COVID-19 Vaccination Associated with Reductions in COVID-19 Mortality and Morbidity in the United States, and an Approach to Valuing these Benefits

Key Points

- COVID-19 vaccines have been crucial in mitigating adverse public health and economic impacts of the COVID-19 pandemic, but uptake has varied over numerous domains, including demographic and geographic factors.
- Using a regression model and county-level data on vaccination rates, cases, hospitalizations, and deaths, we estimate that COVID-19 vaccination was associated with reductions of 25.32 million cases, 1.38 million hospitalizations, and 213,000 deaths in the United States between December 2020 and July 2021.
- Our sensitivity analyses provide a range of estimates for cases (15.70 million to 27.97 million), hospitalizations (1.10 million to 1.86 million), and deaths (178,000 to 422,000).
- We value the health benefits of COVID-19 vaccination based on individual willingness to pay (WTP) to reduce one's own morbidity and mortality risks.[1] We estimate a total value of COVID-19 risk reductions attributable to vaccination ranging between $1.38 trillion and $4.49 trillion. Using the mid-point value of the willingness to pay, the total health benefits are estimated at $2.95 trillion, including reductions in deaths (mid-point $2.45 trillion; range: $1.15 trillion to $3.74 trillion), hospitalizations (midpoint: $354.14 billion; range: $165.27 billion to $539.08 billion), and cases (midpoint: $139.96 billion; range: $65.32 billion to $213.05 billion).

INTRODUCTION

On March 11, 2020, the World Health Organization (WHO) declared the novel coronavirus disease 2019 (COVID-19) outbreak a global pandemic and called on countries to take action to

[1] In economics, WTP is the maximum value, usually price, an individual is willing to give in exchange for a product or service. In this context, it is the maximum amount of money an individual would willingly exchange to reduce one's risk of getting infected with COVID-19, being hospitalized with COVID-19 or dying of COVID-19, while reducing his or her ability to purchase other things.

contain the virus.[2] The rapid development of COVID-19 vaccines was seen as crucial to mitigating the public health and economic impacts of the COVID-19 pandemic. By the end of March 2020, with the launch of the first clinical trials in the United States, the race was on to accelerate the development of a COVID-19 vaccine.[3,4] On December 11, 2020, the Food and Drug Administration issued an emergency use authorization for the first COVID-19 vaccine in the United States. As of November 2, 2021, three COVID-19 vaccines are now available in the United States. The rapid development of COVID-19 vaccines is the result of various collaborations and massive investments (at least $10 billion) from the federal government in research and development, manufacturing capacity, and purchasing.[5,6,7,8]

The COVID-19 pandemic has had and continues to have widespread impacts on Americans. Data from the Centers for Disease Control and Prevention (CDC) show that between January 21, 2020 and November 2, 2021, there have been over 46 million COVID-19 laboratory-confirmed cases and over 700,000 deaths.[9] The number of reported cases, deaths, and hospitalizations peaked on January 12, 2021, when CDC data showed that there were there were 4,103 new COVID-19 deaths, over 123,000 new COVID-19 hospitalizations, and 210,000 new COVID-19 confirmed cases (see Figure 1). [10]

---

[2] AP News. WHO declares coronavirus a pandemic, urges aggressive action. Available at: https://apnews.com/article/united-nations-michael-pence-religion-travel-virus-outbreak-52e12ca90c55b6e0c398d134a2cc286e, last accessed October 15, 2021.

[3] NIH. NIH clinical trial of investigational vaccine for COVID-19 begins. Available at: https://www.nih.gov/news-events/news-releases/nih-clinical-trial-investigational-vaccine-covid-19-begins#:~:text=A%20Phase%201%20clinical%20trial,Institute%20(KPWHRI)%20in%20Seattle, last accessed October 15, 2021.

[4] GAO. COVID-19: Federal efforts accelerate vaccine and therapeutic development, but more transparency needed on emergency use authorizations. Available at: https://www.gao.gov/products/gao-21-207, last accessed October 15, 2021.

[5] The White House. Fact Sheet: Biden Administration announces historic $10 billion investment to expand access to COVID-19 vaccines and build vaccine confidence in hardest-hit and highest-risk communities. Available at: https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/25/fact-sheet-biden-administration-announces-historic-10-billion-investment-to-expand-access-to-covid-19-vaccines-and-build-vaccine-confidence-in-hardest-hit-and-highest-risk-communities/, last accessed October 15, 2021.

[6] Congressional Research Service. Domestic Funding for COVID_19 Vaccines: An Overview. Available at: https://crsreports.congress.gov/product/pdf/IN/IN11556, last accessed October 15, 2021.

[7] Health Affairs. It was the government that produced COVID-19 vaccine success. Available at: https://www.healthaffairs.org/do/10.1377/hblog20210512.191448/full/, last accessed October 15, 2021.

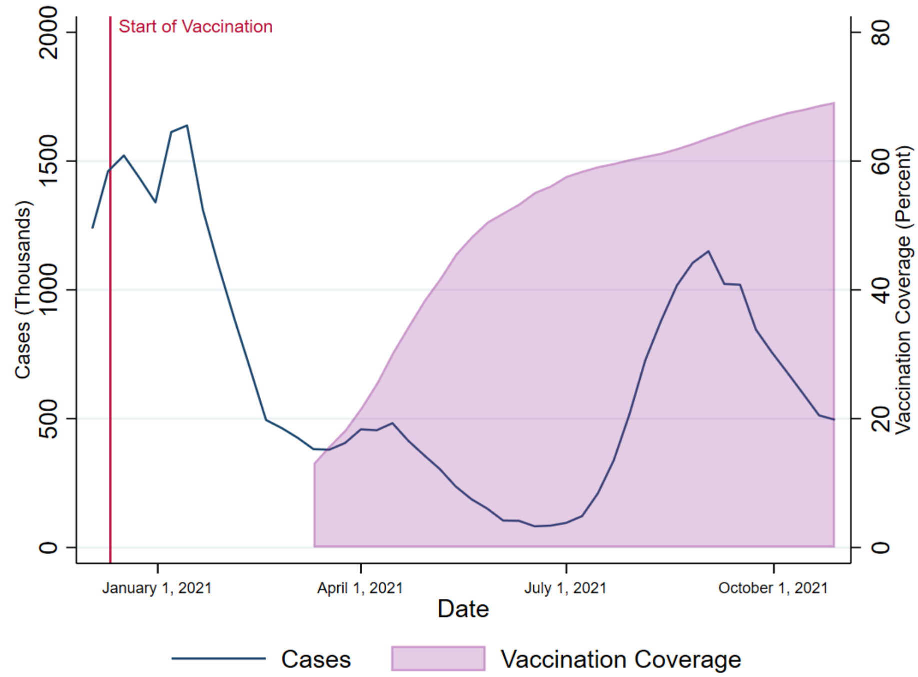
[8] GAO. Operation Warp Speed: Accelerated COVID-19 vaccine development status and efforts to address manufacturing challenges. Available at: https://www.gao.gov/assets/gao-21-319.pdf, last accessed October 15, 2021.

[9] CDC. COVID Data Tracker: United State COVID-19 cases, deaths, and laboratory testing (NAATs) by state, territory, and jurisdiction. Available at: https://covid.cdc.gov/covid-data-tracker/#cases_deathsper100klast7days, last accessed November 3, 2021.

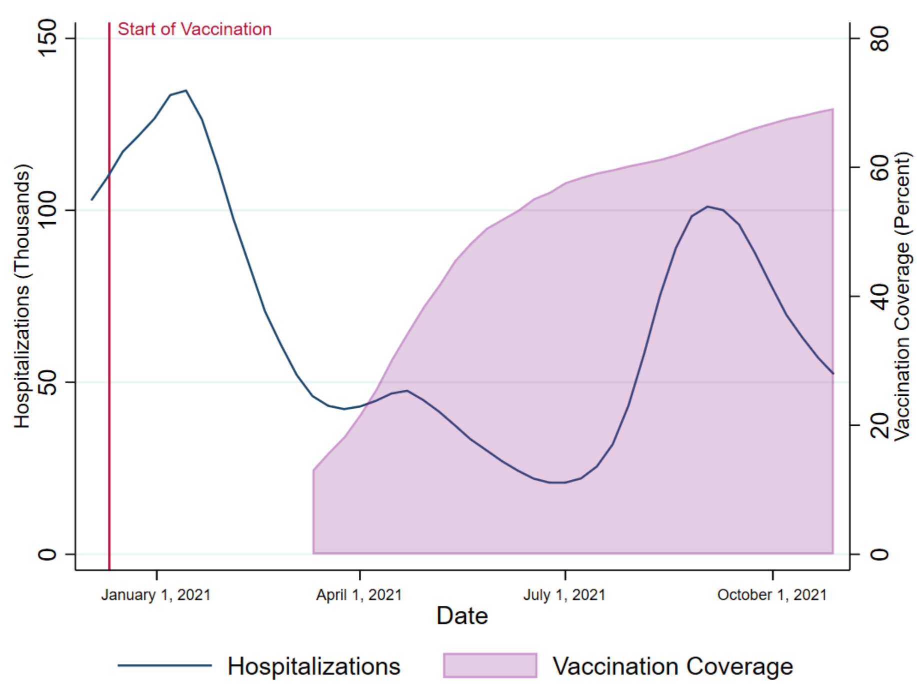
[10] CDC. COVID Data Tracker: United State COVID-19 cases, deaths, and laboratory testing (NAATs) by state, territory, and jurisdiction. Available at: https://covid.cdc.gov/covid-data-tracker/#trends_dailycases_currenthospitaladmissions, last accessed October 15, 2021.

Figure 1. COVID-19 Cases, Hospitalizations, Deaths, and Vaccination Rates Over Time

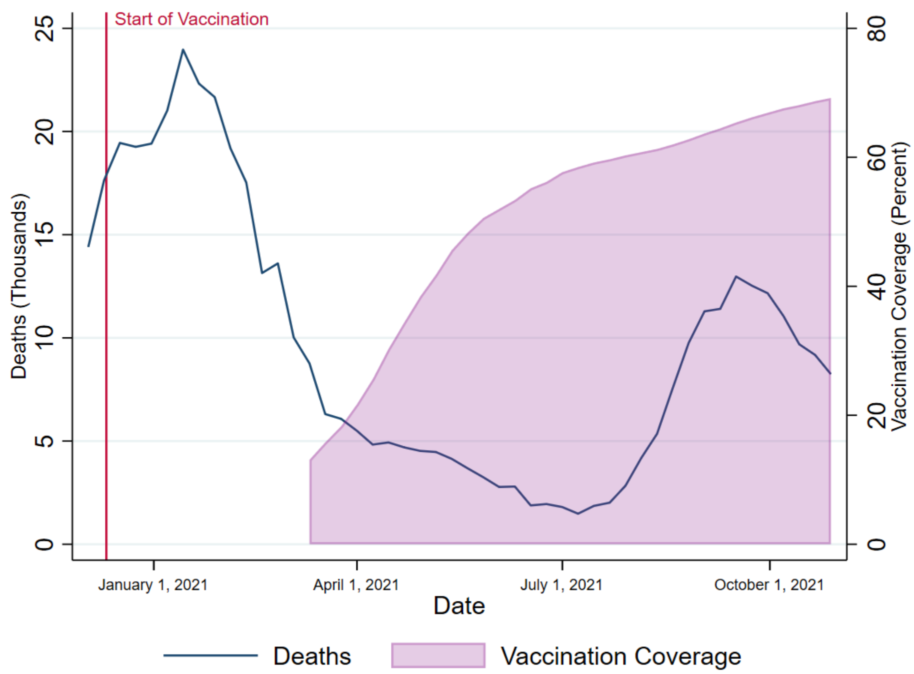
Panel A. COVID-19 Cases and Vaccination Coverage



Panel B. COVID-19 Hospitalizations and Vaccination Coverage



Panel C. COVID-19 Deaths and Vaccination Coverage



Notes: Vaccination data represents the percentage of the 18 years and older population that is fully vaccinated. Data for this metric are not available prior to March 2021, but the red line denotes when COVID-19 vaccinations began in the United States. COVID-19 outcome variables are presented as the number of new COVID-19 cases, hospitalizations, or deaths in a given week, as reported in the CDC COVID Data Tracker.

Source: ASPE analysis of multiple data sources for December 2020-November 2, 2021

From January until July of 2021, new cases, hospitalizations, and deaths declined following the introduction of vaccines. Over that time period, there was significant progress in increasing COVID-19 vaccine availability and COVID-19 vaccination coverage of the population. As of November 2, 2021, 80 percent of the US population ages 18 years and older had received at least one dose of the vaccine (67 percent of the total US population).[11] In July 2021, the highly transmissible Delta variant became the predominant variant in the United States, which subsequently caused a new wave of cases, hospitalizations, and deaths. These new cases, hospitalizations, and deaths were concentrated primarily among the unvaccinated, further highlighting the importance of increased COVID-19 vaccination coverage.[12]

---

[11] CDC. COVID Data Tracker: COVID-19 Vaccinations in the United States. Data as of October 7, 2021. Available at: https://covid.cdc.gov/covid-data-tracker/#vaccinations_vacc-total-admin-rate-total, last accessed November 2, 2021.

