

**Projecting COVID-19 Hospitalizations
in Jefferson County, KY,
Based upon the Uptake of Vaccination in 5-11 Year Olds**

**Projection Period:
4 November 2021 – 31 January 2022**



DEPARTMENT OF
**PUBLIC HEALTH
AND WELLNESS**

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Abstract

Background: COVID-19 cases, deaths, and hospitalizations sharply increased from early July to mid-September 2021 in Jefferson County, Kentucky. The increases were correlated with the introduction of the Delta variant in the community and changes in mobility patterns. COVID-19 outcomes, however, started to decrease from mid-September 2021.

Projection Scenarios: On 31 October 2021, the Food and Drug Administration granted Pfizer's COVID-19 an emergency use authorization for 5-11 year old children. This study focused on projecting COVID-19 active hospitalizations in the county for three scenarios based on the uptake of vaccinations in 5 to 11 year olds:

- 1) *an expected vaccination rate growth:*
20% of 5 to 11 year old children will be fully vaccinated by the end of 2021
- 2) *an accelerated vaccination rate growth:*
40% of 5 to 11 year old children will be fully vaccinated by the end of 2021
- 3) *a decelerated vaccination rate growth:*
10% of 5 to 11 year old children will be fully vaccinated by the end of 2021

Projection period: 4 November 2021 to 31 January 2022

Key Projection Assumptions:

- 1) 54% full vaccination of 12 to 15 year old children by the end of 2021.
The full vaccination rate in this age group was 49.9% by 3 November 2021.
- 2) No further vaccination in other age groups.
- 3) 10% missing rate of the second dose.
This is the observed rate of missing the second dose among 12 to 15 year old children.
- 4) No change in the current contact rate and mobility in the population.
- 5) Similar transmission and clinical parameters of the recently identified variant (the Omicron variant) to the Delta variant.

The assumptions were made to isolate the effect on overall COVID-19 outcomes of 5-11 years vaccination scenarios from our factors, hence conveying a clear message to parents about the public health impact of their decision to vaccinate their children.

Epidemic Modeling Approach: A Susceptible-Exposed-Infectious-Recovered (SEIR) epidemic dynamics model was adopted and estimated in this study. The susceptible population in the model was the county population that did not contract COVID-19 before the vaccination campaign started in the county in mid-December 2020. The model allowed for different transmission and clinical parameters for unvaccinated and breakthrough cases. Additionally, hospitalization and death among breakthrough cases were allowed.

Data: The epidemic model's parameters were estimated using the

- 1) Kentucky State Contact Tracing and Tracking (CTT) database,
- 2) State of Kentucky Web Emergency Operation Center (WebEOC) system,
- 3) State of Kentucky Immunization Registry (KYIR), and
- 4) a systematic review of COVID-19 literature.

Data and information from 1 July 2021 (the beginning of the Delta variant era in the U.S.) were used in estimations.

Results: According to the CTT data, from 1 July 2021 until 20 November 2021 (the latest date analyzed), 42,140 COVID-19 cases with positive specimen collection dates were unvaccinated, 201 partially vaccinated, and 6,311 fully vaccinated. During the period, 1,847 COVID-19 hospitalizations were unvaccinated, 37 partially vaccinated, and 360 fully vaccinated (*Note:* CTT has historically included approximately 60% of active COVID-19 hospitalizations). Also, 331 deaths were unvaccinated, 4 partially vaccinated, and 85 fully vaccinated.

Characteristics of Unvaccinated and Breakthrough Cases: While there were much fewer hospitalizations in vaccinated than in unvaccinated cases, the fatality rate among hospitalized cases was greater in vaccinated cases (20.6%) than unvaccinated cases (15.4%) according to the CTT data from 1 July 2021, that is driven by differences in age and comorbid conditions (see below). The proportion of symptomatic cases that required hospitalization was estimated at 8.2%–10.0% among vaccinated cases, but at 4.6%–10.6% among unvaccinated cases. To understand why COVID-19 outcomes in vaccinated cases were worse than those in unvaccinated cases, demographic characteristics and preexisting conditions of vaccinated and unvaccinated cases, hospitalizations, and deaths were extracted and compared. The results showed that:

- Vaccinated persons who contracted COVID-19 were significantly older than unvaccinated cases: the median age difference between vaccinated and unvaccinated cases was 19 years.
- The percentage of hospitalized COVID-19 cases with one or more preexisting conditions was greater in vaccinated cases (81.7%) than unvaccinated cases

(61.2%). Also, the percentage of deceased COVID-19 cases with one or more preexisting conditions was greater in vaccinated cases (95.3%) in comparison to unvaccinated cases (82.5%).

- The most prevalent preexisting condition among hospitalized and deceased cases was hypertension. The prevalence of hypertension among vaccinated hospitalized cases was 60.3%, 34.9% among unvaccinated hospitalized cases. Its prevalence among vaccinated deceased cases was 78.8%, 57.1% among unvaccinated deceased cases.
- The second, third, and fourth most common preexisting conditions among hospitalized and deceased cases were cardiovascular diseases, hyperlipidemia, and diabetes. Among hospitalized and deceased cases, the prevalence of all these diseases was remarkably greater in vaccinated individuals versus unvaccinated individuals.

Projection Results: Projected number of active COVID-19 hospitalizations on selected dates under the 5-11 years vaccination scenarios:

Selected Dates	Number of Daily Active Hospitalizations at Selected Dates, under:			Difference with Expected Scenario	
	Expected Scenario	Accelerated Scenario	Decelerated Scenario	Accelerated Scenario	Decelerated Scenario
11/30/2021	126	102	152	-24	27
12/15/2021	106	76	144	-31	38
12/31/2021	81	54	127	-28	46
1/15/2022	69	41	120	-29	51
1/31/2022	54	32	110	-23	56

Key Takeaways:

- By vaccinating 40% of the 5-11 year olds in Jefferson County, we project approximately 54 overall (not age-specific) active hospitalizations by 12/31/2021, assuming no change in other mitigation factors. However, if only 10% of the 5-11 year olds are vaccinated, we project double the number of active hospitalizations, approximately 127. By 1/31/2022, we would have nearly 4 times as many active hospitalizations if only 10% of the 5-11 year-olds are vaccinated compared to if 40% of the 5-11 years olds are vaccinated.
- Therefore, it is pivotal to vaccinate this age group as best as possible through the most age-appropriate avenues (e.g., in schools and pediatrician offices) to decrease the overall rate of COVID-19 hospitalizations in the county.

Policy Implications: More intense vaccination of children than the expected can decrease hospitalizations in the next three months. Even though children comprise a small proportion of the hospitalized population, they still have a considerable impact on the COVID-19 hospitalization rate in Jefferson County, KY. The magnitude of the decrease is approximately two dozen on a daily basis. Importantly, it is expected that the COVID-19 infection will continue to spread. Therefore, social distancing and other COVID-19 protection measures (for example, mask-wearing and limiting unnecessary mobility and large gatherings) must continue – *should they be relaxed, another “during vaccination surge” will occur and should be expected in the late December-January period particularly when a more transmissible variant emerges.*

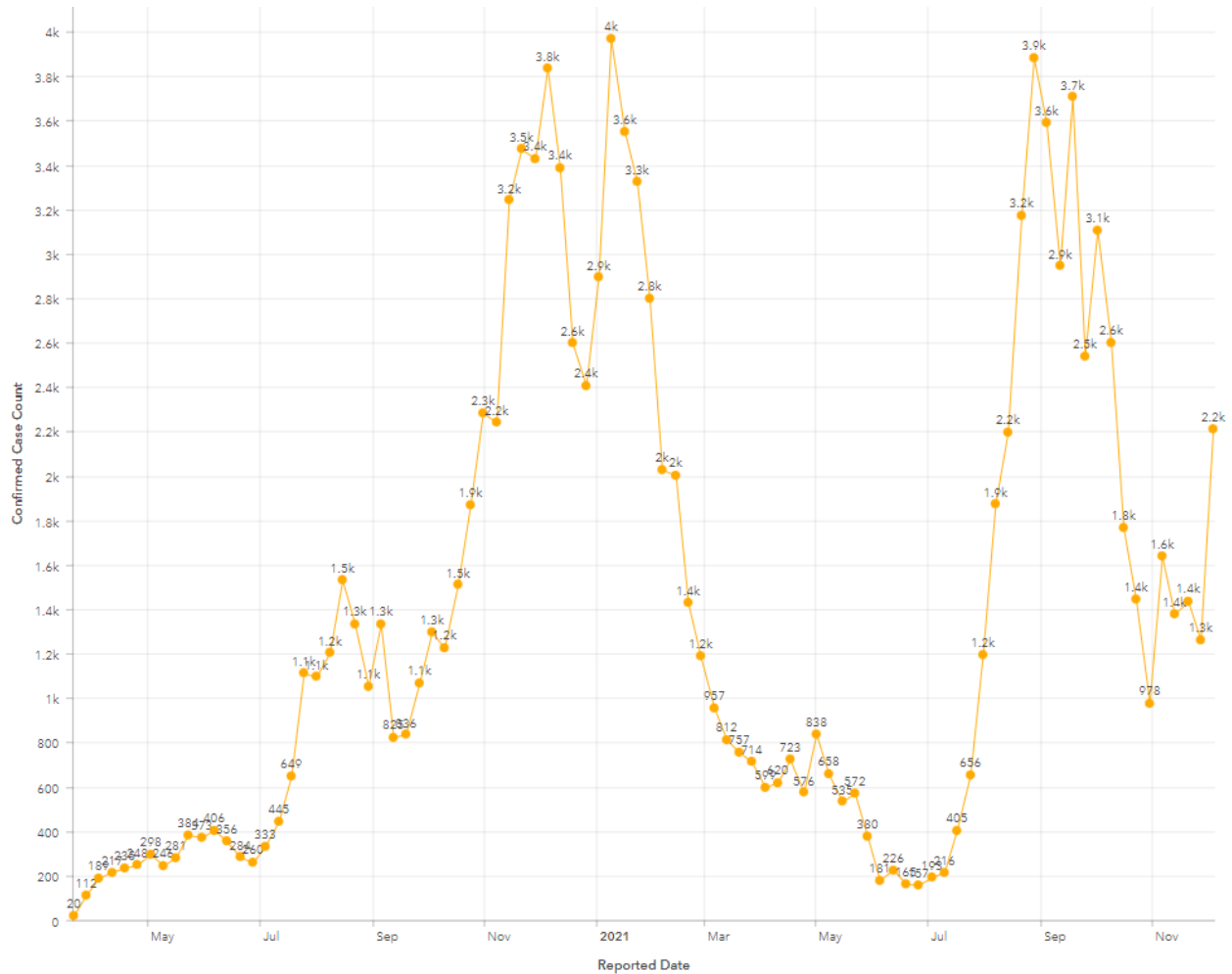
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Section 1:

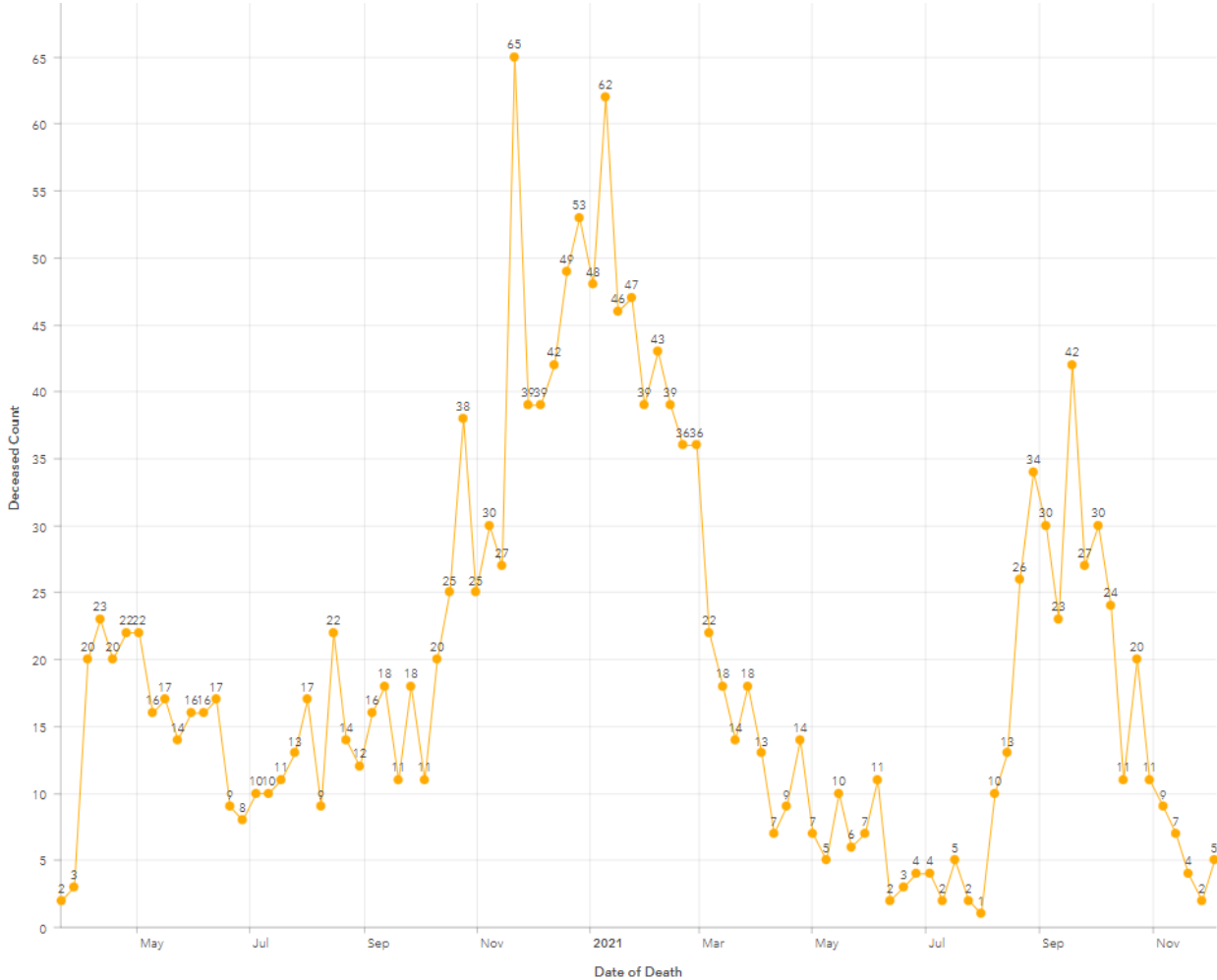
Trends in COVID-19 Outcomes in Jefferson County, Kentucky

Figure 1.1: Total Confirmed COVID-19 Cases by Week in Jefferson County, Kentucky



Source: Louisville Metro Department of Public Health & Wellness (LMPHW) COVID-19 Data Dashboard ([link](#))¹

Figure 1.2: Total COVID-19 Deaths by Week in Jefferson County, Kentucky



Source: Louisville Metro Department of Public Health & Wellness (LMPHW) COVID-19 Data Dashboard ([link](#))¹

Figure 1.3: Active Daily COVID-19 Hospitalizations from 10 July 2020 to 20 November 2021 in Jefferson County, Kentucky



Source: Authors' calculations using State of Kentucky Web Emergency Operation Center (WebEOC) system

Section 2:

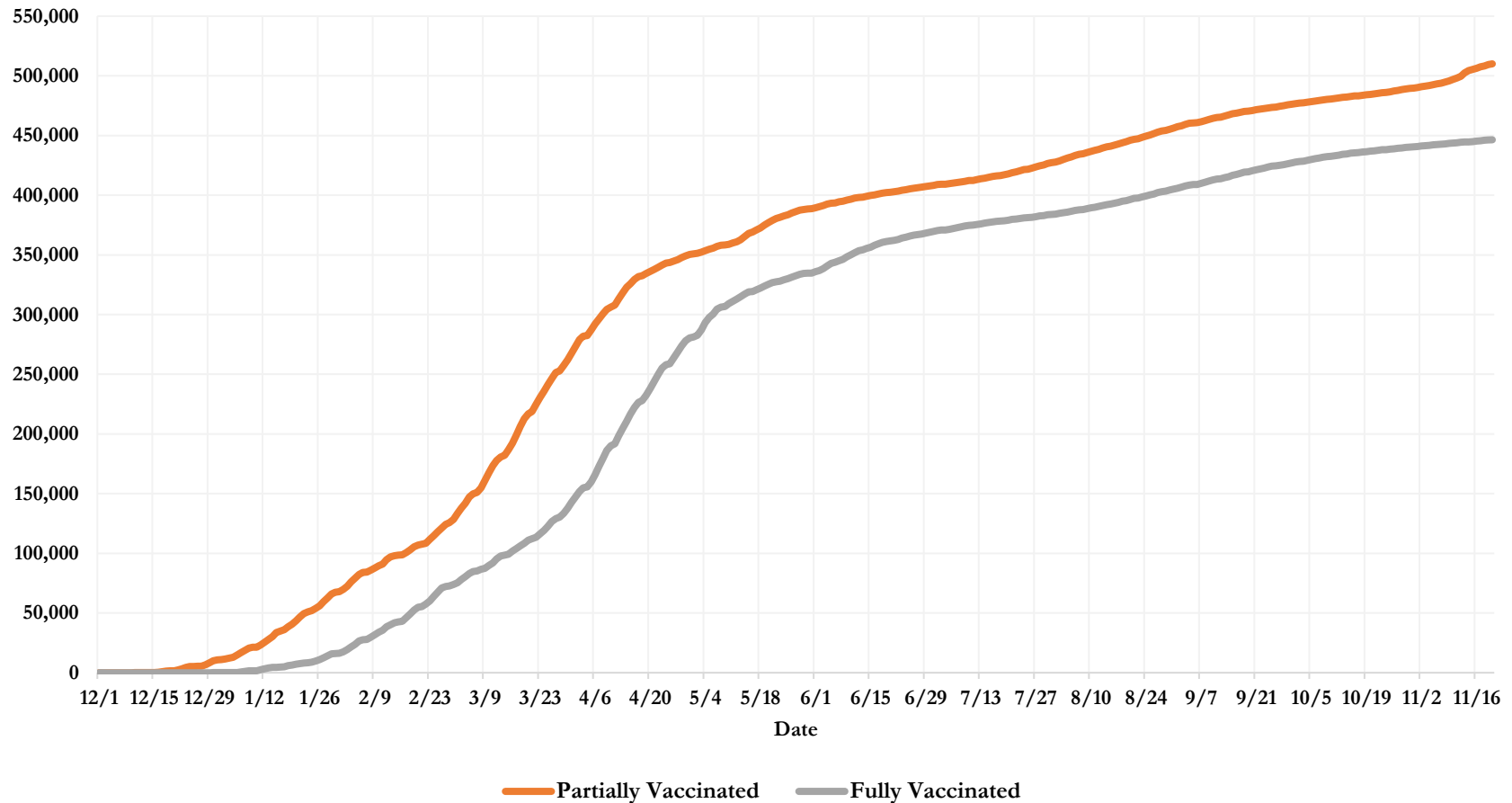
Contributors to COVID-19 Outcomes in Jefferson County, Kentucky

