The Vaccine Boost: Quantifying the Impact of the COVID-19 Vaccine Rollout on Measures of Activity[*]

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Abstract

This paper investigates the impact of U.S. vaccine administration on three dimensions of activity: spending, mobility, and employment. To address concerns of endogeneity, we rely on the introduction of vaccine lotteries across U.S. states and instrument for vaccine uptake. Using a dynamic event design setting, we find that lotteries have significantly boosted vaccination rates. This boost in vaccination rates, in turn, translates into a significant increase in retail spending but does not significantly affect other measures of activity. All told, our findings imply that the vaccine rollout added, on average, 0.5 percentage point to U.S. GDP growth in 2021.

Keywords: COVID-19 Vaccine Rollout, Economic Activity

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1 Introduction

Several measures of economic activity have shown improvement since the start of the COVID-19 vaccine rollout. However, over the same period, other factors—such as the course of the pandemic and the associated policy interventions—have influenced the response in activity.

With a focus on three main dimensions of activity—spending, mobility, and employment—our analysis looks at the impact of vaccinations on activity across U.S. states using vaccine lottery announcements to identify vaccine uptake; we argue that this identification strategy allows us to isolate the effect of vaccine administration on activity from other confounders. In fact, vaccine lotteries were specifically designed to boost vaccination rates, offer variation across states and over time, and provide an ideal instrumental variable strategy for our analysis because they were unexpected before the official announcement. In the first stage of our analysis, we identify the impact of lotteries on vaccinations using a dynamic event design setting that controls for a large set of characteristics—such as day- and state-month fixed effects; the presence of other incentives; the time to extraction; new vaccine distribution; the trends in new cases, hospitalizations, and deaths; temperatures; and the Oxford Stringency Index, a measure of policy responses to the COVID-19 outbreaks. In this part, we find that lotteries have significantly boosted vaccination rates about a week after announcement, with an effect that lasts over the next several days and increases new vaccinations between 3.5 and 5 percent across lottery adopters compared with states without lotteries–that is, compared with never adopters and not-yet adopters. In the second stage, we exploit predictions of vaccine uptake from the first-stage analysis to address the impact on activity. Our findings point to a significant boost of vaccinations to retail spending, while the impact on mobility or employment appears muted. Focusing on spending and looking at magnitudes, we find that a one standard deviation increase in vaccinations explains 2.25 standard deviations increase in retail spending about 30 days post-vaccination and over the following two weeks. This effect is consistent with an increase in retail spending at the monthly rate of 27 percent.

Finally, we also map the effect we documented on retail spending to the impact on

GDP. Our estimates imply that vaccine administration, through retail sales, boosted GDP growth, on average, 0.5 percentage point (pp) in 2021. The impact of vaccinations is overwhelmingly positive also looking at a cost-benefit analysis. While Robertson et al. [2021a] estimate a lottery cost per marginal vaccination of 55 USD, our estimates of the impact of vaccinations attribute an increase in GDP of about 400 billion USD or 1500 USD per vaccination, suggesting an important contribution of those interventions to the recovery.

Our work contributes to the vast literature on evaluating public policy interventions. There have been two main studies in the narrower field of the effects of vaccination on economic activity, Deb et al. [2022] and Hansen and Mano [2021]. While Deb et al. [2022] looks at the impact across countries, our paper is most closely related to Hansen and Mano [2021], who document the impact of vaccinations on economic activity at the U.S. county level through an instrumental variable strategy that relies on local pharmacy density. While what they find in terms of spending is significantly lower than our estimates, their empirical strategy is not robust to some endogenous factors—such as demand shocks, which affected the local reallocation of vaccine doses across counties, or urban density, which is significantly correlated with the shape of the recovery.[1] In contrast, lotteries and other monetary incentives are likely to be an exogenous instrument.[2]

2 Data

Our analysis looks at the impact of vaccinations on economic activity across U.S. states using vaccine lottery announcements as an instrument for vaccine uptake; thus, in this section, we describe our data sources for the three main components in our study: vaccine lotteries, vaccinations, and economic activity.

First, we hand-collect data on vaccine lotteries, assembling, in particular, data on the date of first announcement, monetary prizes, and dates of extraction. To ensure consistency, we also compare those data with what has been used in other papers that examine

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[1] Specifically, Hansen and Mano [2021] find an that increase in initiated vaccination rates of 1 percentage point increases weekly consumer spending by 0.6 percent, while our findings imply a weekly increase of 11 percent.

