Privacy Regulation and Barriers to Public Health

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The COVID-19 pandemic has gravely disrupted the world's economy and killed millions of people. A safe and effective vaccine was developed remarkably swiftly, but as of yet uptake of the vaccine has been slow. This paper explores one potential explanation of delayed adoption of the vaccine, which is data privacy concerns. We explore two contrasting regulations that vary across states that have the potential to affect the perceived privacy risk associated with receiving a COVID-19 vaccine. The first regulation - an 'identification requirement' - increases privacy concerns by requiring individuals to verify personal information with government approved documentation. The second regulation - 'anonymity protection' - lowers privacy concerns by allowing individuals to remove personally identifying information from state-operated immunization registry systems. We investigate the effects of these privacy-reducing and privacy-protecting regulations on U.S. state-level COVID-19 vaccination rates. Using a panel data set, we find that identification requirements decrease vaccine demand, but that this negative effect is offset when individuals are able to remove information from an immunization registry. Our results remain consistent when controlling for CDC-defined barriers to vaccination, levels of misinformation, vaccine incentives, and states' phase distribution of vaccine supply. These findings yield significant theoretical and practical contributions for privacy policy and public health.

Key words: Privacy, COVID-19, Regulation, Public Health, Identification Requirement

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1. Introduction

The COVID-19 pandemic has led to millions of deaths around the world (Feehan 2021). Thanks to a historic collaboration between public and private institutions and the medical community, several vaccines were developed and have been proven effective at reducing death rates. Despite the U.S. securing an abundance of these lifesaving vaccines, many Americans have not yet chosen to be vaccinated. Nationwide, at the time of writing this paper, thirty percent of U.S. residents either do not want the vaccine or are unsure if they will get vaccinated because of a wide range of barriers (Brumfiel 2021). This limits the U.S. from reaching vaccinating the number of residents which experts estimate to be the necessary amount for herd immunity (Berg 2021).

There are many potential barriers to improving vaccination rates, such as distrust in public health institutions and lack of access. However, this paper focuses on a potential explanation of vaccine hesitancy that has received less attention - data privacy concerns that arise from the government-coordinated effort of documenting who has been vaccinated. Privacy concerns related to vaccination emerge from the significant amount of personal information requested to receive a vaccine. Specifically, all states currently use immunization registry systems to collect, monitor, and report confidential information on individuals that receive a COVID-19 vaccine. Among the data collected and stored is personally identifiable information such as name, address, and date of birth. Moreover, each state governs and operates their own immunization registry without federal coordination, leading to variation in data privacy regulations associated with registry systems and receiving a COVID-19 vaccine. It is important to investigate and understand privacy concerns stemming from these regulations because they can deter individuals from public health participation, thereby reducing community welfare. We identify two unique privacy regulations that vary across states and have the potential to affect the perceived privacy risk associated with receiving a COVID-19 vaccine.

The first regulatory approach increases privacy concerns by requiring the verification of personal information with a government approved document such as a driver's license - we refer to this as an "identification requirement." Under such regulations, individuals scheduled to receive a COVID-19 vaccine provide an accepted form of identification to validate their name, birth date, and residency status. The objective of an identification requirement is to deter outsiders, such as people who don't reside in that state, from receiving vaccines. However, these requirements are thought to contribute to the exclusion of minorities who may be less likely to have up-to-date, government-issued identification (LeBrón et al. 2018a). Given that frontline workers are disproportionately comprised of individuals from minority communities (Rho et al. 2020), vaccine hesitancy due to identification requirements are likely to have significant public health implications. In addition to these concerns, identification requirements can pose a significant barrier to individuals with higher privacy concerns, migrants, refugees, and people lacking legal status in the U.S. (Marskell et al. 2021).

The second regulatory approach reduces privacy concerns by allowing individuals to remove personally identifying information from an immunization registry system - we refer to this as 'anonymity protections.' This allows the system to record that a vaccine was administered but removes identification information such that the record cannot be traced to a specific individual. States without anonymity protections require that individuals' personal information be stored in state immunization registry systems without exclusion. National public health experts have warned that prohibiting individuals from excluding personal information could create a barrier to vaccination coverage and recommended the use of anonymity protections to alleviate data privacy concerns (Linkins and Feikema 1998, Collins et al. 2006). Despite these reported privacy concerns, immunization registry systems have increased their requirements for personal information over the past several years (Martin et al. 2015).

We exploit variation in identification requirements and anonymity protections during the COVID-19 vaccine rollout to estimate the effect of these two types of privacy laws on vaccination rates. Using a state-level panel data set, we find that identification requirements decrease vaccine demand, but that this negative effect is offset when individuals are allowed to remove information from an immunization registry. We also find that states with Immigration and Customs Enforcement (ICE) detention centers exhibit a stronger negative effect of identification requirements, suggesting that one explanation of our findings is that a central repository of government-held personal information is unappealing if there is a perceived risk of deportation and detention due to irregularities in immigration status. Our results remain consistent when controlling for CDC-defined barriers to vaccination, levels of misinformation, and phase distribution. The results are also robust to consideration of alternate explanations including variation between states in the level of vaccine misinformation, state protection from ICE enforcement, vaccine supply, and barriers to access of government-approved identification. Overall, our results suggest that privacy concerns contribute significantly to vaccine hesitancy, but that this hesitancy can be counteracted by privacy protections.

