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Supplementary appendix

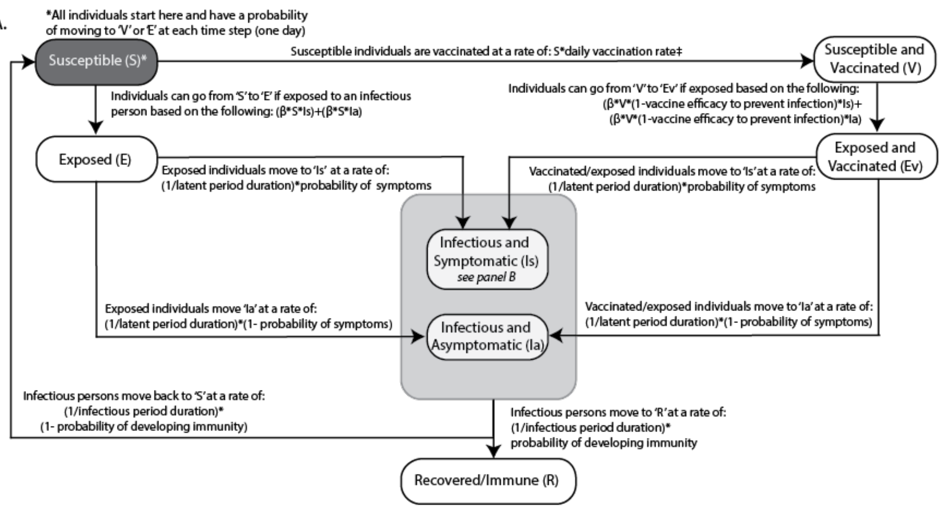
This appendix formed part of the original submission and has been peer reviewed. We post it as supplied by the authors.

Supplement to: Bartsch SM, O'Shea KJ, Chin KL, et al. Maintaining face mask use before and after achieving different COVID-19 vaccination coverage levels: a modelling study. *Lancet Public Health* 2022; published online March 8. https://doi.org/10.1016/S2468-2667(22)00040-8.

Appendix to: Maintaining Face Mask Use Before and After Achieving Different COVID-19 Vaccination Coverage Levels: A Modelling Study

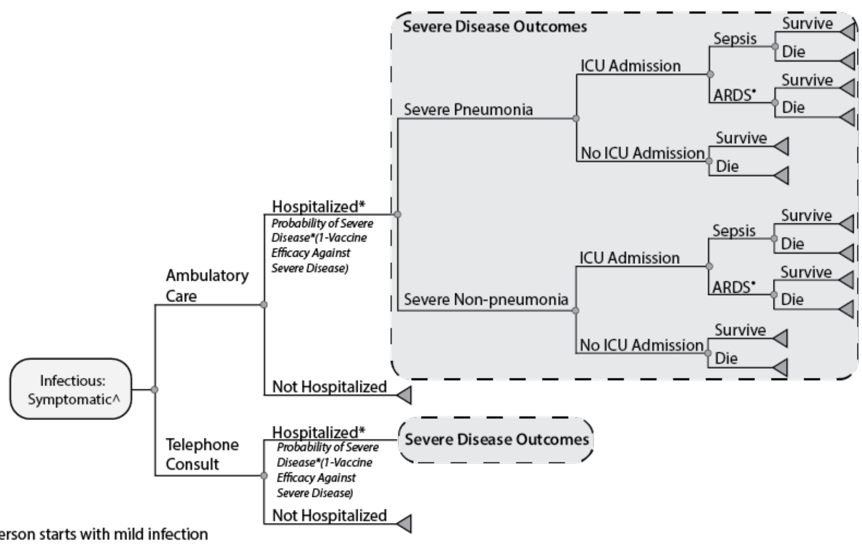
Appendix Figure 1. Model structure A) transmission model and B) probability tree of different age-specific outcomes that infections persons travel through. The individual has an age drawn from the age-distribution of U.S. population and accrues relevant age-specific costs and health effects.

A.