[2] As a salient sign of exogeneity, we document insignificant changes in vaccination trends across states before the introduction of lotteries in our empirical analysis.

vaccine lotteries.

Second, we draw on the U.S Centers for Disease Control and Prevention's COVID-19 vaccinations by jurisdiction data to quantify the progress in vaccine administration across states.

Third, we measure economic activity using proxies for spending, individual mobility, and employment.

The spending indicators in our investigation are based on data from Fiserv, which is one of the largest card intermediaries in the country. We rely on a database where transaction data for retail and restaurant speding are aggregated to the state level.[3]

To quantify mobility patterns, we rely on two indicators: the Apple driving index and the INRIX index of passenger distance traveled.

Measures of employment conditions come from Homebase, a provider of clock-in/clock-out tracking software focused on small businesses, and include measures of hours worked and the number of open businesses.[4]

Finally, our analysis also includes a wide set of controls, and, thus, we complement the indicators listed above with additional information from the New York Times COVID-19 cases and deaths database, the Health and Human Services' data on hospitalization, the Oxford stringency index, and the National Oceanic and Atmospheric Administration's National Climatic Data.

All our data sources are at the daily level, and our sample covers the period between February 10, 2021 and March 19, 2022 because of common availability across all sources.

3 Empirical Analysis

Vaccination uptake and economic activity tend to be correlated with a number of observable and unobservable state-level factors. This section develops a strategy for the identification of vaccination effects on economic indicators that is robust to concerns of omitted variables and endogeneity. Our investigation combines two stages. In the first stage, we rely on vaccine lotteries to quantify their impact on new vaccinations. In the second stage,

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[3] For more details, see Aladangady et al. [2019].

[4] For more details on Homebase, see Crane et al. [2020].

we use the prediction of vaccine uptake based on the introduction of lotteries as the main regressor in models analyzing economic activity.

3.1 First Stage: The Impact of Lotteries on Vaccination

Between May 10 and July 1, 2021, 19 U.S. states announced lotteries to boost vaccination rates. Participation in the lotteries required having received or receiving one shot of the vaccine; while, in some instances, individuals were not required to take any additional steps, most states set up web portals for the submission of the vaccination record. Table A1 summarizes announcements and last extraction dates by state.

Vaccine lottery announcements were fairly unexpected: For example, Gov. DeWine's announcement, which was among the earliest to establish vaccine lotteries, attracted very mixed reactions, even raising concerns about legality of such measure.[5] While legality issues were discussed and settled over the next several days, states' announcements to adopt vaccine lotteries remained unexpected. In support to the claim that lottery announcement did not depend on pre-existing state characteristics, our preliminary analysis documents that several demographic features were not significantly different between adopters and non-adopters before any announcement of lottery adoption, with the single exception of the employment rate. [6] Notwithstanding these similarities, our empirical strategy does not exclude that adopters might be different from non-adopters across some dimensions, included as controls in our analysis, as discussed more below.

Looking first at vaccination rates, the main target of the analysis in this section, figure 1 compares trends between states that have announced a lottery at any time in our sample and states that never did. Interestingly, future adopters of vaccine lotteries display higher levels of vaccine uptake since mid-March of last year; while we'll perform a specific test on differences later, this sign of the difference also argues that vaccine lotteries were unexpected before announcement. While generally the trends in vaccination are not

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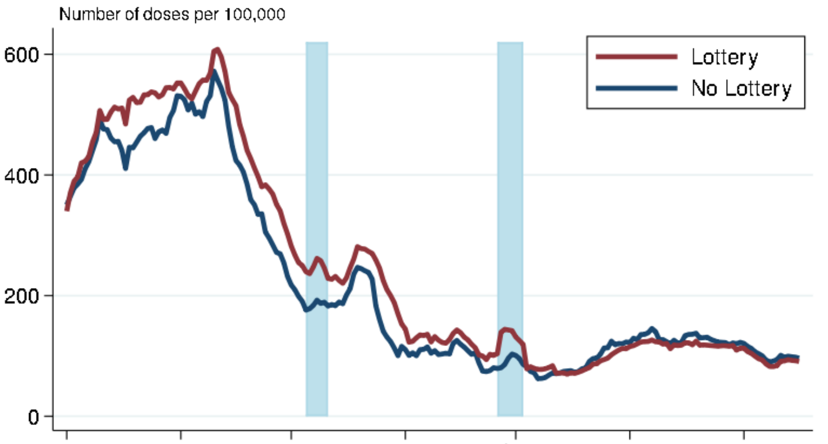
[5] Significantly, on May 13, 2021, Ohio Attorney General Dave Yost released the following statement to the FOX 8 I-Team in response to DeWine's idea: "Like many of you, I first learned about this idea yesterday. At first blush, the concept does not appear to violate state law, though that will be dependent upon how it is designed. We will continue to review as additional details are made public. Just because a thing may be legally done does not mean it should be done. The wisdom and propriety of this expenditure is a question for the Governor and the General Assembly." Quoted from this article.