[12] CDC. Delta variant: What we know about the science. Available at: https://www.cdc.gov/coronavirus/2019-ncov/variants/delta-variant.html?s_cid=11609:is%20there%20a%20vaccine%20for%20delta%20variant:sem.ga:p:RG:GM:gen:PTN.Grants:FY22, last accessed October 15, 2021.

In this study, we examine associations between vaccination rates and COVID-19 cases, hospitalizations, and deaths across counties in the United States from December 2020 to July 2021. Specifically, we use a regression model to estimate the association between increased COVID-19 vaccine coverage and reductions in cases, hospitalizations, and deaths. In addition, we use estimates of willingness to pay (WTP) for reductions in health risks to value the improvement observed in COVID-19 outcomes. In economics, WTP is the maximum value, usually price, an individual is willing to give in exchange for a product or service. In this context, it is the maximum amount of money an individual would willingly exchange to reduce one's risk of getting infected with COVID-19, being hospitalized with COVID-19, or dying of COVID-19, while reducing an individual's ability to purchase other things. This valuation approach is widely used in benefit-cost analysis.[13,14]

METHODS AND DATA

Data

We employ multiple databases that capture county-level COVID-19 vaccination rates and COVID-19-related outcomes: cases, hospitalizations, and deaths, as discussed below. The data are aggregated on a weekly basis (from Friday to Thursday) from December 4, 2020[15] through July 29, 2021; for brevity we refer to our period of analysis to be between December 2020 and July 2021. Appendix 1 provides additional information on the frequency and sources of the data.

- **COVID-19 Vaccine Administration Data:** We use county-level data on vaccine doses administered and reported to the CDC.[16] The county information represents the county in which the individual resides.[17] This variable is defined as the percent of the population ages 18 years and older that is fully vaccinated[18] against COVID-19 as of the reported week in a given county. During our review of the data we identified five states (Georgia, Hawaii, Texas, Virginia, and West Virginia) that either did not report county-

[13] Office of Management and Budget, Circular A-4, September 17, 2003. Available at: https://obamawhitehouse.archives.gov/omb/circulars_a004_a-4/, last accessed November 1, 2021.
[14] U.S. Department of Health and Human Services. Guidelines for Regulatory Impact Analysis. 2016. Available at: https://aspe.hhs.gov/sites/default/files/private/pdf/242926/HHS_RIAGuidance.pdf, last accessed November 1, 2021.
[15] Data for COVID-19 vaccinations begin on December 10, 2020.
[16] CDC. COVID-19 Vaccinations in the United States, County. Available at: https://data.cdc.gov/Vaccinations/COVID-19-Vaccinations-in-the-United-States-County/8xkx-amqh, last accessed October 22, 2021.
[17] CDC. Reporting County-Level COVID-19 Vaccination Data. Available at https://www.cdc.gov/coronavirus/2019-ncov/vaccines/distributing/reporting-counties.html, last accessed October 21, 2021.
[18] In this dataset, "fully vaccinated" refers to those who have received the second dose in a two-dose COVID-19 vaccine series or one dose of the single-shot Johnson and Johnson's Janssen COVID-19 vaccine.

level vaccinations or for which >40% of vaccinations lacked county information. We use state-level vaccination data for counties in these states in order to include them in our analysis.[19]

- **COVID-19 Cases:** We utilize COVID-19 case data collected by Johns Hopkins University's Center for Systems Science and Engineering's COVID-19 Data Repository.[20,21] The data in our analysis include confirmed, and where reported, probable COVID-19 cases and include all age groups. This variable is defined as new COVID-19 cases per 10,000 population in a given week and county.
- **COVID-19 Hospitalizations:** Facility-level hospital utilization data were obtained from HealthData.gov.[22] These data represent facility-level reporting via HHS TeleTracking or reporting provided directly to HHS Protect by state/territorial health departments.[23] These data are aggregated on a weekly basis at the county level and represent adult inpatient beds. This variable is defined as total laboratory-confirmed or suspected COVID-19 hospitalizations per 10,000 population in a given week and county.
- **COVID-19 Deaths:** Data on COVID-19 deaths were gathered from Johns Hopkins University's Center for Systems Science and Engineering's COVID-19 Data Repository.[24,25] These data are aggregated on a weekly basis at the county level and include all age groups. The variable is defined as new COVID-19 deaths per 10,000 population in a given week and county.

We encountered data quality issues with the vaccination and outcomes data. These included systematically missing data for certain counties (including counties in California, Utah, Massachusetts, Alaska, and New York), states (Texas, Hawaii) or for certain periods of analysis (Nebraska). It also included data that our analysis suggested may not have been consistently reported or reliable, e.g., counties in Georgia, West Virginia, and Virginia. Addressing these

---

[19] CDC. COVID-19 Vaccinations in the United States, Jurisdiction. Available at: https://data.cdc.gov/Vaccinations/COVID-19-Vaccinations-in-the-United-States-Jurisdi/unsk-b7fc, downloaded on October 8, 2021.
[20] COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University, https://github.com/CSSEGISandData/COVID-19, downloaded on August 18, 2021.
[21] Dong, E., Du, H., Gardner. (2020). An Interactive Web-based Dashboard to Track COVID-19 in Real Time. The Lancet, 20(5): 533-534. https://doi.org/10.1016/S1473-3099(20)30120-1
[22] COVID-19 Reported Patient Impact and Hospital Capacity by Facility, https://healthdata.gov/Hospital/COVID-19-Reported-Patient-Impact-and-Hospital-Capa/anag-cw7u, downloaded on August 18, 2021.
[23] The hospital population includes all hospitals registered with Centers for Medicare & Medicaid Services (CMS) as of June 1, 2020. It includes non-CMS hospitals that have reported since July 15, 2020. The data do not include psychiatric, rehabilitation, Indian Health Service (IHS) facilities, U.S. Department of Veterans Affairs (VA) facilities, Defense Health Agency (DHA) facilities, and religious non-medical facilities.
[24] COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University, https://github.com/CSSEGISandData/COVID-19, downloaded on August 18, 2021.
[25] Dong, E., Du, H., Gardner. (2020). An Interactive Web-based Dashboard to Track COVID-19 in Real Time. The Lancet, 20(5): 533-534. https://doi.org/10.1016/S1473-3099(20)30120-1

issues involved removing data from our analysis or imputing values where appropriate. Appendix 2 provides more information on these issues and how they were addressed.

In addition to our COVID-19 metrics, our analysis includes other time-varying information that may be associated with intentions to vaccinate and COVID-19 outcomes of interest. These data include the status of state-level mask mandates or stay-at-home orders, county-specific data on worker mobility, and region-specific information on the prevalence of the Delta variant. More information about these metrics, including data sources, is provided in Appendix 1.

Examining Associations between COVID-19 Vaccination and Outcomes

We examine the association between vaccination rates and three separate outcomes: COVID-19 cases, hospitalizations, and deaths. We do this in four steps. First, we use a Poisson regression model to estimate the association between vaccination rates and each of our three outcomes: cases, hospitalizations, or deaths.[26] There are five key predictors: county-level COVID-19 vaccination rates in the current week and for each of the four preceding weeks (i.e., four weeks before, three weeks before, two weeks before, and one week before). These measures of vaccination rates are intended to reflect the time that it may take to achieve maximum protection from the vaccine. The model includes variables that can explain changes in vaccination rates and COVID-19 outcomes. Specifically, we include state-level changes in COVID-19 mitigation policies such as mask mandates, county-level mobility patterns, and region-level information on the proportion of cases that are attributed to the Delta variant. Our Poisson model includes county fixed effects to control for differences in counties' unobserved COVID-19 mitigation efforts and other unmeasured demographic and health-related differences that are stable within counties over the period of analysis. The model also includes quarterly fixed effects to control for nationwide temporal trends and fluctuations in COVID-19 outcomes over the period of study.

Second, using this relationship we generate predicted values for each of our outcomes. Third, we set the vaccination rates for all counties in all weeks equal to zero, and then generate new predicted values, which we refer to as our counterfactual values. Lastly, we subtract our predicted values from our counterfactual values. These resulting differences are our estimates of associated reductions in cases, hospitalizations, and deaths. We also conduct additional sensitivity analyses with varying specifications and samples. These and additional information on our empirical approach are discussed in Appendix 2.

[26] We examine other functional forms, including a linear model, and present these results in Appendix 2.

Our statistical approach is similar to that of Gupta et al[27] with a few deviations to allow for estimates at a smaller geographical scale. Specifically, we use county-level data rather than state-level data to enhance the variation in the data and facilitate analysis of the associated reductions at a more disaggregate measure. Secondly, we use the incidence of cases, hospitalizations, or deaths per 10,000 population reported each week, rather than the cumulative measures, to use the variation over time and across counties. Our model includes quarterly fixed effects rather than weekly fixed effects to avoid diluting the variation that we try to use. Finally, we include a set of region- and state-level variables that change over time to capture changes in mitigation policies and the proportion of cases from the Delta variant.

Valuing Morbidity and Mortality Risk Reductions

In benefit-cost analysis, the value of an improvement in health, such as a reduction in mortality or morbidity risk, is typically based on individual willingness to pay (WTP). This value is "derived from how much money affected individuals would exchange for a risk reduction they expect to experience, given their budget constraints and preferences for spending on other goods and services."[28] The WTP estimates apply an estimate of the value per statistical life (VSL)[29] when valuing expected changes in mortality risks and apply a value per statistical case (VSC) when valuing non-fatal risk reductions (cases, hospitalizations). HHS guidelines recommend VSL values ranging from $5.36 million to $17.51 million. This range of estimates is based on a literature review tailored to the types of risks HHS regulates. ASPE considered several factors specific to COVID-19 risks that may affect the VSL estimates, such as the age profile of fatal cases and the substantial morbidity experienced prior to death, and concluded that the same range of estimates were appropriate for COVID-19.[30] We adopt estimates per VSC that range from $2,728 to $8,900 for mild cases, from $6,115 to $19,947 for severe cases, and from

[27] Gupta, S., Cantor J., Simon, K., Bento, A., Wing, C., and Whaley, C. Vaccinations Against COVID-19 May Have Averted Up to 140,00 Deaths in The United States, *Health Affairs,* 2021 40(9): 1465-1472 https://doi.org/10.1377/hlthaff.2021.00619

[28] Robinson, L., Eber, M., Hammitt, J. (2021). Valuing COVID-19 mortality and morbidity risk reductions in U.S. Department of Health and Human Services Regulatory Impact Analyses. Available at: https://aspe.hhs.gov/reports/valuing-covid-19-risk-reductions-hhs-rias, last accessed October 22, 2021.

[29] VSL is not the value the analyst, the researcher, or the government places on saving an individual from certain death, but the extent to which individuals are willing to exchange money for small changes in their own risks within a defined time period.

[30] See Table ES.2 (pg. 7) for factors considered in Robinson, L., Eber, M., Hammitt, J. (2021). Valuing COVID-19 mortality and morbidity risk reductions in U.S. Department of Health and Human Services Regulatory Impact Analyses. Available at: https://aspe.hhs.gov/reports/valuing-covid-19-risk-reductions-hhs-rias, last accessed October 22, 2021. https://aspe.hhs.gov/sites/default/files/2021-08/valuing-covid-risks-july-2021.pdf

$846,720 to $2.76 million for critical cases from a recent ASPE report on valuing COVID-19 risk reductions.[31]

To monetize the value in risk reductions in mortality and morbidity we multiply the VSL or VSC with the corresponding number of reductions in mortality or morbidity. Further, we use the mid-point value of the estimated VSL or VSC for our primary analyses but also consider the low and high estimates as part of our sensitivity analysis. Before valuing morbidity risk reductions, we subtract the number of deaths and hospitalizations from the number of cases to avoid double-counting.[32] Similarly, to avoid double-counting hospitalizations, we subtract mortality from hospitalizations that required intensive care unit admission.

FINDINGS

Estimated Number of Associated Reductions in Cases, Hospitalizations, and Deaths

Our model estimates that COVID-19 vaccination was associated with reductions of 25.32 million cases, 1.38 million hospitalizations, and 213,000 deaths.