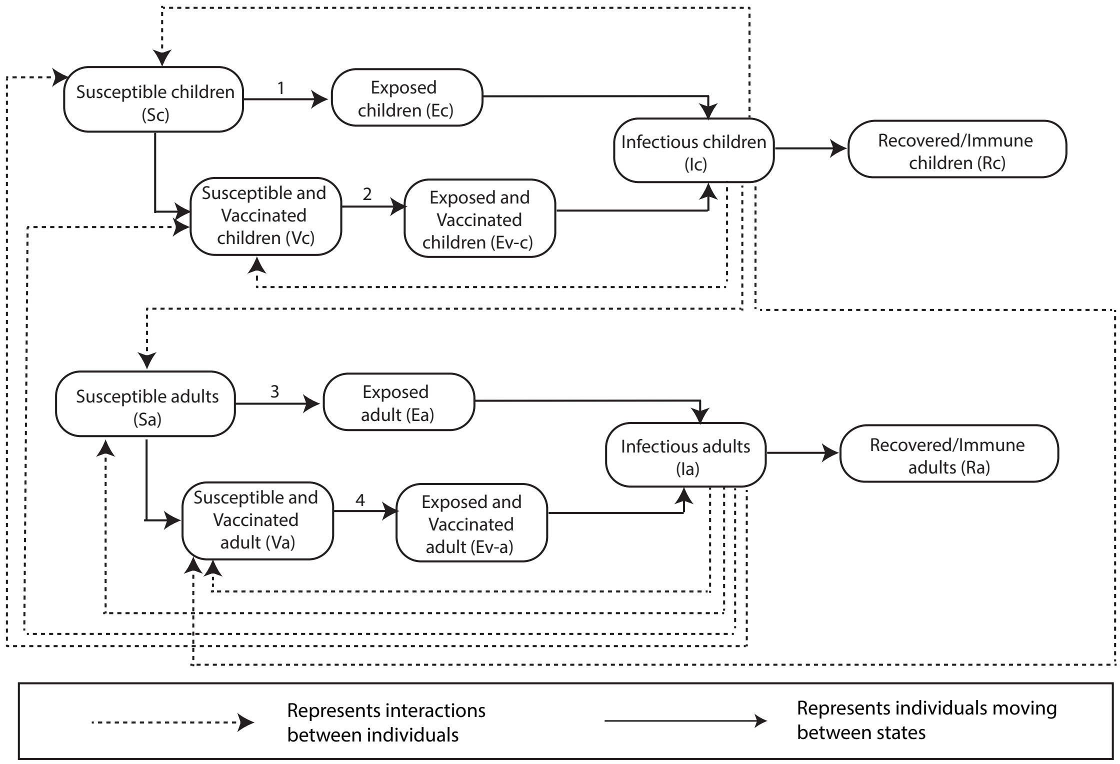
β = beta, the transmission coefficient and equals R_t/infectious period duration/population size.
R_t is the reproductive rate of the virus on a given day (t) and is the R_0 (the number of secondary cases generated by a single infectious case in a fully susceptible population) adjusted by observed seasonal variation.
The latent period is the time between exposure and ability to transmit. Infectious individuals can transmit prior to symptom onset.
When face masks are used, $R_t = R_t$*(1-Face Mask Effectiveness)

B.



^Person starts with mild infection
*Person progresses to severe disease requiring hospitalization
*ARDS= acute respiratory distress syndrome, with or without sepsis
Each COVID-19 infection loses QALY values based on age-dependent healthy QALY value and infection-specific utility weights for infection duration. Absenteeism results in productivity losses for symptom duration.

Appendix Figure 2. Example model structure stratifying by age.



Where not otherwise noted, movement between states is governed by the same equations shown in Appendix Figure 1.