- **Vaccination**
- **Social Distancing Approximated by Mobility**

2.1. Vaccination Trends in Jefferson County, Kentucky

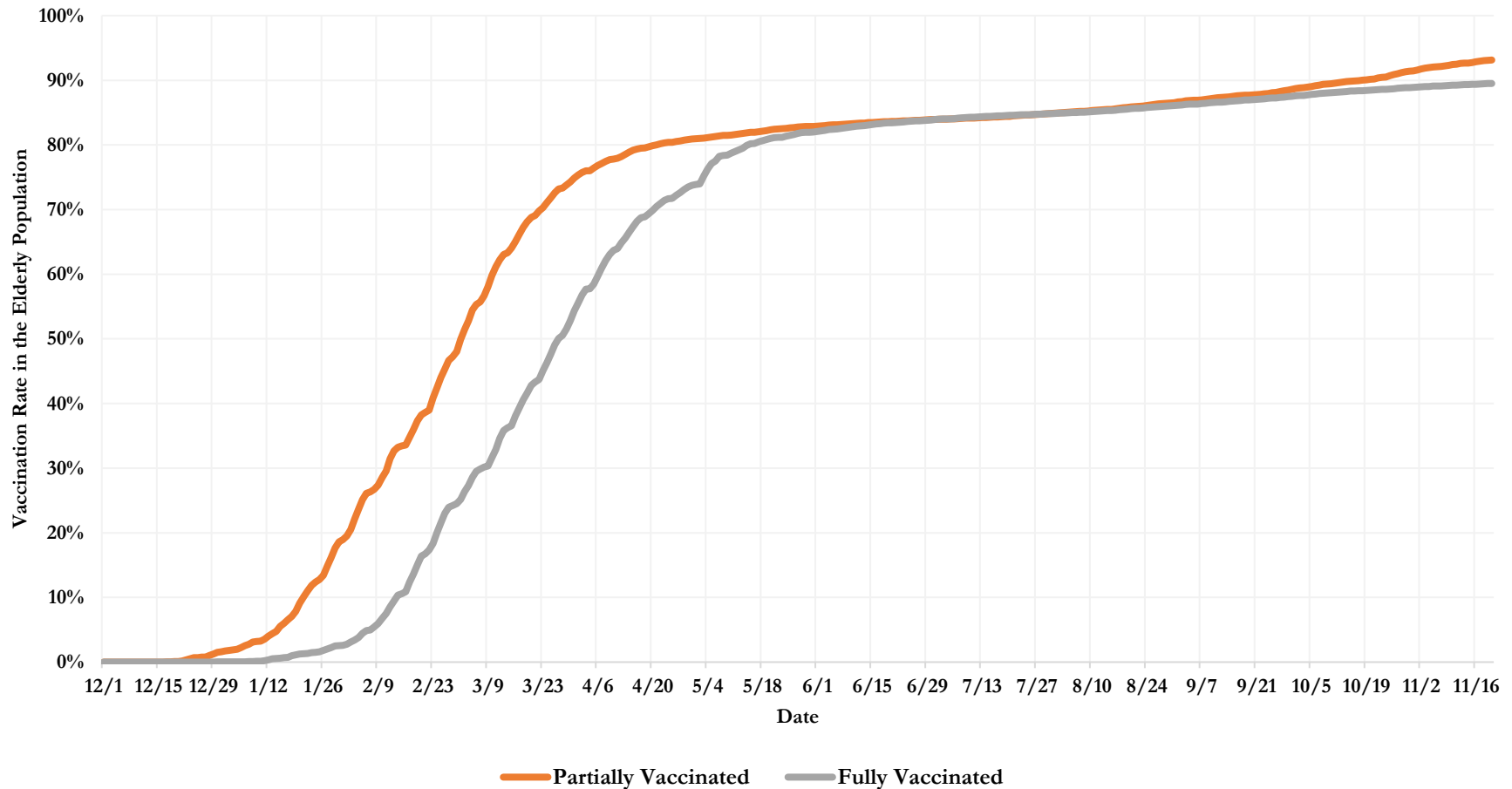
- COVID-19 vaccination campaign started on 16 December 2020 in Jefferson County, Kentucky ([LMPHW data dashboard](#)).¹
- The weekly number of COVID-19 vaccine doses distributed and administered to the county residents peaked in March and April 2020 ([LMPHW data dashboard](#)).¹
- By 20 November 2021, approximately 510,000 residents received at least a dose of Pfizer or Moderna vaccines (defined as partially vaccinated in this study); 446,000 received at least two doses of Pfizer and Moderna vaccines and one dose of the Johnson & Johnson vaccine (defined as fully vaccinated in this study) (**Figure 2.1**).
- The elderly (65 years or older) residents have had the highest rate of vaccination in the county: by 20 November 2021, approximately 90% of them were fully vaccinated (**Figure 2.2**).
- The rate of vaccination has been negatively correlated with age. By 20 November 2021, approximately 66% of adults (18 to 64 years old) and 55% of 16 to 17 year old children were fully vaccinated (**Figures 2.3-2.4**).
- The full vaccination rate by 20 November 2021 among 12 to 15 year old children was 51%. The Food and Drug Administration (FDA) granted the Pfizer COVID-19 vaccine an Emergency Use Authorization (EUA) for this age group on 10 May 2021 (**Figure 2.5**).
- On 29 October 2021, the FDA granted the Pfizer COVID-19 vaccine an EUA for 5 to 11 year old children. Vaccination of children in this age group started in the county on 3 November 2021. By 20 November 2021, 16.5% of 5 to 11 year old children received a dose of Pfizer vaccine.

Figure 2.1: COVID-19 Vaccination in Jefferson County, Kentucky (Cumulative Numbers)



Notes: Partial vaccination numbers are numbers of Jefferson County, Kentucky, residents who received one dose of a COVID-19 vaccine. Full vaccination numbers are numbers of Jefferson County, Kentucky, residents who received two doses of a COVID-19 vaccine.
Source: Calculated by authors using vaccination data from State of Kentucky Immunization Registry (KYIR)

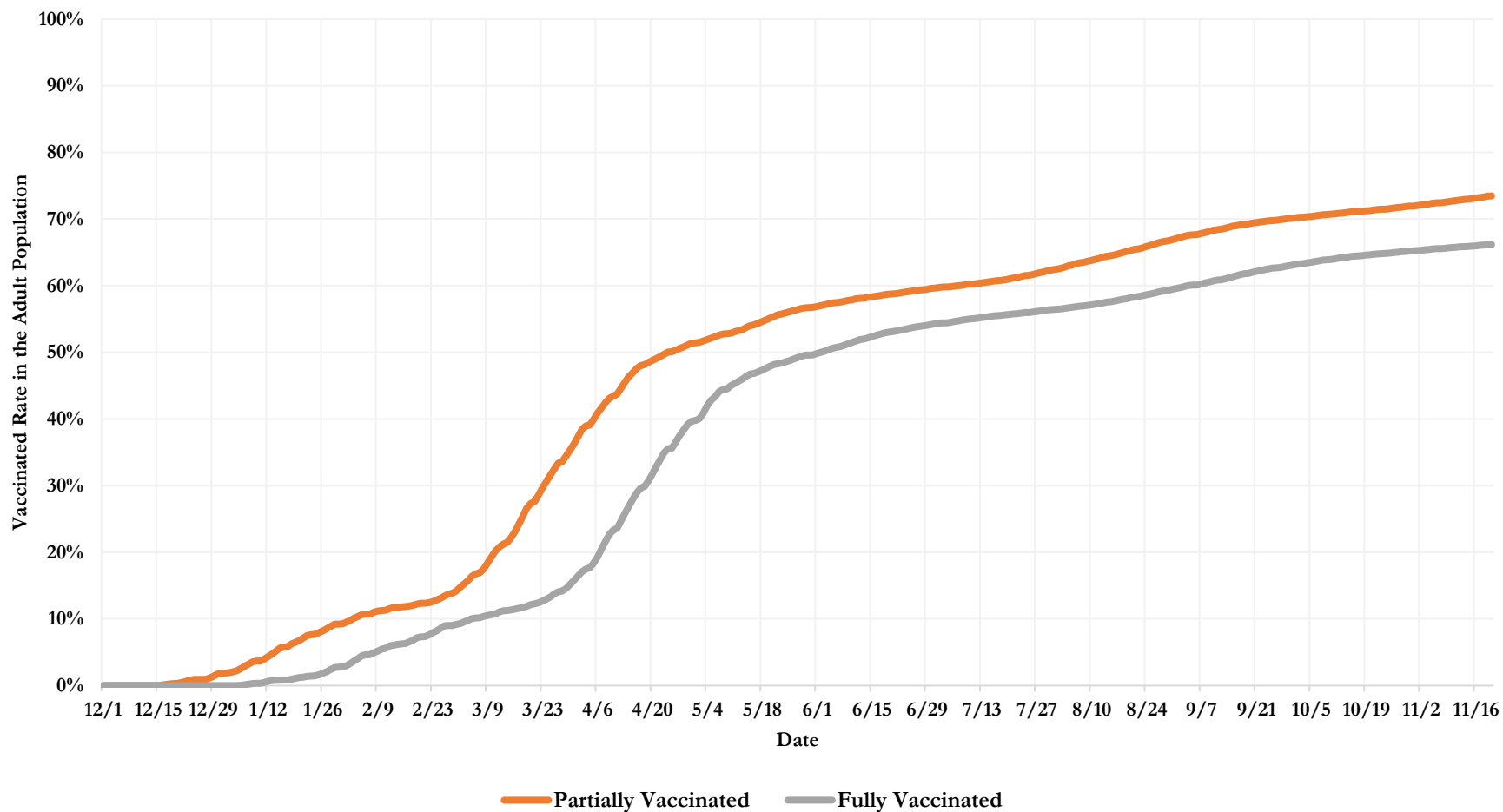
Figure 2.2: COVID-19 Vaccination among the Elderly (65 Years or Older) in Jefferson County, Kentucky
(Cumulative Population Shares)



Notes: Partial vaccination numbers are numbers of Jefferson County, Kentucky, residents who received one dose of a COVID-19 vaccine. Full vaccination numbers are numbers of Jefferson County, Kentucky, residents who received two doses of a COVID-19 vaccine. The elderly population was calculated by authors using 2019 Census Bureau data.

Source: Calculated by authors using vaccination data from State of Kentucky Immunization Registry (KYIR)

Figure 2.3: COVID-19 Vaccination among Adults (18 to 64 Years Old) in Jefferson County, Kentucky
(Cumulative Population Shares)

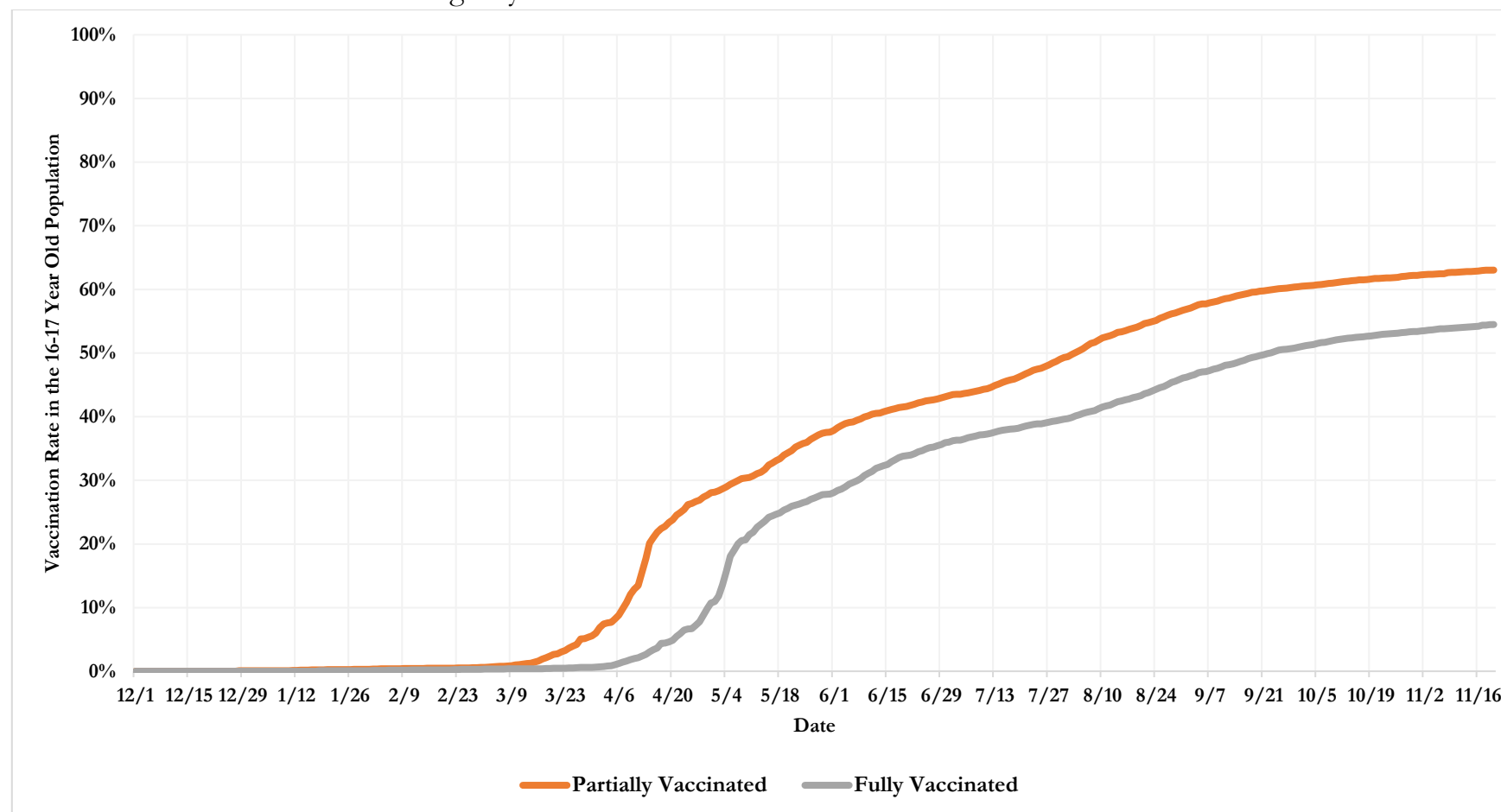


Notes: Partial vaccination numbers are numbers of Jefferson County, Kentucky, residents who received one dose of a COVID-19 vaccine. Full vaccination numbers are numbers of Jefferson County, Kentucky, residents who received two doses of a COVID-19 vaccine. The adult population was calculated by authors using 2019 Census Bureau data.

Source: Calculated by authors using vaccination data from State of Kentucky Immunization Registry (KYIR)

Figure 2.4: COVID-19 Vaccination among 16 and 17 Year Old Children in Jefferson County, Kentucky
(Cumulative Population Shares)

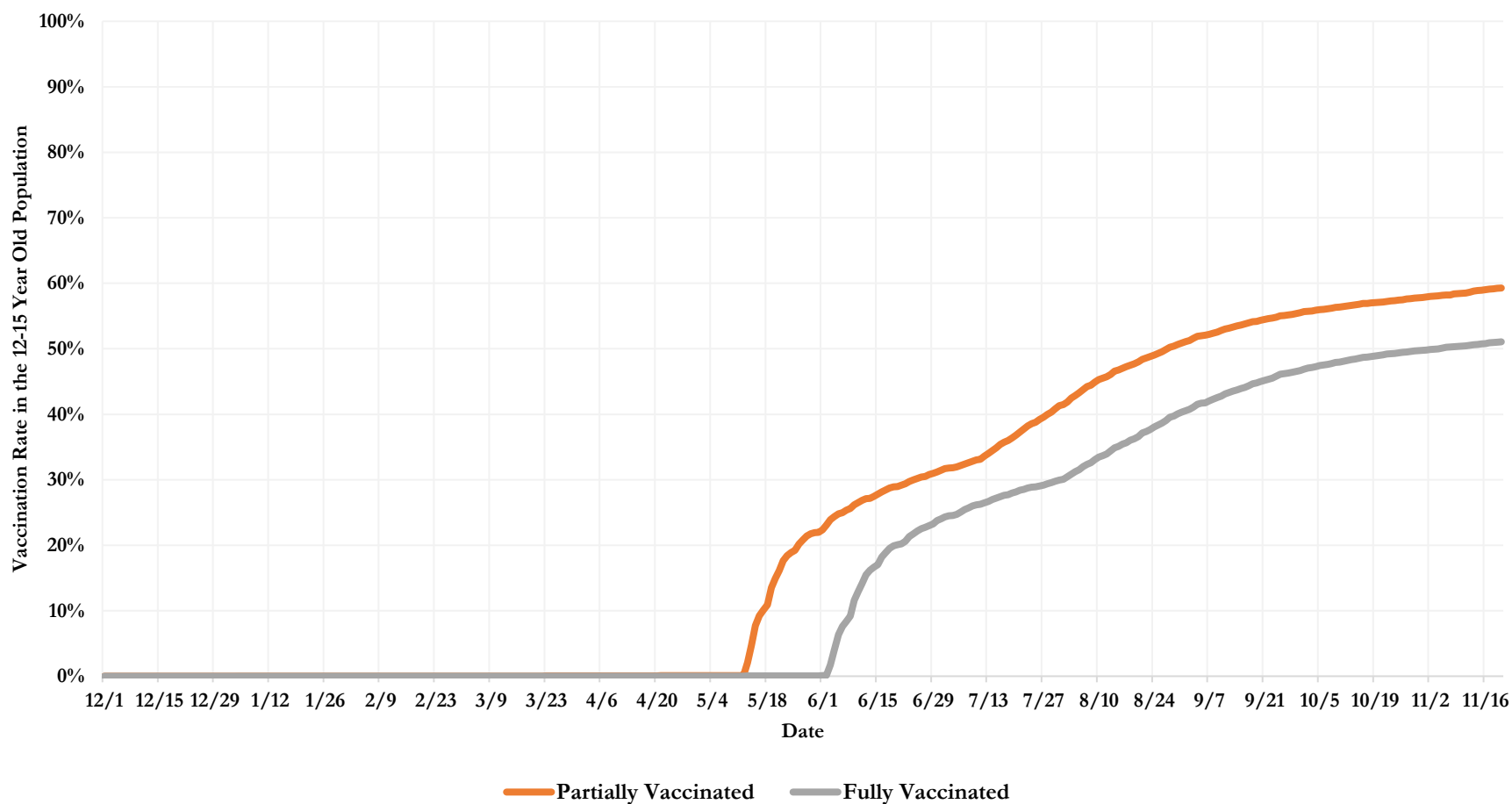
Pfizer's Received Emergency Use Authorization on 11 December 2020 for 16 Years and Older²



Notes: Partial vaccination numbers are numbers of Jefferson County, Kentucky, residents who received one dose of a COVID-19 vaccine. Full vaccination numbers are numbers of Jefferson County, Kentucky, residents who received two doses of a COVID-19 vaccine. The 16-17 year old population was calculated by authors using 2019 Census Bureau data.