Our findings offer significant research and practical contributions. The first contribution is to the information systems and economics literature evaluating the effect of privacy regulations on various aspects of technology (Adjerid et al. 2015, Goldfarb and Tucker 2011b). Specifically, privacy regulations in general have been shown to reduce technology diffusion and usage (Miller and Tucker 2009, Goldfarb and Tucker 2011a, 2012). However, regulations that emphasize individuals' rights over their data have demonstrated more nuanced dynamics, including positive outcomes for consumers (Miller and Tucker 2018, Adjerid et al. 2016) and firms (Godinho de Matos and Adjerid 2021). This paper extends this literature by considering how information systems' privacy protections interact with regulations increasing privacy concerns by requiring personal information. Our results highlight that privacy concerns associated with offline requirements for personal information can be addressable if privacy protections are in place for related digital systems. Importantly, these results highlight the potential to achieve policy aims of offline requirements for personal information (e.g., validation of recipients of treatment and benefits) while avoiding undesirable policy outcomes (e.g., vaccine hesitancy from privacy concerns).

The second contribution is the empirical effects of privacy regulations on a large-scale public health initiative that can have critical consequences on individuals' long-term health compared to other privacy policies. Two key domains within public health emergency management and response that significantly influence health equity are policy and information collection and sharing (Rose et al. 2017). There is substantial controversy surrounding the use of identification requirement policies to receive health services (LeBrón et al. 2018a). In Flint, Michigan during the lead water contamination crisis, residents had to provide ID to get publicly distributed bottled water. The identification requirements contributed to racial profiling (Wallace 2014), with minority groups facing skepticism and doubt even when proper identification was presented (LeBrón et al. 2018b). Subsequently, identification requirements have been linked to disproportionately poor health outcomes among minority groups (LeBrón et al. 2018a). This paper contributes to the growing literature on identification requirements by providing novel empirical evidence of a negative effect, attributable to privacy concerns, on public health participation.

Finally, we contribute to the discussion among policymakers on optimal approaches to regulating individuals' privacy while advocating for public health participation. Healthcare providers across the U.S. have progressively integrated reporting and exchanging information with public health registries for many different treatments, cancers, and infectious diseases. Transferring large amounts of confidential health information to these registry databases illustrates the power of seamless health information exchange and data storage and has become integral to the success of public health programs as it improves coordination and cost effectiveness (Ammenwerth et al. 2003, Foldy et al. 2014). However, a necessary condition for success is interoperability of complete data records (Roberts 2018). Authorized system users are allowed to access and share the confidential health information electronically, but the sensitive nature and identifiability of the data have introduced important ethical and privacy considerations (Gliklich et al. 2014). Specifically, data stored in public health registries may be used for purposes outside of its original scope, which may elicit privacy concerns that influence public health participation (Lee and Gostin 2009). For instance, federal agencies have submitted requirements to state officials that all personal information collected in public health registries be shared with federal systems at the Department of Homeland Security and ICE (Stolberg 2020). This generates tension in establishing policy that supports the data requirements for successful public health information systems while not deterring public health program participation. The findings presented in this paper are among the first to empirically show the impact of privacy regulation on public health participation.

2. Data

To study the effects of privacy regulation on COVID-19 vaccination rates, we first collected the daily ratio of vaccinations initiated in a state relative to the state's population. We collected these data from COVID Act Now–an independent nonprofit that compiles COVID-19 data from the Department of Health and Human Services, the Centers for Disease Control and Prevention (CDC), and official state dashboards. We use initiated vaccinations (i.e., receiving the first dose) because we are interested in individuals' willingness to begin the vaccination process. Vaccination data is at the state level and collected daily. Our state-level vaccination data is from January 14, 2021 to June 30, 2021 across all fifty states and the District of Columbia.

We collected data on state privacy regulations from two unique sources. First, we obtained the identification requirement policies from Kaiser Family Foundation (KFF), a nonprofit organization that provides national health policy data. KFF tracked identification requirement policies and provided updates when a policy was changed. States established identification requirement policies with their phased rollout plan at the beginning of vaccine distribution. Thirty-two states began distribution with an identification requirement but six of these states later removed the requirement during the observational period. The nineteen states that did not implement an identification requirement at the beginning of vaccine distribution never introduced such a requirement.

Next, we examined regulations that govern the storing of personal information in state immunization registry systems. We obtained the anonymity protections for each state from the CDC. Eight states do not have anonymity protections while 43 states have anonymity protections. States that do not have anonymity protection require all individuals' personal information be stored in the state immunization registry with no ability to remove their personal information from the registry. States that have anonymity protection provide individuals the option to restrict the storage of their personal information in the registry. These anonymity protections were time invariant for the duration of this study. Tables displaying summary statistics and a listing of the privacy regulations in each state and the time of change (if one is made) can be found in the Online Appendix.

The regulatory requirements we evaluate are likely to be salient to individuals considering vaccination. During the observational period, individuals seeking vaccination were strongly encouraged to create an appointment with a vaccine provider. In creating an appointment, individuals in identification requirement states were informed of the approved identification documents needed for checking in at the appointment and failure to provide them would result in cancellation. At the time of vaccination, recipients are provided an informational packet containing details on the vaccine they received as well as details on the state's immunization registry system and their privacy options.

Further, segments of the population that may be most concerned about the regulatory requirements are likely to be among the most informed about their presence. Advocacy groups for immigrant populations made significant efforts to proactively inform communities and highlight variation in residency requirements and privacy protections. [1] Thus, unlike other privacy decision contexts where protections and uses of data are subdued or opaque (e.g., online commerce), the requirements and protections around COVID-19 vaccination are highly salient.