Adults and children have different probabilities of interacting within and between age groups, resulting in moving from susceptible to exposed compartments based on the following equations:

1. Movement from Sc to Ec: $(\beta c\text{-}c*Sc*Ic)+(\beta a\text{-}c*Sc*Ia)$
2. Movement from Vc to Ev-c: $(\beta c\text{-}c*Vc*Ic)+(\beta a\text{-}c*Vc*Ia)$
3. Movement from Sa to Ea: $(\beta c\text{-}a*Sa*Ic)+(\beta a\text{-}a*Sa*Ia)$
4. Movement from Va to Ev-a: $(\beta c\text{-}a*Va*Ic)+(\beta a\text{-}a*Va*Ia)$

βa-a: transmission coefficient representing interactions between infectious adults and susceptible adults;
βc-c: transmission coefficient representing interactions between infectious children and susceptible children;
βa-c: transmission coefficient representing interactions between infectious adults and susceptible children;
βc-a: transmission coefficient representing interactions between infectious children and susceptible adults

Data Sources

Appendix Table 1 shows key model input parameters, values, and sources. All costs, clinical probabilities, and durations were age-specific when available and come from scientific literature or nationally representative data sources [e.g., Centers for Medicare and Medicaid Services (CMS)]. In the absence of literature, data from the CDC was preferred. In the absence of specific data, the probability of diagnosis given symptoms, derived from seroprevalence surveys and case reports, served as a proxy for the probability of ambulatory care.[1] The cost of face masks, consisted of the cost of disposable masks (surgical: $0.08, N95: $0.50[2]), how often masks disposable masks are replaced (average of once every two days[3]), the cost of cloth masks (amortized to $0.014 per day assuming a person has two masks at $2.50 per mask and they last for one year[4,5]), and the cost to wash masks (average $0.007 per day, based on the average cost per load of laundry[6,7]) and recommendations to wash daily[4]). Based on the proportion of each type of mask used (i.e., N95, surgical, cloth)[8] early in the pandemic (March-July 2020) and how often each type of mask was replaced[3], this equals $0.32 per person per day. As cost data come from several sources published across different years, we utilized a standard 3% rate to inflate all past costs, regardless of year, per recommendations from the Panel of Cost-Effectiveness in Health and Medicine.[9,10] Appendix Figure 4 shows the impact of varying key parameters on model outcomes when using face masks while Appendix Figure 5 shows how key model outcomes change when varying values of model input parameters in Appendix Table 1.

Model Calibration and Validation
We calibrated the model such that number of cases reflected case data reported as of October 1, 2021[11] (last date of reported data at the time) given available evidence on underreporting in the US[12-14] as well as vaccination rates over time (55.9% fully vaccinated by October 1).[15] This was equivalent to 52.3 million in the unvaccinated susceptible compartment, 89.3 million in the vaccinated susceptible compartment, 0.7 million unvaccinated exposed, 0.1 million vaccinated exposed, 1.0 million symptomatic unvaccinated cases, 0.8 million asymptomatic unvaccinated cases, 0.2 million symptomatic vaccinated cases, 0.2 million asymptomatic vaccinated cases, and 182.6 million recovered. As predicting the specific course of the current pandemic can be challenging with such variations in the application of social distancing measures and face mask use policies as well as variations in the types and efficacy of face masks, we simulated general non-pharmaceutical intervention (NPI) use until October 1, 2021. For example, NPIs used at various points through the pandemic include use of face masks, social distancing, school closures, curfews/gathering limits, and closing of non-essential businesses, however these NPIs and mandates vary greatly by state.[16-19] We fit R_t (i.e., average number of secondary cases generated by one infectious case at time t) to estimate the shape of the pandemic curve (using the rolling 7-day average) and new incident cases through October 1, 2021.[11] This fitting of R_t allows us to represent various conditions such as NPIs and their compliance, seasonal variations in respiratory virus transmission, and more transmissible variants. Modeled cases (i.e., simulated truth) were higher than reported cases, given that not all cases are diagnosed, resulting in underreporting.[12-14]

We also performed model validation including face validity and criterion validity. We achieved face validity as the progression of the simulated unmitigated epidemic proceeded in a trend following widely accepted epidemiological trends. For example, the peak number of cases per day (e.g., the peak of the epidemic curve) occurred when the population achieved herd immunity, which aligns with previously demonstrated trends in population infection control. For criterion validation, we compared the number of simulated age-stratified infections and deaths with NPIs to CDC age-stratified data from day 602. Day 602 corresponds to the most recent date of available COVID-19 data from the CDC (October 1, 2021[20-21]), assuming that community spread began in the US at the beginning of February 2020. Appendix Table 2 shows the age-stratified simulated data compared to the available CDC data. To note, there are a number of limitations to the CDC data when making comparisons. The hospitalization data is published in rates per 100,000, which we extrapolate to estimate total hospitalizations in the population. The hospitalization data also have many missing data points and has a 15-day lag. Additionally, an overall limitation of surveillance data is the inability to capture the cases in individuals who do not seek testing. Given these limitations, we expect there to be some discrepancy between model-simulated data and CDC reported data, but the overall trends and patterns hold.