Table 1 shows the total reported number of COVID-19 cases, hospitalizations, and deaths between December 2020 and July 2021, compared with our model estimates with and without vaccinations. The first row in Table 1 presents the total number of cases, hospitalizations, and deaths during the period of analysis. The second row in Table 1 presents the number of cases, hospitalizations, and deaths estimated by the model based on the observed association between our three COVID-19 outcomes, vaccination, and other covariates. The third row shows the estimated total for each COVID-19 outcome as if no vaccines were available, the counterfactual scenario. The results show that without the administration of vaccines, cases may have more than doubled, and hospitalizations and deaths may have increased by two thirds. To obtain an estimate of the total number of associated reductions in COVID-19 outcomes, we calculate the difference between our estimates without vaccines (Table 1, row 3) and with vaccines (Table 1, row 2).

[31] Robinson, L., Eber, M., Hammitt, J. (2021). Valuing COVID-19 mortality and morbidity risk reductions in U.S. Department of Health and Human Services Regulatory Impact Analyses. Available at: https://aspe.hhs.gov/reports/valuing-covid-19-risk-reductions-hhs-rias, last accessed October 22, 2021.
[32] National Center for Health Statistics. In-Hospital Mortality Among Hospital Confirmed COVID-19 Encounters by Week from Selected Hospitals. Available at https://www.cdc.gov/nchs/covid19/nhcs/hospital-mortality-by-week.htm; last accessed October 30, 2021.

Our results suggest that the introduction of COVID-19 vaccinations was associated with reductions of 25.32 million cases, 1.38 million hospitalizations, and 213,000 deaths.[33]

Table 1. Number of Associated Reductions in COVID-19 Cases, Hospitalizations, and Deaths from December 2020 to July 2021			
	Cases	Hospitalizations	Deaths
Reported	20,226,104	2,085,410	331,151
Estimated with Vaccines	20,193,720	2,080,594	330,748
No Vaccines (Counterfactual)	45,518,022	3,464,854	544,097
Associated Reductions[1]	25,324,302	1,384,260	213,349
Minimum[2]	15,708,113	1,103,825	178,348
Maximum[2]	27,970,049	1,860,893	421,874

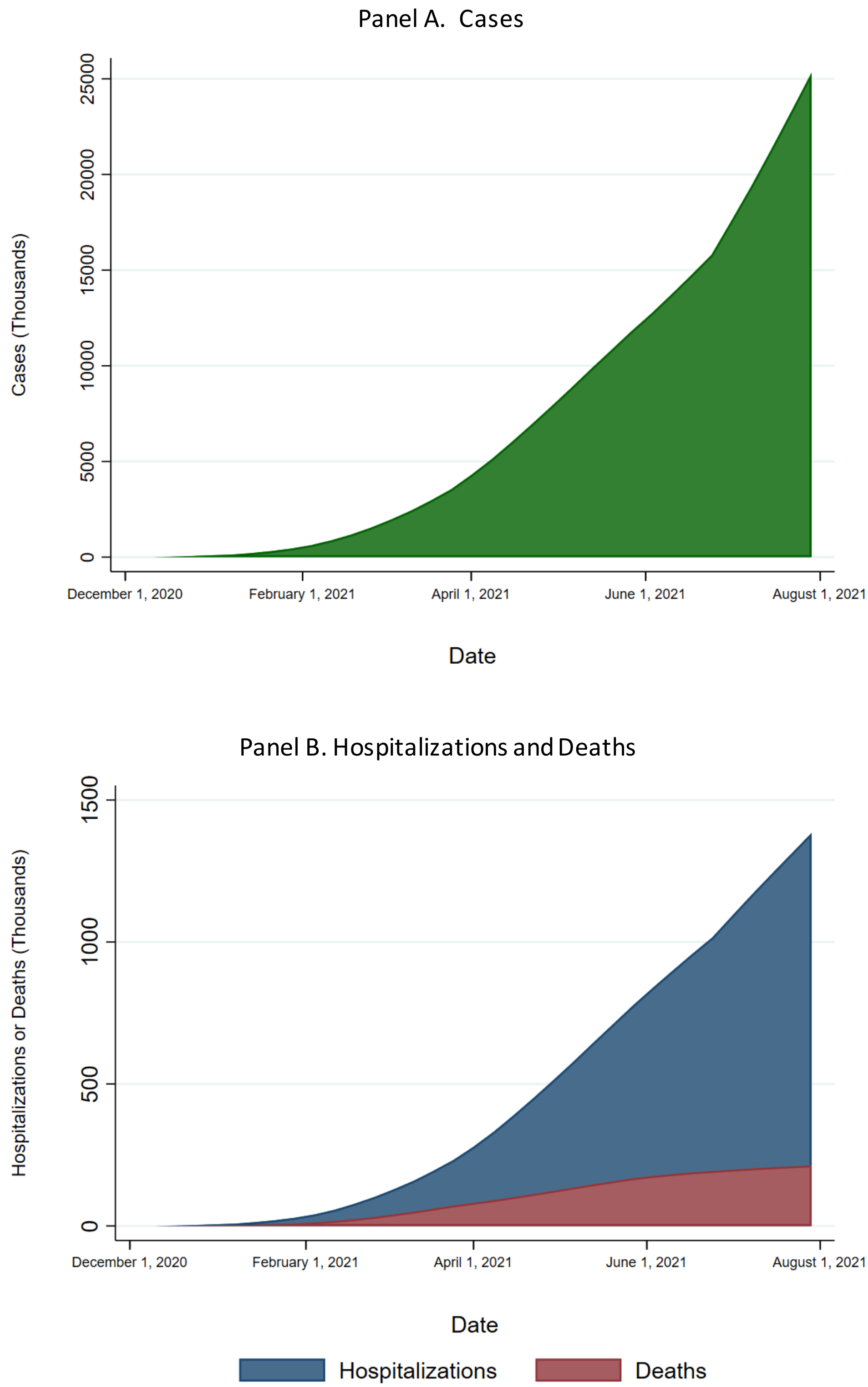
Notes: 1. Estimates from Poisson regression model that includes the following variables: vaccination rate for a given week and for each of the prior four weeks, state-level information about stay at home orders, state-level information on mask mandates, a county-level measure of worker mobility, and proportion of COVID-19 cases from the Delta variant across ten regions in the United States. The regression model also includes county and quarter fixed effects. See Appendix 1 and Appendix 2 for additional information on the model and the data.
2. See Table S-3 and Table S-4 for the specification and samples used to obtain the minimum and maximum number of associated reductions.
Source: ASPE analysis of multiple data sources for December 2020-July 2021.

We also estimate our model using other functional forms and samples (see Table S-3 and Table S-4). These estimates range from 15.71 million to 27.97 million cases, from 1.10 million to 1.86 million hospitalizations, and from 178,000 to 422,000 deaths. Our preferred specification is a Poisson model with our full set of controls and all states included in our sample. We prefer using a Poisson model because we believe it better captures the nonlinearity of vaccination rates and spread of COVID-19.

Figure 2 displays the cumulative number of associated reductions in COVID-19 outcomes over time. The estimated reduction in cases, hospitalizations, and deaths substantially increased week after week (see also Table S-5), with impacts already evident within the first several weeks of the vaccine rollout.

[33] We also compared the reported number of cases (Figure S-1), hospitalizations (Figure S-2) and deaths (Figure S-3) to their corresponding predicted and counterfactual estimates over time. Overall, the trends fall below the reported values and the model tracks the trends more closely for hospitalizations and deaths than cases.

Figure 2. Cumulative Number of Associated Reductions in COVID-19 Outcomes Over Time



Notes: See Appendix 1 for additional information on the model and the data.
Source: ASPE analysis of multiple data sources for December 2020-July 2021

Associated Reductions in Cases, Hospitalizations and Deaths by State and County

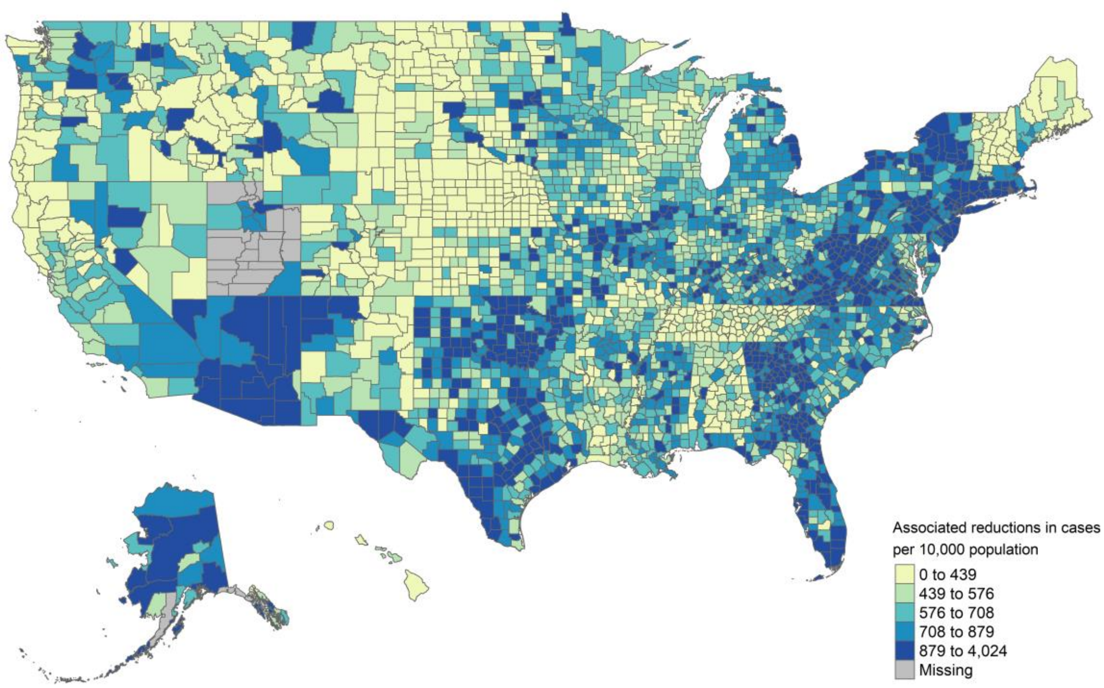
In Figure 3 we present estimates of associated reductions in cases (Panel A), hospitalizations (Panel B), and deaths (Panel C), as well as vaccinations (Panel D) by county. Because county population density can vary widely, we present averted cases, hospitalizations, and deaths in population-adjusted terms (per 10,000 population). Some counties could not be estimated due to missing case, hospitalization, or death data. These counties are shown in gray.

In all four panels, counties were divided into quintiles, with yellow representing counties with the lowest associated reductions in cases, hospitalizations, and deaths per 10,000 population, and blue representing counties with the highest rates. These data indicate that COVID-19 vaccinations were associated with significant reductions in cases, hospitalizations, and deaths per 10,000 population in all parts of the country.

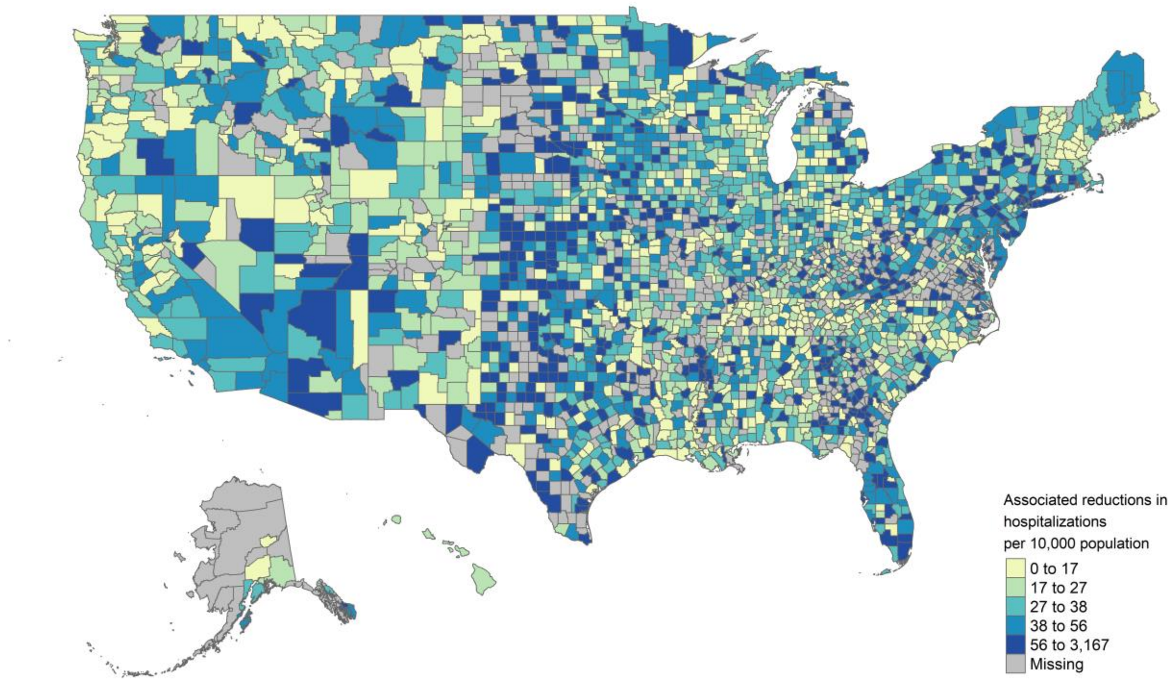
We also generated state-specific estimates by aggregating the county-level estimates for all 50 states and the District of Columbia. Table 2 shows the estimates of reductions in COVID-19 outcomes for the 25 most populous states (see Table S-6 for the entire list).