3. Empirical Strategy

We use a state-day panel to estimate a two-way fixed effects model to identify the effect of the different regulations on COVID-19 vaccination rates. COVID-19 vaccination rates steadily increased during the observational period to 53% of the population by the end of our data set. Although progress has continued, the U.S. continues to struggle to reach CDC recommended levels; which presents opportunities to further increase vaccination.

Our empirical approach can be summarized in the following equation:

$$\begin{aligned} VaccinationRate_{it} = \beta_0 + \beta_1(IdRequirement_{it}) + \beta_2(IdRequirement_{it}) \times (AnonProtection_i) + \\ \beta_3(IdRequirement_{it}) \times (ICEDetention_i) + \sigma(\mathbf{X_{it}}) + \theta_i + \lambda_t + \gamma_i \times t + \epsilon_{it} \end{aligned} \tag{1}$$

where $VaccinationRate_{it}$ is the ratio of individuals that have received their first dose of a COVID-19 vaccine on day t relative to the population of state i. Our key regulation variables are $IdRequirement_{it}$ and $AnonProtection_i$, which are indicators for whether a state has an identification requirement and whether a state has an anonymity protection regulation. The model also includes $ICEDetention_i$, which is the number of ICE detention centers in a state. β_1 identifies the effect of ID requirements whereas β_2 and β_3 identify differential effects of these requirements when states have anonymity protections or a strong ICE presence. Further, we incorporate state fixed effects (θ_i) to account for time-invariant differences between states and time-fixed effects (λ_t) to account for any common shocks in our data. Given heterogeneity in the rollout and distribution of vaccines across states, we include state-specific linear time trends ($\gamma_i \times t$). Together with the state and time fixed effects, these time trends help us identify the discontinuous effect of these regulations on COVID-19 vaccination rates.

Because we are studying the effects of regulation change, it is important to consider motivations that may simultaneously affect regulation change and vaccination rates. Specifically, we focus on vaccine distribution and demand constraints. We found no evidence of states changing their regulation to because of these constraints. For example, Indiana removed its identification requirement to better align with the Federal Emergency Management Agency's guidelines (Nelson 2021). Maine removed its identification requirement to entice out-of-state college

[1] https://www.nilc.org/2021/04/12/immigrant-access-to-the-covid-19-vaccines/
https://www.boundless.com/blog/can-immigrants-get-the-covid-19-vaccine/

students to return after universities began to reopen (Russell 2021). Although anecdotal, these reports increase confidence that regulation change is exogenous to vaccine demand. In later analysis (see Section 5.2), we find supporting evidence that vaccine supply did not contribute to policy change. Similarly, anonymity protections were quite common, and prior work has found that diverse states have these types of regulations (Tucker 2015).

We also extend our estimation with several controls (X_{it}) to account for potential confounds in our data. First, states planned their COVID-19 vaccination rollout in phases that restricted eligibility according to age and pre-existing medical conditions. Individuals that did not meet the eligibility requirements for a given phase were not permitted to receive a vaccine. Although states were allowed to devise their own rollout plan and specific eligibility requirements, many states followed guidelines and recommendations provided by the CDC Advisory Committee on Immunization Practices. Therefore, we identified three overarching phases. Eligible individuals in the first phase (Phase 1) included those aged 75 and above, frontline essential workers, and health care workers. Phase 2 included individuals aged 65 and above as well as anyone aged 16 or older with at least one higher risk medical condition (e.g., cancer, heart disease, pregnancy). Phase 3 opened vaccination to anyone aged 16 or older regardless of medical condition. States transitioned between phases at varying points in time. KFF tracked states' progression through each phase and provided the date on when new vaccine eligibility occurred. This allows us to control for changes in vaccination rates over time according to increasing vaccine eligibility.

Second, although COVID-19 vaccines are readily available at distribution sites across the U.S., reports have suggested that individuals do not have equitable access to the vaccine according to where they live. Surgo Ventures, a nonprofit data analytics organization that works with the CDC, identified four unique factors affecting the vaccination rollout in different communities. The factors included: (1) historic under-vaccination, (2) sociodemographic barriers, (3) resource-constrained health systems, and (4) healthcare accessibility barriers. Under-vaccination represents the degree in which a community has lower than average vaccination rates or higher refusal rates for routine vaccines such as polio, tetanus, and measles. Sociodemographic barriers include the wealth gap and access to health information among different racial and ethnic groups in a community. Resource-constrained health systems represent the financial and labor resources available in a community. Healthcare accessibility captures cost and transportation barriers. Scores for each factor were calculated across states using historical measures from past CDC surveys and a variety of economic indicators. These measures are time-invariant in our estimation, but they enter our estimation as interactions with a linear time trend.

Third, the spread of COVID-19 misinformation has been shown to affect vaccine hesitancy and increase the public's distrust of medical professionals (Brumfiel 2021). We use two different measures for controlling the extent of COVID-19 misinformation in a state and its impact on vaccination rates. The first measure is the proportion of tweets containing COVID-19 misinformation per 1,000 people in each state in 2020 (Forati and Ghose 2021). The second measure is the Google Trends metric for "hydroxychloroquine" each day of the observational period. A campaign pushing hydroxychloroquine has been one of the leading misinformation campaigns among anti-vaccination groups. Misinformation on the drug's effectiveness for treating COVID-19 was significant for much of 2020 but had subsided by early 2021. It then saw a resurgence with the progression of the vaccine rollout. Both measures provide insight into the presence and diffusion of COVID-19 misinformation.

