control and Prevention, 2021). With herd immunity still out of reach, additional vaccinations are important for reducing transmission, hospitalizations, and deaths.

Ohio introduced its “Vax-a-Million” lottery campaign to nudge unvaccinated residents 12 years and older to receive a Covid-19 vaccine. In the week after the announcement, the Ohio Department of Health reported immediate success from the program, citing that the campaign had caused a 28 percent increase in vaccinations among those 16 and older (Ohio Department of Health, 2021). Media reports published much larger increases, with Governor DeWine claiming on CNN there was a 45 percent increase in all vaccinations and a 94 percent increase in vaccinations among 16 and 17 year olds by the day of the first drawing. ABC News reported increases in vaccination rates of 43 to 53 percent over the course of the lottery (Lenthang and Periera, 2021; Welsh-Huggins, 2021). However, these estimates are based on week-to-week changes in vaccination numbers within Ohio, without looking at vaccination trends in comparison states. This caveat is

1For CNN clip, see https://twitter.com/NewDay/status/1397539038458961920
particularly important because other factors could also have influenced vaccinations; around the same time as the lottery announcement, the Pfizer vaccine was approved for individuals aged 12 to 15, and the CDC updated its mask guidance so that vaccinated individuals could stop wearing masks and social distancing in most settings (Rabin et al., 2021).

We use two empirical approaches to provide a causal estimate of the response of vaccination rates to the Ohio lottery. First, we estimate an event-study, comparing daily starting vaccination rates in border counties in Ohio and Indiana before and after the lottery announcement. Second, we use synthetic control analysis to provide causal estimates even when the parallel trends assumption required for difference-in-differences does not hold. We use a pooled synthetic control method to construct a counterfactual for each of the treated Ohio counties (Abadie and Gardeazabal, 2003; Abadie et al., 2010). We then estimate a state-level effect for all of Ohio by summing the county treatment effects and determine statistical significance using placebo tests.

We find the lottery resulted in between 50,000 and 100,000 additional vaccine doses, mostly during the first two weeks following the announcement. We estimate that Ohio paid $75 per additional starting dose. In this short-run analysis, it is unclear to what extent the increase in vaccinations are along the intensive (pull-forward) or extensive (newly induced vaccinations) margins. Nevertheless, even if all the additional vaccinations are pulled forward, there would still be a reduction in transmission due to achieving a higher vaccination rate earlier. Compared to estimates of the value of statistical life of $9.8 million, the $5.6 million-dollar initiative need only save one life to be worth the cost (Robinson, 2007). Back-of-the-envelope calculations suggest that vaccinating an additional 75,000 individuals will save between six and several hundred lives, assuming that they are additional vaccinations and not merely pulled-forward.

Citing the success of Ohio’s lottery, more than ten other states have initiated similar programs, designed as a lottery among vaccinated residents or as offers of free lottery tickets to those who get a vaccine. Previous studies show financial incentives do increase vaccination rates, though these findings are in the context of randomized trials with modest awards (Jacob et al., 2016; Mantzari et al., 2015; Greengold et al., 2009). To our knowledge, Ohio’s Vax-a-Million public health initiative

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2As shown below, the parallel trends assumption fails using control groups of border counties in Michigan and Pennsylvania. We do not use data from West Virginia and Kentucky for two reasons. First, West Virginia’s savings bond program was announced at the end of April, and Kentucky’s lottery was announced at the start of June. These programs mean that our “control” counties would also be treated. Second, neither West Virginia nor Kentucky provides sufficient county-level vaccination data by administration date.
is the first of its kind intending to increase vaccination rates among the broader population.

This paper adds to existing research on financial incentives and vaccination decisions by documenting responses among the broader population, rather than in a randomized trial, and at a lower cost per vaccination compared to other estimates of the effect of financial incentives (Jacob et al., 2016). With rising vaccine hesitancy and below-target vaccine coverage not only for the Covid-19 vaccines, but also for more established and studied vaccines for many infectious diseases, these findings point to the potential of similarly designed public health policies for other vaccines (e.g., see Centers for Disease Control and Prevention (2018)).

2 Background and Incentives

The U.S. Food and Drug Administration issued emergency-use authorizations for the Pfizer-BioNTech Covid-19 Vaccine (for individuals 16 and older) and the Moderna Covid-19 Vaccine (for individuals 18 and older) in December 2020. Emergency-use authorization for the Pfizer vaccine was expanded to include adolescents 12 through 15 years old on May 10, 2021. The Janssen (Johnson & Johnson) Covid-19 Vaccine received emergency-use authorization in February 2021 (U.S. Food and Drug Administration, 2021a,b,c).