[6] Mean-comparison tests are reported in table A2.



Source: CDC.
Notes: Average daily vaccine administration per 100,000 across groups of states that announced a vaccine lottery and those that offered no or other types of incentives around lottery implementations. Shaded areas denote deviations between the two trends.

Figure 1: Comparison of Vaccine Administration Trends between States with and without Vaccine Lotteries

too dissimilar between the two groups of states, the figure highlights a couple of instances where deviations in the trends are more visible (shaded blue areas); those deviations occur in early May, around the time of the earliest lottery announcements, and around July 1st, when several extractions for various lotteries occurred. This quick comparison, however, is very rudimentary and does not take into account the different timing of the announcements or differences in other state-level factors.

To precisely identify the impact of lotteries on vaccinations, we rely on a dynamic difference-in-difference estimation that contrasts the variation in vaccination rates in states that have implemented the lottery with that of states that have not implemented it—but may at some point in the future. In particular, our baseline specification is the following

$$\text{New Adm.}_{st} = \delta_0 + \sum_{j=-15}^{45} \delta_{1,j} \text{Post Announc.}_{s,t-j} + \xi X_{st} + d_{sm} + d_t + u_{st} \tag{1}$$

where Post Announc.$_{s,t-j}$ collects the leads and lags relative to the lottery announcement.[7] $\delta_{1,j}$, $j \in \{-15, ..., 45\}$ are our coefficient of interests in our first stage analysis and iden-

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[7] In our baseline results, all periods beyond some specified values are accumulated into final lag and lead points to avoid unbalanced leads and lags; our results are not sensitive to this restriction.

tify the dynamic treatment effects under the assumption of conditional parallel trends of lottery adopters relative to the groups of not-yet adopters and never adopters; thus, a causal identification requires that adopters do not significantly differ from non-adopters in a window before the lottery announcement, conditional on the controls included in our specification.

Under the parallel trend assumption, the coefficients could be interpreted as a weighed average of the average treatment effect on the treated (ATT). Importantly, in our setting, treatment effects are heterogeneous in time since lotteries are adopted in different time periods across different states. As noted by Goodman-Bacon [2021], this setting may lead to estimates that are biased away from a weighed average of the ATT. This problem, however, is addressed in our panel event study design with a dynamic specification that includes two-way (state- and day-) fixed effects.[8]

While states may be different among various dimensions, the reactions to lottery announcements and our comparison of demographics characteristics suggest that it is unlikely that significant factors vary systematically between adopters and non-adopters and explain the decision to introduce vaccine lotteries. To further support the validity of our strategy, we also include in our specification a rather exhaustive set of controls, accounting for many pre-existing differences among the two groups of states. First, we rely on new vaccine distribution to capture supply shocks in vaccine availability. Second, we include new cases, new hospitalizations, and new deaths to account for the effect of the pandemic on vaccine administration. Third, we add the Oxford stringency index, a composite measure of non-pharmaceutical interventions that records policy responses to the course of the disease. Fourth, we control for heating and cooling degree days because of the interactions among health, behavioral outcomes, and weather variables. Fifth, we add a regressor that

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[8] As an alternative robustness strategy, we have identified the impact of lotteries on vaccinations for the groups of never adopters following the methodology proposed by Callaway and Sant'Anna [2021] and under the assumption that the comparison against not-yet adopters might be biased by some characteristics of those states. The results, shown in figure A1, are in line with our baseline estimates. In particular, we find no significant pre-trends for lottery adopters relative to never adopters as well as a significant impact on vaccinations a week after announcement, although the effect is significant over a shorter time horizon. While the results are roughly similar across the two methods, the estimation based on Callaway and Sant'Anna [2021] relies on a smaller set of control because of insufficient variation between the treated and the relevant comparison group and, thus, we do not rely on this strategy for our baseline.

captures the time to extraction and a dummy for the presence of other types of incentives.[9] Sixth, we include state-month dummies to capture differences in the monthly timing of lottery adoption across states as well as economic conditions and other demographic characteristics, which, according to Robertson et al. [2021b], have been important correlates of vaccine hesitance.[10] Finally, day-fixed effects absorb common shocks across states.