Fourth, we control for the implementation of state-funded vaccine incentive programs. Several states attempted to incentivize residents to get vaccinated by entering those that received a vaccine, during a specified time, into a lottery. Lottery winners would receive a substantial monetary payoff. These lottery programs varied across states and implementation date and may overcome privacy concerns generated from the regulations we study. For instance, vaccination rates in a state may increase as individuals attempt to win a monetary payout, thereby negating the effects of privacy regulations.

4. Impact of Regulation on Vaccination Rates

Table 1 displays the initial results of identification requirements and anonymity protections on state-level vaccination rates. The analysis begins with only the main and interaction effects of the privacy regulations and state and day fixed effects. We then progressively incorporate control measures and additional time trends. We do not present estimates for the control measures for brevity, but full tables with all estimates can be found in the Online Appendix.

Column (1) provides the effects of privacy regulations on COVID-19 vaccination rates without control measures in the specification. We find a significant negative effect on state vaccination rates when an identification requirement is enacted. Conversely, the interaction between identification requirements and anonymity protections has a significant positive effect. Column (2) provides that the effects of privacy regulations persist after controlling for rollout phase, barriers to vaccination, and the degree of misinformation in the state. Column (3) includes a state-specific time trend to control for differing linear trends in state vaccination rates. The magnitude of our findings decreases when controlling for state trends but continues to be significant. Column (4) includes an interaction between the presence of identification requirements and the presence of ICE detention centers. We find that the interaction has a marginally significant negative effect on vaccination. The interaction between ICE detention centers and anonymity protections is omitted because there is no variation between these measures.

To put our findings into perspective, consider that the average population in states that never removed their identification requirement is 4,426,214 people. The estimates in Column (4) provide that identification requirements in these states decrease their vaccination rate by 4.87%, thereby resulting in an average of 215,557 fewer vaccinations per state. Providing individuals in states with identification requirements the ability to remove their personal information from immunization registry systems offsets the negative effect of having an identification requirement by increasing vaccination by 5.59%, or 247,426 more vaccinations per state. That is, unless the state has an identification requirement and an ICE detention center. Our results indicate that identification requirements in states with ICE detention centers further decrease vaccination by 0.66%, or 29,213 fewer vaccinations. Because all but one state with ICE detention centers provides the ability to remove personal information from immunization registry systems, the interaction between identification requirements and ICE detention centers suggests that identification requirements are a significant barrier to vaccination among minorities who are sensitive to ICE presence and activity.

Table 1. Initial Results

	(1)	(2)	(3)	(4)
Identification requirement	-0.1607**	-0.1749**	-0.0486**	-0.0487**
	(0.0092)	(0.0261)	(0.0047)	(0.0046)
Identification*Protection	0.1465**	0.1348**	0.0450**	0.0560**
	(0.0332)	(0.0399)	(0.0117)	(0.0154)
Identification*Detention				-0.0066†
				(0.0037)
Controls	No	Yes	Yes	Yes
State and Day Fixed Effects	Yes	Yes	Yes	Yes
State-Specific Time Trend	No	No	Yes	Yes
Observations	8,307	8,307	8,307	8,307
States	51	51	51	51

Notes. Dependent variable is the vaccination rate in state *s* at day *t*. OLS regressions with robust standard errors clustered by state.
** < 0.01; * < 0.05; † < 0.10.

5. Robustness Checks

Table 2 displays the results from several robustness checks we perform. Column (1) considers that it is plausible that the negative effect of identification requirements we find in the main results is caused by the difficulty in obtaining government-approved identification and not privacy concerns. Specifically, immigrant populations may be among the most sensitive to privacy risk while also having a more difficult time obtaining government-approved documentation. However, consistent results for identification requirements when the barrier to obtaining government-approved identification is lessened provides evidence that the impact of identification requirements on vaccination rates is rooted in privacy concerns. Several states have policies that assist with obtaining a driver's license by allowing undocumented immigrants to get a driver's license after providing a foreign birth certificate, foreign visa, or consular cards. This grants immigrants a driver's license, the most common identification document satisfying an identification requirement, without proof of lawful presence or a social security number. We use the subsample of states with driver's license assistance policies to estimate the effect of privacy regulations on vaccination rates. The interaction effects from our initial results are omitted because all states in the subsample offer anonymity protection and do not have detention centers. Our results provide a significant negative effect of identification requirements on vaccination rates, which supports our argument that the requirement's effect stems from an individual's privacy concerns.

Column (2) considers that elected officials within states vary in their cooperation with ICE and other law enforcement agencies on matters of immigration. Specifically, some elected officials implement policies or publicly announce that they will comply with detainer requests and investigations of persons suspected of being undocumented immigrants. States with these elected officials may bias our results such that the decrease in vaccination rates is strictly related to areas with high underlying anti-immigrant sentiment. Ballotpedia.com provides a list of states with elected officials that have publicly stated their level of cooperation. We use the list to form a subsample of states that do not have elected officials with anti-immigration sentiment and estimate the full model from our initial results. We find consistent results in which there is a significant negative effect of identification requirements on vaccination rates, but enacting anonymity protections offsets the negative effect. The interaction