Source: Calculated by authors using vaccination data from State of Kentucky Immunization Registry (KYIR)

Figure 2.5: COVID-19 Vaccination among 12 to 15 Year Old Children in Jefferson County, Kentucky
Cumulative Population Shares
Emergency Use Authorization Date: 10 May 2021³



Notes: Partial vaccination numbers are numbers of Jefferson County, Kentucky, residents who received one dose of a COVID-19 vaccine. Full vaccination numbers are numbers of Jefferson County, Kentucky, residents who received two doses of a COVID-19 vaccine. The 12-15 year old population was calculated by authors using 2019 Census Bureau data.

Source: Calculated by authors using vaccination data from State of Kentucky Immunization Registry (KYIR)

2.2. Mobility Trends in Jefferson County, Kentucky

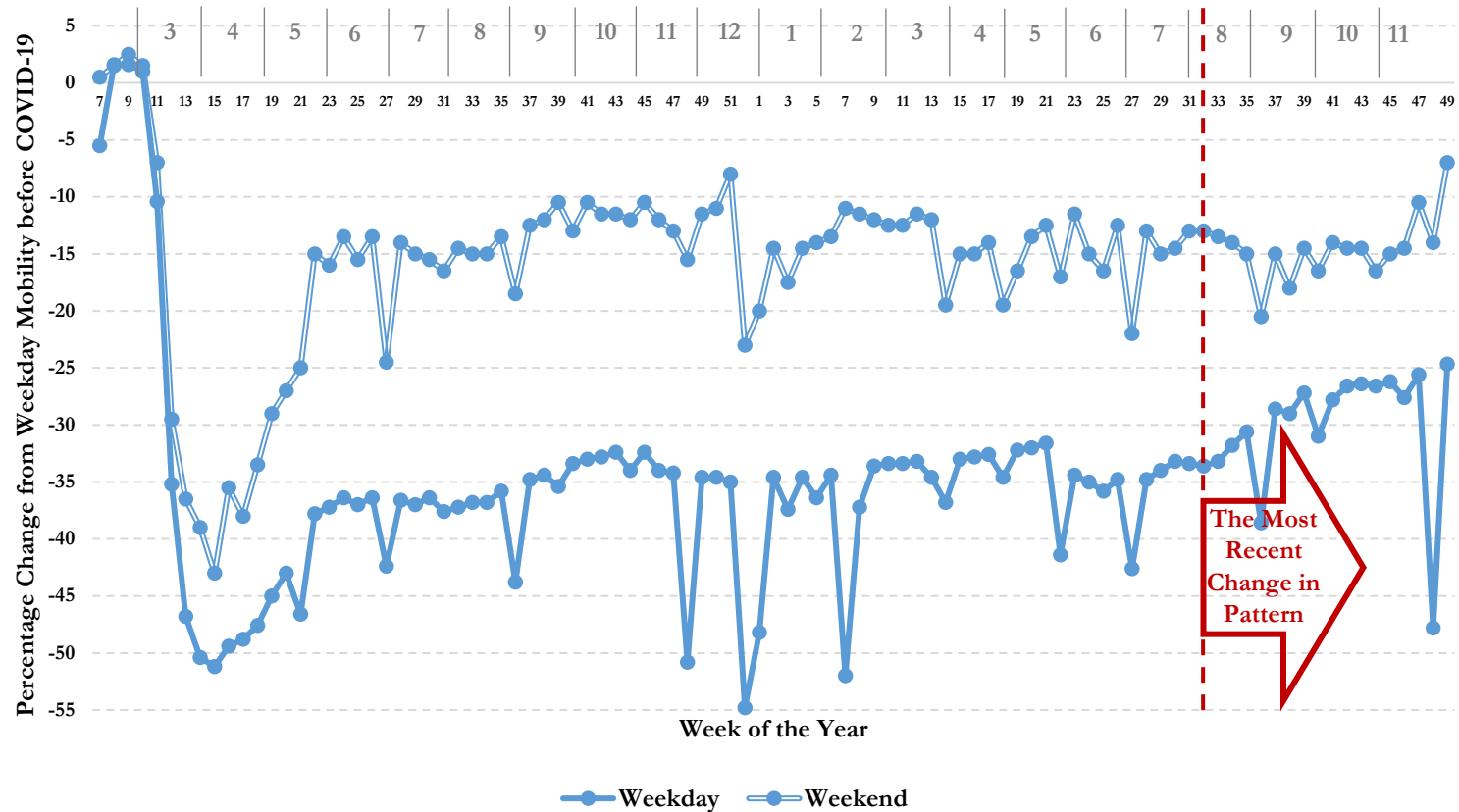
Change in mobility relative to the period prior to the pandemic is presented below. Mobility decreased drastically during the pandemic. While mobility has not been restored to pre-pandemic levels, there have been increases in mobility since the pandemic began.

Workplace mobility remained stable for almost a year until August 2021. However, between early August and late November 2021, workplace mobility continually increased by 9%. The increase in Workplace mobility was accompanied by increases in Transit Stations mobility and continuous decreases in Grocery & Pharmacy mobility and Retail & Recreation mobility. In the following, weekday trends in five mobility indices are summarized. Google's community mobility reports were used in calculating the indices.

1. **Workplace mobility** on weekdays remained stable between -30% to -35% of its pre-pandemic level from August 2020 to August 2021. However, weekday Workplace mobility continuously increased by 9% from -34% to -25% of its pre-pandemic level from early August 2021 to late November 2021 (**Figure 2.6**).
2. **Grocery & Pharmacy mobility** on weekdays continuously increased by about 17% during the first three months of 2021 from about -10% to about $+7\%$ of its pre-pandemic level in the county but remained between $+5\%$ and $+10\%$ of its pre-pandemic levels from March 2021 to mid-August 2021. However, it continuously decreased from $+10\%$ to $+1\%$ of its pre-pandemic level from mid-August 2021 to early November 2021. It remained almost equal to its pre-pandemic level from thereafter (**Figure 2.7**).
3. **Retail & Recreation mobility** on weekdays continuously increased by about 20% during the first three months of 2021 from about -30% to about -10% of its pre-pandemic level but remained between -10% and -5% of its pre-pandemic level from March 2021 to August 2021. However, it continuously decreased from -7% to -14% of its pre-pandemic level from mid-August 2021 to mid-September 2021. It stayed at about -10% of its pre-pandemic level thereafter (**Figure 2.8**).
4. **Transit Stations mobility** on weekdays continuously increased by about 20% during the first four months of 2021 from about -35% to -15% of its pre-pandemic level. It remained between -17% and -12% of its pre-pandemic level from April 2021 to August 2021 but continuously increased by about 5% from -19% to -12% of its pre-pandemic level from late August 2021 to mid-October 2021. It stayed at about -10% of its pre-pandemic level thereafter (**Figure 2.9**).

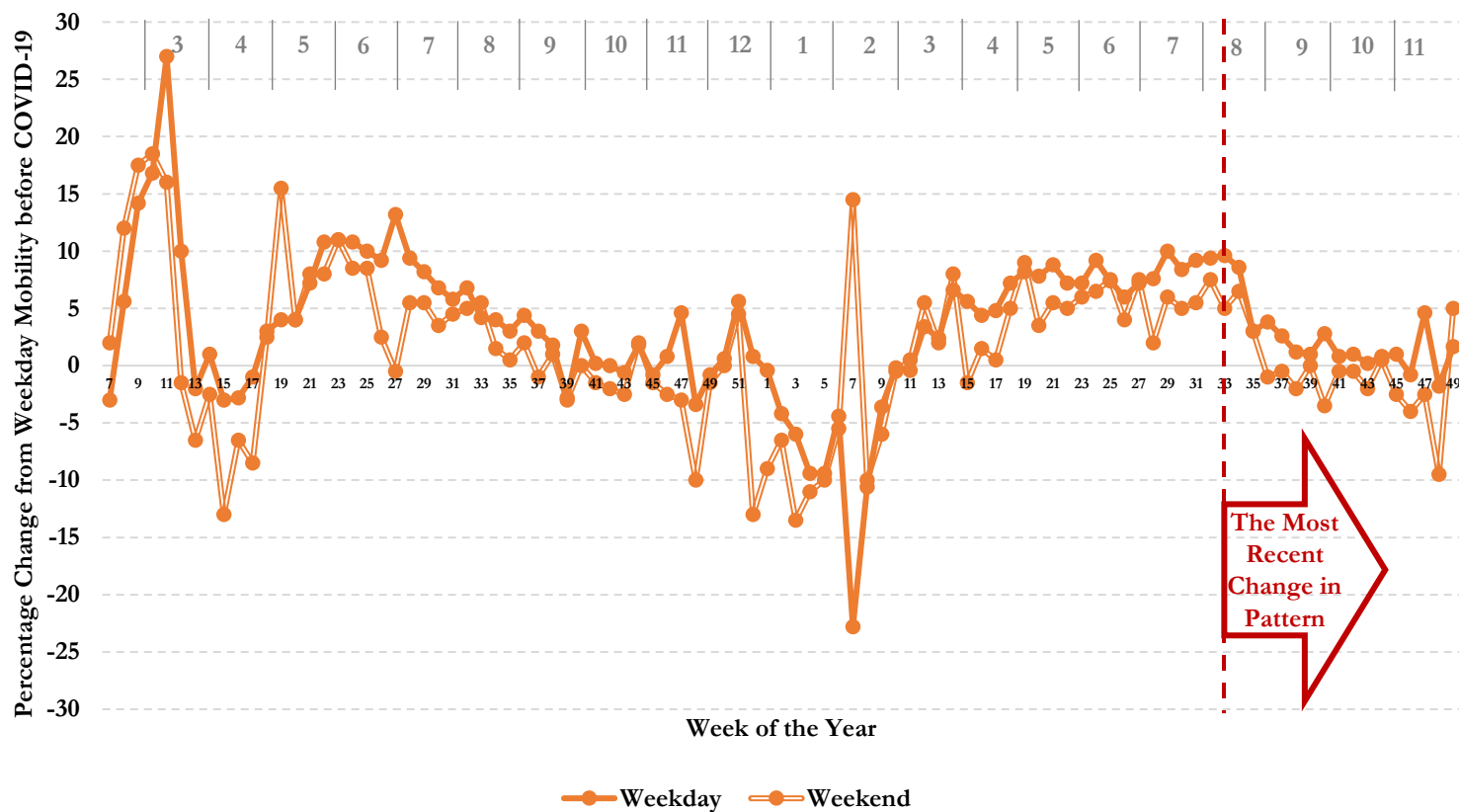
5. **Residential mobility** on weekdays continuously decreased during the first six months of 2021 from about +15% to about +5% of its pre-pandemic level but remained at about +5% of its pre-pandemic level thereafter (**Figure 2.10**).

Figure 2.6: Workplace Mobility as a Percentage of Its Pre-COVID-19 Mobility by Month and Week of the Year (Feb. 2020 to Nov. 2021)



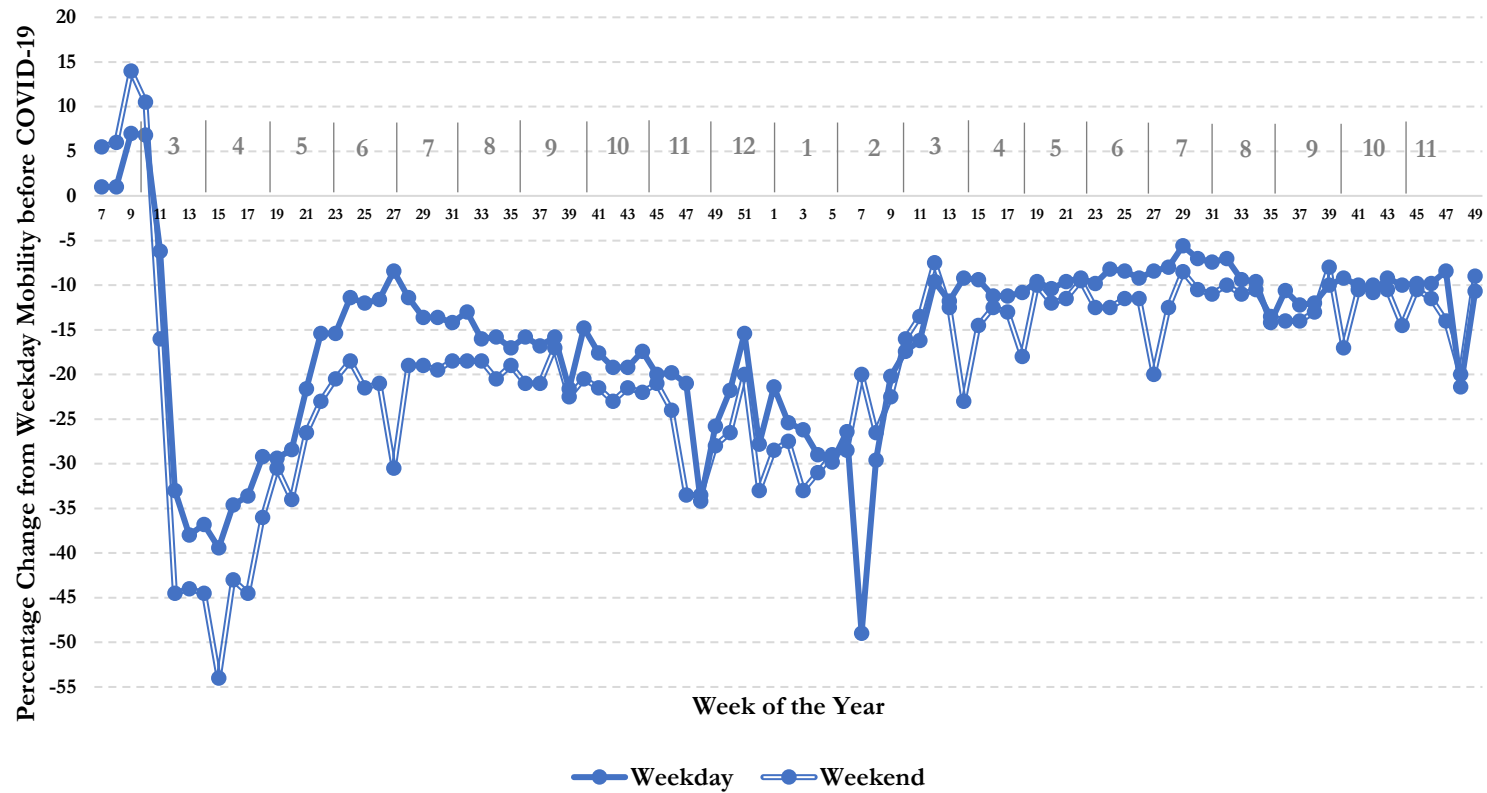
Note: Authors' calculations using Google's Community Mobility Reports ([link](#))⁴

Figure 2.7: Grocery & Pharmacy Mobility as a Percentage of Its Pre-COVID-19
Mobility by Month and Week of the Year (Feb. 2020 to Nov. 2021)



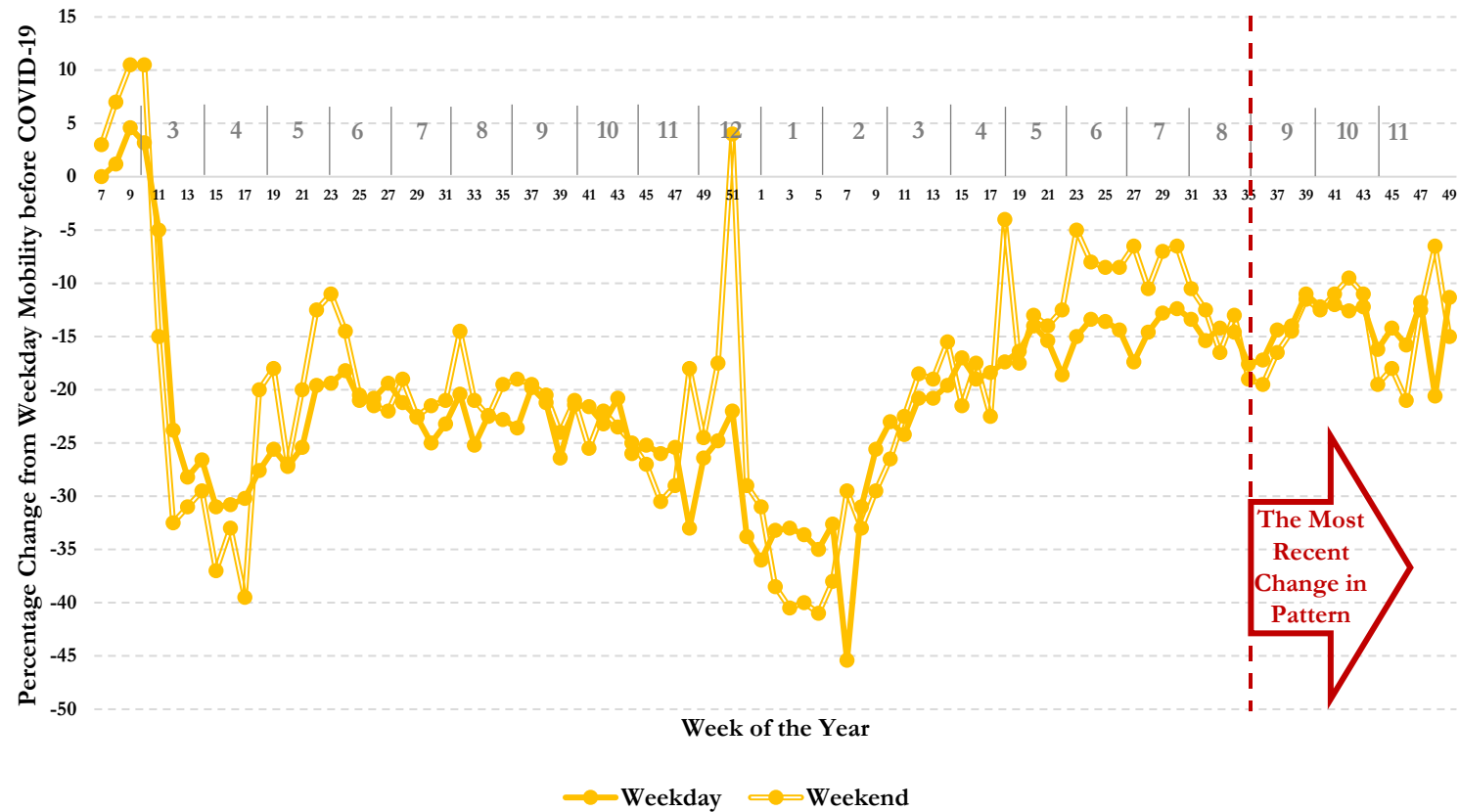
Note: Authors' calculations using Google's Community Mobility Reports ([link](#))⁴