While our paper is the first to exploit the variation offered by the lotteries to identify the impact of vaccinations on economic activity, other papers have investigated the influence of lotteries on vaccine uptake with mixed results. In particular, the closest papers to this part of our analysis, Dave et al. [2021] and Robertson et al. [2021a], document contrasting findings.[11] Looking across various state lotteries, Dave et al. [2021] argue that lotteries had no impact on vaccine administration, while Robertson et al. [2021a] suggest that 10 of the 12 statewide lotteries they studied generated a positive and statistically significant impact on vaccine uptake. Those papers differ in terms of the level of the analysis (state-level for Dave et al.,2021 vs. county-level for Robertson et al.,2021a) and the controls used in the study, but both rely on data through early July. While we perform our analysis at the state-level, we extend the lottery data to encompass all extractions; we also adopt a more exhaustive specification.[12]

3.2 Second Stage: Vaccinations and Economic Activity

In the second stage of our empirical analysis, we use the prediction of new vaccine administration from model (1) to evaluate its cumulative effects on various economic outcomes. In particular, our baseline specification relates the predicted number of new people in state s that received the first dose of the vaccine at day $t-j$, $\widehat{\text{New Adm.}}_{s,t-j}$, $j = \{30, ..., 45\}$, with

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[9] Information on incentives is collected from a publication of the National Governors Association available here.

[10] State-month dummies also absorb the impact of employment conditions which are systematically different in the two groups of states according to table A2.

[11] Several other papers have looked at the impact of lotteries or other monetary incentives on vaccinations. In particular, Brehm et al. [2021] and Mallow et al. [2021] document a positive impact on vaccinations for the Ohio lottery, in contrast with the findings of Lang et al. [2021]. Other evidence points to a positive impact of guaranteed monetary incentives in Sweden (Campos-Mercade et al.,2021) and in the U.S. (Dai et al.,2021), but not for the vaccine hesitant population (Chang et al.,2021).

[12] Our sample covers data through March 2022, well after the last extraction on August 26 in the Kentucky and Nevada lotteries.

current indicators of activity,

$$y_{st} = \beta_0 + \sum_{j=31}^{45} \beta_{1,j} \widehat{\text{New Adm.}}_{s,t-j} + \gamma X_{st} + d_{sm} + d_t + \varepsilon_{st}, \tag{2}$$

where y_{st} denotes measures of spending, mobility, or employment. In our model, we exclude the first month post-vaccination to account for the time before receiving the second dose of vaccines; furthermore, we limit our analysis to 15 lags because we have a limited window of predictions from the first stage regressions.[13] Our estimates of interest are $\sum_{j=31}^{45} \beta_{1,j}$, the linear combinations of coefficients associated with predicted new vaccine administration, which identifies the cumulative impact on measures of activity. As a final note, model 2 includes the same explanatory variables as in equation (1).

Results

Figure 2 summarizes the first-stage result. The coefficient estimates of the leads and lags around the lottery announcements, the blue diamonds, are relative to the period before announcement, coded as -1 and identified by the black vertical bar; the blue thin bars in the figure denote the 95 percent confidence interval. The chart highlights no significant effects on new vaccinations in the 15 days before announcement, consistent with the parallel trend assumptions required in our estimation. However, we also find that there is no immediate increase in vaccinations after announcement; this finding is consistent with the fact that eligibility in several lotteries required registering through an online portal before scheduled extraction dates. On the 8th day post-announcement, the coefficient estimate is positive and significant as is in a few other instances over the following two weeks.

Table 1 summarizes the cumulative impact on new vaccine administration in the pre- and post-announcement period—that is, the reported coefficients are linear combination of the estimates over specified periods. Column (1) reports that the cumulative effect in the pre-period is effectively zero, supporting the claim that the conditional parallel trend assumption is satisfied in the 15 days before announcement. After excluding the first 7 days post-announcement, we find a significant effect of lotteries on new vaccinations