Figure 3. Number of Associated Reductions in Cases, Hospitalizations, and Deaths per 10,000 Population by County

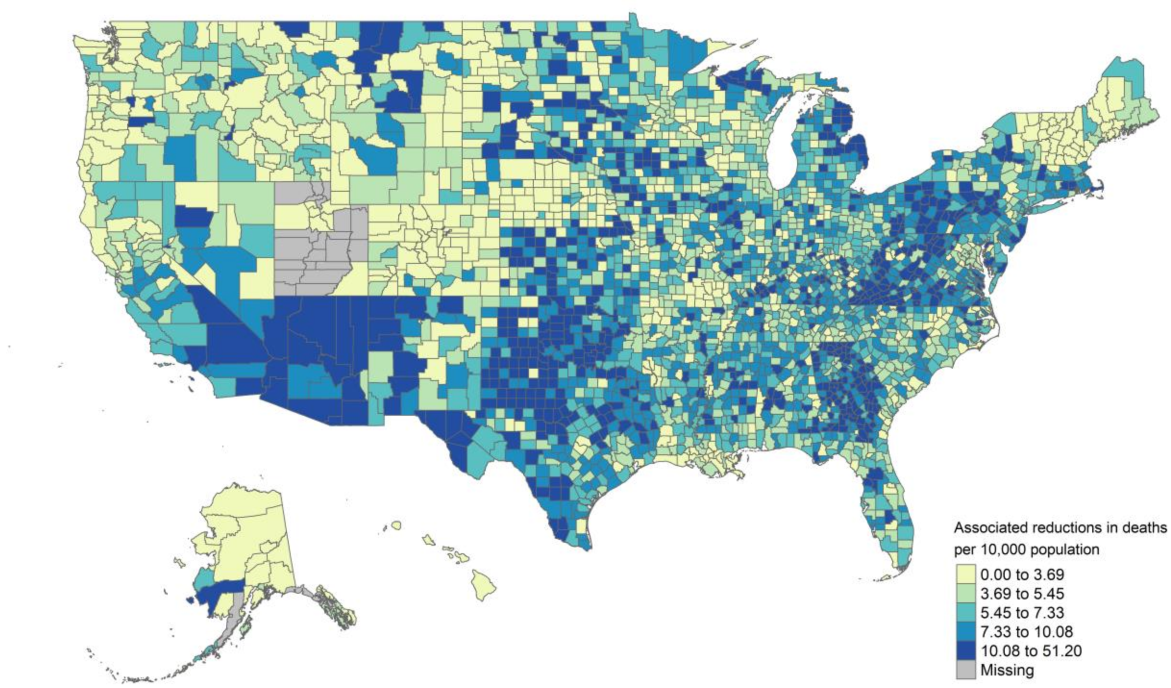
Panel A. Number of Associated Reductions in Cases per 10,000 Population



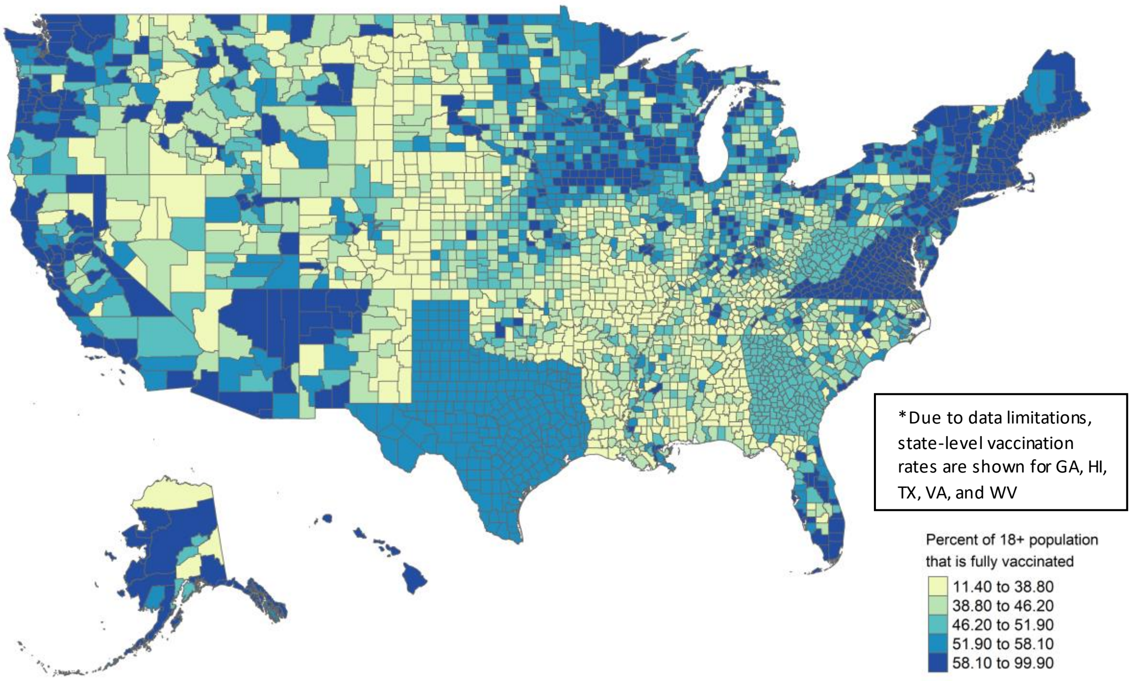
Panel B. Number of Associated Reductions in Hospitalizations per 10,000 Population



Panel C. Number of Associated Reductions in Deaths per 10,000 Population



Panel D: Percent of the 18+ Population that is Fully Vaccinated, as of July 29, 2021*



Notes: Estimates are not available for certain counties (shown in gray) due to missing COVID-19 case, hospitalization, or death data. Vaccination data for certain counties in California, Massachusetts, and New Mexico, as well as all counties in Georgia, Hawaii, Texas, Virginia, and West Virginia, were imputed with state-level vaccination rates due to missing data or data quality issues. Vaccination data are shown through July 29, 2021, representing vaccination rates on the final day of the study period. Due to a discontinuation of Nebraska's COVID-19 data dashboard, estimates for the state of Nebraska represent through June 3, 2021. For additional details on how missing or incomplete data were handled in the analysis, see Appendix 2.
Source: ASPE analysis of multiple data sources for December 2020-July 2021

Table 2. Number of Associated Reductions in Cases, Hospitalizations, and Deaths by State for 25 Most Populous States

State	Population	Cases	Hospitalizations	Deaths
Alabama	5,024,279	272,114	18,830	3,300
Arizona	7,151,502	859,233	38,499	7,836
California	39,538,223	2,566,307	145,545	33,484
Colorado	5,773,714	265,805	10,540	1,316
Florida	21,538,187	2,215,557	107,370	12,522
Georgia	10,711,908	995,450	53,286	7,963
Illinois	12,812,508	818,561	48,432	6,951
Indiana	6,785,528	459,390	27,376	4,008
Louisiana	4,657,757	299,756	14,525	2,225
Maryland	6,177,224	338,698	29,145	3,564
Massachusetts	7,029,917	567,943	21,003	5,073
Michigan	10,077,331	748,899	43,788	7,455
Minnesota	5,706,494	357,433	17,417	2,685
Missouri	6,154,913	447,357	29,053	3,146

Table 2. Number of Associated Reductions in Cases, Hospitalizations, and Deaths by State for 25 Most Populous States				
State	**Population**	**Cases**	**Hospitalizations**	**Deaths**
New Jersey	9,288,994	854,690	45,949	6,376
New York	20,201,249	2,387,463	131,120	13,953
North Carolina	10,439,388	767,595	34,810	4,879
Ohio	11,799,448	834,285	50,132	7,742
Pennsylvania	13,002,700	1,059,848	69,080	11,535
South Carolina	5,118,425	395,715	15,746	2,795
Tennessee	6,910,840	280,338	16,458	3,727
Texas	29,145,505	2,263,058	139,812	17,923
Virginia	8,631,393	713,673	36,765	6,350
Washington	7,705,281	459,922	19,965	2,585
Wisconsin	5,893,718	303,834	16,132	2,615
Total United States	331,449,281	25,324,302	1,384,260	213,349

Notes: Results shown for the 25 most populous states. See Table S-5 for the entire list of 50 states and the District of Columbia. Population data from the 2020 Census.
Source: ASPE analysis of multiple data sources for December 2020-July 2021

Estimating Associated Reductions in Cases, Hospitalizations and Deaths by Social Vulnerability Index

In Table 3 we present the estimated reduction in COVID-19 cases, hospitalizations, and deaths based on CDC's Social Vulnerability Index (SVI) for a given county. This is done by summing up the total number of estimated reductions across counties with a given SVI. In this table we also present the percent of the population covered in each SVI category. The SVI summarizes the extent to which a community is socially vulnerable to disaster.[34] The overall SVI for a county is calculated using the American Community Survey (ACS) data across four main themes: (1) socioeconomic status, (2) household composition and disability, (3) minority status and language, and (4) housing type and transportation. SVI values range from 0 (least vulnerable) to 1 (most vulnerable). Counties with very low or low social vulnerability tended to make up a lower proportion of the associated reductions in cases, hospitalizations, and deaths than would be expected based on their population (Table 3). In contrast, counties with high or very high social vulnerability tended to make up a higher proportion associated reductions in cases, hospitalizations, and deaths than would be expected based on their population. Table S-7 presents the results for each of the four themes.

[34] Agency for Toxic Substances and Disease Registry, CDC/ATSDR SVI Data and Documentation Download, available at https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html, last accessed October 20, 2021.

Table 3. Estimated Associated Reductions in COVID-19 Related Outcomes by Social Vulnerability Index								
Overall Social Vulnerability Index Category	**Percent of Population in the United States**	**Cases (%)**		**Hospitalizations (%)**		**Deaths (%)**	
Very Low (0-0.19)	16.19%	3,741,523	14.77%	167,209	12.08%	28,492	13.35%
Low (0.20-0.39)	19.51%	4,775,729	18.86%	235,332	17.00%	36,514	17.11%
Moderate (0.40-0.59)	23.38%	5,969,199	23.57%	340,377	24.59%	47,414	22.22%
High (0.60-0.79)	25.60%	6,645,468	26.24%	410,025	29.62%	61,773	28.95%
Very High (0.80-1.00)	15.32%	4,192,383	16.55%	231,318	16.71%	39,156	18.35%

Notes: CDC's Social Vulnerability Index (SVI) values range from 0 (least vulnerable) to 1 (most vulnerable). Table S-7 presents the results for four separate SVI themes. Population data from the 2019 American Community Survey.
Source: ASPE analysis of multiple data sources for December 2020-July 2021

Valuing COVID-19 Morbidity and Mortality Risk Reductions

As noted in our methods section, to value risk reductions in morbidity and mortality we apply estimates based on the value of individual willingness to pay to avoid a COVID-19 outcome using estimates of the value per statistical life and estimates of the value per statistical case that vary by case severity.[35] Specifically, mortality risk reductions are valued at $11.5 million per death. Morbidity risk reductions are valued based on the severity of the disease: mild cases are valued at $5,846 per case, severe cases that require a regular hospital admission are valued at $13,104 per case, and critical cases that involve intensive care unit (ICU) admissions are valued at $1.8 million per case.