Appendix Table 1. Model input parameters, values, and sources.

Parameter	Distribution Type	Mean or Median	Standard Error or Range	Source
COVID-19 Coronavirus Transmission				
Seasonality scaling factor for R_t				
Spring and fall	Point Estimate	0.659	-	[22]
Summer	Point Estimate	0.318	-	[22]
Winter	Point Estimate	1	-	[22]
Latent period (days)	Triangular	5.2	4.1-7.0	[23]
Infectious period (days)	Uniform	-	4-15	[24-27]
Costs (2021 US$)*				
Surgical face masks	Point Value	0.08	ranged in sensitivity analyses: 0.16-0.24	[2]
N95 face masks	Point Value	0.50	ranged in sensitivity analyses: 1-1.50	[2]
Cloth face masks	Point Value	2.50	ranged in sensitivity analyses: 5-7.5	Assumption
Washing a cloth face mask (per day)	Point Value	0.007	-	[4,6,7]
COVID-19 vaccine (per dose)	Point Value	20	-	[28]
Vaccination administration (per dose for administering the vaccine, supplies, public health reporting[29]	Point Value	40	-	[30]
Annual wages (all occupations; proxy for productivity losses)	Beta Pert	42,223	21,950-104,403[a]	[31]
Ambulatory care visit	Uniform	-	110.43-148.33	[32]
Over the counter medications, daily				
0-12 years old[b]	Gamma	3.99	2.10	[33]
≥13 years old[c]	Gamma	0.47	0.17	[33]
Hospitalization for pneumonia[d]				
0-17 years old	Gamma	12,877.37	1,508.04	[34]
18-44 years old	Gamma	10,945.96	1,045.06	[34]
45-64 years old	Gamma	14,129.68	1,238.76	[34]
65-84 years old	Gamma	12,632.32	478.40	[34]
≥85 years old	Gamma	11,312.21	518.29	[34]
Hospitalization for severe non-pneumonia (all ages)[e]	Gamma	7,093.13	1,182.99	[34]
Hospitalization for sepsis[f]				
0-17 years old[g]	Gamma	23,375.13	1,861.33	[34]
18-44 years old	Gamma	45,091.74	5,382.40	[34]
45-64 years old	Gamma	39,896.27	2,725.10	[34]
65-84 years old	Gamma	31,217.54	1,367.91	[34]
≥85 years old	Gamma	23,375.13	1,861.33	[34]
Hospitalization for ARDS[h]				
0-17 years old	Gamma	43,621.10	4,198.97	[34]
18-44 years old	Gamma	26,997.29	1,558.61	[34]