Table 2. Robustness Checks

	(1)	(2)	(3)	(4)	(5)	(6)
	States with License Assistance	*States without ICE Cooperation*	*States without Misinformation*	*Additional Time Trends*		
Identification Requirement	-0.0316**	-0.0547**	-0.0553**	-0.0546**	-0.0563**	-0.0225**
	(0.0063)	(0.0062)	(0.0091)	(0.0057)	(0.0080)	(0.0032)
Identification*Protection	Omitted	0.0591**	0.0409†	0.0721**	0.0728**	0.0355**
		(0.0161)	(0.0162)	(0.0151)	(0.0157)	(0.0060)
Identification*Detention	Omitted	-0.0075†	Omitted	-0.0087*	-0.0082*	-0.0026*
		(0.0039)		(0.0032)	(0.0033)	(0.0012)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
State and Day Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
State-Specific Time Trend	Yes	Yes	Yes	Yes	Yes	Yes
State-Specific Phase Trend				Yes	Yes	Yes
Phase-Specific Time Trend				No	Yes	Yes
State-Phase-Specific Time Trend				No	No	Yes
Observations	2,765	5,216	978	8,307	8,307	8,307
States	17	32	6	51	51	51

Notes. Dependent variable is the vaccination rate in state *s* at day *t*. OLS regressions with robust standard errors clustered by state.
** < 0.01; * < 0.05; † < 0.10.

effect between identification requirements and ICE detention centers is omitted because these states did not have a detention center. This suggests that our results persist even in states with lower anti-immigration sentiment.

Column (3) considers that the extent of misinformation in a state can bias our findings. Misinformation has become a national discussion with its prevalence during the COVID-19 pandemic. Although we control for misinformation by state, using Google Trend metrics for "hydroxychloroquine", we further consider the extent of COVID-19 misinformation through social media platforms. Forati and Ghose (2021) identified the number of tweets and retweets containing misinformation across the U.S. over several months in 2020 to determine the geographic dispersion of misinformation. We use their state-level findings to form a subsample of states that had fewer than one thousand tweets or retweets per capita, which indicated little to no misinformation sharing for that state. We focus on this subsample because of the potential bias toward non-vaccination that misinformation may generate. Consistent results when using the subsample of states that had little to no misinformation help further address the concern that our effects are driven by misinformation and not by the regulations of interest.

Columns (4), (5), and (6) model time trends more rigorously to ensure that the effect of privacy regulations is not an artifact of key states following different trends in vaccination. For instance, states' phased approach to vaccine distribution provides an additional time dimension beyond the daily vaccination rate. Therefore, vaccination rates in a state may follow different time trends according to the phase of vaccine rollout, leading to increases in vaccination rates according to phase transition rather than privacy regulation. Although our models control for the average effect of each rollout phase, we interact the phase indicators with state and time variables to control for these possible trends. Column (4) includes an interaction between each state and the phase indicators to control for trends in states transitioning between phases. Column (5) includes an interaction between each phase and the linear daily time trend to control for trends in the length of time spent in each phase. Column (6) includes a three-way interaction between each state, phase, and the linear daily time trend. The interaction across the three dimensions controls for the trend in vaccination rates according to a specific state and the duration that the state is in each phase. The significance of our findings remains consistent as we include each of these controls for linear trend although the effect sizes decrease.

Table 3. Supply Effects on Identification Requirement Enactment

	(1)	(2)
	Initial Identification Enactment	*Identification Removal*
Vaccine Supply	1.9083	-0.1296
	(3.1353)	(0.1989)
State Fixed Effect	No	Yes
Day Fixed Effect	No	Yes
Observations	51	8,307
States		51

Notes. Dependent variable is the presence of an identification requirement in state s at day t. OLS regressions with robust standard errors clustered by state.
** < 0.01; * < 0.05; † < 0.10.

5.1. Effects of Vaccine Supply

Further, we explore supply-side effects that may bias our findings. One intention of identification requirements is to preserve the supply of a public good for specific individuals when supply limitations are present. Therefore, it is possible that the negative effect of identification requirements on vaccination rates is linked to lower supply rather than privacy concerns. We test for the effects of vaccine supply in two ways. First, we estimate the effect of initial vaccine supply on whether states enacted an identification requirement at the beginning of the observational period. States that began the vaccine rollout with less supply may be more likely to adopt identification requirements to ensure its availability to residents. Second, we estimate the effect of changes in vaccine supply on the removal of identification requirements. As vaccine supply grew during the rollout it is possible that states removed identification requirements because of supply increases. This would indicate that the change we observe may be attributed to earlier supply limitations. Table 3 presents the results from these estimations. We find that enactment and removal of identification requirements are not affected by vaccine supply.

5.2. Additional Robustness Checks

Lastly, we consider several other robustness checks to further support our findings, which can be found in the Online Appendix. The first additional test weights states' daily vaccination rate by the vaccination barriers present. The second additional test explores heterogeneous effects across vaccination barrier subsamples.

6. Discussion

In this paper, we explore the effects of privacy reducing and privacy protecting policies on COVID-19 vaccination rates. Studying the impact of these policies is important because of the expanding collection and exchange of confidential health information in public health information systems, which also introduces privacy challenges that may interfere with public health participation. Our results demonstrate that privacy reducing policies such as identification requirements decrease vaccination rates by nearly five percent. Additionally, we find that enacting anonymity protections in states with identification requirements offsets the negative effect. The significance of these effects during a global pandemic, when there is a clear and available vaccine to protect one's health and those around them, illustrate the importance of privacy considerations when implementing public health policy.