Figure 2.8: Retail & Recreation Mobility as a Percentage of Its Pre-COVID-19 Mobility by Month and Week of the Year (Feb. 2020 to Nov. 2021)



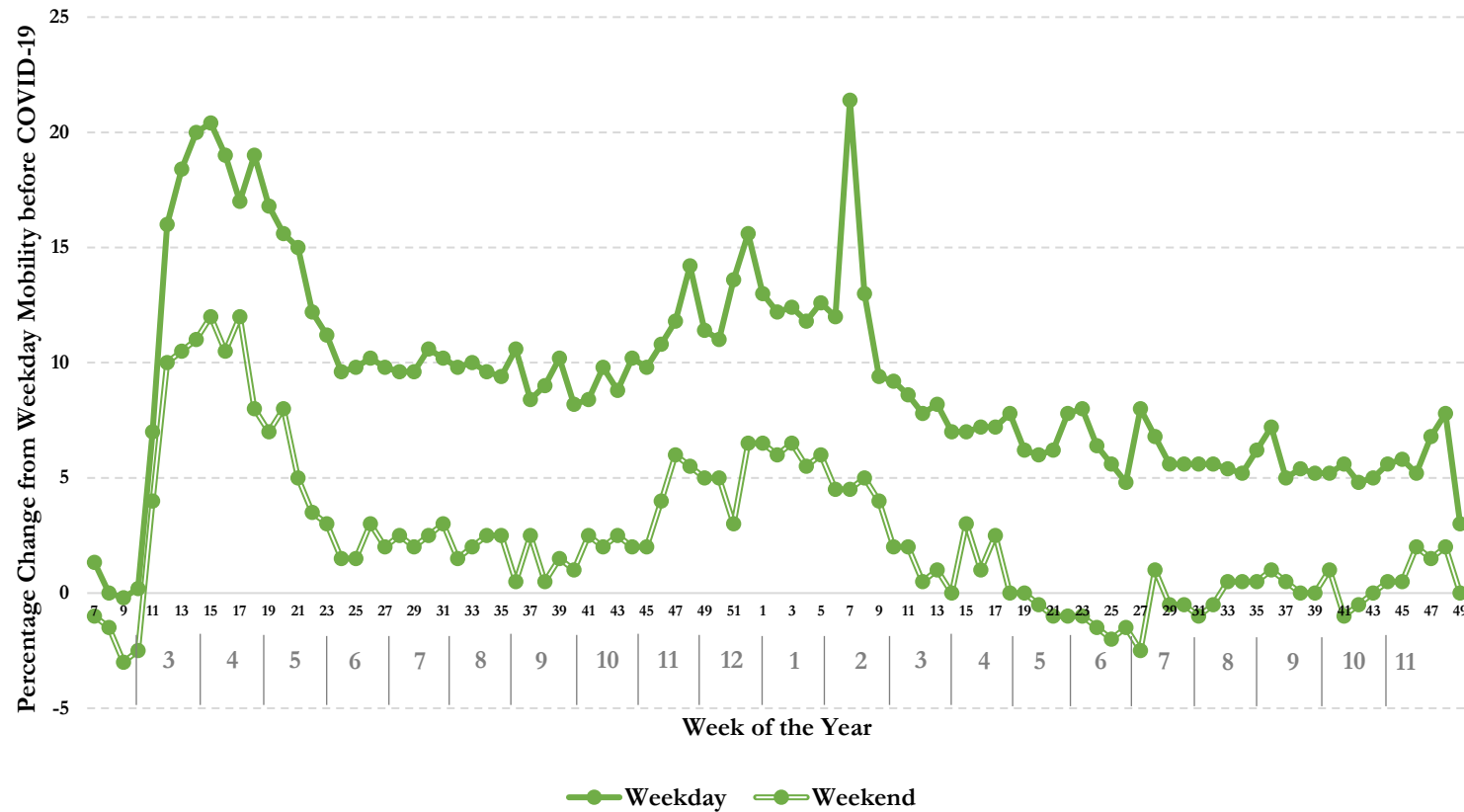
Note: Authors' calculations using Google's Community Mobility Reports ([link](#))⁴

Figure 2.9: Transit Stations Mobility as a Percentage of Its Pre-COVID-19 Mobility by Month and Week of the Year (Feb. 2020 to Nov. 2021)



Note: Authors' calculations using Google's Community Mobility Reports ([link](#))⁴

Figure 2.10: Residentisl Mobility as a Percentage of Its Pre-COVID-19 Mobility by Month and Week of the Year (Feb. 2020 to Nov. 2021)



Note: Authors' calculations using Google's Community Mobility Reports ([link](#))⁴

Section 3:

Projection Scenarios

3.1. The Projections' Focus: 5 to 11 Year Olds Vaccination

This study focused on projecting COVID-19 hospitalizations for scenarios of COVID-19 vaccination among the most recently authorized age group, 5 to 11 years. Three vaccination scenarios were considered for 5 to 11 year old children:

- (1) an expected vaccination rate growth (20% of 5-11 year olds become vaccinated before 2022)
- (2) an accelerated vaccination rate growth (40% of 5-11 year olds become vaccinated before 2022)
- (3) a decelerated vaccination rate growth (10% of 5-11 year olds become vaccinated before 2022)

Also, it was assumed that 54% of 12 to 15 year old children will get fully vaccinated by the end of 2021 (The full vaccination rate in this age group was 49.9% by 3 November 2021, **Figure 2.5**).

Additionally, it was assumed that 10% of 5-11 year old children who will receive the first dose would miss the second dose. 10% is the observed rate of missing the second dose among 12 to 15 year old children.

Moreover, it was assumed

- no change in the vaccination rate of other age groups would occur,
- no change in residents' social distancing behavior would happen, and
- any recent SARS-CoV-19 variant (e.g., the Omicron variant) would have similar transmission and clinical parameters to the Delta variant.

3.2. Modeling Vaccination Growth

The expected vaccination growth scenario was constructed based on modeling the vaccination growth pattern among 12 to 15 year old children, the closest age group to 5 to 11 year olds.

After Pfizer's COVID-19 vaccine received an EUA for 12 to 15 year old children from the FDA on 10 May 2021, vaccination of children in this age group started on 13 May 2021 in the county. The administration of the first dose of the vaccine followed three distinct growth phases:

- An initial rapid increase in vaccination: lasted about 18 days, during which approximately 22% of 12–15 year old children received a dose;
- A moderate but steady growth period: lasted about 95 days, during which another 31% of 12–15 year old children received their first dose;

- A slow growth period during which only additional 6% of the children have received the first dose so far.

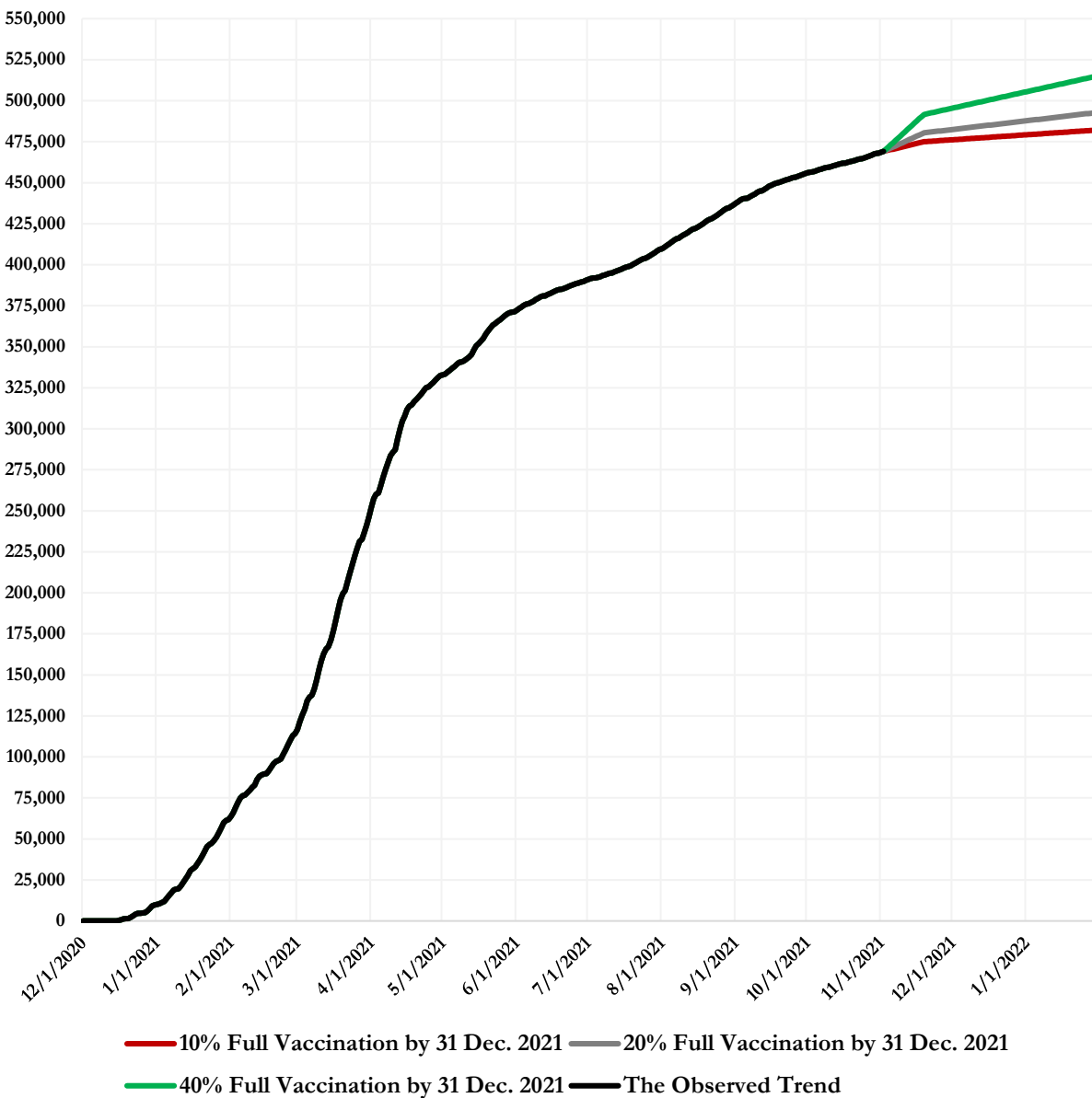
Each growth phase can be fitted linearly with a greater than 95% precision. According to the county's vaccination records, the administration of the second dose of the vaccine was not reported for approximately 10% of 12 to 15 year old children.

As parents decide on children's vaccination, one may assume the same vaccination pattern will occur with three linearly approximated phases for 5 to 11 year old children. This method was adopted in this study with a modification arising from the observation that, by 20 November 2021 (18 days after vaccination of 5 to 11 year old children started in the county), approximately 17% of them were vaccinated. Therefore, as observed so far, the vaccination rate among 5 to 11 year olds has grown slower than that in 12 to 15 year olds by about 23%.

The 23% slower vaccination growth rate was applied to other phases of the 5 to 11 year vaccination pattern. If phases of 5–11 years vaccination would last exactly as long as phases of 12–15 years vaccination, one would expect about 33% and 45% of 5 to 11 year old children to become partially vaccinated by the end of 2021 and the end of January 2022, respectively—consequently, 26% and 34% get fully vaccinated, respectively. However, with a 23% slowdown, the expected first dose vaccination rates by the end of 2021 and January 2022 would be 35% and 27%, and the resultant full vaccination rates would be 20% and 26%, respectively.

Therefore, according to the expected scenario, approximately 20% of 5 to 11 year old children will be fully vaccinated by the end of 2021. For the accelerated scenario, the full vaccination rate by the end of the year was considered 40%. And, for the decelerated scenario, the full vaccination rate by the end of the year was considered 10%. The influence of the vaccination scenarios on the county's overall vaccination number is shown in **Figure 3.1**. The figure shows the overall first dose vaccination with a 10% loss; that is, 10% of the first dose vaccination number in each day is dropped as the receipt of the second dose is not reported for 10% of first dose recipients.

Figure 3.1: Illustration of the Effect of 5 to 11 Year Olds Vaccination Scenarios on the Overall COVID-19 Dose One Vaccination Trend in Jefferson County, Kentucky



Source: Calculated by authors using vaccination data from State of Kentucky Immunization Registry (KYIR)

Section 4:

Methodology

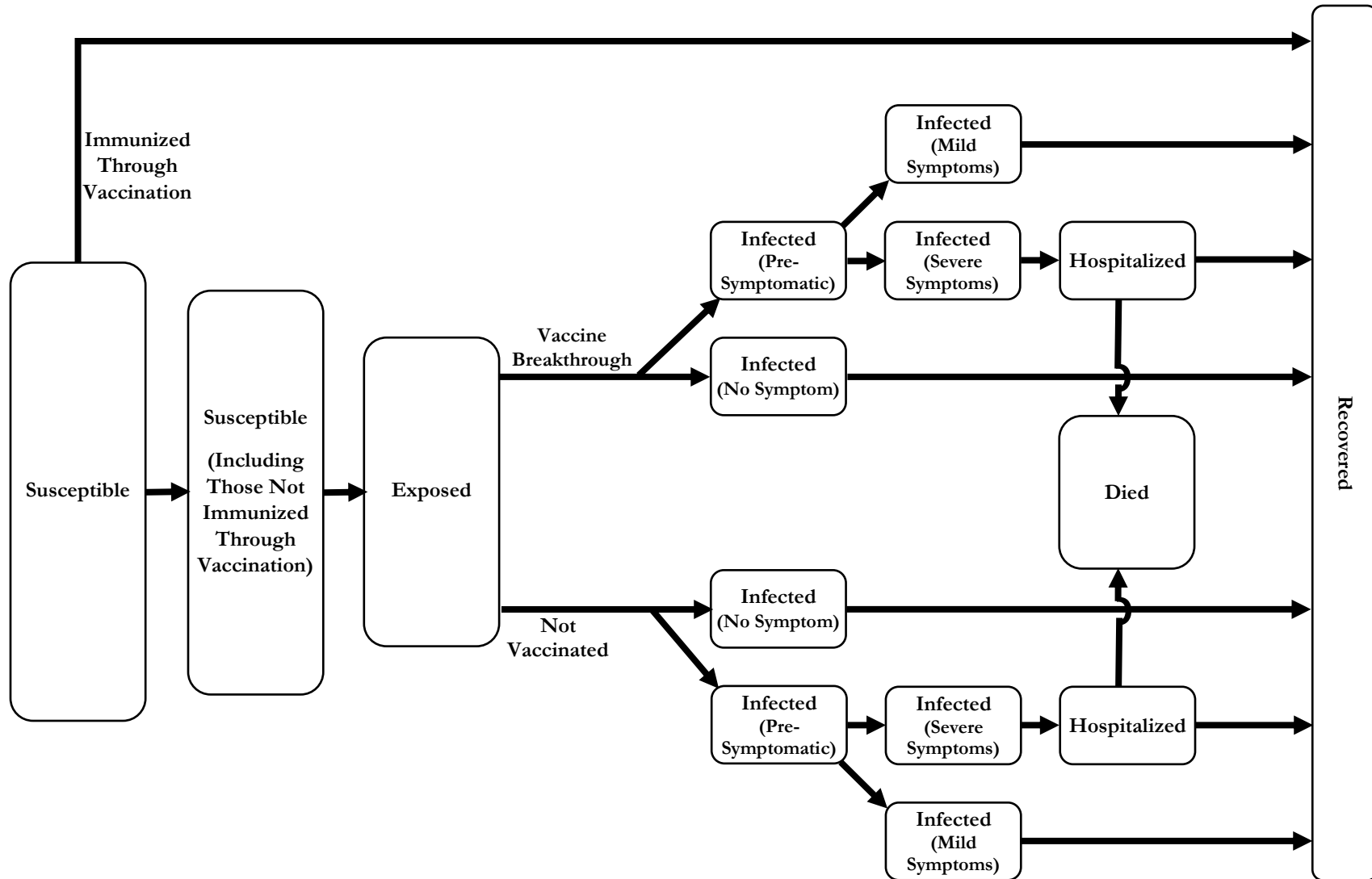
4.1. Epidemic Modeling: The Conceptual Framework

A Susceptible-Exposed-Infectious-Recovered (SEIR) epidemic dynamics model was adopted and estimated in this study.⁵ **Figure 4.1** presents the conceptual framework of the model. The susceptible population in the model is the county population that did not contract COVID-19 before vaccination started in the county in mid-December 2020. Therefore, this study assumed that unvaccinated persons who recovered after contracting SARS-CoV-19 would not become infected again during the study period (beginning of the pandemic in March 2020 to the end of projection period, 1/31/2022). This assumption may not be perceived as a strong one because COVID-19 reinfection was reported 879 times (or for 0.78% of cases) in the county by 20 November 2021. Other studies found Reinfection rates of 0.65% (Denmark),⁶ 0.31% (Italy),⁷ and 0.70% (U.S.).⁸

We also assumed that a given percentage of the susceptible population that were fully vaccinated (which we defined as those who received either two doses of Pfizer and Moderna vaccines or one dose of Johnson and Johnson vaccine) became immunized and would not contract SARS-CoV-19 during this study period. In our previous epidemic modeling for Jefferson County, Kentucky, we assumed that double-dose vaccination was 95% effective in preventing COVID-19 infection.⁹ The effectiveness rate was found in the clinical trials of two dominant vaccine types in the county, manufactured by Pfizer and Moderna.^{10,11} Therefore, we subtracted 95% of the fully vaccinated from those who are susceptibles dynamically and considered them recovered after 7 to 14 days from receiving the second dose of Pfizer or Moderna and from the first dose of Johnson and Johnson. Consequently, we included the remaining 5% of fully vaccinated individuals among the susceptible population. If they contracted the virus, they would be known as breakthrough cases.

One shortcoming of our previous epidemic modeling was assuming the same COVID-19 parameters (e.g., infectious periods, hospitalization rate, length of hospital stays, and fatality rate) for unvaccinated and breakthrough cases.⁹ The limitation might not significantly affect projection results if the vaccine's efficacy rates remained as high as estimated in the clinical trials. However, the prevalence of the SARS-CoV-19 Delta variant, which is more contagious than the other variants,¹² led us to reassess the efficacy rate. Therefore, in the new model, we separated unvaccinated and breakthrough paths of infection and used information from local COVID-19 cases data to calculate the transmission and clinical parameters specific to unvaccinated and vaccinated cases (**Figure 4.1**).