On May 12, 2021, Ohio Governor DeWine announced the “Vax-a-Million” drawing to incentivize people to receive at least one dose of a Covid-19 vaccine. The lottery consisted of five drawings over five weeks, with each drawing providing a $1 million prize for an Ohio resident 18 years and older or a full-ride scholarship to an Ohio four-year university for residents between 12 and 17 years old. Governor DeWine explained in a New York Times guest essay that the five-drawing design was intended to generate additional enthusiasm and vaccinations each time a winner is announced (DeWine, 2021). All Ohio residents who had received at least one dose of the vaccine by the Sunday before the weekly Wednesday drawing were eligible. Residents only needed to register one time by filling out a brief questionnaire on ohiovaxamillion.com or calling the Ohio Department of Health hotline. The first drawing was Wednesday, May 26. The Ohio Department of Health funded the initiative using Federal Coronavirus Relief Funds. The stated purpose of the initiative was to raise awareness of the availability and effectiveness of the Covid-19 vaccines.

The Covid-19 vaccines are free, regardless of health insurance status or immigration status.
Appointments were plentiful at the time of the announcement and residents could directly schedule with local pharmacies or use gettheshot.coronavirus.ohio.gov to make an appointment. Although all residents 16 and older were eligible to receive the vaccine, the full vaccination rate of Ohioans was about 36 percent prior to the announcement (Vigdor and Paybarah 2021). While free and highly effective, vaccine hesitancy remains prevalent. Across several nationwide surveys conducted in 2020, 31 to 54 percent of respondents said they would not want to get vaccinated even if the vaccine was freely available (Khubchandani et al. 2021). One reason for vaccine hesitancy is lack of confidence in the approval process for the Covid-19 vaccines; 62 percent of respondents in a September 2020 poll believed political factors would result in a rush to approve vaccines without proper attention to safety and effectiveness (Kaiser Family Foundation 2020).

With a large share of the population holding unfavorable beliefs about the Covid-19 vaccines, incentive programs are an appealing strategy because they are not designed to change beliefs, but to alter the cost-benefit calculation about whether to receive the vaccine (Brewer et al., 2017). The Ohio lottery increased the marginal benefit of receiving a vaccine. If meaningful, we expect to see a short-run increase in vaccinations, reflecting either pull-forward of vaccinations among those who were planning to get vaccinated eventually, or new vaccinations among those not originally intending to be vaccinated. The odds of winning the first $1 million lottery were placed at about 1 in 2.7 million (Mervosh 2021). While small, these are better than the 1 in 12 million odds of winning the equivalent amount in the Ohio Mega Millions state lottery (Ohio Lottery, 2021).

Two state-level analyses have found no effect of the lottery in Ohio. First, Walkey et al. (2021) uses an interrupted time series method to compare starting vaccination rates in Ohio with those in the rest of the United States. Our findings likely differ because we use a different comparison group and different data. We use neighboring states to construct counterfactual vaccination trajectories for Ohio rather than the United States as a whole. We also use county-level data from individual state health departments, rather than from the CDC. Second, Lang et al. (2021) use synthetic controls to compare Ohio to a synthetic Ohio built from the remaining states and also finds no effect on full vaccination rates through the day of the last lottery. One possibility for this conclusion is that measuring changes in full vaccination rates may lead to muted estimates. First, individuals who received their first dose prior to the lottery announcement already qualified for the lottery; for these individuals, the second dose is not a response to the lottery. Second, those who do receive a
first dose in response to the lottery are not fully vaccinated for at least an additional three weeks. It is also possible that vaccine-hesitant individuals respond to the lottery by receiving only the first dose, due to the perceived risk of the second dose and small marginal benefit. Early estimates suggest as many as 10 percent of vaccine recipients did not receive their second dose (Kriss et al., 2021). A measure of full vaccination rates over a short time frame could miss an increase in first doses followed by no, or even a several-weeks delayed, second dose. Finally, a third study that also uses a state-level synthetic control method finds the lottery increased the starting dose vaccination rate (Barber and West, 2021); their estimated magnitude is similar to ours.

There is prior empirical evidence that vaccination decisions respond to financial incentives. Many studies estimating the effect of financial incentives are designed as randomized trials, with small samples of participants and modest awards. Most relevant for the lottery studied here, Yokley and Glenwick (1984) find that sending parents tickets for a cash lottery increases vaccination rates among their preschool-aged children. Mantzari et al. (2015) show vouchers increase uptake of HPV vaccinations, and Greengold et al. (2009) finds monetary incentives motivate homeless individuals to return for additional doses of hepatitis B vaccinations. Bronchetti et al. (2015) show financial incentives increase flu vaccinations among those who did not receive a flu shot the previous year.

It is possible the lottery may lead to a short-run increase in vaccinations but lower uptake in the long-run because the lottery could signal the vaccination is risky (Cryder et al., 2010). Recent surveys by the UCLA Covid-19 Health and Politics project show that some people report they are less likely to receive the vaccine with incentive payments (Vavrek, 2021).