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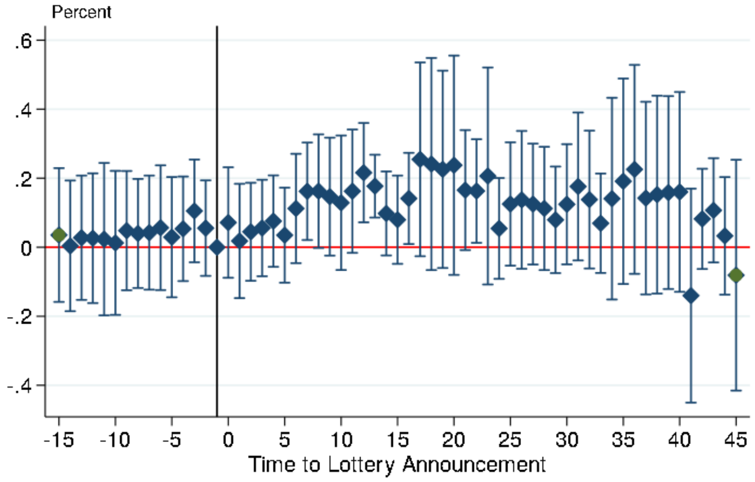
[13] Additional lags substantially reduces the number of observations used in the estimation, although results are robust to the inclusion of more lags.



Note: Point estimates of lottery announcement on new vaccine administration, controlling for new distribution; new cases, hospitalizations, and deaths; Oxford stringency index; heating and cooling degree days; time to extraction; presence of other incentives; state-month dummies; and day-fixed effects. Vertical bars denote 95 percent confidence interval.

Figure 2: Lottery Announcements and Impact on New Vaccinations

through the 45th day post-announcement (columns (2) and (3)). When extending the window through day 60 (column (4)), we find a similar point estimate as in the previous two columns, although less tightly estimated. Looking at magnitudes and using the coefficient from column (2), the effect implies that states that announced lotteries experienced a 3.5 percent increase in vaccinations a week after announcement and over the next 20 days relative to those that did not introduce or had not yet made an announcement. As an alternative quantification, the effect of lotteries translates into an increase in vaccinations of almost 2.5 standard deviations for lottery adopters when comparing to never or not-yet adopters.

Table 2 looks at the cumulative impact of vaccinations on our main measures of economic activity; the reported coefficients are elasticities—that is, the percent increase in measure of economic activity per percent increase in new vaccine administration—and are evaluated over 15 days, between day 31 and day 45 post-vaccination.[14] Our results point to a significant effect only for retail spending. In particular, our estimates imply

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[14] To look at the evolution of the behavioral response after vaccine administration, we have also estimated the impact of vaccinations at each different lag—up to 45 days—from receiving the first dose of a COVID vaccine. Those results are shown in figures A2-A4 and confirm that the effect of vaccination is robust only on retail spending. See the working paper version, available here, for more details on these estimates or on reduced-form results.

Table 1: Cumulative Impact of Lotteries on New Vaccinations around Announcement

	(1)	(2)	(3)	(4)
Variable	New Vaccine Adm.			
	Before	After		
	2 - 15 days	8-30 days	8-45 days	8-60 days
Cum Impact	0.559	3.565**	5.121**	3.545
	(1.114)	(1.624)	(2.326)	(2.686)
Other Controls[1]	y	y	y	y
State-Month FE	y	y	y	y
Day FE	y	y	y	y
Obs.	14,026	14,026	14,026	14,026
R-squared	0.580	0.580	0.580	0.580
Number of States	51	51	51	51

Source: CDC and NOAA.

[1] Other controls include new vaccine distribution; new cases, hospitalizations, and deaths; heating and cooling degree days; the Oxford stringency index; the time to extraction; and a dummy for the presence of other incentives.

New Vaccine Adm.: Log-number of the 7-day moving average of new daily vaccine administration.

Legend: *** significant at 1%, ** at 5%, * at 10%.

Notes: Dynamic difference-in-difference regressions, cumulated effects before (column (1)) and after (columns (2)-(4)) lottery announcement. In the post-announcement period, we exclude the first 7 days to account for learning about eligibility conditions. Robust standard errors, clustered at the state level, are reported in parenthesis.

that an increase in vaccinations by 1 percent raises retail spending by 23.8 percent—or 2.25 standard deviations per standard deviation—after 30 days from receiving the first dose of the vaccine and over the following two weeks. In other words, our effect suggest a daily boost to retail sales of about 1.6 percent per day for 15 days per percentage increase in vaccinations–which translates into a monthly rate of 27 percent.