Figure 4.1: The Conceptual Framework Used for Modeling SARS-CoV-19 Transmission in Jefferson County, Kentucky



4.2. Characterizing the Epidemic Model

Transmission through different phases of the COVID-19 epidemic model, shown in **Figure 4.1**, is regulated with transmission and clinical dynamics parameters. Key transmission dynamics parameters are (1) the susceptible population, (2) the rate of immunization rates from contraction of the virus and vaccine, (3) basic and effective reproduction factors, (4) periods of immunization, incubation, pre-infectiousness, infectiousness with and without symptoms, and (5) percentages of breakthrough cases, asymptomatic infections, and symptomatic infectious leading to hospitalization.

Key clinical dynamics parameters are (1) lengths of hospitalizations for severe cases that lead to recovery or death and (2) the fatality rate among the hospitalized cases. A severe case was defined as a COVID-19 case that led to hospitalization. The lengths and the rate were calculated separately for severe breakthrough and unvaccinated cases.

A set of the parameters could not be calculated using local data sources. These include the immunization rate through vaccination, incubation period, the proportion of infections that are asymptomatic, the infectious period for asymptomatic cases, and the pre-symptomatic period. These parameters were extracted from the COVID-19 literature. Nonetheless, the remaining parameters can be calculated using local cases data.

This study focused on simulating the dynamics of the SARS-CoV-19 Delta variant in the county, which has been the variant of concern in the U.S. since July 2021.¹² Hence, local data since 1 July 2021 were used in parameter calculations. Also, the literature review focused on studies that analyzed the Delta variant.

Because of the uncertainties about immunization rate from vaccination and infectious period among the asymptomatic cases in the Delta variant era, these parameters were determined through the simulation process. In addition, the calculation of basic and effective reproduction factors and the rate of breakthrough cases were internalized.

The parameter values used in this study are presented in **Table 4.1**. Although median parameter values are given in the table, ranges of values were used in simulations. For period parameters, the first quartiles (or 25th quantiles) were selected as lower bounds, the third quartiles (or 75th quantiles) as upper bounds. For percentage parameters, 5% or 10% above and below the observed values were used as initial values for the range. The epidemic model was programmed in R statistical computing software and stochastically estimated for Jefferson County, Kentucky.¹³

Table 4.1: Transmission and Clinical Parameters Used in This Study's Epidemic Model

		Median	Lower Bound	Upper Bound	Source
Proportion of Vaccinated That Get Immunized (%) ¹⁴⁻²¹			80	95	Literature & Simulation
Time from Vaccination to Immunization (Days) ²²⁻²⁴		32	28	36	Literature & Local Data
Incubation Period (Days) ²⁵⁻²⁷		5	2	7.5	Literature
Proportion of Infections That Are Asymptomatic (%)					
	Unvaccinated ^{26,28-32}		30	48	Literature & Simulation
	Vaccinated ^{20,21,32,33}		60	80	Literature & Simulation
Infectious Period for Asymptomatic Infections (Days) ^{26,34,35}		4	3	5	Literature
Pre-Symptomatic Period (Days) ^{26,36}		3	1	5.5	Literature
Infectious Period for Mildly Symptomatic Infections (Days)					
	Unvaccinated	6.5	4	9	Local Data
	Vaccinated	5.5	4	7	Local Data
Proportion of Symptomatic Infections That Are Severe—Require Hospitalization (%)					
	Unvaccinated		4.6	10.7	Local Data
	Vaccinated		8.2	11.0	Local Data
Time for Severely Symptomatic to Get Hospitalized (Days)					
	Unvaccinated	6.5	2	9	Local Data
	Vaccinated	4	1	7	Local Data
Duration of Hospital Stay of Those Who Recover from the Infection (Days)					
	Unvaccinated	6	4	10	Local Data
	Vaccinated	6	4	9	Local Data
Time from Hospitalization to Death (Days)					
	Unvaccinated	14	8	21	Local Data
	Vaccinated	11	7	16	Local Data
Fatality Rate Among Hospitalizations					
	Unvaccinated	15.4	10.4	20.4	Local Data & Simulation
	Vaccinated	20.6	15.6	25.6	Local Data & Simulation

4.3. Sources of Data and Information

Information on the epidemic model's parameters was collected from the following sources:

- Kentucky State Contact Tracing and Tracking (CTT) database:
Deidentified individual-level information on COVID-19 cases, hospitalizations, and deaths in Jefferson County
- State of Kentucky Web Emergency Operation Center (WebEOC) system:
Aggregated daily COVID-19 hospitalizations in Jefferson County
- State of Kentucky Immunization Registry (KYIR):
Deidentified individual-level COVID-19 vaccination data for Jefferson County, Kentucky
- Systematic Review of COVID-19 Literature
- Google Community Mobility Reports

4.4. Characteristics of Vaccinated and Unvaccinated Case

The results showed that the vaccinated persons who contracted SARS-CoV-19 from 1 July 2021 were significantly older than the unvaccinated persons. For example, the median age difference between vaccinated and unvaccinated cases was 19 years. The median age difference between vaccinated and unvaccinated hospitalized cases was 16 years, 8 years for cases that led to death. The age of vaccinated and unvaccinated COVID-19 cases, hospitalizations, and deaths were also calculated by race and ethnicity (**Appendix A Tables Cases.Part1, Hosps.Part1, and Deaths.Part1**).

In addition, although the presence of preexisting conditions was not reported for most cases, the percentage of cases that reported with one or more preexisting conditions was greater in vaccinated cases (26.0%) versus unvaccinated cases (13.7%) (**Appendix A Table Cases.Part2**). Preexisting conditions, however, were more often reported for hospitalized and deceased cases. Again, the percentage of hospitalized cases with one or more preexisting conditions was greater in vaccinated cases (81.7%) in comparison to unvaccinated cases (61.2%) (**Appendix A Table Hosps.Part2**); the percentages for deceased cases were 95.3% and 82.5%, respectively (**Appendix A Table Deaths.Part2**). The most prevalent preexisting condition among hospitalized and deceased cases was hypertension. The prevalence of hypertension among vaccinated hospitalized cases was 60.3%, 34.9% among unvaccinated hospitalized

cases; its prevalence among vaccinated deceased cases was 78.8%, 57.1% among unvaccinated deceased cases. The second, third, and fourth most common preexisting conditions among hospitalized and deceased cases were cardiovascular disease, hyperlipidemia, and diabetes. Among hospitalized and deceased cases, the prevalence of all these diseases was remarkably greater in vaccinated individuals than unvaccinated individuals.

In summary, analyzing COVID-19 cases, hospitalizations, and deaths data from Jefferson County, Kentucky, showed that vaccinated cases were significantly older than unvaccinated cases. The prevalence of preexisting conditions was also remarkably greater in vaccinated cases compared to unvaccinated cases. The significant age and comorbidity differences explain the confounded results in **Table 4.1** that COVID-19 disease progression is worse in vaccinated cases than unvaccinated cases in Jefferson County. For example, the proportion of symptomatic cases that required hospitalization was estimated between 8.2% and 10.0% among vaccinated cases but between 4.6% and 10.6% among unvaccinated cases.

Having two different estimates for the parameter in each group was due to the different methods of counting cases with no reported symptoms. For example, if unvaccinated cases that were not specified as asymptomatic and had no reported specific symptoms (such as fever, chills, cough, diarrhea, and loss of smell or taste) were counted as symptomatic, the proportion was 4.6%. This assumption was motivated by (1) considering the fact that testing for COVID-19 is predominantly voluntary and upon the observance of a flue-like symptom by a person and (2) the observation that COVID cases' symptoms information was less frequently collected in November and October 2021 compared to previous months. The proportion was 10.6% if this group was counted as asymptomatic. The range between these two values was used in simulations.

More strikingly, the fatality rate among hospitalized cases was greater in vaccinated cases (20.6%) than unvaccinated cases (15.4%), although these differences wash away when standardized by age. For more details on differences in demographic characteristics and preexisting conditions of vaccinated and unvaccinated cases, hospitalizations, and deaths, see **Appendix A** Tables.

4.5. Stages of the Estimation of the Epidemic Model

COVID-19 hospitalizations and deaths were modeled in five steps:

Step 1: Fitting an SEIR model to the observed hospitalizations and deaths during the pre-vaccination period

A modified version of the SEIR model portrayed in **Figure 4.1** was fitted to the trends of hospitalization and deaths in Jefferson County, Kentucky, from the beginning of COVID-19 (8 March 2020) to the day before mass vaccination (15 December 2020). The SEIR model's modification involved the elimination of all the vaccination compartments.

Information from the CTT database, WebEOC system, and literature review was used to extract COVID-19 transmission and clinical dynamics during the pre-vaccination era. In addition, the timing and intensity of non-pharmaceutical interventions (such as the stay-at-home order, mask order, mobility changes, and targeted measures) were used to calibrate the model.

The outputs of the SEIR models for 15 December 2020 were used as initial values for the SEIR model designed for the vaccination era (*Step 4*).

Step 2: Scenario building

Trends of vaccination in Jefferson County, Kentucky, were studied. Vaccination scenarios were built for different vaccination rates in 5 to 11 year old children. An expected vaccination growth scenario was constructed based on mathematical modeling of the vaccination growth pattern among 12 to 15 year old children, the closest age group to 5 to 11 year olds. Then, one accelerated and one decelerated vaccination rate were considered.

The three 5 to 11 years vaccination scenarios in this study were:

- The expected scenario: 20% of 5 to 11 year old children will be fully vaccinated by 31 December 2021.
- The accelerated scenario: 40% of 5 to 11 year old children will be fully vaccinated by 31 December 2021
- The decelerated scenario: 10% of 5 to 11 year old children will be fully vaccinated by 31 December 2021.

Under all three scenarios, it was assumed that the vaccination rate of 12 to 15 year old children follows its expected pattern, such that 54% of them will be fully vaccinated by 31 December 2021.

To isolate the effect of children’s vaccination scenarios from other factors, vaccination rates for adults and the elderly were assumed to remain unchanged during the study’s projection period (3 November 2021 to 31 January 2022). Since the latter rates have been very slowly growing in the past two months (**Figures 2.2 and 2.3**), the assumption is reasonably justified. Also, no change in mobility and social-distancing behavior were considered during the study’s projection period. Additionally, the introduction and identification of new variants (e.g., the Omicron variant) in the county were not considered during the projection period.

The influence of the vaccination scenarios on the county’s overall vaccination pattern was calculated and used as bases for projections (**Figure 3.1**).

Step 3: Calculating COVID-19 transmission and clinical parameters using the CTT database from 1 July 2021 to 3 November 2021 and the Delta variant literature (**Table 4.1**).

Step 4: Fitting the SEIR model to each scenario of vaccination

Step 1’s fitted model’s predictions for all variables were used as initial values for the SEIR model shown in **Figure 4.1**. The model was calibrated with parameters values calculated using data from 1 July 2021, the time from which the Delta variant has been dominant in the country (**Table 4.1**). The SEIR model was fitted to the observed vaccination trend (**Figure 3.1**) and observed trend in active COVID-19 hospitalizations (**Figure 1.3**). Non-pharmaceutical interventions were included to capture the effect of behavioral and social-distancing patterns reflected in the community mobility indices (**Figures 2.6–2.10**).

Step 5: Projecting COVID-19 trends for the vaccination scenarios

Projections of the fitted model in *Step 4* for the three scenarios were extracted and organized.

4.6. Limitations

This study aimed to show the effect of different growth rates of vaccination of 5 to 11 year old children (the group that most recently was approved to receive COVID-19 vaccine) to COVID-19 hospitalization trends in the county. To show the effect of the scenarios in isolation from other possible changes, population contact rates and mobility were assumed constant during the projection period (3 November 2021 to 31 January 2022). If the contact and mobility rates change over this period, the results would be affected accordingly. However, the differential effects of the vaccination scenarios would be significantly different from what was estimated in this study.

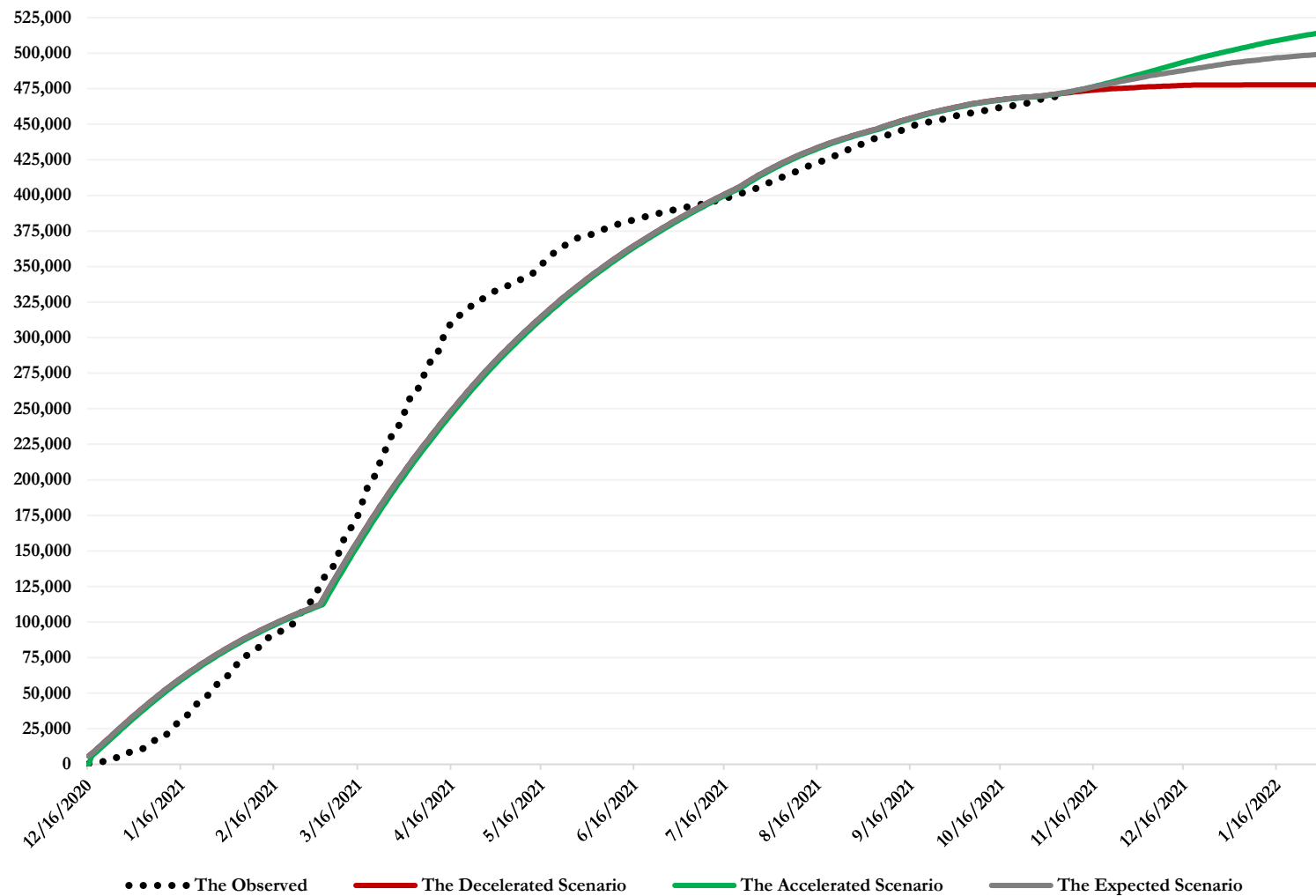
COVID-19 hospitalization parameters (i.e., the proportion of systematic infections that are severe and require hospitalization, time for severely the symptomatic to get hospitalized, duration of hospital stay for those who recover, time from hospitalization to death, and fatality rate among the hospitalized) were extracted from the individual-level CTT database. COVID-19 hospitalization information in the CTT database, however, is not complete. On average, the total daily number of COVID-19 hospitalizations from CTT has been about 60% of that from WebEOC. Therefore, if the subsample of COVID-19 hospitalizations appearing in the CTT database were biased, then values of the extracted COVID-19 hospitalization parameters from CTT would be biased. We attempted to mitigate the problem by using interquartile ranges of the parameters' values.

The projections were made before the identification of the Omicron variant and subsequent concerns about its transmission within the U.S. and Jefferson County, Kentucky. At present, too little is known about the virus to include meaningful projections about its impact.

Section 5:

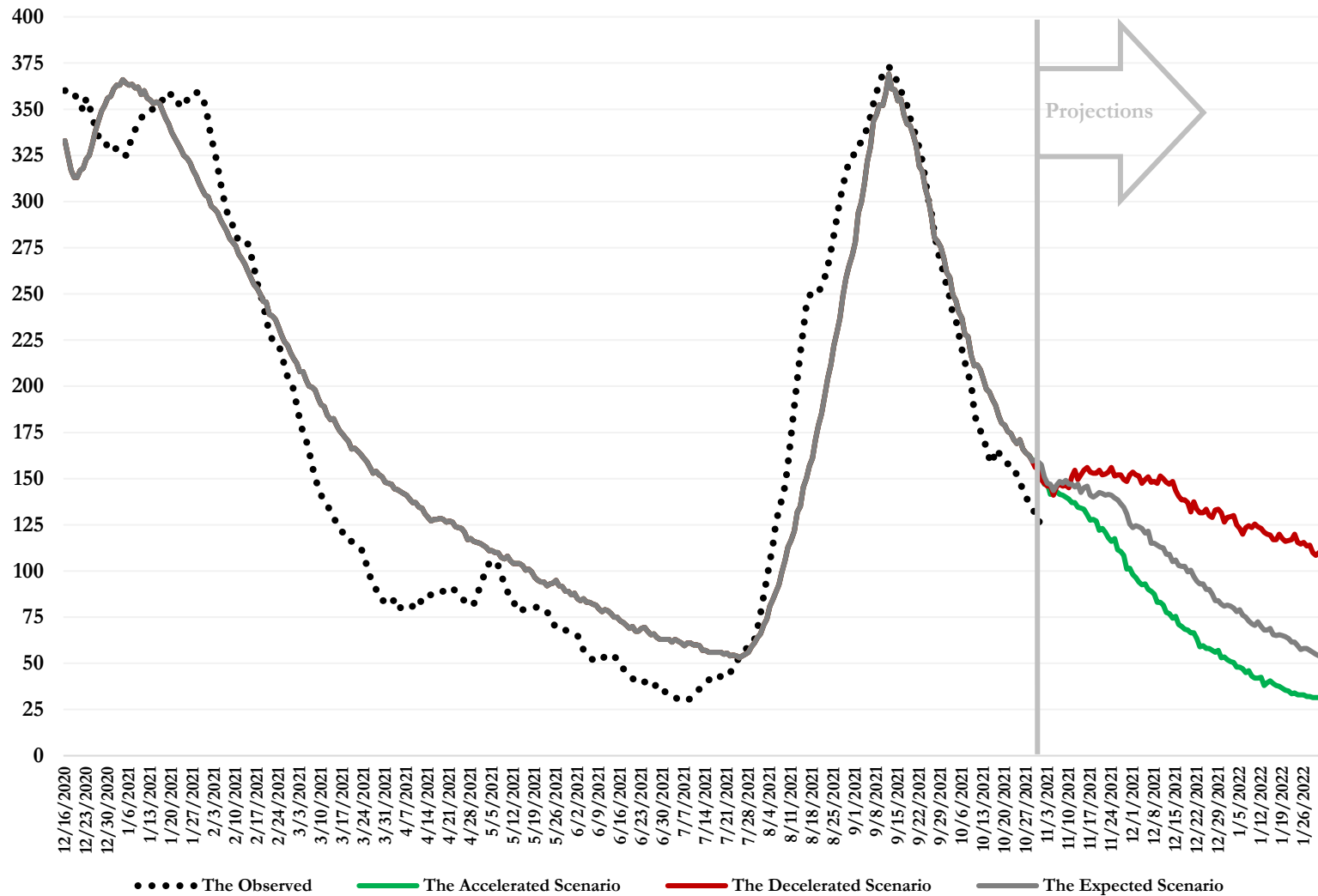
Simulations Results

Figure 5.1: The SEIR Model's Fit of the Observed and Scenario Trends of Cumulative Number of First Doses



Notes: The dots form the observed trend of first dose vaccination in Jefferson County, Kentucky. The observed numbers are 10% of reported first dose numbers to account for those with no second dose information reported in the KYIR data. The solid-line trends are medians of 500 simulations for each projection scenario. The trends for all 500 simulations are presented in **Appendix B, Figure 1**. Under the expected scenario, 20% of 5 to 11 year old children would be fully vaccinated by 31 December 2021, 10% under the decelerated scenario and 40% under the accelerated scenario.