Fifteen states and three Canadian provinces have joined Ohio in creating a vaccine lottery program as an incentive for vaccination. The number of drawings and size of prizes vary. For example, Maryland’s lottery doled out $2 million over 40 daily drawings for $40,000 each and a $400,000 grand prize the last day. New Mexico’s lottery offers the largest grand prize of $5 million to a single winner. Some states automatically enroll all eligible residents while others are opt-in programs like Ohio’s. In addition to these large lottery programs, states are offering smaller incentives to those who receive a vaccination. For example, New Jersey and Connecticut offered residents 21 and older a free beer after their first dose. West Virginia announced at the end of

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3The National Governor’s Association published a July 1 memo outlining all state Covid-19 vaccine incentives, available at https://www.nga.org/center/publications/covid-19-vaccine-incentives/.
April 2021 a program giving $100 savings bonds to 16 to 35 year olds who get the vaccine, including those who received the vaccine prior to the announcement (West Virginia 2021).

3 Data and Methodology

3.1 Data

We use daily data on the number of first dose Covid-19 vaccinations by county of residence from the health departments of Ohio, Indiana, Michigan, and Pennsylvania. We do not use data from West Virginia and Kentucky, the other two states bordering Ohio, because of West Virginia’s savings bond program announced at the end of April, and Kentucky’s lottery announced at the start of June. Additionally, West Virginia’s and Kentucky’s health department’s vaccination data are insufficient for our analysis. The Indiana, Michigan, and Ohio data provide the number of vaccinations started by date, with separate counts of the number of first doses of the Pfizer and Moderna vaccines and the number of single-shot J&J vaccines. The Pennsylvania data report the number of partially vaccinated doses (first dose of Pfizer or Moderna) and fully vaccinated (second dose of Pfizer or Moderna or the single-shot J&J). We cannot separate the number of J&J doses, which should be included in the count of starting doses, from second doses of Pfizer and Moderna.

To generate a measure of the approximate number of first doses in Pennsylvania counties, we assume that 1% of final doses are first and final doses of the J&J vaccine. We use first doses to calculate the daily starting vaccination rate per 10,000 residents in each county. Using the number of starting doses rather than the total number of doses allows us to better identify short-run responses to the lottery due to the three- to four-week span between first and second doses.

In addition to the daily vaccination data, we obtain data on race/ethnicity, age, and county-level population estimates as of July 1st, 2019 from the US Census. We also use data on median

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4We drop Philadelphia, which only reports a subset of vaccinations at the daily level, and counties that are missing data. We use data reported by the individual state health departments rather than the CDC’s Covid-19 Vaccine Tracker. Inspection of the data suggest state health departments report the date vaccines were administered, while the CDC data is lagged. Online Appendix Section A.2 shows that J&J administration patterns in the state data better align with the CDC’s recommended pause in the J&J vaccine. The date in the CDC data may reflect when data is received by the CDC, rather than the date of vaccine administration. This makes it impossible to have a clean break point after the announcement of the lottery using the CDC data.

5Michigan’s lottery was announced on July 1, 2021, after the conclusion of Ohio’s lottery.

6The J&J shot was paused during the first weeks of our sample; we only apply this correction after April 23rd when the vaccine resumed use. Assuming 3.5% instead of 1% changes our main result by less than 0.5%.
household incomes, urbanicity, unemployment rates, poverty rates, and college education levels that are prepared by the USDA and drawn from the American Community Survey. Finally, we include data on the percentage of votes in the 2020 presidential election that were for Donald Trump.\textsuperscript{7}

### 3.2 Difference-in-Differences

We first compare starting vaccination rates in contiguous Ohio and Indiana border counties before and after the lottery announcement. Figure 1 plots the daily seven-day moving average of the number of starting doses per 10,000 residents separately in Ohio and Indiana border counties. Border counties in Indiana are a good control group for estimating the lottery effect in Ohio if the populations are similar except for eligibility for the Ohio lottery. The red solid line is the average starting dose vaccination rate for Ohio counties that border Indiana, and the dashed blue line is the average starting dose vaccination rate in Indiana counties that border Ohio. Online Appendix Section A.1 shows that vaccination rates in Michigan and Pennsylvania border counties do not trend parallel to those in their Ohio border county counterparts prior to the lottery announcement.

In the weeks before the lottery announcement, vaccination rates were trending downward for both groups. A reversal of this trend appears for Ohio counties starting on May 13th, 2021, the day after Governor DeWine’s evening Tweet announcing the lottery. Over the next week, the vaccination rate increased from approximately 10 doses per 10,000 to approximately 16 doses per 10,000. This trend accounts for the media reports in which it was claimed that vaccination rates were up nearly 60 percent since the announcement of the lottery (Lenthang and Periera, 2021). Around the same time, vaccination rates in neighboring border counties also increased, suggesting that some of the increase would have happened in Ohio in the absence of the lottery. The most likely explanation for this is the approval of the Pfizer vaccine for individuals ages 12 to 15 on May 10th. On May 13th, the CDC announced it would lift its mask recommendation for vaccinated individuals, which may have also increased vaccinations (Cohen, 2021).