4 Implications for U.S. GDP growth

Our analysis suggests that retail spending has received a significant boost from the progress in the vaccine rollout. But what do those effects ultimately tell us about aggregate economic activity? We have drawn a direct inference—summarized in table 3—based on two features: (1) the relation between our main spending indicator and the retail sales component of personal consumption expenditures (PCE) and (2) its contribution to GDP. First, we estimate the growth rate of Census' retail sales, the official source of GDP data released by the Bureau of Economic Analysis (BEA), using our Fiserv indicator. Our Fiserv spending measure is highly correlated with the Census's data on retail sales, and our estimate suggests an average growth of 0.87 percent per month in 2021. As a result, our estimates predict that retail sales grew at almost 10 percent at an annual rate in 2021 (line 1, table 3)—vs. 10½ percent using the BEA GDP Data. Second, we calculate the contribution of our vaccine effects to retail sales and to GDP. Based on the average growth of new vaccine administration since the beginning of the year, we estimate that the vaccine uptake explains about 15 percent of the average increase in retail sales and, as a result, accounts for about 0.5 percentage point of GDP growth over the same time horizon (line 3). The impact of vaccinations on GDP we calculated, however, is likely a lower bound as it focuses on a single channel—although the most important, according to our estimates.

Finally, we propose a cost-benefit analysis, comparing our GDP implications with cost estimates for the lotteries implemented. Our calculation suggest that the vaccine rollout added 400 billion to GDP in 2021—or about 1500 USD per vaccination. Robertson et al. [2021a] estimate that the cost of lotteries per marginal vaccination was 55 USD. Even accounting for the fact that the implementation of lotteries largely occurred between the

Table 2: Second Stage Effects of the Vaccine Rollout on Activity

	(1)	(2)	(3)	(4)	(5)	(6)
	Spending		Mobility		Employment	
VARIABLES	Retail	Restaurant	INRIX	Apple	Hours	Open Businesses
New Adm.	23.770***	3.535	-41.412	-6.213	-1.822	-0.950
	(5.661)	(6.078)	(88.460)	(7.070)	(3.065)	(1.745)
Other Controls[1]	y	y	y	y	y	y
State-Month FE	y	y	y	y	y	y
Day FE	y	y	y	y	y	y
Obs.	1,127	1,127	94	1,127	1,127	1,127
R-squared	0.810	0.805	0.949	0.976	0.979	0.986
Number of States	50	50	20	50	50	50

Source: Fiserv, Inc., INRIX, Apple, Homebase, CDC and NOAA.

[1] Other controls include new vaccine distribution; new cases, hospitalizations, and deaths; heating and cooling degree days; the Oxford stringency index; the time to extraction; and a dummy for the presence of other incentives.

Retail Spending: Percentage change in retail sales spending relative to 2019.

Restaurants Spending: Percentage change in restaurant spending (NAICS 722) relative to 2019.

INRIX: Percentage change in the 7-day moving average of passenger distance traveled.

Apple: Percentage change in the 7-day moving average of the driving index.

Hours worked: Percentage change in the number of total hours worked relative to 2019 for small business establishments.

Open Businesses: Percentage change in the number of open businesses relative to 2019 for small business establishments.

New Adm.: Log-number of 7-day moving average of new daily vaccine administration, cumulated effect after vaccination.

Legend: *** significant at 1%, ** at 5%, * at 10%.

Notes: Second-stage FE regressions. Point estimates for the main explanatory variable are based on linear combinations of coefficients from the 31st-day through the 45th-day post-vaccination. Robust standard errors, clustered at the state level, are reported in parenthesis.

Table 3: Vaccinations: Impact on GDP Growth

	2021
1. Retail Sales Growth[1]	9.98%
2. Retail Sales Contribution to GDP	3.38%
3. Vaccinations Impact	0.54%

Source: BEA, Census, and Fiserv, Inc.

[1] Retail sales growth prediction based on Fiserv data.

Notes: Estimates of vaccine rollout effects on GDP growth.

middle of the second quarter and the third quarter, the benefit per quarter—or around 375 USD—remains much higher than the cost of lotteries, pointing to the importance of the vaccine rollout and of the state-level lotteries for economic activity.

5 Conclusions

In this paper, we analyzed the impact of vaccine administration on three main dimensions of activity across U.S. states: spending, mobility, and employment. Our investigation relies on the implementation of vaccine lotteries to instrument vaccine uptake and predict the impact on activity. We find that lotteries have significantly boosted vaccination rates about a week after announcement, with an effect that lasted over the next several days and, overall, increased new vaccinations by at least 3.5 percent across lottery adopters compared to states without a lottery (never adopters and not-yet adopters). This boost in vaccination rates, in turn, translates into a significant increase in retail spending, with a 1 percent increase in new vaccinations associated with an increase of 27 percent at a monhtly rate in retail spending. All told, our findings imply that the vaccine rollout added, on average, about 0.5 percentage point to U.S. GDP growth in 2021 and that the cost of lotteries was well below the boost to retail sales.