45-64 years old	Gamma	20,459.90	453.92	34
65-84 years old	Gamma	19,280.11	335.69	34
≥85 years old	Gamma	17,056.54	754.12	34
Hospitalization for myocarditis	Gamma	35,289.60	2,222.34	34
Hospitalization for pericarditis	Gamma	16,002.76	291.16	34
Hospitalization for allergic reaction/anaphylaxis[i]	Triangular	7,753.38	6,774.80 - 8,280.31[j]	34
Probabilities				
Face mask effectiveness	Beta Pert	0.18	0.16-0.20[a]	35
Using surgical masks	Point Estimate	0.2	-	8
Using N95 masks	Point Estimate	0.345	-	8
Using cloth masks	Point Estimate	0.455	-	8
Developing immunity after infection (seroconversion)	Point Estimate	0.91	-	36,37
Vaccine efficacy against COVID-19 hospitalization	Beta Pert	0.86	0.82-0.89[a]	38
Side effects due to vaccination				
Minor	Uniform	-	0.33 - 0.42	39-41
Severe: myocarditis/pericarditis	Uniform	0.000023	0.0000156-0.000027[a]	42
Severe: allergic reaction/anaphylaxis	Triangular	-	0.000003 - 0.000011	43,44
Asymptomatic infection	Triangular	0.45	0.305-0.495[j]	45,46
Relative infectiousness of asymptomatic infection	Point Estimate	1	-	46
Missing work/school	Point Estimate	1.0	-	Assumption
Ambulatory care	Triangular	0.15	0.06-0.26	1
Hospitalization, given infection				
0-17 years old	Beta Pert	0.0092	0.0081-0.0101[j]	12
18-44 years old	Beta Pert	0.0081	0.0073-0.0089[j]	12
45-64 years old	Beta Pert	0.0826	0.0744-0.909[j]	12
≥65 years old	Beta Pert	0.257	0.2314-0.2828[j]	12
ICU admission, given hospitalization				
0-17 years old	Beta Pert	0.171	0.154-0.1881[j]	47
18-44 years old	Beta Pert	0.238	0.214-0.262[j]	48
45-64 years old	Beta Pert	0.361	0.325-0.397[j]	48
≥65 years old	Beta Pert	0.353	0.318-0.388[j]	48
Mortality, given hospitalization				
0-17 years old	Beta Pert	0.0061	0.0055-0.0067[j]	12,49
18-44 years old	Beta Pert	0.089	0.0801-0.0979[j]	12,49
45-64 years old	Beta Pert	0.058	0.0520-0.0635[j]	12,49
≥65 years old	Beta Pert	0.155	0.1392-0.1702[j]	12,49
Pneumonia, given hospitalization	Beta	0.79	0.711-0.869[k]	50
ARDS, requiring ventilator use in ICU	Beta	0.771	0.053	51-55
Reduced work productivity (presenteeism) due to long COVID	Triangular	0.452	0.429-0.472	56
Durations (days)				
Get vaccinated in any setting (hours)	Uniform	-	0.1-2	57
Minor side effects	Uniform		1-2	Assumption[l]
Ambulatory care	Point Estimate	0.5	-	Assumption
Duration of symptoms with mild illness	Triangular	7	3-17	26,58,59
Duration of symptoms prior to hospital admission	Triangular	7	3-9[m]	60,61

Hospitalization, not admitted to ICU				
0-49 years old	Beta Pert	3	2-5[k]	48
50-64 years old	Beta Pert	4	2-7[k]	48
≥65 years old	Beta Pert	6	3-10[k]	48
Hospitalization, ICU (all ages)	Gamma	9	4-17[k]	53-55,62
Hospitalization, ventilator use	Gamma	9	5-12[k]	53,54,63
Hospitalization, myocarditis	Gamma	5.9	0.28	34
Hospitalization, pericarditis	Gamma	4.8	0.06	34
Hospitalization, allergic reaction/anaphylaxis	Gamma	2.3	2.1-2.5	34
Reduced productivity (presenteeism) due to long COVID	Point Estimate	182	-	56
Numbers				
Cloth masks per person	Point Estimate	2	-	4
Disposable masks per day (average)	Point Estimate	0.515	ranged in sensitivity analyses: 0.62-0.77	3
Utility weights				
Healthy QALY				
<17 years old	Point Estimate	1	-	64
18-64 years old	Point Estimate	0.92	-	64
≥65 years old	Point Estimate	0.84	-	64
Mild non-specific symptoms[n]	Beta	0.648	0.103	65-74
Hospitalized, non-pneumonia symptoms[o]	Beta	0.514	0.089	67,74,75
Pneumonia	Beta	0.496	0.17	76-80
Sepsis	Beta	0.467	0.18	80-86
ARDS	Triangular	0.10	0.08-0.15	87
Long COVID symptoms (fatigue, dyspnea, myalgia; proxy for reduction in productivity, i.e., presenteeism)	Uniform		0.66-0.79	88-97

*Note: We utilized a standard 3% rate to inflate all past costs, regardless of year, per recommendations from the Panel of Cost-Effectiveness in Health and Medicine.[9,10] Absenteeism results in productivity losses for the symptom duration. Presenteeism productivity losses are calculated by attenuating an individual's wage by the utility weight for long COVID symptoms. Vaccinated individuals could get 2 or 3 doses (e.g., booster) and accrued productivity losses for the time to get vaccinated. Hospitalization costs include the cost for the entire hospital stay, excluding professional (for example, physician) fees.