The key identification assumption of difference-in-differences is that, in the absence of the vaccine lottery, the trends in the vaccination rates would have been the same in treatment and control counties. The only Ohio border in which this assumption appears plausible is across the Ohio-Indiana border. We test this assumption directly in an event-study framework. The event

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\textsuperscript{7}Election results reported by Fox News, The New York Times, and Politico. Data are available on github.
study allows for a pattern in vaccination rates leading up to and following the lottery announcement date so that we can see whether there is a lottery effect, and how long it lasts. We include nine interaction terms comprised of an indicator for whether the county is in Ohio and indicators for each of the three weeks before and six weeks after the lottery announcement. The week before the announcement is the omitted group, yielding the following equation:

\[ v_{ct} = \alpha_c + \gamma_t + \text{Ohio}_c \times \left[ \sum_{k=-4}^{-2} \pi_k 1(Week_t = k) + \sum_{k=0}^{5} \rho_k 1(Week_t = k) \right] + \epsilon_{ct} \]  

(1)

where \( v_{ct} \) is the starting vaccination rate of county \( c \) on day \( t \). The variable \( \alpha_c \) represents county-level fixed effects and accounts for county-level characteristics that do not vary over time (such as demographics or political, religious, or cultural attitudes). Similarly, \( \gamma_t \) represents day-level fixed effects that accounts for time-specific shocks that affect all counties similarly, such as day of the week or news (e.g., access to the vaccine for 12 to 15 year-olds, or the release of new studies about vaccine efficacy and/or side effects). The coefficients \( \pi_k \) and \( \rho_k \) provide the estimated change in starting vaccination rates relative to the week prior to the lottery announcement \( (k = -1) \). Estimates close to zero on the interaction terms \( \pi_k \) in the pre-announcement weeks provide evidence against concerning pre-trends. The coefficients on the interaction terms \( \rho_k \) in the post-announcement weeks allow for a dynamic response over the duration of the lottery through the week of the last drawing on June 23. To account for serial correlation, we cluster standard errors at the county level. We present estimates using the sample of Ohio-Indiana border counties, with separate estimates using control groups of Michigan or Pennsylvania border counties in Online Appendix Figure A4.

3.3 Synthetic Control Method

To estimate a causal effect for the entire state of Ohio, we turn to a pooled synthetic control method. This approach also has the advantage of not relying on the parallel trends assumption required for the difference-in-differences approach above (Abadie and Gardeazabal 2003; Abadie et al. 2010). The synthetic control method was originally designed for one treated unit, comparing outcomes of the treated unit to that of a counterfactual weighted average of untreated units with weights chosen so that the “synthetic control” closely resembles the treated unit in the pre-treatment period. The method provides causal estimates when the parallel trends assumption required for
difference-in-differences estimation fails. We estimate treatment effects separately for each of Ohio’s 88 counties, with synthetic controls formed from Indiana, Michigan, and Pennsylvania counties. We aggregate to estimate a state-level effect (Abadie, 2021). Previous work has applied the synthetic control method when multiple units are treated at the same time (Kreif et al., 2016; Robbins et al., 2017; Lépine et al., 2018).

The synthetic control for each county is built using observable characteristics in the pre-treatment period. To construct the counterfactual trajectory of vaccination rates in each treated Ohio county in the absence of the lottery, we use four pre-lottery average vaccination rates and the following county-level covariates: population, percent of population with a college degree, median household income, unemployment rate, poverty rate, urbanicity as measured by the urban-rural continuum, percent white, percent male, percent aged 0-14, percent aged 15-49, percent aged 50-85, and percent of votes in the 2020 presidential election for Donald Trump. Due to state differences in day-of-week vaccination patterns, using seven-day average vaccination rates improves matching between treated counties and their synthetic controls. The dependent variable is the daily starting vaccination rate, as used in the difference-in-differences specification above.8

This approach relies on the assumption that there are no spillover effects to untreated counties and that there is no anticipation of treatment. The former assumption is plausible in our setting because the Ohio lottery was open to only Ohio residents. The latter assumption is plausible because Ohio was the first state to announce such a lottery for receiving the Covid-19 vaccines; it is unlikely there were forward-looking individuals who received a vaccine in anticipation of the lottery announcement.

We determine statistical significance of the estimated effects by running placebo tests (Abadie et al., 2010, 2015). In the placebo tests, we drop Ohio from the sample and apply the synthetic control method to each of the counties in Indiana, Pennsylvania and Michigan. We estimate effects using the remaining counties to construct a synthetic control for each. This results in a distribution of placebo treatment effects where we expect no treatment effect.10

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8We use the synth package for Stata and the regression-based technique to calculate weights. Due to computational constraints, results cannot be calculated for all counties using the “nested” option to generate weights, but when possible, results are similar. We also note that McClelland and Gault (2017) find that the “nested” option can result in different estimates if a predictor’s units are rescaled and that “[this] may merit future adjustments.”