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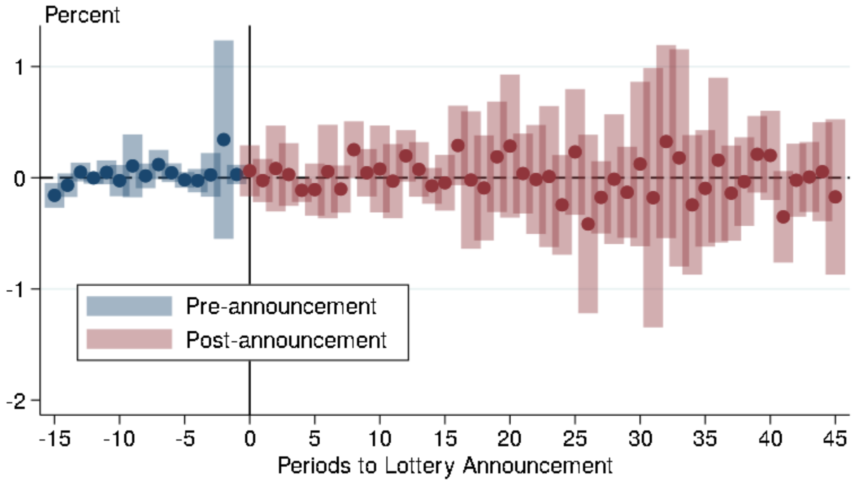
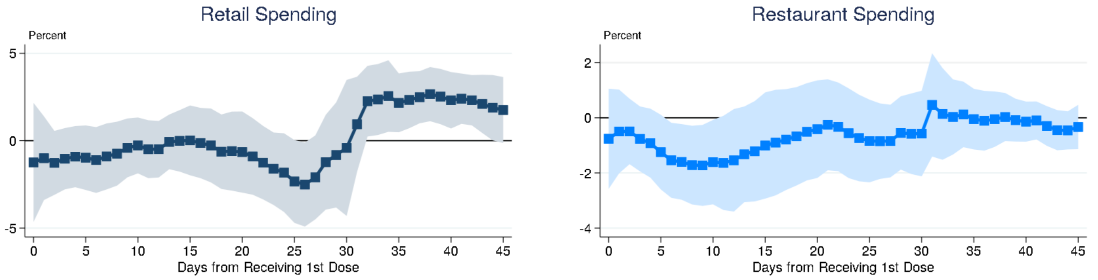
A Additional Figures and Tables



Note: Average treatment effect on the treated of lottery announcement on new vaccine administration relative to never adopters.

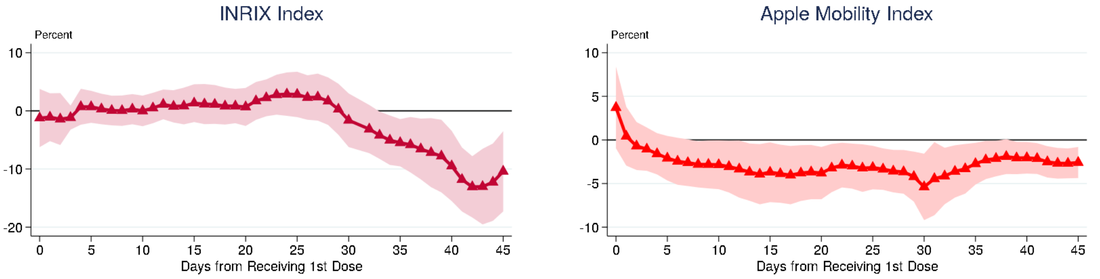
Figure A1: Impact of Lotteries on Vaccinations: Comparison with Never Adopters



Source: Fiserv, Inc.
Notes: Second stage point estimates of the effect of vaccination on retail spending, controlling for new distribution; new cases, hospitalizations, and deaths; Oxford stringency index; heating and cooling degree days; time to extraction; presence of other incentives; and state-month and day-fixed effects. Vaccine administration is instrumented using announcement of vaccine lotteries. Blue-shade area denotes the 95 percent confidence interval.

Source: Fiserv, Inc.
Notes: Second stage point estimates of the effect of vaccination on restaurant spending, controlling for new distribution; new cases, hospitalizations, and deaths; Oxford stringency index; heating and cooling degree days; time to extraction; presence of other incentives; and state-month and day-fixed effects. Vaccine administration is instrumented using announcement of vaccine lotteries. Blue-shaded area denotes the 95 percent confidence interval.