[a]Values are 95% confidence interval

[b]Assumes 5 to 10 mg/kg of ibuprofen orally every 6 to 8 hours as needed OR 10 to 15 mg/kg of acetaminophen orally every 4 to 6 hours as needed

[c]Assumes 200 mg of ibuprofen or acetaminophen orally every 4 to 6 hours as needed

[d]Uses International Classification of Diseases, Tenth Revision, Clinical Modification (ICD10) code #J13 Pneumonia due to Streptococcus pneumoniae

[e]Uses International Classification of Diseases, Tenth Revision, Clinical Modification (ICD10) code #J11.89 Influenza due to unidentified influenza virus with other manifestations

[f]Uses International Classification of Diseases, Tenth Revision, Clinical Modification (ICD10) code #R65.21 Severe sepsis with septic shock

[g]Data for age-group unavailable and uses lowest values of all age-groups as a proxy

[h]Uses International Classification of Diseases, Tenth Revision, Clinical Modification (ICD10) code #J96.22 Acute and chronic respiratory failure with hypercapnia for 18 years and older and ICD10 code #J96.20 Acute and chronic respiratory failure, unspecified whether with hypoxia or hypercapnia for 0 to 17-year olds

[i]Uses International Classification of Diseases, Tenth Revision, Clinical Modification (ICD10) code #T78.2 Anaphylactic shock, unspecified
[j]Values are a relative +/- 10% of the mean or median value
[k]Values are interquartile range
[l]Uses data from influenza vaccinations as a proxy
[m]Values are 10%-90%
[n]Uses influenza without hospitalization as a proxy
[o]Uses influenza with hospitalization as a proxy

Appendix Table 2. Model-generated clinical outcomes and CDC/COVID-NET reported data