9There are no conventional standard error estimates with the synthetic control method.

10This inference approach with multiple treatment units is similar to Dube and Zipperer (2015) and Lépine et al. (2018). This is an extension of the standard placebo approach in Abadie et al. (2010) developed for a single
While not including any controls, Online Appendix Figure A1 shows that Ohio’s increase in the starting vaccination rate was steeper and proportionately larger than all of its neighbors following the announcement.

4 Results

4.1 Difference-in-Differences Results

Panels A and B of Figure 2 display weighted and unweighted estimates from the event-study regression in Equation 1 using Ohio and Indiana border counties. The estimated effects are relative to the week before the lottery announcement and suggest that the lottery increased daily starting vaccination rates. The weighted estimates imply the vaccination rate increased by 6.3 doses per 10,000 residents during the first week and 3.5 doses per 10,000 residents during the second week; the unweighted estimates are 3.7 and 2.9, respectively. The dashed lines present 95 percent confidence intervals. In both regressions, the point estimates in the first and second week are statistically significant at conventional levels. By the third week, vaccination rates return to baseline, and remain small in magnitude and statistically insignificant through the duration of the lottery. None of the pre-treatment weeks are statistically significant, providing empirical support for the necessary identification assumption of parallel trends. The lack of a statistically significant drop in vaccinations suggests that if the additional doses are being pulled forward, they are being re-timed by more than four weeks, beyond the duration of the lottery. However, we cannot rule out that some of the induced first doses are retimed.

We use these event-study estimates to generate an estimate of the approximate number of additional doses induced by the lottery. The weighted estimates are that the lottery increased vaccination rates by 6.3 doses per 10,000 residents in the first week, 3.5 doses per 10,000 residents in the second week, and had no effect thereafter. Scaling this to be statewide, we would find that the total number of doses induced by the lottery is 80,807 \((11,779,448 \times \frac{6.3 \times 7 + 3.5 \times 7}{10,000})\). Using the estimates from the unweighted regression implies the lottery induced an additional 54,421 doses.

\(^{11}\)Event-study results using separate control groups of Michigan and Pennsylvania border counties are in Online Appendix Figure A4. While in both cases there is an upward trend in the pre-treatment estimates, several of which are statistically different from zero, most of the post-announcement point estimates are similar in magnitude to those using Indiana border counties as a control group.
Both of these estimates assume that the lottery effect is the same across the state of Ohio and not just limited to border counties.

It is possible these estimates are biased because Indiana border counties are a poor control group for Ohio border counties and/or the parallel trends assumption does not hold. We next implement our synthetic control approach, which does not rely on the parallel trends assumption, and provide estimates of a lottery effect for the entire state of Ohio, using counties from multiple neighboring states as a comparison group.

### 4.2 Synthetic Control Results

Results from our synthetic control approach are consistent with the findings from the event-study analysis and indicate that the lottery induced roughly 77,000 additional vaccinations, with almost all of the effect over the first two weeks following Governor DeWine’s announcement. Figure 3 presents sample results from Franklin (home of Columbus), Hamilton (home of Cincinnati), Lorain (suburban Cleveland, home of Oberlin College), and Williams (rural, northwest Ohio) counties. The figures plot a seven-day moving average of doses per 10,000 residents in the treated county compared to its synthetic control.\textsuperscript{12} Generally, vaccination rates in the treated counties and their synthetic controls appear similar prior to the announcement. In the first two weeks following the announcement, vaccinations in the treated counties outpace those in their synthetic controls. Afterwards, any differences are smaller and the treated counties are similar to their synthetic controls.

Figure 4 compares the distribution of the estimates of the increase in vaccination rates in each of the Ohio counties to that of the placebo estimates from applying the synthetic control method to each of the counties in the donor pool from Pennsylvania, Michigan, and Indiana. This allows us to see whether the effects estimated in the Ohio counties are sufficiently large relative to the effects in counties where we expect no treatment effect. The distribution of Ohio estimates lies to the right of the placebo distribution and the distributions (and their means) are statistically different from each other, suggesting that our results are not due to chance.