Our findings have implications for the field of information systems because it is the advancement and interoperability of information systems that can assist with public health emergency responses and management. The COVID-19 pandemic has highlighted the capabilities of information exchange as healthcare providers, state public health systems, and federal systems such as the CDC share their information to monitor the spread of the virus, determine the allocation of healthcare resources, study vaccine effectiveness and distribution, and support local and federal decision-making. However, these emergency responses are reliant on individuals' participation in the response and willingness to disclose information to the systems. Therefore, the findings in this paper are important to the study of information systems and emergency management because it is among the first to provide evidence of information privacy's role in public health participation. Future growth in the scale of information systems for public health and emergency management has the potential to improve response efficiency and better outcomes. It is therefore a necessity to understand how policies governing information exchange within these systems serve as a barrier to their success. Furthermore, our results may also be useful in other contexts outside of public health where identification requirements and registry systems are being implemented, such as voting. There has been significant debate on the usage of identification requirements for voting in elections with a prominent view that lack of identification is the cause of its negative effect on voter turnout. Our finding that identification requirements reduce participation even in states that offer identification assistance suggests that a privacy component may be present.

Our study is not without limitations. First, we look at reasonably aggregate data of vaccination rates at the state level. Use of county-level vaccination data is limited at the present time because provision of such data is uneven across states and time. Further, we did not have access to the type of granular vaccination decisions at an individual level that would allow individual-level analysis. Second, though we provide evidence that the regulations we study seem reasonably exogenous, like any other study of regulations we are not able to establish complete exogeneity. Third, we provide suggestive evidence of a mechanism related to immigration concerns, but again this intended to be suggestive rather than proving a single unifying mechanism underlying what we find. Notwithstanding these limitations, this study offers useful insight into the impact of differing privacy regulations on COVID-19 vaccination rates.

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Appendices

This Appendix contains supplemental materials and robustness checks that support the manuscript. First, we provide tables that present the privacy regulations in a state and the date a change was made to an identification requirement. Second, we provide a section on summary statistics for the variables used in our empirical models. Third, we provide a table with all variable estimates from our initial results and robustness check models. Fourth, we weight states' daily vaccination rate by the vaccination barriers present and continue to find significant effects for privacy regulations. Fifth, we provide a full table containing the effects of privacy regulations on vaccination rates for states with low and normal barrier profiles. Finally, we conclude with a model that analyzes trends in vaccination rates prior to changes in identification requirements.

A. Privacy Regulations Across States

Table A1. Privacy Regulations across States

States	*Identification Requirement*	*Anonymity Protections*	*Date Identification Requirement Removed*
Alabama		X	
Alaska	X		
Arizona		X	
Arkansas	X	X	
California		X	
Colorado		X	
Connecticut	X	X	
Delaware	X		
District of Columbia	X		4/30/2021
Florida	X	X	
Georgia	X	X	
Hawaii	X	X	
Idaho	X	X	
Illinois	X	X	
Indiana	X	X	3/23/2021
Iowa		X	
Kansas	X	X	
Kentucky	X	X	
Louisiana		X	
Maine	X	X	5/02/2021
Maryland		X	
Massachusetts	X	X	
Michigan		X	
Minnesota		X	
Mississippi	X		
Missouri	X		
Montana		X	
Nebraska	X	X	
Nevada		X	
New Hampshire	X	X	4/19/2021
New Jersey	X	X	
New Mexico		X	
New York	X	X	
North Carolina			
North Dakota	X	X	
Ohio		X	
Oklahoma	X	X	4/08/2021
Oregon	X	X	
Pennsylvania		X	
Rhode Island	X		
South Carolina			
South Dakota	X	X	
Tennessee		X	
Texas		X	
Utah	X	X	
Vermont	X		5/20/2021
Virginia		X	
Washington	X	X	
West Virginia	X		
Wisconsin	X	X	
Wyoming	X	X	

Notes: Includes and the District of Columbia. For states that later removed their identification requirement, we include the date that the policy was removed. States that did not have anonymity protections required all personal information to be stored in the state immunization registry without a means of removal.

B. Additional Empirical Tables

Table A2. Summary Statistics

	Mean	SD
Vaccination	0.3198	0.1759
Identification requirements	0.5768	0.4941
Anonymity Protections	0.8039	0.3971
ICE detention centers	2.6078	4.5164
Phase 1	0.2203	0.4144
Phase 2	0.2464	0.4309
Phase 3	0.5334	0.4989
Historical under vaccination	0.4976	0.2940
Sociodemographic barriers	0.4965	0.2949
Healthcare resource constraints	0.4957	0.2948
Healthcare accessibility barriers	0.4941	0.2949
Misinformation Tweets	3.3922	1.9812
Hydroxychloroquine	9.7992	20.3809
Vaccine Incentives	0.0280	0.1651

Note: Table includes the mean and standard deviation for the variables used in empirical analysis