Figure 5.2: Projections of Active Hospitalizations under the Vaccination Scenarios



Notes: The dots form the observed trend of active COVID-19 hospitalizations in Jefferson County, Kentucky. The solid-line trends are medians of 500 simulations for each projection scenario. The trends for all 500 simulations are presented in **Appendix B, Figure 2**. Under the expected scenario, 20% of 5 to 11 year old children would be fully vaccinated by 31 December 2021, 10% under the decelerated scenario and 40% under the accelerated scenario.

5.1. Summary of Results

This report investigated the simulated effect of several vaccination scenarios for 5 to 11 year old children (the most recently authorized age group for vaccination) on COVID hospitalizations in Jefferson County, Kentucky.

- **Scenarios:** Three vaccination scenarios were considered for 5 to 11 year old children:
 - an expected vaccination growth:
20% of 5 to 11 year old children will be fully vaccinated by the end of 2021
 - an accelerated vaccination growth:
40% of 5 to 11 year old children will be fully vaccinated by the end of 2021
 - a decelerated vaccination growth:
10% of 5 to 11 year old children will be fully vaccinated by the end of 2021
- **Projection Period:** 4 November 2021 to 31 January 2022 (three months)
- **Key Projection Assumptions:**
 - 54% of 12 to 15 year old children will get fully vaccinated by the end of 2021.
 - Other age groups' vaccination rates will not change during the projection period (4 November 2021 – 31 January 2022).
 - 10% of children who will receive the first dose of the Pfizer COVID-19 vaccine will not receive the second dose.
 - Contact rate and mobility in the population will not change during the projection period (4 November 2021 – 31 January 2022).
 - The recently identified variant of SARS-CoV-19 (the Omicron variant) would have similar transmission and clinical characteristics to the Delta variant.

- **Projected Number of Active COVID-19 Hospitalizations on Specific Dates under the 5-11 years Vaccination Scenarios:**

Selected Dates	Number of Daily Active Hospitalizations at Selected Dates, under:			Difference with Expected Scenario	
	Expected Scenario	Accelerated Scenario	Decelerated Scenario	Accelerated Scenario	Decelerated Scenario
11/30/2021	126	102	152	-24	27
12/15/2021	106	76	144	-31	38
12/31/2021	81	54	127	-28	46
1/15/2022	69	41	120	-29	51
1/31/2022	54	32	110	-23	56

- **Key Takeaways:**
 - By vaccinating 40% of the 5-11 year olds in Jefferson County, we project approximately 54 overall (not age-specific) active hospitalizations by 12/31/2021, assuming no change in other mitigation factors. However, if only 10% of the 5-11 year olds are vaccinated we project over double the number of active hospitalizations (about 127). By 1/31/2022, we would have nearly 4 times as many active hospitalizations if only 10% of the 5-11 year-olds are vaccinated compared to if 40% of the 5-11 years olds are vaccinated.
 - Therefore, it is pivotal to vaccinate this age group as best as possible through the most age-appropriate avenues (e.g., in schools and pediatrician offices) to decrease the overall rate of COVID-19 hospitalizations in the county.

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Appendix A:

Comparing Characteristics of Vaccinated and Unvaccinated Cases

Appendix A Table Cases.Part1: Demographic Characteristics of COVID-19 Cases in Jefferson County, Kentucky
(The last date analyzed: 20 November 2021)

		Pre-Vaccination Period: before 16 December 2020		Entire Vaccination Period: from 16 December 2020		The Delta Variant Period: from 1 July 2021	
		(303 Cases Excluded due to Partial Vaccination)		(504 Cases Excluded due to Partial Vaccination)		(201 Cases Excluded due to Partial Vaccination)	
		(0 Cases w/ No Vaccine Info)		(1181 Cases w/ No Vaccine Info)		(1176 Cases w/ No Vaccine Info)	
		Unvaccinated	Vaccinated	Unvaccinated	Vaccinated	Unvaccinated	Vaccinated
Total # of Observations, <i>N</i>		35,842	0	70,053	6,528	42,140	6,311
Race	White (71.8%)	17,541 (48.9%)	--	41,197 (58.8%)	4,755 (72.8%)	24,971 (59.3%)	4,599 (72.9%)
	Black (22.4%)	6,550 (18.3%)	--	12,746 (18.2%)	733 (11.2%)	7,835 (18.6%)	695 (11.0%)
	Other (5.8%)	7,297 (20.4%)	--	12,123 (17.3%)	882 (13.5%)	7,363 (17.5%)	861 (13.6%)
	Missing	4,454 (12.4%)	--	3,987 (5.7%)	158 (2.4%)	1,971 (4.7%)	156 (2.5%)
Ethnicity	Non-Hispanic (94.1%)	22,942 (64.0%)	--	52,603 (75.1%)	5,507 (84.4%)	31,527 (74.8%)	5,310 (84.1%)
	Hispanic (5.9%)	3,018 (8.4%)	--	4,895 (7.0%)	186 (2.8%)	2,878 (6.8%)	179 (2.8%)
	Other/Missing	9,882 (27.6%)	--	12,555 (17.9%)	835 (12.8%)	7,735 (18.4%)	822 (13.0%)
Gender	Female (51.7%)	19,319 (53.9%)	--	36,584 (52.2%)	3,857 (59.1%)	21,953 (52.1%)	3,721 (59.0%)
	Male (48.3%)	16,366 (45.7%)	--	33,040 (47.2%)	2,669 (40.9%)	19,822 (47.0%)	2,588 (41.0%)
	Other/Missing	157 (0.4%)	--	429 (0.6%)	2 (0%)	365 (0.9%)	2 (0%)
District	Central (17% of Pop)	6,630 (18.5%)	--	12,657 (18.1%)	870 (13.3%)	7,534 (17.9%)	837 (13.3%)
	East & North East (19%)	6,498 (18.1%)	--	11,522 (16.4%)	1,473 (22.6%)	6,591 (15.6%)	1,426 (22.6%)
	North Center (13%)	4,189 (11.7%)	--	6,774 (9.7%)	1,029 (15.8%)	3,652 (8.7%)	994 (15.8%)
	North West (11%)	3,582 (10.0%)	--	7,299 (10.4%)	515 (7.9%)	4,799 (11.4%)	494 (7.8%)
	South&South West(14%)	4,885 (13.6%)	--	11,900 (17.0%)	818 (12.5%)	7,632 (18.1%)	791 (12.5%)
	South East (16%)	6,154 (17.2%)	--	12,051 (17.2%)	1,279 (19.6%)	6,928 (16.4%)	1,249 (19.8%)
	West Center (10%)	3,893 (10.9%)	--	7,829 (11.2%)	544 (8.3%)	4,988 (11.8%)	520 (8.2%)
	Missing District	11 (0%)	--	21 (0%)	0 (0%)	16 (0%)	0 (0%)
Age Statistics, All	Age, <i>N</i>	35,833	--	70,028	6,528	42,115	6,311
	Age, missing #	9	--	25	0	25	0
	Mean Age (Years)	43.5	--	36.2	50.7	33.0	50.6
	SD in Age (Years)	21.1	--	20.8	18.6	20.5	18.5
	Median Age (Years)	42.0	--	34.0	51.0	31.0	50.0
	IQR of Age (Years)	32.0	--	31.0	30.0	31.0	29.0
Age Statistics, White	Age, <i>N</i>	17,541	--	41,190	4,755	24,964	4,599
	Age, missing #	0	--	7	0	7	0
	Mean Age (Years)	45.9	--	37.8	51.5	34.5	51.4
	SD in Age (Years)	21.7	--	21.4	18.7	21.2	18.7
	Median Age (Years)	45.0	--	36.0	52.0	32.0	52.0
	IQR of Age (Years)	35.0	--	33.0	31.0	33.0	30.0
Age Statistics, Black	Age, <i>N</i>	6,548	--	12,745	733	7,834	695
	Age, missing #	2	--	1	0	1	0
	Mean Age (Years)	41.3	--	32.4	48.9	28.8	48.5
	SD in Age (Years)	20.0	--	19.3	17.1	18.5	16.9
	Median Age (Years)	40.0	--	30.0	49.0	27.0	48.0
	IQR of Age (Years)	30.0	--	29.0	25.0	28.0	24.0

Age Statistics, Other Races	Age, <i>N</i>	7,293	--	12,109	882	7,349	861
	Age, missing #	4	--	14	0	14	0
	Mean Age (Years)	40.2	--	34.0	48.0	31.3	48.0
	SD in Age (Years)	19.6	--	19.8	19.0	19.8	19.0
	Median Age (Years)	38.0	--	32.0	46.0	29.0	46.0
	IQR of Age (Years)	28.0	--	30.0	30.0	31.0	30.0
Age Statistics, Missing Race	Age, <i>N</i>	4,451	--	3,984	158	1,968	156
	Age, missing #	3	--	3	0	3	0
	Mean Age (Years)	42.8	--	38.9	50.3	36.0	50.2
	SD in Age (Years)	21.4	--	20.8	16.8	19.7	16.8
	Median Age (Years)	40.0	--	36.0	51.0	34.0	51.0
	IQR of Age (Years)	32.0	--	31.3	27.8	30.0	27.3
Age Statistics, Non-Hispanic	Age, <i>N</i>	22,940	--	52,591	5,507	31,515	5,310
	Age, missing #	2	--	12	0	12	0
	Mean Age (Years)	44.6	--	36.5	51.0	33.0	50.9
	SD in Age (Years)	21.4	--	21.1	18.5	20.8	18.4
	Median Age (Years)	43.0	--	34.0	51.0	30.0	51.0
	IQR of Age (Years)	34.0	--	32.0	30.0	32.0	30.0
Age Statistics, Hispanic	Age, <i>N</i>	3,016	--	4,891	186	2,874	179
	Age, missing #	2	--	4	0	4	0
	Mean Age (Years)	37.4	--	31.1	37.6	28.2	37.6
	SD in Age (Years)	18.0	--	18.2	15.9	18.1	16.1
	Median Age (Years)	37.0	--	31.0	34.0	27.0	34.0
	IQR of Age (Years)	25.0	--	28.0	23.0	28.0	23.0
Age Statistics, Missing Ethnicity	Age, <i>N</i>	9,877	--	12,546	835	7,726	822
	Age, missing #	5	--	9	0	9	0
	Mean Age (Years)	42.9	--	37.2	51.7	34.4	51.6
	SD in Age (Years)	20.9	--	20.6	18.5	20.1	18.5
	Median Age (Years)	40.0	--	35.0	52.0	32.0	52.0
	IQR of Age (Years)	32.0	--	31.0	29.5	31.0	29.0

Appendix A Table Cases.Part2: Preexisting Conditions of COVID-19 Cases in Jefferson County, Kentucky
(The last date analyzed: 20 November 2021)

			Pre-Vaccination Period: before 16 December 2020		Entire Vaccination Period: from 16 December 2020		The Delta Variant Period: from 1 July 2021	
			(303 Cases Excluded due to Partial Vaccination)		(504 Cases Excluded due to Partial Vaccination)		(201 Cases Excluded due to Partial Vaccination)	
			(0 Cases w/ No Vaccine Info)		(1181 Cases w/ No Vaccine Info)		(1176 Cases w/ No Vaccine Info)	
			Unvaccinated	Vaccinated	Unvaccinated	Vaccinated	Unvaccinated	Vaccinated
# Indicated Having Preexisting Condition(s)*			10,323 (28.8%)	--	14,019 (20.0%)	1,778 (27.2%)	5,774 (13.7%)	1,641 (26.0%)
# Indicated No Preexisting Condition			12,000 (33.5%)	--	21,134 (30.2%)	1,319 (20.2%)	9,833 (23.3%)	1,256 (19.9%)
# with Unknown Preexisting Conditions			1,209 (3.4%)	--	893 (1.3%)	73 (1.1%)	582 (1.4%)	73 (1.2%)
# Missing a Response			12,310 (34.3%)	--	34,007 (48.5%)	3,358 (51.4%)	25,951 (61.6%)	3,341 (52.9%)
Prevalence of Specific Conditions	Number with at least one of the conditions listed below**		10,078 (28.1%)	--	13,129 (18.7%)	1,679 (25.7%)	5,337 (12.7%)	1,554 (24.6%)
	Number without any specific preexisting conditions indicated		25,764 (71.9%)	--	56,924 (81.3%)	4,849 (74.3%)	36,803 (87.3%)	4,757 (75.4%)
	Chronic Lung Diseases		3,001 (8.4%)	--	4,288 (6.1%)	493 (7.6%)	1,915 (4.5%)	459 (7.3%)
	Diabetes Mellitus		2,768 (7.7%)	--	3,123 (4.5%)	471 (7.2%)	1,155 (2.7%)	426 (6.8%)
	Severe Obesity		936 (2.6%)	--	1,263 (1.8%)	197 (3.0%)	499 (1.2%)	182 (2.9%)
	Cardiovascular Disease		2,566 (7.2%)	--	2,494 (3.6%)	402 (6.2%)	958 (2.3%)	356 (5.6%)
	Hypertension		4,405 (12.3%)	--	6,330 (9.0%)	968 (14.8%)	2,253 (5.3%)	888 (14.1%)
	Hyperlipidemia		2,260 (6.3%)	--	3,072 (4.4%)	546 (8.4%)	1,067 (2.5%)	502 (8.0%)
	Chronic Kidney Disease		836 (2.3%)	--	787 (1.1%)	139 (2.1%)	307 (0.7%)	131 (2.1%)
	Liver Disease		260 (0.7%)	--	308 (0.4%)	31 (0.5%)	132 (0.3%)	29 (0.5%)
	Autoimmune Condition		717 (2.0%)	--	879 (1.3%)	132 (2.0%)	326 (0.8%)	118 (1.9%)
	Substance Use or Misuse		296 (0.8%)	--	545 (0.8%)	68 (1.0%)	238 (0.6%)	66 (1.0%)
	Psychological Psychiatric Condition		1,155 (3.2%)	--	1,761 (2.5%)	222 (3.4%)	721 (1.7%)	203 (3.2%)
	Immunocompromised Condition		632 (1.8%)	--	600 (0.9%)	119 (1.8%)	261 (0.6%)	105 (1.7%)
	Disability (Neurological or Physical)		1,339 (3.7%)	--	1,291 (1.8%)	175 (2.7%)	535 (1.3%)	157 (2.5%)
	Other Chronic Diseases		2,132 (5.9%)	--	2,150 (3.1%)	328 (5.0%)	996 (2.4%)	304 (4.8%)

*This variable represents responses to a single question on the instrument that asked, broadly, whether the patient had any preexisting condition

**This is the number of observations for which at least one specific preexisting condition was indicated, among all variables relating to specific conditions.