We estimate a state-wide effect by aggregating the estimated treatment effects across Ohio’s 88 counties, weighted by county population. The aggregate increase of about 97,000 vaccinations

\[ (11,779,448 \times \frac{(3.7 \times 7 + 2.9 \times 7)}{10,000}) \]

\textsuperscript{12}While the figures use data beginning April 8 to construct the moving averages, the synthetic control estimates are based on data beginning April 15.
represents about 83 additional vaccinations for every 10,000 residents, or 0.83 percent of the population. We provide a more conservative effect of the lottery by taking into account the placebo estimates. If we aggregate the estimated placebo treatment effects and then scale to Ohio’s population, we find an estimate of 20,000 additional vaccinations when we expect no effect. Subtracting this implied bias from our headline estimate of 97,000 vaccinations, we find that the lottery resulted in about 77,000 additional vaccinations, covering about 0.66 percent of the population.

Finally, the synthetic control analysis allows for estimating heterogeneous effects. We estimate larger effects in more populous counties. After taking into account bias implied by the placebo estimates, we find counties with over 250,000 people average 64 additional vaccinations for every 10,000 residents. Counties with populations under 250,000 see 37 additional vaccinations for every 10,000 residents.

5 Discussion

Using two different empirical methods, we estimate that Ohio’s lottery led to between 50,000 and 100,000 additional vaccinations, with most of the additional vaccinations occurring in the first two weeks after the announcement. With a total lottery payout of $5,600,000, this would imply that Ohio paid about $75 per additional starting dose (DeWine 2021). This is below the range of previous cost estimates per additional vaccinated person from studies on interventions providing financial incentives to increase vaccination rates ($290 - $2,860 in 2021 USD) (Jacob et al. 2016). The program would also pass a cost-benefit analysis if one additional life is saved, with a mean estimate of the value of a statistical life of about $9.8 million (Robinson 2007).

In our short-run analysis, it is unclear how much of the increase in vaccinations reflects responses on the intensive (pull-forward) or the extensive (newly induced vaccinations) margin. It is possible there is pull-forward of vaccinations from beyond the lottery window, with substantial re-timing of vaccinations in order to participate in the lottery. Either type of response achieves

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13 The sum of the estimated placebo treatment effects across the 212 non-Ohio counties, with a total population of 27.5 million, is about 47,000. To scale down to Ohio’s population of 11.7 million, we calculate 47,000 × 11.7/27.5.
14 This bias can result because some counties are oversampled when running the synthetic control analysis. It appears that our oversampled counties have lower-than-average post-May 13th vaccination rates.
15 If we exclude data from Michigan, our estimate drops from roughly 97,000 to 77,000. Dropping Pennsylvania instead increases the estimate to 102,000. Finally, dropping only Indiana causes the estimate to decline to 72,000.
16 Calculated as $5.6 million/75,000.
a higher vaccination rate earlier, providing public health benefits. Our results suggest that the five-drawing design did not result in renewed enthusiasm each week as winners were announced; most additional vaccinations occurred in the first two weeks after the announcement. It is also unclear whether the financial incentive acted as a signal of risk and discouraged some individuals from receiving the vaccine at all, leading to lower uptake in the long-run.

Determining how many lives will likely be saved by the lottery depends on several parameters that are currently unknown, such as what percent of unvaccinated individuals will eventually contract Covid-19 and what their case-fatality rate will be. These latter two parameters could take on a wide range of values, depending on factors like which variant of the virus becomes dominant and how individuals and policy makers endogenously respond to the emergence of these variants. We present a wide range of possible values in Table 1. Each row assumes that either 10%, 40%, or 70% of unvaccinated individuals will contract the disease. The columns assume that the case-fatality rate will be either 0.1%, 0.5%, or 1%. We also assume the lottery induced 75,000 individuals to become vaccinated and that vaccination would have prevented 90% of deaths.\textsuperscript{17} Our estimates of the number of lives saved ranges from 6.75 to 472.5, with a median scenario of 67.5. These estimates also assume the 75,000 additional vaccinations are newly-induced vaccinations, rather than pulled-forward. If all the additional vaccinations were pulled forward by six weeks, the number of lives saved decreases to around one.\textsuperscript{18} However, we believe it is unlikely that \emph{all} the additional vaccinations were re-timed, and that if they were re-timed, vaccinations were accelerated by more than 6 weeks. Overall, these estimates suggest the lottery likely passes a cost-benefit analysis even before considering factors like prevented hospitalizations and the value of reduced morbidity.

The synthetic control analysis allows for some estimates of heterogeneous effects; we find larger effects in more populous counties. This finding is consistent with the larger point estimates from the population-weighted event-study regression compared to unweighted regressions. There are several explanations for this finding. There may be more access to vaccination appointments or locations, greater knowledge of the lottery, stronger peer effects, or lower vaccine hesitancy among

\textsuperscript{17}The assumption that 90% of deaths are prevented by the vaccine is conservatively consistent with recent observational data from Virginia: \url{https://www.vdh.virginia.gov/coronavirus/covid-19-data-insights/covid-19-cases-by-vaccination-status/}. Roughly half the state is fully vaccinated and only 10 out of 150 deaths between May 13th and July 18th occurred among the vaccinated population.