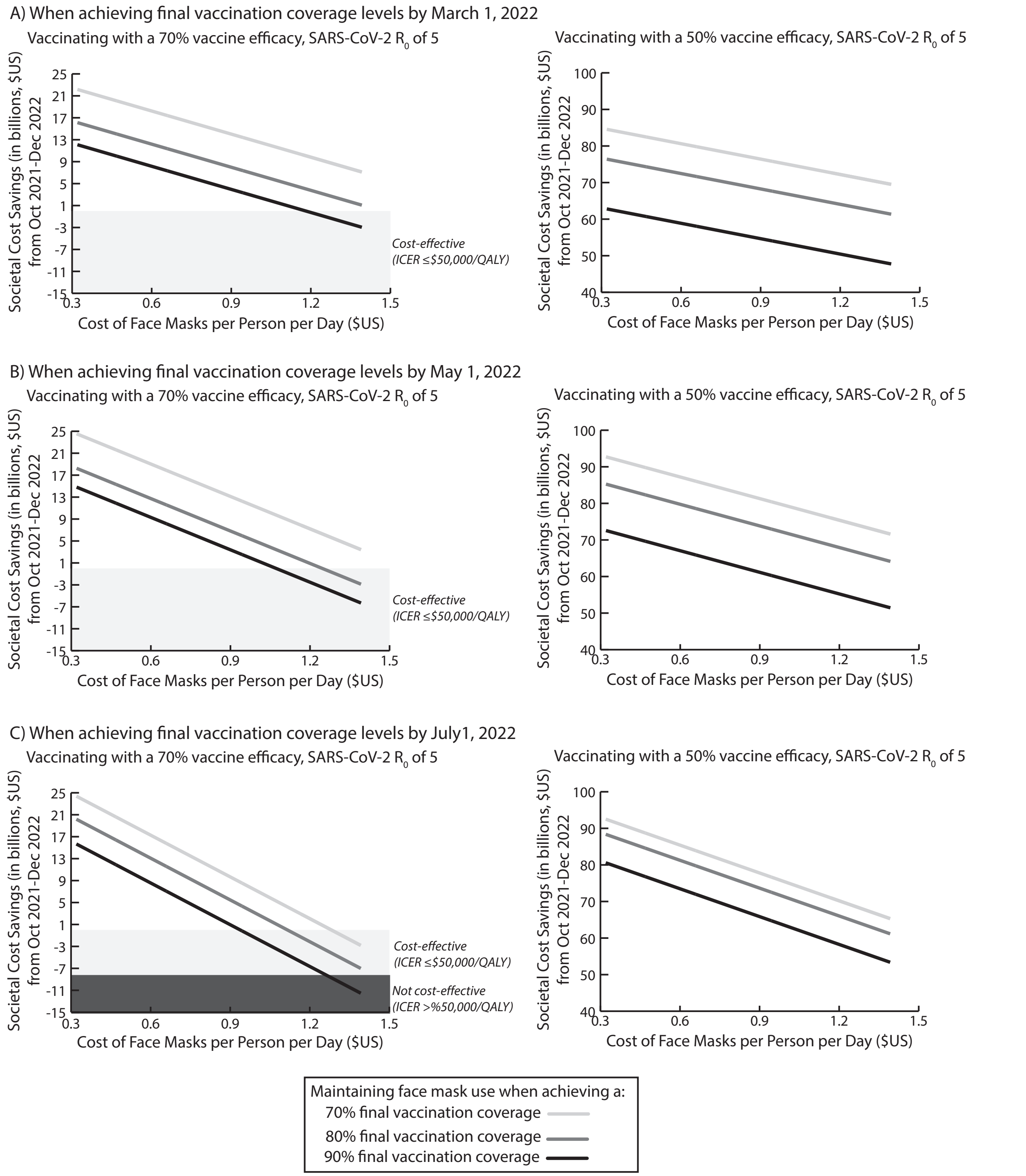
	SARS-CoV-2 Infections	Symptomatic Cases	Hospitalizations**	Number Deaths
Model-generated outcomes through October 1, 2021				
All ages		100,073,580.33	6,739,440	787,375
0 to 17		22,451,302.25	205,931	1,263
18 to 44		35,920,131.12	289,612	25,784
45 to 64		25,664,556.85	2,120,687	122,454
≥65		16,037,590.11	4,123,210	637,874
CDC Data (note different age groups and for which missing data is reported)				
Total*	35,502,419		2,420,372	589,172
0 to 17	5,279,186		44,100	718
18 to 49	18,859,138		512,061	34,415
50 to 64	6,842,295		845,743	97,988
≥65	4,521,800		1,018,468	456,051

NOTE: Cases and Death counts reported by CDC as of October 1, 2021[21]; hospitalizations and ICU admissions reported by CDC through October 1, 2021[20]