Appendix A Table Hosps.Part1: Demographic Characteristics of COVID-19 Hospitalizations in Jefferson County, Kentucky
(The last date analyzed: 20 November 2021)

		Pre-Vaccination Period: before 16 December 2020		Entire Vaccination Period: from 16 December 2020		The Delta Variant Period: from 1 July 2021	
		(27 Cases Excluded due to Partial Vaccination)		(64 Cases Excluded due to Partial Vaccination)		(37 Cases Excluded due to Partial Vaccination)	
		(0 Cases w/ No Vaccine Info)		(61 Cases w/ No Vaccine Info)		(57 Cases w/ No Vaccine Info)	
		Unvaccinated	Vaccinated	Unvaccinated	Vaccinated	Unvaccinated	Vaccinated
Total # of Observations, <i>N</i>		2,772	0	3,732	395	1,847	360
Race	White (71.8%)	1,451 (52.3%)	--	2,362 (63.3%)	284 (71.9%)	1,203 (65.1%)	262 (72.8%)
	Black (22.4%)	729 (26.3%)	--	776 (20.8%)	55 (13.9%)	388 (21.0%)	46 (12.8%)
	Other (5.8%)	411 (14.8%)	--	454 (12.2%)	48 (12.2%)	205 (11.1%)	45 (12.5%)
	Missing	181 (6.5%)	--	140 (3.8%)	8 (2.0%)	51 (2.8%)	7 (1.9%)
Ethnicity	Non-Hispanic (94.1%)	2,126 (76.7%)	--	3,112 (83.4%)	348 (88.1%)	1,543 (83.5%)	317 (88.1%)
	Hispanic (5.9%)	229 (8.3%)	--	197 (5.3%)	6 (1.5%)	109 (5.9%)	6 (1.7%)
	Other/Missing	417 (15.0%)	--	423 (11.3%)	41 (10.4%)	195 (10.6%)	37 (10.3%)
Gender	Female (51.7%)	1,446 (52.2%)	--	1,949 (52.2%)	203 (51.4%)	949 (51.4%)	182 (50.6%)
	Male (48.3%)	1,323 (47.7%)	--	1,781 (47.7%)	192 (48.6%)	898 (48.6%)	178 (49.4%)
	Other/Missing	3 (0.1%)	--	2 (0.1%)	0 (0%)	0 (0%)	0 (0%)
District	Central (17% of Pop)	568 (20.5%)	--	715 (19.2%)	58 (14.7%)	371 (20.1%)	53 (14.7%)
	East & North East (19%)	384 (13.9%)	--	373 (10.0%)	58 (14.7%)	189 (10.2%)	51 (14.2%)
	North Center (13%)	283 (10.2%)	--	286 (7.7%)	38 (9.6%)	116 (6.3%)	34 (9.4%)
	North West (11%)	442 (15.9%)	--	631 (16.9%)	57 (14.4%)	319 (17.3%)	52 (14.4%)
	South & South West (14%)	345 (12.4%)	--	672 (18.0%)	58 (14.7%)	326 (17.7%)	53 (14.7%)
	South East (16%)	391 (14.1%)	--	503 (13.5%)	76 (19.2%)	241 (13.0%)	72 (20.0%)
	West Center (10%)	356 (12.8%)	--	552 (14.8%)	50 (12.7%)	285 (15.4%)	45 (12.5%)
	Missing District	3 (0.1%)	--	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Age Statistics, All	Age, <i>N</i>	2,772	--	3,732	395	1,847	360
	Age, missing #	0	--	0	0	0	0
	Mean Age (Years)	63.4	--	58.7	70.0	55.3	70.0
	SD in Age (Years)	19.7	--	19.9	14.6	20.3	14.5
	Median Age (Years)	65.5	--	61.0	72.0	57.0	73.0
	IQR of Age (Years)	27.0	--	28.0	18.0	28.0	18.0
Age Statistics, White	Age, <i>N</i>	1,451	--	2,362	284	1,203	262
	Age, missing #	0	--	0	0	0	0
	Mean Age (Years)	67.9	--	61.3	71.1	57.8	71.1
	SD in Age (Years)	18.8	--	19.5	14.1	20.2	13.9
	Median Age (Years)	70.0	--	64.0	73.0	60.0	73.0
	IQR of Age (Years)	25.0	--	27.0	17.0	29.0	17.8
Age Statistics, Black	Age, <i>N</i>	729	--	776	55	388	46
	Age, missing #	0	--	0	0	0	0
	Mean Age (Years)	57.9	--	52.6	65.2	49.5	65.0
	SD in Age (Years)	18.9	--	19.9	14.0	19.7	14.1
	Median Age (Years)	60.0	--	54.0	65.0	51.0	65.0
	IQR of Age (Years)	26.0	--	26.3	20.0	27.0	18.5

Age Statistics, Other Races	Age, <i>N</i>	411	--	454	48	205	45
	Age, missing #	0	--	0	0	0	0
	Mean Age (Years)	55.9	--	55.6	69.5	52.6	69.4
	SD in Age (Years)	19.5	--	19.2	16.9	19.6	17.2
	Median Age (Years)	56.0	--	57.0	72.0	53.0	71.0
	IQR of Age (Years)	30.0	--	26.8	23.5	26.0	24.0
Age Statistics, Missing Race	Age, <i>N</i>	181	--	140	8	51	7
	Age, missing #	0	--	0	0	0	0
	Mean Age (Years)	66.0	--	59.6	65.5	51.4	64.7
	SD in Age (Years)	19.2	--	19.9	13.9	20.0	14.8
	Median Age (Years)	70.0	--	62.0	71.5	53.0	72.0
	IQR of Age (Years)	26.0	--	30.3	9.3	23.0	12.5
Age Statistics, Non-Hispanic	Age, <i>N</i>	2,126	--	3,112	348	1,543	317
	Age, missing #	0	--	0	0	0	0
	Mean Age (Years)	65.0	--	59.1	70.5	55.7	70.6
	SD in Age (Years)	19.0	--	19.9	14.2	20.5	14.0
	Median Age (Years)	67.0	--	61.0	73.0	58.0	73.0
	IQR of Age (Years)	25.0	--	27.0	18.0	29.0	18.0
Age Statistics, Hispanic	Age, <i>N</i>	229	--	197	6	109	6
	Age, missing #	0	--	0	0	0	0
	Mean Age (Years)	47.4	--	46.2	55.2	45.3	55.2
	SD in Age (Years)	18.3	--	18.8	10.0	19.2	10.0
	Median Age (Years)	48.0	--	46.0	50.0	44.0	50.0
	IQR of Age (Years)	21.0	--	24.0	11.0	24.0	11.0
Age Statistics, Missing Ethnicity	Age, <i>N</i>	417	--	423	41	195	37
	Age, missing #	0	--	0	0	0	0
	Mean Age (Years)	63.8	--	61.6	67.4	57.5	67.4
	SD in Age (Years)	20.1	--	18.1	17.2	18.4	17.8
	Median Age (Years)	66.0	--	62.0	69.0	59.0	69.0
	IQR of Age (Years)	28.0	--	23.5	21.0	26.0	21.0

Source: Authors' calculations using Kentucky State Contact Tracing and Tracking (CTT) database.

Appendix A Table Hosps.Part2: Preexisting Conditions of COVID-19 Hospitalizations in Jefferson County, Kentucky
(The last date analyzed: 20 November 2021)

		Pre-Vaccination Period: before 16 December 2020		Entire Vaccination Period: from 16 December 2020		The Delta Variant Period: from 1 July 2021	
		(27 Cases Excluded due to Partial Vaccination) (0 Cases w/ No Vaccine Info)		(64 Cases Excluded due to Partial Vaccination) (61 Cases w/ No Vaccine Info)		(37 Cases Excluded due to Partial Vaccination) (57 Cases w/ No Vaccine Info)	
		Unvaccinated	Vaccinated	Unvaccinated	Vaccinated	Unvaccinated	Vaccinated
# Indicated Having Preexisting Condition(s)*		2,080 (75.0%)	--	2,499 (67.0%)	326 (82.5%)	1,130 (61.2%)	294 (81.7%)
# Indicated No Preexisting Condition		363 (13.1%)	--	394 (10.6%)	13 (3.3%)	177 (9.6%)	11 (3.1%)
# with Unknown Preexisting Conditions		131 (4.7%)	--	42 (1.1%)	1 (0.3%)	23 (1.2%)	1 (0.3%)
# Missing a Response		198 (7.1%)	--	797 (21.4%)	55 (13.9%)	517 (28.0%)	54 (15.0%)
Prevalence of Specific Conditions	Number with at least one of the conditions listed below**	2,144 (77.3%)	--	2,448 (65.6%)	325 (82.3%)	1,103 (59.7%)	295 (81.9%)
	Number without any specific preexisting conditions indicated	628 (22.7%)	--	1,284 (34.4%)	70 (17.7%)	744 (40.3%)	65 (18.1%)
	Chronic Lung Diseases	643 (23.2%)	--	742 (19.9%)	102 (25.8%)	316 (17.1%)	97 (26.9%)
	Diabetes Mellitus	893 (32.2%)	--	942 (25.2%)	136 (34.4%)	395 (21.4%)	125 (34.7%)
	Severe Obesity	227 (8.2%)	--	323 (8.7%)	39 (9.9%)	156 (8.4%)	35 (9.7%)
	Cardiovascular Disease	1,085 (39.1%)	--	1,159 (31.1%)	180 (45.6%)	459 (24.9%)	161 (44.7%)
	Hypertension	1,014 (36.6%)	--	1,542 (41.3%)	241 (61.0%)	644 (34.9%)	217 (60.3%)
	Hyperlipidemia	563 (20.3%)	--	805 (21.6%)	158 (40.0%)	333 (18.0%)	140 (38.9%)
	Chronic Kidney Disease	432 (15.6%)	--	395 (10.6%)	93 (23.5%)	177 (9.6%)	86 (23.9%)
	Liver Disease	74 (2.7%)	--	104 (2.8%)	16 (4.1%)	49 (2.7%)	16 (4.4%)
	Autoimmune Condition	131 (4.7%)	--	95 (2.5%)	15 (3.8%)	33 (1.8%)	10 (2.8%)
	Substance Use or Misuse	59 (2.1%)	--	182 (4.9%)	28 (7.1%)	99 (5.4%)	27 (7.5%)
	Psychological Psychiatric Condition	245 (8.8%)	--	458 (12.3%)	86 (21.8%)	195 (10.6%)	80 (22.2%)
	Immunocompromised Condition	189 (6.8%)	--	213 (5.7%)	56 (14.2%)	98 (5.3%)	49 (13.6%)
	Disability (Neurological or Physical)	453 (16.3%)	--	408 (10.9%)	72 (18.2%)	173 (9.4%)	64 (17.8%)
	Other Chronic Diseases	942 (34.0%)	--	1,084 (29.0%)	213 (53.9%)	506 (27.4%)	196 (54.4%)

*This variable represents responses to a single question on the instrument that asked, broadly, whether the patient had any preexisting condition

**This is the number of observations for which at least one specific preexisting condition was indicated, among all variables relating to specific conditions.

Source: Authors' calculations using Kentucky State Contact Tracing and Tracking (CTT) database.

Appendix A Table Deaths.Part1: Demographic Characteristics of COVID-19 Deaths in Jefferson County, Kentucky
(The last date analyzed: 20 November 2021)

		Pre-Vaccination Period: before 16 December 2020		Entire Vaccination Period: from 16 December 2020		The Delta Variant Period: from 1 July 2021	
		(4 Cases Excluded due to Partial Vaccination)		(8 Cases Excluded due to Partial Vaccination)		(4 Cases Excluded due to Partial Vaccination)	
		(0 Cases w/ No Vaccine Info)		(15 Cases w/ No Vaccine Info)		(14Cases w/ No Vaccine Info)	
		Unvaccinated	Vaccinated	Unvaccinated	Vaccinated	Unvaccinated	Vaccinated
Total # of Observations, N		839	0	706	90	331	85
Race	White (71.8%)	483 (57.6%)	--	494 (70.0%)	66 (73.3%)	246 (74.3%)	62 (72.9%)
	Black (22.4%)	146 (17.4%)	--	82 (11.6%)	9 (10.0%)	41 (12.4%)	8 (9.4%)
	Other (5.8%)	124 (14.8%)	--	87 (12.3%)	13 (14.4%)	37 (11.2%)	13 (15.3%)
	Missing	86 (10.3%)	--	43 (6.1%)	2 (2.2%)	7 (2.1%)	2 (2.4%)
Ethnicity	Non-Hispanic (94.1%)	614 (73.2%)	--	576 (81.6%)	77 (85.6%)	284 (85.8%)	72 (84.7%)
	Hispanic (5.9%)	26 (3.1%)	--	16 (2.3%)	0 (0%)	11 (3.3%)	0 (0%)
	Other/Missing	199 (23.7%)	--	114 (16.1%)	13 (14.4%)	36 (10.9%)	13 (15.3%)
Gender	Female (51.7%)	428 (51.0%)	--	350 (49.6%)	34 (37.8%)	151 (45.6%)	32 (37.6%)
	Male (48.3%)	411 (49.0%)	--	356 (50.4%)	56 (62.2%)	180 (54.4%)	53 (62.4%)
	Other/Missing	0 (0%)	--	0 (0%)	0 (0%)	0 (0%)	0 (0%)
District	Central (17% of Pop)	114 (13.6%)	--	134 (19.0%)	11 (12.2%)	68 (20.5%)	10 (11.8%)
	East & North East (19%)	151 (18.0%)	--	82 (11.6%)	18 (20.0%)	35 (10.6%)	15 (17.6%)
	North Center (13%)	124 (14.8%)	--	96 (13.6%)	9 (10.0%)	34 (10.3%)	8 (9.4%)
	North West (11%)	128 (15.3%)	--	80 (11.3%)	13 (14.4%)	40 (12.1%)	13 (15.3%)
	South & South West (14%)	91 (10.8%)	--	132 (18.7%)	13 (14.4%)	65 (19.6%)	13 (15.3%)
	South East (16%)	140 (16.7%)	--	107 (15.2%)	18 (20.0%)	48 (14.5%)	18 (21.2%)
	West Center (10%)	90 (10.7%)	--	75 (10.6%)	8 (8.9%)	41 (12.4%)	8 (9.4%)
	Missing District	1 (0.1%)	--	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Age Statistics, All	Age, N	839	--	706	90	331	85
	Age, missing #	0	--	0	0	0	0
	Mean Age (Years)	79.0	--	73.2	76.6	68.5	76.0
	SD in Age (Years)	13.4	--	15.1	11.3	15.8	10.8
	Median Age (Years)	81.0	--	74.0	78.0	70.0	78.0
	IQR of Age (Years)	18.0	--	21.8	16.0	23.0	15.0
Age Statistics, White	Age, N	483	--	494	66	246	62
	Age, missing #	0	--	0	0	0	0
	Mean Age (Years)	81.2	--	74.6	77.2	70.1	76.2
	SD in Age (Years)	11.5	--	14.7	11.5	15.4	10.9
	Median Age (Years)	82.0	--	77.5	79.0	71.5	79.0
	IQR of Age (Years)	16.0	--	20.0	15.8	22.0	15.0
Age Statistics, Black	Age, N	146	--	82	9	41	8
	Age, missing #	0	--	0	0	0	0
	Mean Age (Years)	73.4	--	65.4	68.9	63.1	69.1
	SD in Age (Years)	13.3	--	13.7	6.9	14.6	7.4
	Median Age (Years)	74.0	--	65.0	69.0	65.0	70.5
	IQR of Age (Years)	17.0	--	17.5	8.0	16.0	9.8

Age Statistics, Other Races	Age, <i>N</i>	124	--	87	13	37	13
	Age, missing #	0	--	0	0	0	0
	Mean Age (Years)	74.4	--	70.1	79.3	66.5	79.3
	SD in Age (Years)	17.1	--	15.2	11.5	17.5	11.5
	Median Age (Years)	78.0	--	70.0	80.0	69.0	80.0
	IQR of Age (Years)	22.0	--	19.0	15.0	19.0	15.0
Age Statistics, Missing Race	Age, <i>N</i>	86	--	43	2	7	2
	Age, missing #	0	--	0	0	0	0
	Mean Age (Years)	82.3	--	77.8	76.0	56.3	76.0
	SD in Age (Years)	12.7	--	15.9	11.3	16.7	11.3
	Median Age (Years)	86.0	--	80.0	76.0	55.0	76.0
	IQR of Age (Years)	17.0	--	19.0	8.0	13.5	8.0
Age Statistics, Non-Hispanic	Age, <i>N</i>	614	--	576	77	284	72
	Age, missing #	0	--	0	0	0	0
	Mean Age (Years)	79.5	--	73.2	76.5	69.0	75.7
	SD in Age (Years)	12.5	--	14.8	11.5	15.5	11.0
	Median Age (Years)	80.0	--	74.0	78.0	70.0	77.5
	IQR of Age (Years)	17.0	--	20.0	16.0	22.0	15.5
Age Statistics, Hispanic	Age, <i>N</i>	26	--	16	0	11	0
	Age, missing #	0	--	0	0	0	0
	Mean Age (Years)	63.6	--	59.1	0.0	57.9	0.0
	SD in Age (Years)	18.1	--	13.6	0.0	16.1	0.0
	Median Age (Years)	60.5	--	59.5	0.0	58.0	0.0
	IQR of Age (Years)	28.0	--	14.5	0.0	21.5	0.0
Age Statistics, Missing Ethnicity	Age, <i>N</i>	199	--	114	13	36	13
	Age, missing #	0	--	0	0	0	0
	Mean Age (Years)	79.4	--	75.4	77.4	67.9	77.4
	SD in Age (Years)	14.2	--	15.9	10.2	17.5	10.2
	Median Age (Years)	82.0	--	76.5	80.0	69.5	80.0
	IQR of Age (Years)	17.0	--	22.0	16.0	22.3	16.0

Source: Authors' calculations using Kentucky State Contact Tracing and Tracking (CTT) database.

Appendix A Table Deaths.Part2: Preexisting Conditions of COVID-19 Deaths in Jefferson County, Kentucky
(The last date analyzed: 20 November 2021)

	Pre-Vaccination Period: before 16 December 2020		Entire Vaccination Period: from 16 December 2020		The Delta Variant Period: from 1 July 2021	
	(4 Cases Excluded due to Partial Vaccination) (0 Cases w/ No Vaccine Info)		(8 Cases Excluded due to Partial Vaccination) (15 Cases w/ No Vaccine Info)		(4 Cases Excluded due to Partial Vaccination) (14 Cases w/ No Vaccine Info)	
	Unvaccinated	Vaccinated	Unvaccinated	Vaccinated	Unvaccinated	Vaccinated
# Indicated Having Preexisting Condition(s)*	622 (74.1%)	--	581 (82.3%)	85 (94.4%)	273 (82.5%)	81 (95.3%)
# Indicated No Preexisting Condition	11 (1.3%)	--	15 (2.1%)	0 (0%)	12 (3.6%)	0 (0%)
# with Unknown Preexisting Conditions	63 (7.5%)	--	15 (2.1%)	0 (0%)	10 (3.0%)	0 (0%)
# Missing a Response	143 (17.0%)	--	95 (13.5%)	5 (5.6%)	36 (10.9%)	4 (4.7%)
Prevalence of Specific Conditions	Number with at least one of the conditions listed below**	653 (77.8%)	--	576 (81.6%)	85 (94.4%)	271 (81.9%)
	Number without any specific preexisting conditions indicated	186 (22.2%)	--	130 (18.4%)	5 (5.6%)	60 (18.1%)
	Chronic Lung Diseases	192 (22.9%)	--	179 (25.4%)	26 (28.9%)	79 (23.9%)
	Diabetes Mellitus	293 (34.9%)	--	242 (34.3%)	40 (44.4%)	107 (32.3%)
	Severe Obesity	47 (5.6%)	--	86 (12.2%)	12 (13.3%)	49 (14.8%)
	Cardiovascular Disease	421 (50.2%)	--	354 (50.1%)	58 (64.4%)	151 (45.6%)
	Hypertension	302 (36.0%)	--	397 (56.2%)	71 (78.9%)	189 (57.1%)
	Hyperlipidemia	174 (20.7%)	--	223 (31.6%)	52 (57.8%)	98 (29.6%)
	Chronic Kidney Disease	183 (21.8%)	--	137 (19.4%)	34 (37.8%)	63 (19.0%)
	Liver Disease	24 (2.9%)	--	34 (4.8%)	7 (7.8%)	15 (4.5%)
	Autoimmune Condition	30 (3.6%)	--	11 (1.6%)	3 (3.3%)	2 (0.6%)
	Substance Use or Misuse	8 (1.0%)	--	31 (4.4%)	7 (7.8%)	17 (5.1%)
	Psychological Psychiatric Condition	65 (7.7%)	--	115 (16.3%)	25 (27.8%)	61 (18.4%)
	Immunocompromised Condition	52 (6.2%)	--	65 (9.2%)	17 (18.9%)	28 (8.5%)
	Disability (Neurological or Physical)	187 (22.3%)	--	101 (14.3%)	25 (27.8%)	48 (14.5%)
	Other Chronic Diseases	315 (37.5%)	--	302 (42.8%)	66 (73.3%)	154 (46.5%)

*This variable represents responses to a single question on the instrument that asked, broadly, whether the patient had any preexisting condition

**This is the number of observations for which at least one specific preexisting condition was indicated, among all variables relating to specific conditions.