\textsuperscript{18}This estimate is based on a comparison of death rates among the vaccinated and unvaccinated populations in Virginia over a six-week period. Virginia had similar caseloads to Ohio around this time and provides data by vaccination status.
more urban populations. We are unable to estimate differential responses by age due to lack of data on vaccination starts by age.

Our results are likely to generalize to other lotteries like Oregon’s or Maryland’s. However, it is possible that Ohio benefited from being the first to announce a lottery and that the novelty improved Ohio’s outcomes; subsequent state lotteries may see smaller returns as the novelty wears off. Additionally, Governor DeWine explicitly chose the lottery instead of a smaller but certain payment with Bill Veeck’s words in mind: “To give one can of beer to a thousand people is not nearly as much fun as to give 1,000 cans of beer to one guy” [DeWine 2021]. While the quote’s claim may not be true, we find it reasonable that West Virginia’s free savings bonds or New Jersey’s free beer could have different effects. Ohio’s program may be less expensive per marginal shot when compared with West Virginia’s savings bond program. We estimate Ohio paid $75 per marginal recipient, while West Virginia’s program provides a $100 savings bond to all recipients (ages 16 to 35) of the vaccine, rather than only those that were induced by the program. It is unclear whether those programs induce more or fewer additional vaccinations. Recent experimental evidence suggests that a lottery is more cost-effective than a lump-sum transfer payment [Kim 2021].

6 Conclusion

Ohio’s “Vax-a-Million” lottery is the first of the now many state-wide lotteries intended to increase Covid-19 vaccinations. With five adult winners of $1 million and five youth (age 12-17) winners of a four-year full-ride college scholarship for receiving at least one dose of the vaccines, the Ohio lottery provides a unique opportunity to study the response of vaccination decisions to financial incentives among the broader population and with a sizeable reward, rather than in a randomized trial. Additionally, as the first announced lottery, there was no anticipation among the public of the program, allowing for clean estimation of the response.

Using two analytical approaches, we find that Ohio’s lottery increased vaccinations in Ohio by between 50,000 and 100,000 doses in the first two weeks after the lottery announcement. While the additional doses due to the lottery only cover about 0.66 percent of Ohio’s population, the cost per dose falls below the range from prior studies of the effects of financial incentives on vaccination rates. It is also likely the total program costs are small relative to the damage caused by Covid-19.
Only one death needs to be prevented in order for the program to pass a cost-benefit analysis; if all the estimated additional vaccinations are new rather than pulled-forward, our lower bound estimate is that the lottery will save at least 6 lives, with the potential for many more.

Our findings are consistent with work using a state-level synthetic control method (Barber and West, 2021), though different from two other state-level analyses finding no effect of the lottery in Ohio (Walkey et al., 2021; Lang et al., 2021). We use neighboring states to construct a counterfactual vaccination trajectory for Ohio, rather than comparing Ohio to the United States as a whole. Additionally, we estimate the effect of the lottery on starting vaccination rates, as opposed to full vaccination rates.

There is still room for states to design incentive programs to encourage Covid-19 vaccinations. Tinkering with the lottery design by changing the number or size of prizes could change the cost-effectiveness or the total vaccination yield. An alternative would be to capitalize on loss aversion by drawing a winner from the entire vaccine-eligible population, but require the winner to give up the earnings if they were not already vaccinated (Levitt and Severts, 2021). It is also possible that smaller but guaranteed payouts will be more successful, signaling less risk and perhaps leading to greater vaccine uptake in the long-run. Indeed, this may be Ohio’s strategy going forward: the day after the last lottery drawing in Ohio, Governor DeWine announced on Twitter a new incentive, offering $25 gift cards to those vaccinated at select locations over the following week.19

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19See https://twitter.com/GovMikeDeWine/status/1408065778583179277?s=20.
References


Figure 1: The Starting Vaccination Rates in Bordering Counties

Notes: Starting vaccination rates are a seven-day moving average of doses per 10,000 residents and do not include second doses of either Pfizer or Moderna. The Vax-a-Million lottery was announced on the evening of May 12th, 2021.
Figure 2: Event Study Estimates of the Lottery Effect on Starting Vaccination Rates

Notes: Starting vaccination rates are doses per 10,000 residents. The omitted group is the week before the lottery announcement (5/6/2021 to 5/12/2021) using weekly bins. The weighted regression weights each observation by the county’s population. The dashed lines display 95 percent confidence intervals.
**Figure 3: Synthetic Control Results: Sample Counties**

(a) Franklin County (Columbus)  
(b) Hamilton County (Cincinnati)  
(c) Lorain County (Cleveland Suburbs)  
(d) Williams County (Rural)

*Notes:* These figures provide sample results from two of Ohio’s most populous counties (Franklin and Hamilton), a Cleveland suburban county (Lorain, where Oberlin College is located), and a rural county (Williams, in the northwest corner of Ohio).
Figure 4: Synthetic Control Method Results Compared with Placebo Results

Notes: The “Treated Counties” distribution gives the estimated probability density function of the estimated increase in the vaccination rate in the first two weeks after the lottery announcement from the synthetic control analysis across all Ohio counties. The “Placebo Counties” distribution does so across all counties in Pennsylvania, Michigan, and Indiana.