Because our estimates of associated reductions in hospitalizations include non-ICU and admissions, we use an estimate of the percent of ICU admissions to estimate the number of associated reductions in ICU admissions. We do this using the percent of ICU admissions among all COVID-19 hospitalizations, which we estimate to be 29 percent using hospitalization data through October 22, 2021.[36] The estimated reductions in ICU admissions is 188,086 (29 percent

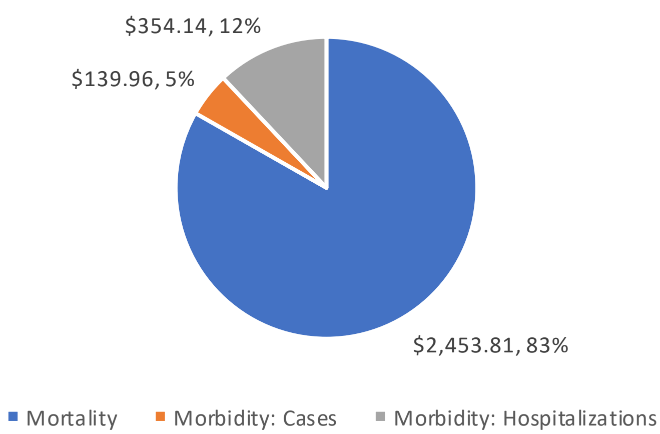
[35] Robinson, L., Eber, M., Hammitt, J. (2021). Valuing COVID-19 mortality and morbidity risk reductions in U.S. Department of Health and Human Services Regulatory Impact Analyses. Available at: https://aspe.hhs.gov/reports/valuing-covid-19-risk-reductions-hhs-rias, last accessed October 2021.
[36] HHS Protect Public Data Hub. Hospital Utilization. Data as of October 22, 2021 available at https://protect-public.hhs.gov/pages/hospital-utilization. Last accessed October 22, 2021.

of the 1,384,260 hospitalizations, minus 213,349 deaths to avoid double-counting).[37] We also subtract all estimated reductions in hospitalizations from reductions in cases to avoid double-counting. Thus, we use 23,940,041 cases (25,324,302 cases minus 1,384,260 hospitalizations), 982,825 non-ICU admissions and 188,086 ICU admissions as the basis to estimate the total health benefits.

We estimate a total value of COVID-19 risk reductions attributable to vaccination in the United States of $2.95 trillion. This valuation comes from reductions in deaths ($2.45 trillion), hospitalizations ($354.14 billion), and cases ($139.96 billion).

Applying an estimate of the VSL and estimates of the VSC, we estimate a total value of COVID-19 risk reductions attributable to vaccination in the United States of $2.95 trillion (Figure 4). This valuation comes from reductions in deaths ($2.45 trillion), hospitalizations ($354.14 billion), and cases ($139.96 billion). The breakdown of these estimates is shown in Table S-8. In Table S-9, we present estimates using low and high values of VSL and VSC. Using those estimates, the value of mortality and morbidity risk reduction ranges from $1.38 trillion to $4.49 trillion. This range of total values includes associated reductions in cases ($65.32 billion to $213.05 billion), hospitalizations ($165.27 billion to $539.08 billion), and deaths ($1.15 trillion to $3.74 trillion).

Figure 4. Valuing Associated Reductions in COVID-19 Outcomes in the United States ($billions)



Notes: Mortality risk reductions are valued at $11.5 million per death, and morbidity risk reductions are valued based on the severity of the disease: mild cases are valued at $5,846 per case, severe cases that require a regular hospital admission are valued at $13,104 per case, and critical cases that involve intensive care unit (ICU) admissions are valued at $1.8 million per case. The estimated value of associated reductions in hospitalizations includes the sum of ICU admissions ($12.88 billion = 982,825 hospitalizations multiplied by $5,846) and non-ICU admissions ($341.26 billion = 188,086 multiplied by $13,104) where ICU admissions represent 29 percent of the total associated reductions in hospitalizations.
Source: ASPE analysis of multiple data sources for December 2020-July 2021

[37] This implicitly assumes that all deaths occurred in individuals who had been admitted to the ICU.

Discussion

In this study, we examined the relationship between COVID-19 vaccination rates and associated reductions in COVID-19 cases, hospitalizations, and deaths. Specifically, our model estimates that COVID-19 vaccinations may be associated with 25.32 million fewer cases, 1.38 million fewer hospitalizations, and 213,000 fewer deaths from December 2020 to July 2021.

Relatively few studies to date have estimated the impact of vaccinations on the full spectrum of COVID-19 outcomes including cases, hospitalizations, and deaths. In a recent analysis that used state-level data on vaccination rates and deaths, Gupta and colleagues estimated that vaccination was associated with reductions of about 140,000 deaths from January to May 2021.[38] We follow a similar empirical approach as Gupta et al, but use county-level data instead of state-level data and extend the analysis period to July 2021. Using an age-stratified, agent-based national model, Galvani et al (2021) estimated that the United States vaccination program prevented 26 million cases, 1.25 million hospitalizations, and 279,000 deaths by the end of June 2021.[39] Galvani et al incorporate several parameters that were not available for our model, such as age-specific risk factors, vaccine efficacy data, and transmission dynamics of variants. In contrast, our model accounts for considerable county-level variation in vaccination rates, which may better account for local trends. Despite these differences, all these models converge on similar national numbers, which supports the validity of our local estimates.

In a separate study using individual-level clinical data and local vaccination rates, ASPE found that COVID-19 vaccinations were associated with an estimated reduction of more than 265,000 cases, 107,000 hospitalizations, and 39,000 deaths among Medicare beneficiaries between January and May 2021.[40] As the authors noted, these estimates were considered conservative since they did not include the summer increase in both cases and vaccinations, and may not have fully captured some high-risk populations who are underrepresented in the Medicare fee-for-service population. Putting the estimates of that report and this one in context, the estimated reductions in Medicare deaths are a sizable portion of our overall mortality estimates through the end of May 2021 – approximately 22.7 percent of the total – while the Medicare estimates accounted for 13.2 percent of our total estimated hospital reductions and just 2.2 percent of estimated cases. This pattern is consistent with older adults and those with disabilities in Medicare being at highest risk for serious complications and deaths from COVID-

[38] Gupta S, Cantor J, Simon KI, Bento AI, Wing C, Whaley CM. Vaccinations Against COVID-19 May Have Averted Up To 140,000 Deaths In The United States. *Health Affairs 40*(9). https://doi.org/10.1377/hlthaff.2021.00619.
[39] Galvani A, Moghadas S., Schneider, E. (2021). Deaths and hospitalizations averted by rapid U.S. vaccination rollout. Available at: https://www.commonwealthfund.org/publications/issue-briefs/2021/jul/deaths-and-hospitalizations-averted-rapid-us-vaccination-rollout, last accessed September 9, 2021.
[40] Samson, LW, Tarazi, W, Orav, EJ, Sheingold, S, De Lew, N and Sommers, BD. (2021). Associations Between County-level Vaccination Rates and COVID-19 Outcomes Among Medicare Beneficiaries. Washington, DC: Office of the Assistant Secretary for Planning and Evaluation, U.S. Department of Health and Human Services. Available at: https://aspe.hhs.gov/reports/covid-19-vaccination-rates-outcomes, last accessed October 15, 2021.

19, and therefore disproportionately likely to benefit from vaccinations for those serious outcomes.

Rates of COVID-19 cases, hospitalizations, and deaths have varied by race/ethnicity and age throughout the pandemic.[41,42,43] Differences in vaccination rates by race/ethnicity and age,[44] as well as the increased transmissibility of the Delta variant, have likely changed the landscape of COVID-19 impacts on these groups. We do not have reliable age or race/ethnicity data on vaccination, cases, hospitalizations, or deaths at the county level to estimate our model using these important characteristics. Further, the regression model includes county-fixed effects which removes any county-level information that does not change over time. Even though there is county-level data from the American Community Survey that provides information at the county-level, these data are constant over the period of the analysis and the model drops them from the regression results. Thus, although we are unable to calculate the associated reductions in outcomes by these demographic characteristics directly from the model, evaluation of associated reductions in outcomes at the county-level showed that areas of high or very high social vulnerability tended to make up a larger proportion of each outcome than would be expected based on their population share. This is not unexpected given that areas of high social vulnerability have experienced some of the highest COVID-19 case and death rates.[45,46] These results underscore the importance of continued COVID-19 vaccination efforts, particularly in areas where vaccination rates may be low due to access barriers, to mitigate the disproportionate impact of COVID-19 on socially vulnerable communities. Future work should attempt to explore the impact on specific demographic groups, including racial and ethnic minorities, more directly.

---

[41] Simmons A, Chappel A, Kolbe AR, Bush L, and Sommers BD. (2021). Health Disparities by Race and Ethnicity During the COVID-19 Pandemic: Current Evidence and Policy Approaches. Washington, DC: Office of the Assistant Secretary for Planning and Evaluation, United States Department of Health and Human Services. Available at: https://aspe.hhs.gov/sites/default/files/migrated_legacy_files//199516/covid-equity-issue-brief.pdf, last accessed October 15, 2021.

[42] CDC. COVID Data Tracker: COVID-19 Weekly Cases and Deaths per 100,000 Population by Age, Race/Ethnicity, and Sex. Available at: https://covid.cdc.gov/covid-data-tracker/#demographicsovertime, last accessed October 15, 2021.

[43] COVID-NET. Laboratory-Confirmed COVID-19-Associated Hospitalizations. Available at: https://gis.cdc.gov/grasp/COVIDNet/COVID19_3.html, last accessed October 15, 2021.

[44] Kolbe, A. (2021). Disparities in COVID-19 Vaccination Rates across Racial and Ethnic Minority Groups in the United States. Washington, DC: Office of the Assistant Secretary for Planning and Evaluation, U.S. Department of Health and Human Services. Available at: https://aspe.hhs.gov/reports/disparities-covid-19-vaccination-rates-across-racial-ethnic-minority-groups-united-states, last accessed October 15, 2021.

[45] Dasgupta S, Bowen VB, Leidner A, et al. (2020). Association Between Social Vulnerability and a County's Risk for Becoming a COVID-19 Hotspot — United States, June 1–July 25, 2020. *MMWR Morb Mortal Wkly Rep* 69: 1535–1541. http://dx.doi.org/10.15585/mmwr.mm6942a3

[46] CDC. COVID Data Tracker: Trends in COVID-19 Cases and Deaths in the United States, by County-level Population Factors. Available at: https://covid.cdc.gov/covid-data-tracker/#pop-factors_7daynewdeaths, last accessed October 15, 2021.

Limitations

Our empirical approach includes several limitations. First, we are unable to fully account for potential confounders in our model, which limits our ability to infer causality. While we include county and quarter fixed effects in conjunction with controls such as mask mandates, worker mobility and the proportion of cases due to the Delta variant, we are unable to control for other factors such as time-varying county-specific information that could be correlated with both vaccination and our outcomes of interest. For instance, it is possible that changes in vaccination rates were correlated with changes in preferences to engage in other COVID-19 mitigation behaviors. If vaccination rates rose in counties where unobserved COVID-19 mitigation behaviors simultaneously strengthened, an estimate of the causal effect of vaccination rates may be biased upward. Moreover, it is possible that changes in COVID-19 cases, hospitalizations, or deaths prompted changes in vaccination rates, which may also bias an estimate of the causal effect of vaccination.

Second, we use county-level rather than individual-level data. Consequently, our ecological model captures potential vaccination spillovers, but is not able to examine how demographic and other individual-specific characteristics may be associated with vaccination and our outcomes of interest. Our model also does not distinguish COVID-19 outcomes by age group. During the study period, December 2020 to July 2021, COVID-19 vaccines were available to individuals aged 12 and over;[47] however, due to data limitations, our variable of interest was the vaccination rate of the adult (18+) population. We assume that the vaccination rate of adults is associated with reductions in COVID-19 outcomes across all age groups.

Third, our counterfactual estimates do not account for a number of potential factors. For instance, in a counterfactual environment in which COVID-19 vaccines do not exist, other interventions may have been enacted to prevent disease spread. Similarly, we are unable to predict the potential economic consequences of such an environment. Furthermore, our model does not explicitly account for natural immunity following COVID-19 infection or for the degree of effectiveness of COVID-19 vaccines; instead, these factors are reflected in the observed data we applied in the model. However, our calculation of the counterfactual “no vaccination” scenario might not fully account for the impact of changes in natural immunity in the population.

Fourth, data quality issues may have biased results for some counties. Due to missing or underreported county-level vaccination data in five states (Georgia, Hawaii, Texas, Virginia, and West Virginia), we impute county-level vaccination data using state-level vaccination data. This eliminates within-state variation in vaccine coverage, which results in an averaging of associated reductions in outcomes within these states. By attributing vaccination coverage that is higher or lower than the actual coverage in a given county, we likely over or under-estimate

[47] On May 10, 2021, FDA authorized the use of a COVID-19 vaccine for emergency use in adolescents 12 through 15 years of age. On October 29, 2021, FDA authorized a COVID-19 vaccine for emergency use in children aged 5 to 11.

associated reductions in outcomes and therefore the county-level estimates for these states should be interpreted with caution. Missing case, hospitalization, or death data in some counties likely resulted in an underestimation of national numbers of associated reductions in the outcomes examined. While our review of the data did not reveal that these missing data could be identified systematically, measurement error due to missing data may impact our ability to fully capture the extent of COVID-19 spread and hence our estimates. Additionally, our data cannot account for COVID-19 cases that were not reported or identified, such as those in asymptomatic individuals.