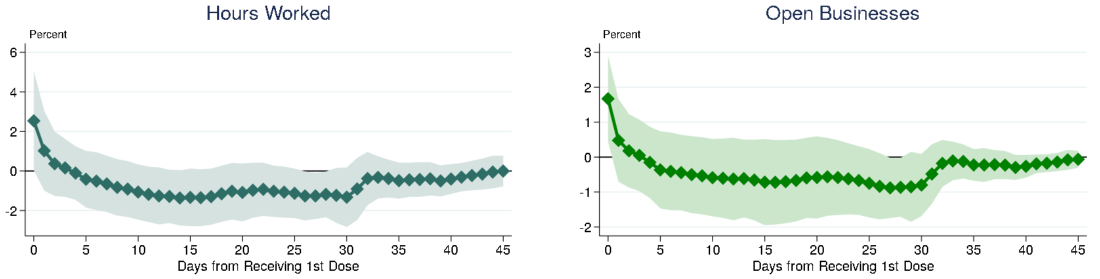
Figure A2: Second Stage Effect of Vaccinations: Impact on Spending



Source: INRIX.
Notes: Second stage point estimates of the effect of vaccination on passenger distance traveled, controlling for new distribution; new cases, hospitalizations, and deaths; Oxford stringency index; heating and cooling degree days; time to extracti presence of other incentives; and state-month and day-fixed effects. Vaccine administration is instrumented using announcement of vaccine lotteries. Red-shaded area denotes the 95 percent confidence interval.

Source: Apple.
Notes: Second stage point estimates of the effect of vaccination on apple mobility index, controlling for new distribution; new cases, hospitalizations, and deaths; Oxford stringency index; heating and cooling degree days; time to extraction; presence of other incentives; and state-month and day-fixed effects. Vaccine administration is instrumented using announcement of vaccine lotteries. Orange-shaded area denotes the 95 percent confidence interval.

Figure A3: Second Stage Effect of Vaccinations: Impact on Mobility



Source: Homebase.
Notes: Second stage point estimates of the effect of vaccination on hours worked, controlling for new distribution; new cases, hospitalizations, and deaths; Oxford stringency index; heating and cooling degree days; time to extraction; presence of other incentives; and state-month and day-fixed effects. Vaccine administration is instrumented using announcement of vaccine lotteries. Green-shaded area denotes the 95 percent confidence interval.

Source: Homebase.
Notes: Second stage point estimates of the effect of vaccination on open businesses, controlling for new distribution; new cases, hospitalizations, and deaths Oxford stringency index; heating and cooling degree days; time to extraction; presence of other incentives; and state-month and day-fixed effects. Vaccine administration is instrumented using announcement of vaccine lotteries. Green-shaded area denotes the 95 percent confidence interval.

Figure A4: Second Stage Effect of Vaccinations: Impact on Employment

Table A1: State Lottery Summary

State	Announcement Date	Extraction Date (Last)
Arkansas	May 25	-[1]
California	May 27	July 1
Colorado	May 25	July 6
Delaware	May 25	June 29
Illinois	June 17	August 16
Kentucky[2]	June 4	August 26
Louisiana	June 17	July 31
Maine	June 16	June 30
Maryland	May 20	July 3
Massachusetts	June 15	August 19
Michigan	July 1	August 3
Nevada	June 17	August 26
New Mexico	June 1	August 6
New York	May 20	June 11
North Carolina	June 10	August 1
Ohio	May 12	June 20
Oregon	May 21	June 27
Washington	June 3	July 13
West Virginia	June 1	August 1

[1] Arkansans who get a COVID-19 vaccination after May 24 could choose between a $20 Arkansas Game and Fish certificate for fishing/hunting licenses or a scratch-off lottery ticket.

[2] On May 10, Kentucky offered a coupon for a free lottery ticket ($225,000 maximum cash award to winner) to those ages 18+ who received a COVID-19 vaccine only at 180 Kroger and WalMart locations statewide.

Notes: Announcement dates and last extraction dates across states that instituted lotteries.

Table A2: Mean Comparisons by Lottery Adoption Status

Characteristic	Adopter	Non-Adopter	P-Value
Aged between 16 and 24 (Share)	0.141	0.145	0.23
Aged between 25 and 64 (Share)	0.643	0.645	0.74
Aged 65 or more (Share)	0.216	0.210	0.37
White Non-Hispanic Share	0.691	0.726	0.44
Male Share	0.484	0.487	0.35
High School Graduates/Dropouts Share	0.414	0.400	0.24
Employed (Share)	0.577	0.610	0.01

Source: BLS Current Population Survey.

Notes: Reported p-values refer to two sided-testing hypothesis of a difference in means across the two groups.