Table 1: Lives Saved from the Lottery under Various Assumptions

<table>
<thead>
<tr>
<th>Case-fatality rate</th>
<th>0.1%</th>
<th>0.5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>6.75</td>
<td>33.75</td>
<td>67.5</td>
</tr>
<tr>
<td>40%</td>
<td>27</td>
<td>135</td>
<td>270</td>
</tr>
<tr>
<td>70%</td>
<td>47.25</td>
<td>236.25</td>
<td>472.5</td>
</tr>
</tbody>
</table>

Notes: Each cell presents the number of lives saved for various assumptions on the infection rate (10%, 40%, and 70%) among unvaccinated individuals. Each column assumes a different case-fatality rate (0.1%, 0.5%, and 1%). We additionally assume the lottery induced 75,000 people to become vaccinated and that vaccination prevents 90% of deaths. For example, the upper right cell is calculated as $75,000 \times 0.1 \times 0.01 \times 0.9 = 67.5$. 
Online Appendix

A Empirical Appendix

A.1 State-wide starting vaccination rates in Ohio and neighboring states

Figure A1 plots the starting vaccination rate separately in Ohio, Indiana, Michigan, and Pennsylvania. Ohio’s increase in starting vaccination rates, following the lottery announcement, was larger than its neighbors.

Figure A1: State-wide starting vaccination rates by state and date

A.2 Johnson & Johnson Vaccine Pause Analysis

In this section, we compare the timing of vaccine administration in the data from the CDC Covid-19 Vaccine Data Tracker versus the individual state health departments. To do so, we look at the number of J&J doses over the period of the CDC’s recommended pause in J&J vaccines. While Ohio and Pennsylvania do not specifically break out J&J doses, the Indiana and Michigan
Health Departments provide this information. While Michigan does not report the exact date doses are administered, it does include the “Data as of” date.

Figure A2 plots the number of J&J doses as reported in the CDC data and by the Indiana and Michigan Health Departments. On April 13th, 2021, the CDC and FDA recommended a pause in the administration of the J&J vaccine that was lifted April 23rd, 2021. Both the Indiana and Michigan state Health Department data series show a drop in the J&J vaccine that coincides with the beginning of the pause. For example, in the Michigan data, 9,886 doses were administered on April 12th, whereas 688, 152, and 36 were administered on April 13th, 14th, and 15th respectively. In contrast, the CDC data appears to be lagged by a few days, with the decrease in J&J vaccines occurring after the start of the pause in both states. While vaccination reports may trickle in a few days after administration, this effect appears to be limited in the states’ data.\(^{20}\)

At the end of the pause, while there is not much of a resumption in the J&J vaccine in Michigan, in Indiana, there is an immediate jump in J&J doses. Again, the resumption of the J&J vaccine appears delayed using the CDC data. The figures provide suggestive evidence the CDC data is lagged and that the data from the individual state health departments more accurately reports the date of vaccine administration.

A.3 OH/MI and OH/PA Differences-in-Differences Analysis

This section provides a brief summary of differences-in-differences analysis using the other two borders available to us. Figure A3 provides time series data for Michigan/Ohio and Pennsylvania/Ohio border counties that are analogous to Figure 1. Figure A4 provides event-study results using separate control groups of Michigan and Pennsylvania border counties that are analogous to Figure 2. In both cases, the estimates in the pre-treatment period are negative, and several are statistically different from zero. There is also an upward trend in the pre-treatment estimates, suggesting that the parallel trends assumption does not hold. Nevertheless, it is worth noting that most of the post-announcement point estimates are similar in magnitude to those using Indiana border counties as a control group.

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\(^{20}\)It is also possible that there are no “late” reports in the state data; the pause was a widely-followed recommendation, not a requirement.
Figure A2: Doses of J&J Administered by Date and Data Source

Notes: The two vertical bars represent when the CDC/FDA paused (4/13) and resumed (4/23) administration of the J&J vaccine.
Figure A3: The Starting Vaccination Rates in Michigan and Pennsylvania Border counties

Notes: Starting vaccination rates are a seven-day moving average of doses per 10,000 residents and do not include second doses of either Pfizer or Moderna. The Vax-a-Million lottery was announced on the evening of May 12th, 2021.
Figure A4: Event study estimates using MI and PA border counties

Indiana

Panel A: Weighted

Panel B: Unweighted

Michigan

Panel A: Weighted

Panel B: Unweighted

Pennsylvania

Panel A: Weighted

Panel B: Unweighted