To address these issues with missing or underreported data, we employ a number of sensitivity analyses. These results appear in the Sensitivity Analysis section in the Appendix. The results of these analyses suggest that our national-level estimates are robust to these data limitations.

Finally, our data and approach do not permit us to incorporate time invariant information, such as the demographic composition of a county that would enable us to examine our estimated associations by groups of interest, e.g., age, race/ethnicity. Relatedly, our estimates of economic health benefits assume that the willingness to pay to reduce morbidity and mortality risks are the same across the population. The literature suggests that they may vary by individual and risk characteristics but there is no consensus on appropriate estimates to use generally and in the context of COVID-19. Future research should explore alternate data sources and methods to examine these questions.

Conclusions

Our county-level regression-based estimates suggest that COVID-19 vaccinations were associated with reductions of approximately 25.32 million cases, 1.38 million hospitalizations, and 213,000 deaths in the United States from December 2020 and through the summer of 2021. With 60.1 percent of Americans ages 18 years and older fully vaccinated at the end of the study period, these results emphasize the importance of continued outreach to unvaccinated individuals and communities with low vaccination rates. In terms of willingness to pay for morbidity and mortality risk reductions, these translate to total estimated benefits of $2.95 trillion, which far outweighs the estimated cost of federal investment in vaccine development and distribution, at least $10 billion.

Our results emphasize the importance of vaccination for reducing the spread of COVID-19 and saving lives. Moreover, they highlight the incredibly high societal rate of return on vaccine investment in conjunction with vaccine uptake.

Appendix 1: Data Sources

Table S-1. Description of Variables and Data Sources Used in ASPE's Analysis		
Data Description	**Level/Frequency**	**Source**
Percent of people 18+ who are fully vaccinated (have second dose of a two-dose vaccine or one dose of a single-dose vaccine) based on the jurisdiction and county where recipient lives	County/Daily*	COVID-19 Vaccinations in the United States, County (CDC)
Confirmed and probable (where reported) COVID-19 cases for all ages	County/Daily*	COVID-19 Data Repository by the Center for Science and Engineering (CSSE) at Johns Hopkins University
Average number of patients currently hospitalized in an adult inpatient bed who have laboratory-confirmed or suspected COVID-19, including those in observation beds reported during the 7-day period	Facility/Weekly	COVID-19 Reported Patient Impact and Hospital Capacity by Facility (Department of Health and Human Services)
Confirmed and probable (where reported) COVID-19 deaths for all ages	County/Daily*	COVID-19 Data Repository by the Center for Science and Engineering (CSSE) at Johns Hopkins University
Stay at Home Order is Active (yes/no)	State/Daily*	COVID-19 State Policy US Database
Face Mask Mandate in Public Spaces is Active (yes/no)	State/Daily*	COVID-19 State Policy US Database
Mobility Trends for Places of Work	County/Daily*	COVID-19 Community Mobility Reports (Google)
Proportion of Delta Variant Causing Cases	Region/Weekly	CDC's National SARS-CoV-2 Genomic Surveillance Program

*Note: * Denotes frequency of the data available in the original source files; where appropriate data were aggregated to capture measures on a weekly basis or to match the last day of a week.*

Appendix 2: Methodology

Regression Model

We use a Poisson regression model to estimate the number of associated reductions in cases, hospitalizations, and deaths due to vaccination. Our baseline model is Equation (1) where $y_{c,t}$ denotes one of three measures (m = cases, hospitalizations, or deaths) per 10,000 population in county c during week t. Each measure m is the number of new cases, hospitalizations, or deaths at week t in county c. $vax\_rate_{c,t}$ is the county-level vaccination rate (percent of population 18 years and over fully vaccinated) in county c at week t. To account for the lag between vaccination and COVID-19 outcomes (i.e., the current rate of COVID-19 outcomes being driven by vaccinations administered in previous weeks), our model incorporates four lags of vaccination rates in each county; these are denoted as $vax\_rate_{c,t-1}$ through $vax\_rate_{c,t-4}$.[48] X is a vector of region- and state-specific variables that vary over time: whether a state has a stay-at-home order active at week t, whether a state has a face mask mandate in public spaces in effect at week t, county-specific mobility trends for places of work at week t, and the proportion of the Delta variant causing cases in regions of the US at week t. τ denotes quarterly fixed effects. ∂_c includes county-specific fixed effects.[49] The standard errors are clustered at the county-level.

$$(1)\quad y_{c,t}^{m} = \exp\left(a + b_0 * vax\_rate_{c,t} + b_1 * vax\_rate_{c,t-1} + b_2 * vax\_rate_{c,t-2} + b_3 * vax\_rate_{c,t-3} + b_4 * vax\_rate_{c,t-4} + d * X + \tau + \partial_c + e_{c,t}\right)$$

Estimating Associated Reductions in Cases, Hospitalizations and Deaths

Using estimates from Equation (1) we predict the number of cases, hospitalizations, and deaths for each county in each week. We call these our predicted values ($\widehat{y_{c,t}^{m}}$). We then set vaccination rates equal to zero for every county in every week in our sample and generate a new set of counterfactual predicted values that estimate our outcomes in the absence of vaccination. The difference between these counterfactual predicted values and our original predicted values are our estimates of associated reductions in cases, hospitalizations and deaths in a given county and week due to vaccination. We then sum these counts over all counties and weeks to arrive at a total number of associated reductions in cases, hospitalizations, and deaths for all 50 states and the District of Columbia over our entire study period.

Results of the Model

In Table S-2 we present the exponentiated coefficients of the Poisson model, or the incidence rate ratio (IRR), in Equation (1). An IRR of 0.91 in the first column of Table S-3 suggests that, holding all other variables constant, on average a one unit increase in vaccination coverage is associated with a decrease in the rate ratio of cases by a factor of 0.91. Our model suggests a similar association for hospitalizations and deaths. Because our model includes both the contemporaneous vaccination rate and its four lags, to estimate the association with vaccination and its lags we would multiply the corresponding coefficients. For instance, when using cases as our outcome, this would be 0.955 (0.955 = 0.911*1.040*1.028*1.012*0.969). Furthermore, we test for the joint significance of our

[48] Our choice of four lags follows the approach of Gupta et al. (2021).

[49] We use quarterly fixed effects as weekly and monthly fixed effects excessively eliminated useful variation.

contemporaneous measure of vaccination and its four lags. We find that for each outcome they are jointly significant at the 1 percent level.

Table S-2. Estimated Incidence Rate Ratio of the Poisson Model Used to Estimate Associated Reductions in Cases, Hospitalizations and Deaths			
	Cases per 10,000 Population	**Hospitalizations per 10,000 Population**	**Deaths per 10,000 Population**
Vaccine Doses per 10,000 Population	0.911***	0.940***	0.905***
	(0.00556)	(0.00617)	(0.00847)
Vaccine Doses per 10,000 Population 1 Week Prior	1.040***	1.027***	1.075***
	(0.0105)	(0.00815)	(0.0173)
Vaccine Doses per 10,000 Population 2 Weeks Prior	1.028**	1.002	0.975
	(0.0114)	(0.00765)	(0.0166)
Vaccine Doses per 10,000 Population 3 Weeks Prior	1.012	1.020***	0.958**
	(0.0111)	(0.00705)	(0.0177)
Vaccine Doses per 10,000 Population 4 Weeks Prior	0.969***	0.991	1.081***
	(0.00592)	(0.00697)	(0.0123)
Stay at Home Order	2.238***	1.556***	0.806**
	(0.152)	(0.0995)	(0.0744)
Mask Mandate	1.584***	1.281***	1.729***
	(0.0369)	(0.0377)	(0.0604)
Workplace Mobility	1.004***	0.997***	1.005***
	(0.000420)	(0.000564)	(0.000935)
Delta Variant	2.786***	0.546**	0.0235***
	(0.544)	(0.136)	(0.00871)
Number of Observations	104,150	80,252	102,483

*Notes: All specifications are estimated using a Poisson model, and include county and quarterly fixed effects. Each observation is at the county-week level. Standard errors appear in parentheses and are clustered at the county level. * p-value <0.10; ** p-value <0.05; *** p-value <0.01.*

Source: ASPE analysis of multiple data sources for December 2020-July 2021.

Addressing Data Quality Issues

We adopt a number of approaches to deal with data quality issues. First, in terms of our vaccination data obtained from CDC, Texas and Hawaii do not report vaccination data at the county-level. We also find that over 40 percent of vaccinations in Georgia, Virginia, and West Virginia have no associated county data. Consequently, for all five of these states we use CDC state-level vaccination data instead of county-level vaccination data. Additionally, certain counties in California and Massachusetts do not report county-level vaccination data. Therefore, we drop these counties from our analysis.[50,51]

There are also several states or counties with missing data in the case and death data obtained from the Center for Science and Engineering at Johns Hopkins University. First, Nebraska stopped reporting COVID-19 case and death data on June 3, 2021.[52] Therefore, we treat all case and death data after June 3, 2021 in Nebraska as missing, so estimates of associated reductions in outcomes in Nebraska should be considered underestimates. Second, a number of counties in Utah report their case and death data in combination with other counties. Since we are unable to identify the individual contributions of each county, we treat case and death data in these counties as missing.[53] We also treat as missing four Alaska counties that combine their case and death data when using cases and deaths as outcomes; these counties are considered too small to report their data separately.[54] Finally, case and death data for Dukes and Nantucket counties in Massachusetts are not reported, and so these counties are dropped from our sample when using cases or deaths as outcomes.[55]

Moreover, our hospitalization data in their original form include missing data. Some facilities had missing data for some weeks during our period of analysis. We replace these missing values by interpolating within facility using the number of hospitalizations available for the nearest known date. We also recode some hospitalization values. Specifically, to protect the privacy of individuals, any facility reporting fewer than 4 hospitalizations is originally top-coded with a value of -99999. We replace these top-coded values with a value of 4. Lastly, we then sum total hospitalizations by week and county. We drop from our analysis any county that does not have hospitalization data available for any week during our sample when using hospitalizations as an outcome.

We also modify our workplace mobility variable to account for missing data. This variable is the change in visits to workplaces (using aggregated data from Google users) in a given day compared to the median value of visits to workplaces for that same day of the week during the five-week period January 3, 2020 to February 6, 2020. Since this variable is at the daily-county level, we average it to the weekly-county level. Moreover, data is missing for some counties. We replace these missing data with the weekly-state average.

Sensitivity Analysis

[50] For California, these counties include Alpine, Inyo, Mariposa, Modoc, Mono, Plumas, Sierra, and Trinity. For Massachusetts, these counties include Barnstable, Dukes, and Nantucket.

[51] Additionally, McKinley County, New Mexico, overreports its vaccination coverage, and so is dropped from our sample.

[52] Between July 1, 2021 and September 21, 2021, there is no county-level data available due to a temporary discontinuation of the Nebraska COVID-19 Dashboard. See https://nebraska.tv/news/a-new-nebraska-covid-dashboard-is-up-and-available.

[53] These counties in Utah include Beaver, Box Elder, Cache, Carbon, Daggett, Duchesne, Emery, Garfield, Grand, Iron, Juab, Kane, Millard, Morgan, Piute, Rich, Sanpete, Sevier, Uintah, Washington, Wayne, and Weber.

[54] These counties include Bristol Bay, Lake and Peninsula, Yakutat, and Hoonah-Angoon.

[55] Additionally, New York City does not report probable deaths by county, so these are not included in our analysis.

We examine whether our estimates of associated reductions in cases, hospitalizations and deaths are robust to the choice of specification in Equation (1) and changes in our sample. The results of this sensitivity analysis are presented in Table S-3. In general, we find that our baseline estimates are robust to these variations.