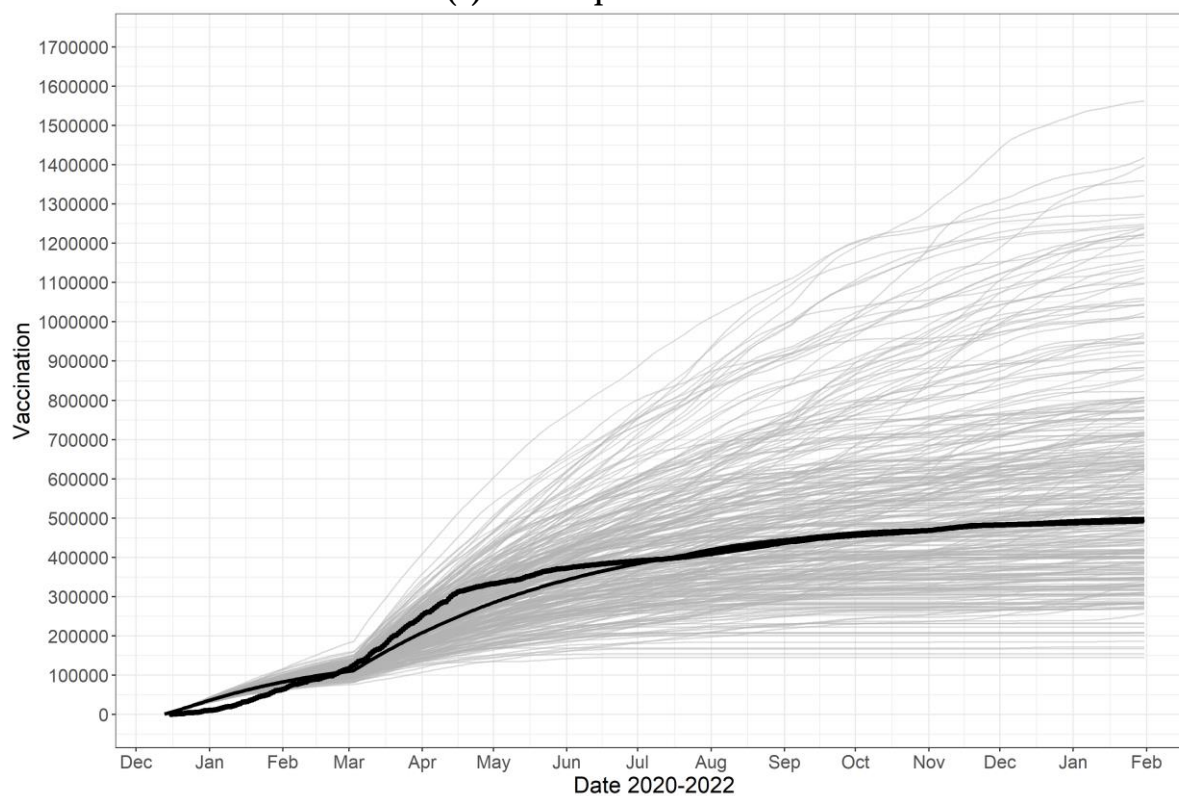
Source: Authors' calculations using Kentucky State Contact Tracing and Tracking (CTT) database.

Appendix B:

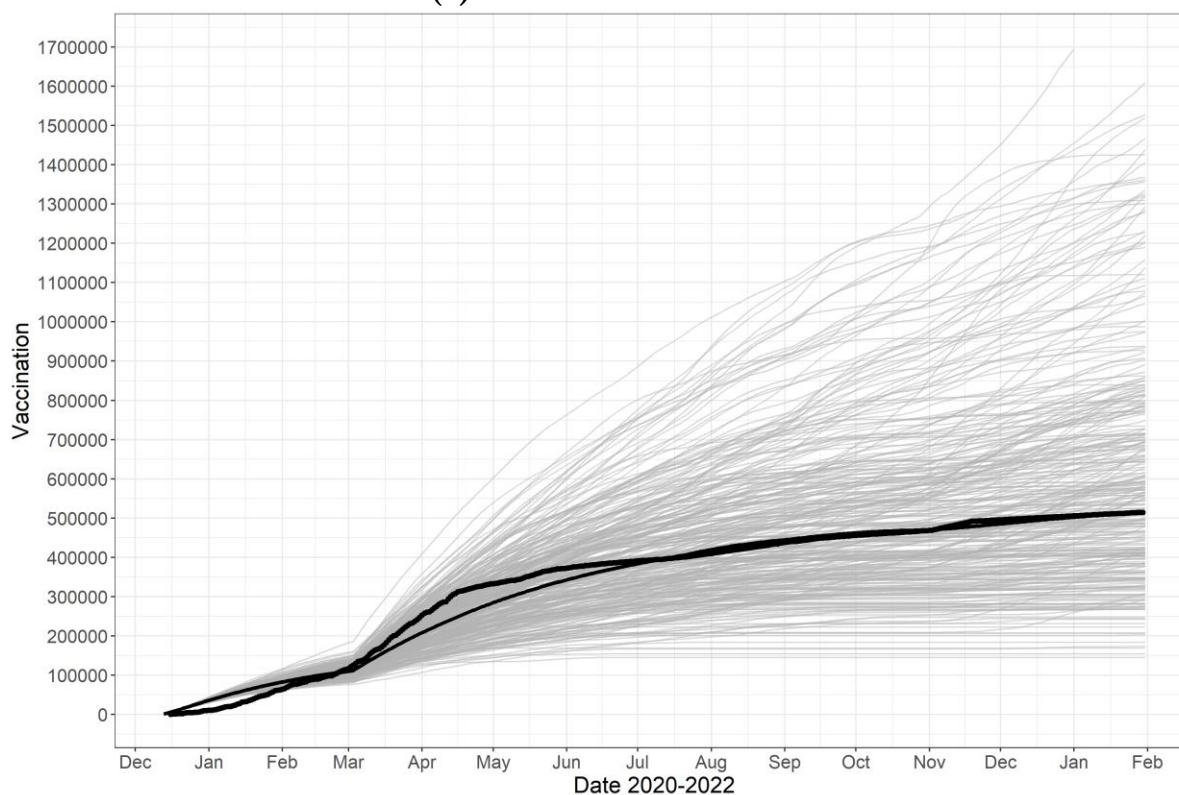
Detailed Simulation Results

Appendix B, Figure 1: Vaccination Trends (Scenarioed vs. Simulated)

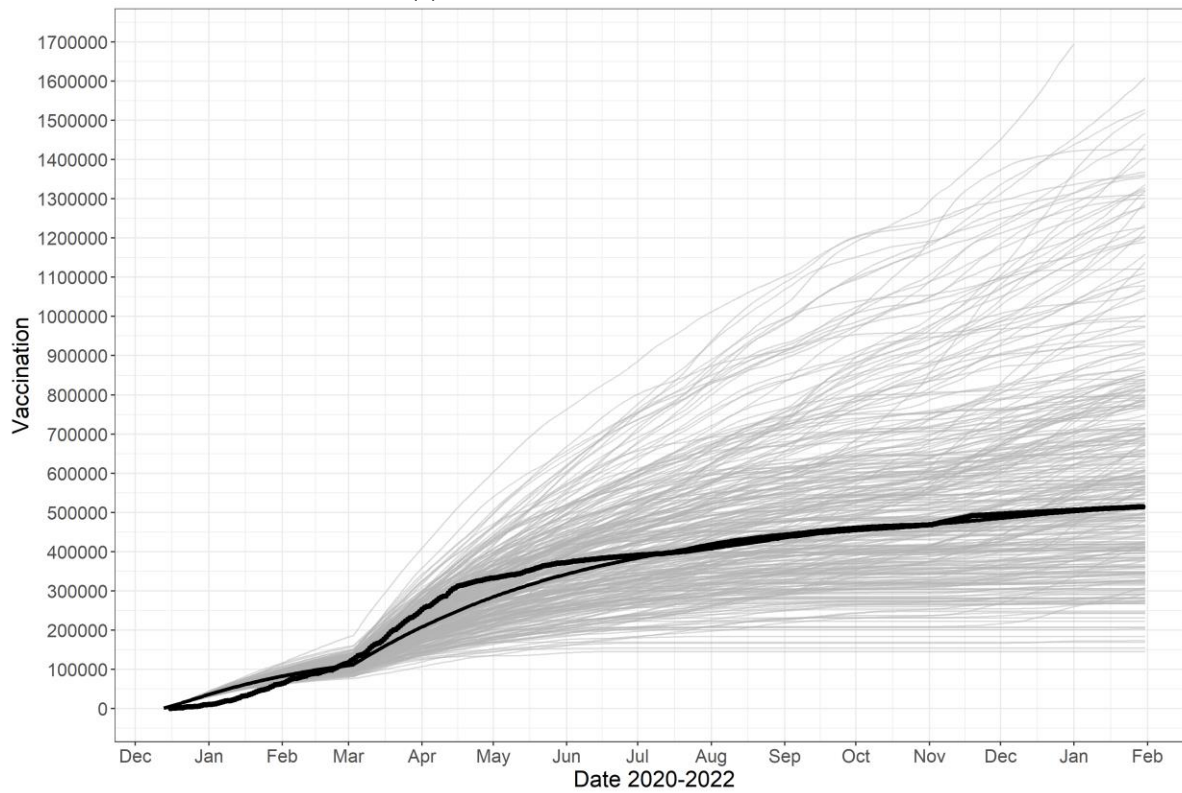
(a) The Expected Scenario



(b) The Accelerated Scenario

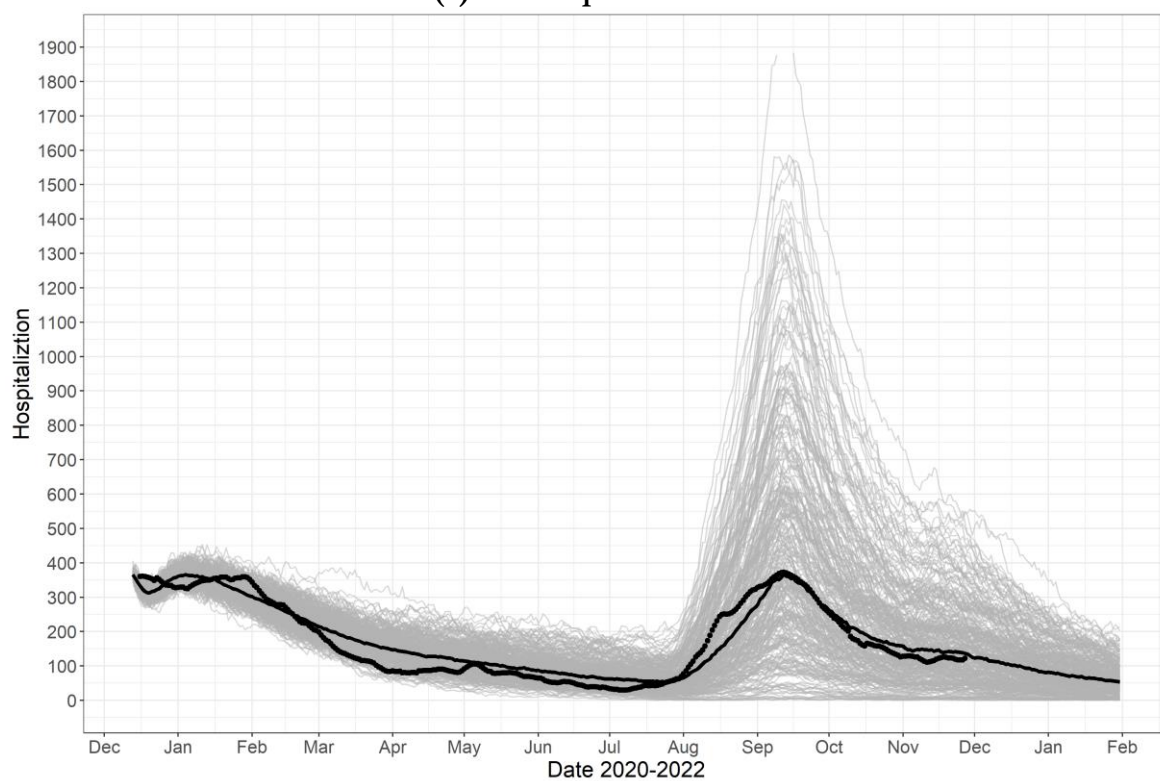


(c) The Decelerated Scenario

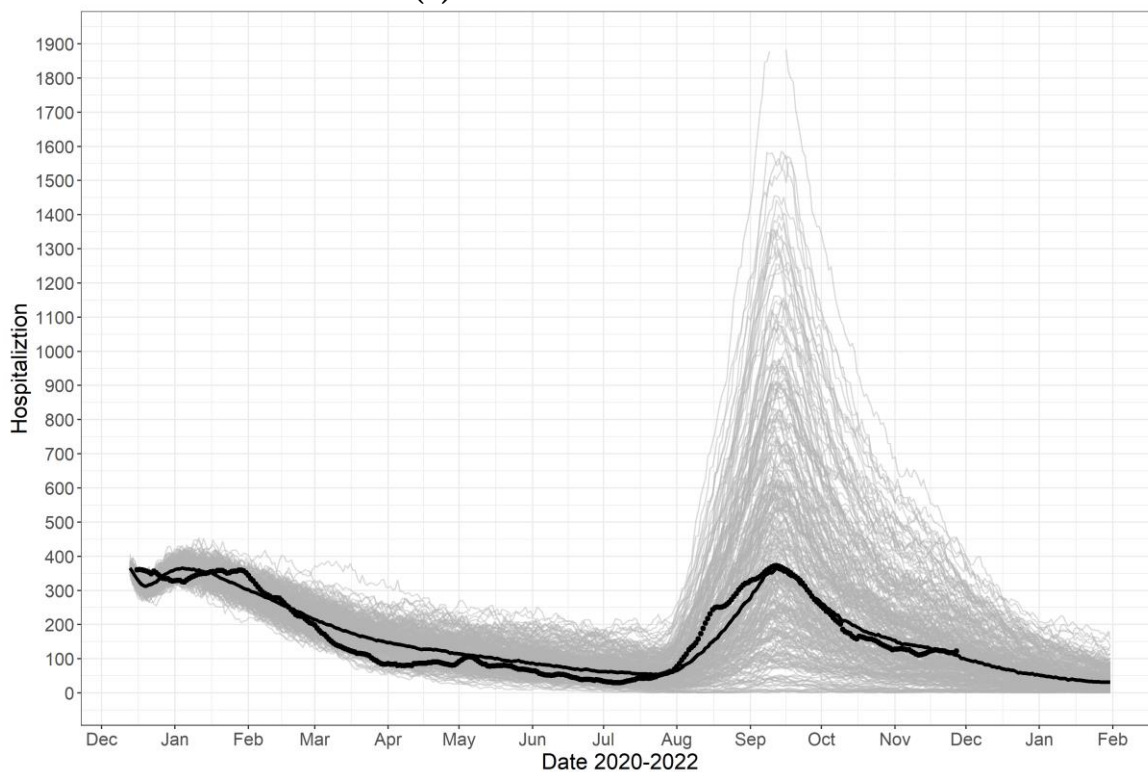


Note: The dots form the observed trend of first dose vaccination in Jefferson County, Kentucky. The observed numbers are 10% of reported first dose numbers to account for those with no second dose information reported in the KYIR data. The solid-line trends are medians of 500 simulations, shown by gray-colored trends. Under the expected scenario, 20% of 5 to 11 year old children would be fully vaccinated by 31 December 2021, 10% under the decelerated scenario and 40% under the accelerated scenario.

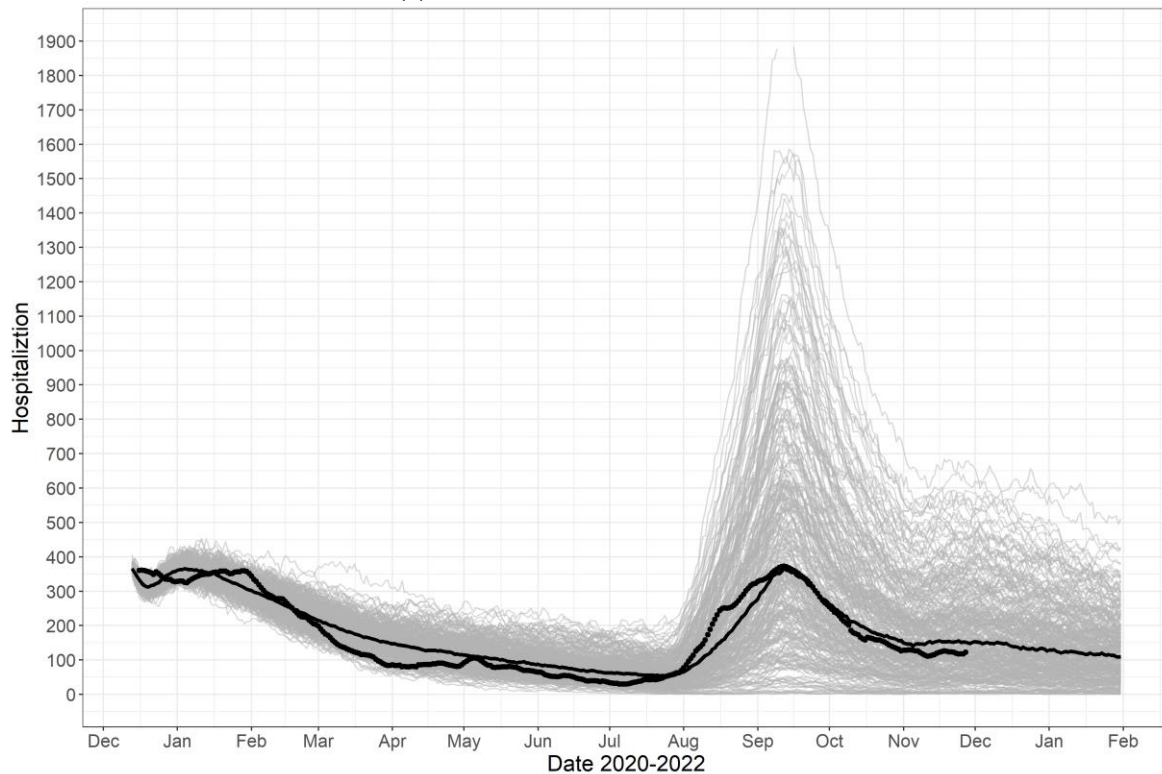
Appendix B, Figure 2: Projected Active Hospitalizations under Simulated Vaccination Trends (Actual vs. Simulated)
(c) The Expected Scenario



(d) The Accelerated Scenario



(c) The Decelerated Scenario



Note: The dots form the observed trend of active COVID-19 hospitalizations in Jefferson County, Kentucky. The solid-line trends are medians of 500 simulations, shown by gray-colored trends. Under the expected scenario, 20% of 5 to 11 year old children would be fully vaccinated by 31 December 2021, 10% under the decelerated scenario and 40% under the accelerated scenario.