Table A3. Initial Results with All Estimates

	(1)	(2)	(3)	(4)
Identification requirement	-0.1607**	-0.1749**	-0.0486**	-0.0487**
	(0.0092)	(0.0261)	(0.0047)	(0.0046)
Identification*Protection	0.1465**	0.1348**	0.0450**	0.0559**
	(0.0332)	(0.0399)	(0.0117)	(0.0154)
Identification*Detention				-0.0066†
				(0.0037)
Phase 2 rollout		-0.0107	-0.0020	-0.0021
		(0.0083)	(0.0043)	(0.0043)
Phase 3 rollout		-0.0041	0.0064	0.0065
		(0.0097)	(0.0066)	(0.0065)
Historic under vaccination*t		-0.0006*	-0.0078**	-0.0078**
		(0.0003)	(0.0002)	(0.0002)
Sociodemographic barriers*t		-0.0006*	-0.0107**	-0.0107**
		(0.0002)	(0.0003)	(0.0003)
Healthcare resource constraints*t		-0.0004	-0.0101**	-0.0101**
		(0.0003)	(0.0002)	(0.0002)
Healthcare accessibility barriers*t		-0.0009**	0.0031**	0.0031**
		(0.0003)	(0.0001)	(0.0001)
Misinformation tweets*t		0.0001**	0.0008**	0.0008**
		(0.00003)	(0.00002)	(0.00002)
Hydroxychloroquine		0.00001	0.00001	0.00001
		(0.00002)	(9.36e-06)	(9.38e-06)
Vaccine Incentives		0.0214†	0.0112†	0.0114†
		(0.0115)	(0.0058)	(0.0058)
State Fixed Effect	Yes	Yes	Yes	Yes
Day Fixed Effect	Yes	Yes	Yes	Yes
State-Specific Time Trend	No	No	Yes	Yes
Observations	8,307	8,307	8,307	8,307
States	51	51	51	51

Notes. Dependent variable is the vaccination rate in state s at day t. OLS regressions with robust standard errors clustered by state.
** < 0.01; * < 0.05; † < 0.10.

Table A4. Robustness Checks with All Estimates

	(1)	(2)	(3)	(4)	(5)	(6)
	States with License Assistance	*States without ICE Cooperation*	*States without Misinformation*	*Additional Time Trends*		
Identification Requirement	-0.0316**	-0.0547**	-0.0553**	-0.0546**	-0.0563**	-0.0225**
	(0.0063)	(0.0062)	(0.0091)	(0.0057)	(0.0080)	(0.0032)
Identification*Protection	Omitted	0.0591**	0.0409†	0.0721**	0.0728**	0.0355**
		(0.0161)	(0.0162)	(0.0151)	(0.0157)	(0.0060)
Identification*Detention	Omitted	-0.0075†	Omitted	-0.0087*	-0.0082*	-0.0026*
		(0.0039)		(0.0032)	(0.0033)	(0.0012)
Phase 2 rollout	0.0014	-0.0093	0.0058	-0.0007	-0.0047	0.0150*
	(0.0060)	(0.0057)	(0.0178)	(0.0046)	(0.0096)	(0.0075)
Phase 3 rollout	0.0172*	-0.0019	0.0150	0.0098	0.0263	0.0821*
	(0.0065)	(0.0095)	(0.0259)	(0.0110)	(0.0432)	(0.0373)
Historic under vaccination*t	-0.0019**	-0.0015**	-0.0032**	-0.0077**	-0.0076**	0.0133**
	(0.00002)	(0.00004)	(0.0001)	(0.0008)	(0.0010)	(0.0018)
Sociodemographic barriers*t	-0.0052**	0.0022**	0.0002	-0.0103**	-0.0099**	0.0201**
	(0.0001)	(0.0001)	(0.0005)	(0.0011)	(0.0016)	(0.0027)
Healthcare resource constraints*t	-0.0005*	-0.0020**	-0.0057**	-0.0091**	-0.0088**	0.0162**
	(0.0002)	(0.0001)	(0.0003)	(0.0009)	(0.0012)	(0.0019)
Healthcare accessibility barriers*t	0.0025**	-0.0058**	-0.0008†	0.0042**	0.0041**	-0.0123**
	(0.0003)	(0.0001)	(0.0003)	(0.0007)	(0.0009)	(0.0018)
Misinformation tweets*t	0.0002**	-0.0006**		0.0009**	0.0008**	-0.0018**
	(4.96e-06)	(0.00002)		(0.0001)	(0.0001)	(0.0002)
Hydroxychloroquine	-6.64e-06	5.71e-06	5.85e-06	9.40e-06	9.59e-06	-4.18e-06
	(0.00001)	(9.53e-06)	(0.00002)	(8.95e-06)	(8.83e-06)	(4.22e-06)
Vaccine Incentives	0.0020	0.0132*	0.0184**	0.0169*	0.0166**	-0.0028
	(0.0070)	(0.0049)	(0.0030)	(0.0070)	(0.0067)	(0.0028)
State Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Day Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
State-Specific Time Trend	Yes	Yes	Yes	Yes	Yes	Yes
State-Specific Phase Trend				Yes	Yes	Yes
Phase-Specific Time Trend				No	Yes	Yes
State-Phase-Specific Time Trend				No	No	Yes
Observations	2,765	5,216	978	8,307	8,307	8,307
States	17	32	6	51	51	51

Notes. Dependent variable is the vaccination rate in state s at day t. OLS regressions with robust standard errors clustered by state.
** < 0.01; * < 0.05; † < 0.10.