Sensitivity Analysis (1) is our baseline specification as presented above in Equation (1). We show it here for ease of comparison. In Sensitivity Analysis (2), we re-estimate our model dropping the worker mobility variable as a control. We do this to ensure that imputation of missing values does not substantially bias our results. Our robustness check shows that it does not as estimated associated reductions in cases, hospitalizations and deaths do not substantially change. In Sensitivity Analysis (3), we exclude all region-, state-, and county-level controls. Our estimates increase, suggesting that omission of these controls may bias our results upward. In Sensitivity Analysis (4), we exclude Hawaii and Texas to compare our estimates with estimates that others have published that similarly exclude these states. Our estimates decrease, which is expected given that Texas is one of the most populous states. Similarly, in Sensitivity Analysis (5) we exclude a group of five states (Georgia, Virginia, West Virginia, Texas and Hawaii) as vaccination data for these states were imputed. Our estimates decrease by between 10 percent and 23 percent relative to our baseline estimates. Again, this result is expected given that these states account for a notable portion of the United States population. In Sensitivity Analysis (6), we use a linear regression model instead of a Poisson model. Relative to our baseline scenario, our estimates substantially decrease in terms of cases and hospitalizations, but increase in terms of deaths. Finally, in Sensitivity Analysis (7) we use a linear regression model with quadratics in contemporaneous vaccination rates and their lags. Compared to the baseline model, associated reductions in cases decrease by approximately 1 percent, but there is a substantial increase in associated reductions in hospitalizations (32 percent) and deaths (106 percent). We prefer using a Poisson model because we believe it better captures the nonlinearity of vaccination rates and the outcomes of interest

Table S- 3. Sensitivity Analysis: Estimated Associated Reductions in Cases, Hospitalizations, and Deaths

Sensitivity Analysis	Cases	Hospitalizations	Deaths
(1) **Model uses a non-linear Poisson regression, baseline model**	25,324,302	1,384,260	213,349
(2) **Model uses a non-linear Poisson regression, excluding worker mobility**	24,680,971	1,414,165	205,174
(3) **Model uses a non-linear Poisson regression, excluding all region-, state- and county-level controls**	27,970,049	1,640,618	266,997

Table S- 3. Sensitivity Analysis: Estimated Associated Reductions in Cases, Hospitalizations, and Deaths			
Sensitivity Analysis	Cases	Hospitalizations	Deaths
(4) **Model uses a non-linear Poisson regression, excluding the states of Texas and Hawaii**	22,122,403	1,228,794	184,798
(5) **Model uses a non-linear Poisson regression, excluding the states of Georgia, Hawaii, Texas, Virginia and West Virginia**	18,924,595	1,103,825	183,808
(6) **Model uses a linear functional form (ordinary least squares regression)**	15,708,113	1,235,956	247,280
(7) **Model uses ordinary least squares where vaccination rates are modeled as quadratics**	24,482,573	1,860,893	421,874

Notes: Unless noted, all specifications include county and quarterly fixed effects. Standard errors are clustered at the coun ty level.
Source: ASPE analysis of multiple data sources for December 2020-July 2021

As noted above, we find that county-level vaccination rates are underreported for some states. Therefore, as an additional sensitivity analysis, we explore whether other sources of state-level measurement error may bias our estimates of associated reductions. To do so, we estimate the total number of associated reductions in cases, hospitalizations, and deaths after dropping one state at a time from our sample. We repeat this estimation procedure for all 50 states and the District of Columbia. The results are presented in Table S-4.

Changes in total associated reductions due to dropping a single state stem from two different factors. The first is that when a given state is dropped from our sample, total counts may decrease due to subtraction of this given state's associated reductions. For instance, if California is dropped from our sample, then the associated reduction in counts experienced by California would not be included in the total estimate of associated reductions, resulting in a lower estimate. The second factor is that dropping a single state from our sample may change the coefficients estimated for Equation (1). Depending on how the coefficients change, this could result in total associated reduction in counts either increasing or decreasing.

In general, Table S-4 reinforces the validity of our estimation strategy. Dropping single states from our estimation procedure does not substantially affect our estimates in a way that suggests systematic state-level measurement error substantially biases our results. For instance, the largest changes in our estimates occur when California, New York, and Texas are dropped. This is not surprising given that these are some of the most populous states.

Table S-4. Sensitivity Analysis: Estimated Associated Reductions in Cases, Hospitalizations, and Deaths when Individual States Are Excluded from the Model

State Excluded from Model	Cases	Hospitalizations	Deaths
Alabama	25,203,952	1,367,314	206,301
Alaska	26,175,702	1,395,567	213,448
Arizona	24,253,682	1,337,347	204,955
Arkansas	24,025,278	1,329,052	208,866
California	22,873,150	1,232,484	178,348
Colorado	26,749,732	1,387,504	217,437
Connecticut	24,913,960	1,360,013	209,846
Delaware	25,222,954	1,377,075	212,897
District of Columbia	25,278,368	1,379,730	213,011
Florida	23,211,188	1,280,078	202,513
Georgia	23,679,080	1,313,613	200,112
Hawaii	25,318,648	1,383,579	213,075
Idaho	25,208,208	1,388,236	213,478
Illinois	24,190,600	1,328,859	205,960
Indiana	24,285,804	1,337,558	207,050
Iowa	25,576,350	1,409,115	212,643
Kansas	24,705,598	1,340,085	207,099
Kentucky	24,429,132	1,338,620	228,510
Louisiana	23,933,082	1,357,844	210,054
Maine	25,595,048	1,403,134	213,727
Maryland	24,938,428	1,356,241	212,449
Massachusetts	24,680,350	1,360,558	208,053
Michigan	25,148,604	1,367,892	208,582
Minnesota	26,154,054	1,419,625	212,395
Mississippi	24,793,728	1,374,047	209,426
Missouri	27,140,506	1,330,992	210,666
Montana	25,778,300	1,427,077	212,443
Nebraska	25,389,704	1,400,922	214,134
Nevada	25,142,670	1,357,929	210,911
New Hampshire	25,273,890	1,392,562	213,741
New Jersey	24,450,516	1,329,106	207,884
New Mexico	25,427,418	1,394,053	213,569
New York	22,429,736	1,214,244	193,555
North Carolina	24,298,872	1,345,468	209,225
North Dakota	25,777,476	1,390,282	213,189
Ohio	24,096,162	1,317,400	199,804
Oklahoma	24,285,342	1,347,530	203,415
Oregon	25,545,790	1,401,748	212,488

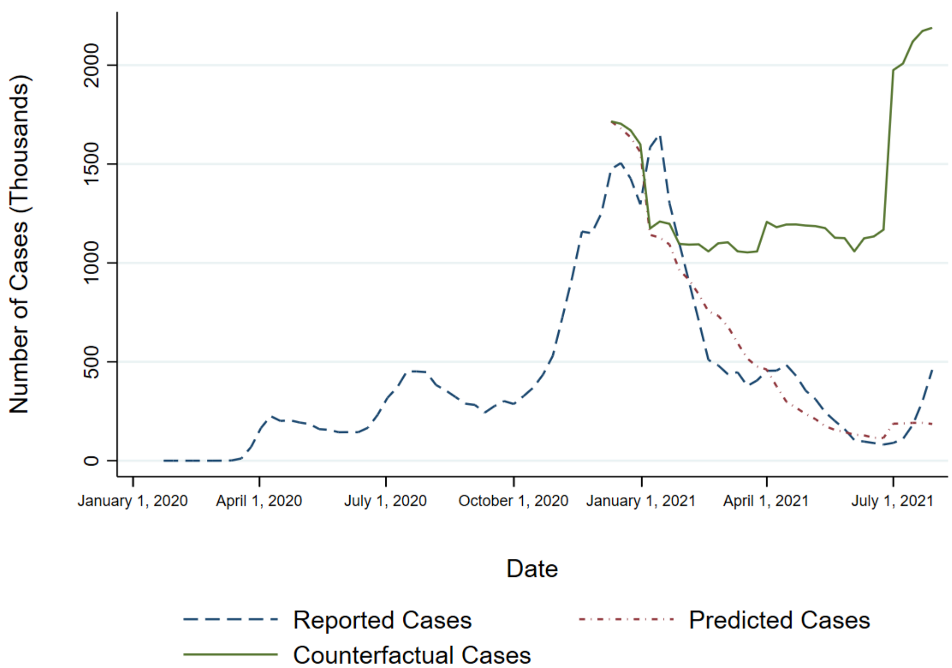
Table S-4. Sensitivity Analysis: Estimated Associated Reductions in Cases, Hospitalizations, and Deaths when Individual States Are Excluded from the Model			
State Excluded from Model	**Cases**	**Hospitalizations**	**Deaths**
Pennsylvania	23,865,562	1,335,479	194,925
Rhode Island	25,218,534	1,378,526	211,949
South Carolina	24,805,162	1,356,176	209,530
South Dakota	25,679,484	1,394,796	218,504
Tennessee	25,064,466	1,343,071	209,846
Texas	22,128,476	1,229,519	185,056
Utah	25,142,820	1,374,274	213,088
Vermont	25,274,648	1,383,552	213,276
Virginia	23,922,878	1,347,313	225,824
Washington	25,367,514	1,389,425	212,892
West Virginia	24,726,330	1,362,139	210,570
Wisconsin	24,871,552	1,396,817	212,011
Wyoming	25,238,750	1,373,265	210,629
None (Baseline Model)	25,324,302	1,384,260	213,349

Notes: Unless noted, all specifications include county and quarterly fixed effects. Standard errors are clustered at the county level.

Source: ASPE analysis of multiple data sources for December 2020-July 2021

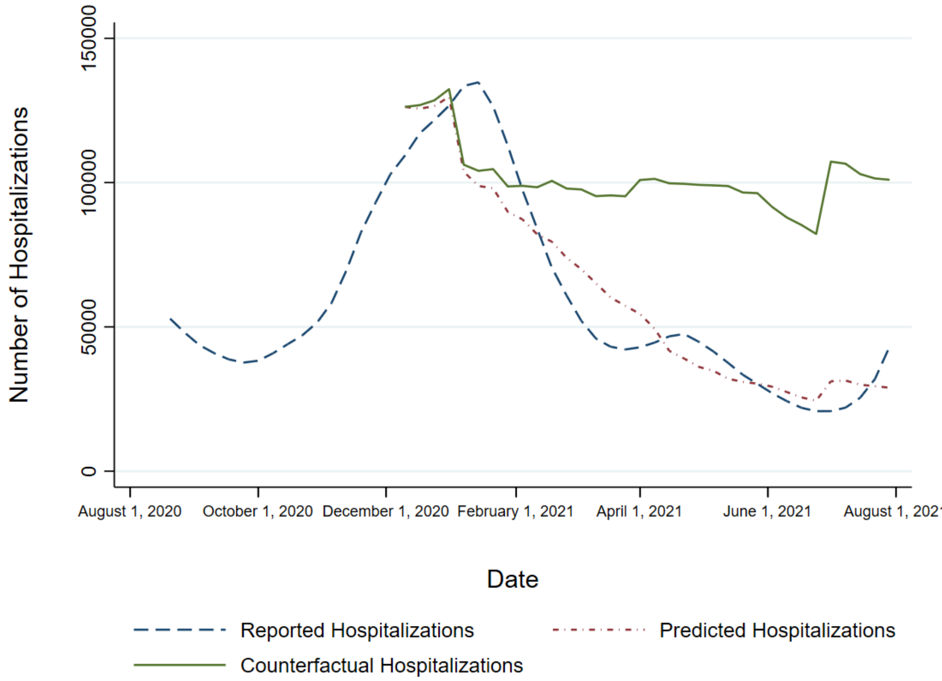
Appendix 3. Supplementary Analysis

Figure S-1. Reported, Predicted, and Counterfactual Cases



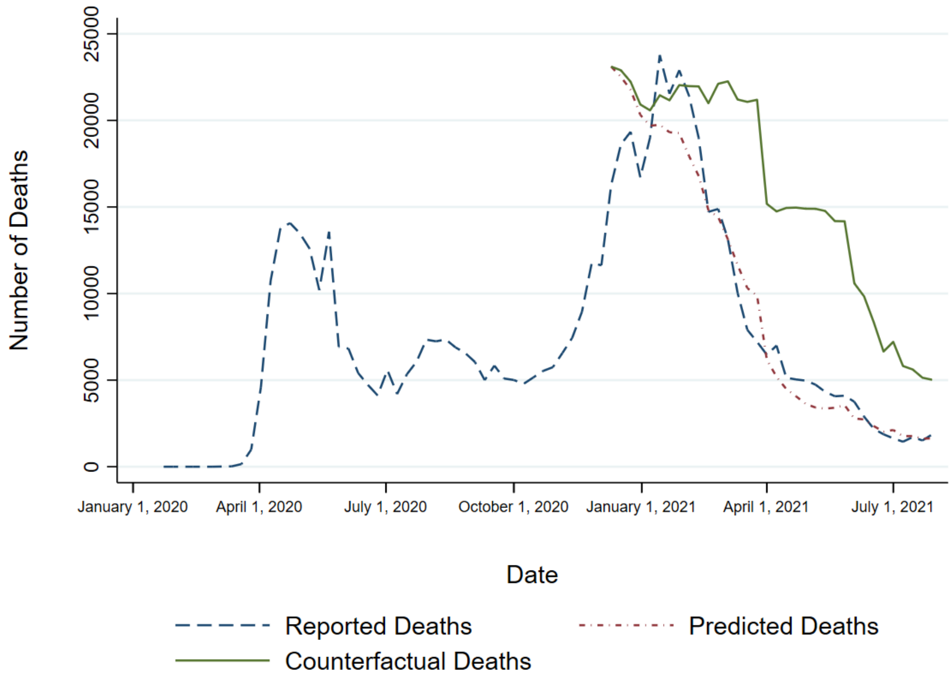
Source: ASPE analysis of multiple data sources for December 2020-July 2021.

Figure S-2. Reported, Predicted, and Counterfactual Hospitalizations



Source: ASPE analysis of multiple data sources for December 2020-July 2021.

Figure S-3. Reported, Predicted, and Counterfactual Deaths



Source: ASPE analysis of multiple data sources for December 2020-July 2021.

Table S-5. Estimated Associated Reductions in Cases, Hospitalizations, and Deaths, and COVID-19 Vaccine Doses Administered Over Time				
Week	Cumulative Reductions in Cases	Cumulative Reductions in Hospitalizations	Cumulative Reductions in Deaths	Cumulative Vaccine Doses Administered
12/10/2020				127,342
12/17/2020	23,765	1,254	383	1,697,791
12/24/2020	59,170	3,222	845	3,738,130
12/31/2020	98,567	5,894	1,447	6,555,680
1/7/2021	130,879	8,316	2,338	11,961,374
1/14/2021	212,317	13,566	4,041	17,546,374
1/21/2021	316,823	20,196	5,889	26,193,682
1/28/2021	448,510	29,015	8,658	35,203,710
2/4/2021	626,624	40,653	12,686	46,390,270
2/11/2021	878,844	56,943	17,858	57,737,767
2/18/2021	1,182,231	78,011	24,036	68,274,117
2/25/2021	1,548,012	101,987	31,727	82,572,848
3/4/2021	1,973,596	129,606	40,850	98,203,893
3/11/2021	2,436,892	159,773	50,404	115,730,008
3/18/2021	2,973,430	195,148	61,159	133,305,295
3/25/2021	3,555,190	233,122	72,467	153,631,404
4/1/2021	4,301,527	279,524	81,471	174,879,716
4/8/2021	5,105,811	331,459	91,019	198,317,040
4/15/2021	6,000,820	389,536	101,477	218,947,643
4/22/2021	6,926,951	450,042	112,370	237,360,493
4/29/2021	7,879,947	513,093	123,640	251,973,752
5/6/2021	8,855,912	577,339	135,118	266,596,486
5/13/2021	9,857,257	644,115	146,533	279,397,250
5/20/2021	10,829,007	709,744	157,312	290,724,607
5/27/2021	11,809,535	775,738	167,930	297,720,928
6/3/2021	12,736,600	838,010	175,736	305,687,618
6/10/2021	13,733,079	898,494	182,841	314,969,386
6/17/2021	14,750,723	958,227	188,828	320,687,205
6/24/2021	15,803,732	1,016,019	193,462	328,152,304
7/1/2021	17,591,712	1,092,115	198,549	332,345,797
7/8/2021	19,411,702	1,167,239	202,601	336,054,953
7/15/2021	21,339,670	1,240,231	206,448	339,763,765
7/22/2021	23,321,174	1,312,192	209,964	344,071,595
7/29/2021	25,324,302	1,384,260	213,349	348,966,419

Source: ASPE analysis of multiple data sources for December 2020-July 2021

Table S-6. Estimated Associated Reductions Cases, Hospitalizations, and Deaths by State				
State	Population	Cases	Hospitalizations	Deaths
Alabama	5,024,279	272,114	18,830	3,300
Alaska	733,391	72,399	1,434	227
Arizona	7,151,502	859,233	38,499	7,836
Arkansas	3,011,524	196,800	10,993	1,602
California	39,538,223	2,566,307	145,545	33,484
Colorado	5,773,714	265,805	10,540	1,316
Connecticut	3,605,944	392,837	18,215	2,663
Delaware	989,948	88,527	4,426	558
District of Columbia	689,545	40,400	4,132	308
Florida	21,538,187	2,215,557	107,370	12,522
Georgia	10,711,908	995,450	53,286	7,963
Hawaii	1,455,271	46,410	2,770	283
Idaho	1,839,106	130,567	5,304	764
Illinois	12,812,508	818,561	48,432	6,951
Indiana	6,785,528	459,390	27,376	4,008
Iowa	3,190,369	174,335	10,179	1,809
Kansas	2,937,880	181,324	10,518	1,830
Kentucky	4,505,836	353,443	19,963	3,352
Louisiana	4,657,757	299,756	14,525	2,225
Maine	1,362,359	77,246	4,607	490
Maryland	6,177,224	338,698	29,145	3,564
Massachusetts	7,029,917	567,943	21,003	5,073
Michigan	10,077,331	748,899	43,788	7,455
Minnesota	5,706,494	357,433	17,417	2,685
Mississippi	2,961,279	226,837	12,869	2,101
Missouri	6,154,913	447,357	29,053	3,146
Montana	1,084,225	59,678	3,331	532
Nebraska	1,961,504	58,120	7,213	629
Nevada	3,104,614	277,252	17,720	2,332
New Hampshire	1,377,529	51,627	2,127	217
New Jersey	9,288,994	854,690	45,949	6,376
New Mexico	2,117,522	146,434	7,030	1,720
New York	20,201,249	2,387,463	131,120	13,953
North Carolina	10,439,388	767,595	34,810	4,879
North Dakota	779,094	38,159	3,213	311
Ohio	11,799,448	834,285	50,132	7,742
Oklahoma	3,959,353	399,325	19,143	3,849
Oregon	4,237,256	187,332	9,485	1,362
Pennsylvania	13,002,700	1,059,848	69,080	11,535
Rhode Island	1,097,379	122,016	5,691	1,004
South Carolina	5,118,425	395,715	15,746	2,795
South Dakota	886,667	59,947	3,972	634
Tennessee	6,910,840	280,338	16,458	3,727

Table S-6. Estimated Associated Reductions Cases, Hospitalizations, and Deaths by State				
State	Population	Cases	Hospitalizations	Deaths
Texas	29,145,505	2,263,058	139,812	17,923
Utah	3,271,616	174,502	6,562	507
Vermont	643,077	23,344	996	114
Virginia	8,631,393	713,673	36,765	6,350
Washington	7,705,281	459,922	19,965	2,585
West Virginia	1,793,716	180,819	9,827	1,880
Wisconsin	5,893,718	303,834	16,132	2,615
Wyoming	576,851	31,700	1,760	262
Total United States	**331,449,281**	**25,324,302**	**1,384,260**	**213,349**

Source: Population estimates from the 2020 Census. ASPE analysis of multiple data sources for December 2020-July 2021

Table S-7. Estimated Associated Reductions in COVID-19 Related Outcomes by Social Vulnerability Index							
Social Vulnerability Index Category	**% of Population**	**Cases (%)**		**Hospitalizations (%)**		**Deaths (%)**	
Theme 1: Socioeconomic							
Very Low (0-0.19)	26.47%	6,221,288	25.57%	299,953	21.67%	45,237	21.20%
Low (0.20-0.39)	24.43%	6,189,630	24.44%	327,638	23.67%	47,226	22.14%
Moderate (0.40-0.59)	23.67%	6,315,098	24.94%	398,169	28.76%	51,819	24.29%
High (0.60-0.79)	16.78%	4,501,861	17.78%	246,856	17.83%	45,479	21.32%
Very High (0.80-1.00)	8.65%	2,096,425	8.28%	111,645	8.07%	23,589	11.06%
Theme 2: Household Composition or Disability							
Very Low (0-0.19)	44.83%	11,508,946	45.45%	615,049	44.43%	87,440	40.98%
Low (0.20-0.39)	23.59%	6,108,288	24.12%	334,683	24.18%	48,018	22.51%
Moderate (0.40-0.59)	14.15%	3,534,841	13.96%	202,963	14.66%	34,261	16.06%
High (0.60-0.79)	11.86%	2,856,746	11.28%	165,681	11.97%	28,476	13.35%
Very High (0.80-1.00)	5.58%	1,315,481	5.19%	65,884	4.76%	15,154	7.10%
Theme 3: Minority Status or Language							
Very Low (0-0.19)	6.80%	1,477,448	5.83%	65,535	4.73%	15,266	7.16%
Low (0.20-0.39)	6.70%	1,471,022	5.81%	71,521	5.17%	14,804	6.94%
Moderate (0.40-0.59)	10.22%	2,348,469	9.27%	102,231	7.39%	20,900	9.80%
High (0.60-0.79)	20.19%	5,044,663	19.92%	274,195	19.81%	42,198	19.78%
Very High (0.80-1.00)	56.09%	14,982,699	59.16%	870,779	62.91%	120,181	56.33%
Theme 4: Housing Type or Transportation							
Very Low (0-0.19)	11.23%	2,680,947	10.59%	107,398	7.76%	20,667	9.69%

Table S-7. Estimated Associated Reductions in COVID-19 Related Outcomes by Social Vulnerability Index							
Social Vulnerability Index Category	**% of Population**	**Cases (%)**		**Hospitalizations (%)**		**Deaths (%)**	
Low (0.20-0.39)	12.37%	3,048,956	12.04%	128,622	9.29%	25,242	11.83%
Moderate (0.40-0.59)	16.55%	4,002,013	15.80%	196,960	14.23%	32,088	15.04%
High (0.60-0.79)	28.17%	7,230,523	28.55%	455,584	32.91%	61,259	28.71%
Very High (0.80-1.00)	31.68%	8,361,863	33.02%	495,697	35.81%	74,094	34.73%

Notes: CDC's Social Vulnerability Index (SVI) values range from 0 (least vulnerable) to 1 (most vulnerable). Population data from the 2019 American Community Survey.

Source: ASPE analysis of multiple data sources for December 2020-July 2021

Table S-8. Valuing Morbidity and Mortality Risk Reductions			
Outcome	**Estimated Associated Reduction**	**VSL or VSC**	**Value of Risk Reduction**
Mortality	213,349	$11,501,365	$2,453,807,201,000
Morbidity			
Mild	23,940,041	$5,846	$139,963,056,240
Severe	982,825	$13,104	$12,878,938,613
Critical	188,086	$1,814,400	$341,263,844,956
Total Value of Mortality and Morbidity Risk Reductions			$2,947,913,040,809

Notes: VSL denotes value of statistical life; VSC denotes value of statistical case. Value of risk reduction is estimated by multiplying the number reduced by the VSL or VSC. All cases are considered mild and are adjusted for reductions in mortality and hospitalizations. Specifically Mild Morbidity is calculated by subtracting 1,384,260 hospitalizations from 25,324,302 cases to avoid double-counting. Critical Morbidity is assumed to be associated with ICU admissions and is calculated assuming that 29 percent of all hospitalizations are ICU admissions and by subtracting 213,349 deaths to avoid double-counting.

Table S-9. Sensitivity Analysis of Valued Mortality and Morbidity Risk Reductions					
Outcome	**Estimated Associated Reduction**	**Low VSL or VSC**	**High VSL or VSC**	**Low Value of Risk Reduction ($billion)**	**High Value of Risk Reduction ($billion)**
Mortality	213,349	$5.36 million	$17.51 million	$1,145	$3,735
Morbidity					
Mild	23,940,041	$2,728	$8,900	$65	$213
Severe	982,825	$6,115	$19,947	$6	$20
Critical	188,086	$846,720	$2.76 million	$159	$519
Total Value of Mortality and Morbidity Risk Reductions				$1,376	$4,487

Notes: VSL denotes value of statistical life; VSC denotes value of statistical case. Estimates assume that 29 percent of hospitalizations are critical and require ICU admission. Value of risk reduction is estimated by multiplying the number reduced by the VSL or VSC. All cases are considered mild and are adjusted for reductions in mortality and hospitalizations. Specifically, Mild Morbidity is calculated by subtracting 1,384,260 hospitalizations from 25,324,302 cases to avoid double-counting. Critical Morbidity is assumed to be associated with ICU admissions and is calculated assuming that 29 percent of all hospitalizations are ICU admissions and by subtracting 213,349 deaths to avoid double-counting.

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES

Office of the Assistant Secretary for Planning and Evaluation

200 Independence Avenue SW, Mailstop 434E
Washington, D.C. 20201

For more ASPE briefs and other publications, visit:
aspe.hhs.gov/reports

ABOUT THE AUTHORS

Nicholas Holtkamp is an Economist in the Office of Science and Data Policy at ASPE.
Allison Kolbe is a Health Science Policy Analyst in the Office of Science and Data Policy at ASPE.
Trinidad Beleche is a Senior Economist in the Office of Science and Data Policy at ASPE.

SUGGESTED CITATION

Holtkamp, N., Kolbe, A., and Beleche, T. COVID-19 Vaccination Associated with Reductions in COVID-19 Mortality and Morbidity in the United States, and an Approach to Valuing these Benefits. Washington, DC: Office of the Assistant Secretary for Planning and Evaluation, U.S. Department of Health and Human Services. December 2021.

____

For general questions or general information about ASPE:
aspe.hhs.gov/about