C. Weighted Vaccination Rate

Our empirical models estimate the effects of identification requirements and anonymity protections on COVID-19 vaccination rates. However, several barriers to vaccination have been found that can affect the vaccination rates in different areas. Individuals in states with higher levels of barriers may not have equitable access to vaccine relative to states with lower levels of barriers. Because of this variation in vaccination according to the barriers present, it is reasonable to consider that state vaccination rates are a function of the barriers to vaccination within the state. As such, we calculate the average of the vaccination barriers identified by the CDC to weight each state's vaccination rate. For illustration, consider that there are two states with differing levels of vaccination barriers. The first state, Connecticut, has low levels of vaccination barriers and a high vaccination rate. The second state, Ohio, has high levels of vaccination barriers and a low vaccination rate. The influence of the barriers on vaccination may affect the comparability of the rates across states. In other words, the higher vaccination rate in Connecticut may be contributed to the low barriers and is not representative of most states. Therefore, we use the average of the barriers in a state to weight the state's vaccination rate and provide an equal comparison across states. Weights are on a zero to one scale with states having higher levels of barriers given more weight than states with lower levels of barriers. This also provides a robustness check for if our findings are drive by states with greater vaccination because of lower barriers. We use the weighted vaccination rates as the dependent variable in our models. Table A5 displays the results. Column (1) investigates the effects of privacy regulations without rigorous time trends. Column (2) investigates the effects of privacy regulations with rigorous time trends. We find consistency in our results that identification requirements negatively affect vaccination, but anonymity protections offset the negative effect.

Table A5. Weighted Vaccination Rate

	(1)	(2)
Identification requirement	-0.0257**	-0.0126**
	(0.0024)	(0.0024)
Identification*Protection	0.0239**	0.0119**
	(0.0044)	(0.0028)
Identification*Detention	-0.0019†	-0.0014**
	(0.0011)	(0.0003)
Phase 2 rollout	0.0008	0.0128*
	(0.0022)	(0.0048)
Phase 3 rollout	0.0070*	0.0371
	(0.0027)	(0.0242)
Misinformation tweets	0.0001**	-0.00003*
	(2.57e-06)	(0.00001)
Hydroxychloroquine	1.59e-06	-2.04e-06
	(4.64e-06)	(2.05e-06)
Vaccine Incentives	0.0118**	0.0035
	(0.0040)	(0.0032)
State Fixed Effect	Yes	Yes
Day Fixed Effect	Yes	Yes
State-Specific Time Trend	Yes	Yes
State-Specific Phase Trend	No	Yes
Phase-Specific Time Trend	No	Yes
State-Phase-Specific Time Trend	No	Yes
Observations	8,307	8,307
States	51	51

Notes. Dependent variable is the vaccination rate in state *s* at day *t* weighted by the average of the CDC barriers to vaccination. OLS regression with robust standard errors clustered by state.
** < 0.01; * < 0.05; † < 0.10.

D. Vaccination Barrier Profiles

Table A6. Vaccination Barrier Profiles

	(1)	(2)	(3)	(4)	(5)	(6)
	Normal Vaccination History	*Low Socio-demographic*	*Normal Socio-demographic*	*Low Resources*	*Normal Resources*	*Normal Accessibility*
Identification Requirement	-0.0574**	-0.0607*	-0.0473**	-0.0528**	-0.0559**	-0.0531**
	(0.0066)	(0.0214)	(0.0046)	(0.0134)	(0.0100)	(0.0058)
Identification*Protection	0.0931**	Omitted	0.0743**	0.0505**	Omitted	0.0448*
	(0.0109)		(0.0097)	(0.0107)		(0.0212)
Identification*ICE	-0.0747**	Omitted	-0.0091**	Omitted	0.0069**	-0.0023
	(0.0204)		(0.0022)		(0.0011)	(0.0046)
Phase Indicators	Yes	Yes	Yes	Yes	Yes	Yes
Misinformation Controls	Yes	Yes	Yes	Yes	Yes	Yes
Vaccine Incentive Controls	Yes	Yes	Yes	Yes	Yes	Yes
State Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Day Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
State-Specific Time Trend	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,379	1,467	5,536	1,467	5,536	5,373
States	33	9	34	9	34	33

Notes. Dependent variable is the vaccination rate in state *s* at day *t*. OLS regressions with robust standard errors clustered by state.
** < 0.01; * < 0.05; † < 0.10.

Next, we consider the potential for heterogreneous effects across vaccination barriers to identify whether the effects we observe are present when barriers are either low or in a normal range. Because we find that identification requirements negatively affect vaccination rates, we consider if the negative effect is driven by states with higher barriers. Although we include the barriers as controls, consistent findings among states with relatively lower barriers provides support that our findings are not influenced by the presence of vaccination barriers.

To analyze the heterogeneous effects, we divide states into low, normal, and high categories for each barrier. Low and high barrier categories consist of the collection of states at extremes such that the barrier is heavily present (high) or minimally present (low). The normal barrier category is the collection of states that are between the normal and high categories. Numerically, each vaccination barrier variable is on a scale of zero to one with zero representing virtually no barrier and one representing a significant barrier. We categorize states as having a low barrier if they have a barrier score of less than 0.18. We categorize states as having a high barrier if they have a barrier score of greater than 0.82. We categorize states as having a normal barrier if they have a score between 0.18 and 0.82. This translates into about nine states in the low barrier subsample, eight states in the high barrier subsample, and thirty-three states in the normal barrier subsample. With these subsamples, we estimate the model from Column (4) in Table 1 of the manuscript.

Table A6 shows the results from our estimations. We find consistent results among our privacy regulations. Specifically, identification requirements have a negative effect on vaccination rates but offering privacy protections offsets the negative effect. We find consistency in the interaction effect between identification requirements and ICE detenetion centers in Column (1) and Column (3). However, the interaction effect is positive in Column (5) and a null effect in Column (6).The positive and null effects offer that this extension may be more nuanced according to the healthcare resources and accessibility in the state. We exclude the estimations using the sample of states with low under vaccination and low healthcare accessibility because these states did not change their identification requirements.