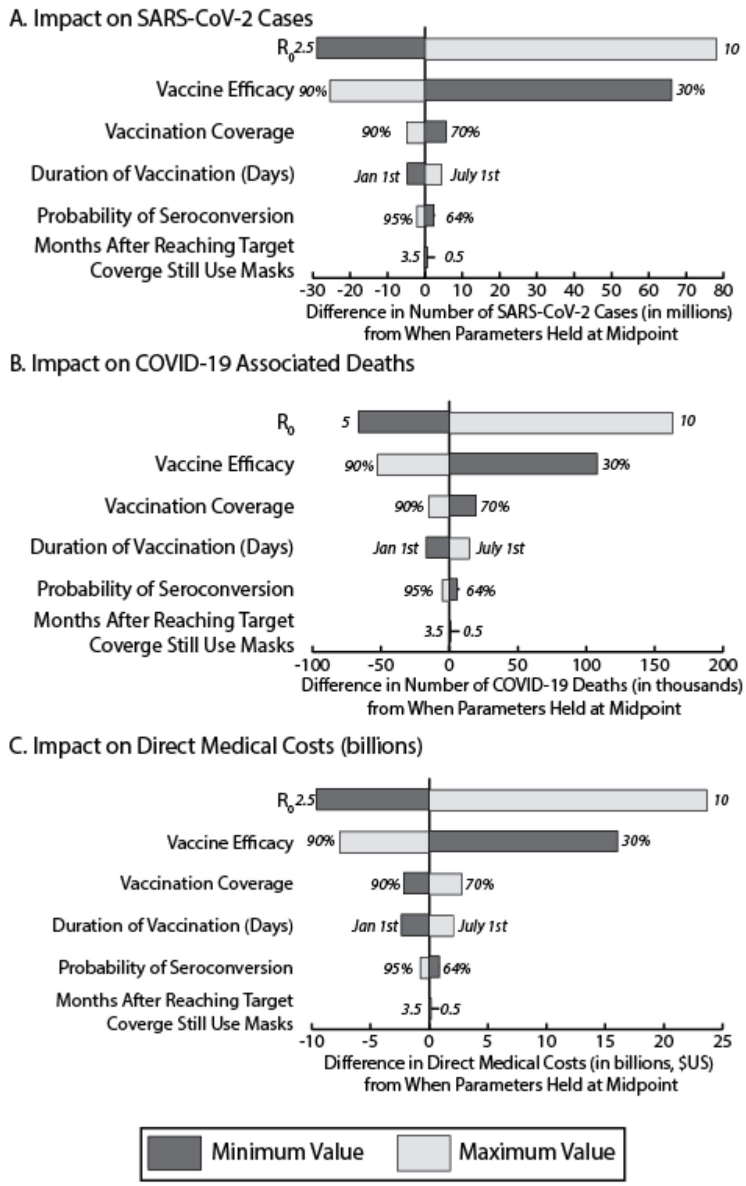
*Age group not available for 2% of cases and 1% of deaths

** The Coronavirus Disease 2019 (COVID-19)-Associated Hospitalization Surveillance Network (COVID-NET) hospitalization data are preliminary and subject to change as more data become available. In particular, case counts and rates for recent hospital admissions are subject to lag. As data are received each week, prior case counts and rates are updated accordingly. COVID-NET conducts population-based surveillance for laboratory-confirmed COVID-19-associated hospitalizations in children (less than 18 years of age) and adults. COVID-NET covers nearly 100 counties in the 10 Emerging Infections Program (EIP) states (CA, CO, CT, GA, MD, MN, NM, NY, OR, TN) and four Influenza Hospitalization Surveillance Project (IHSP) states (IA, MI, OH, and UT). Incidence rates (per 100,000 population) are calculated using the National Center for Health Statistics' (NCHS) vintage 2019 bridged-race postcensal population estimates for the counties included in the surveillance catchment area**. The rates provided are likely to be underestimated as COVID-19 hospitalizations might be missed due to test availability and provider or facility testing practices.***[emphasis added]*"[98]

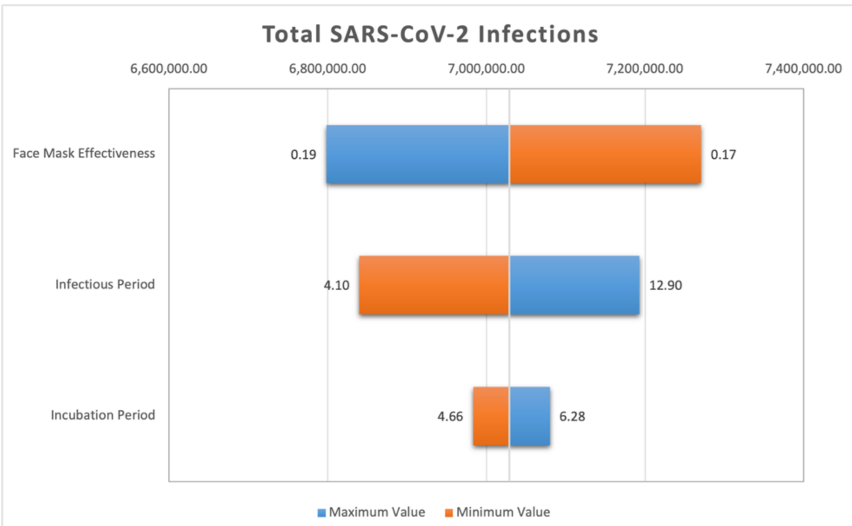
Appendix Figure 3. How cost-savings/cost-effectiveness of face masks use changes with the cost of face masks.

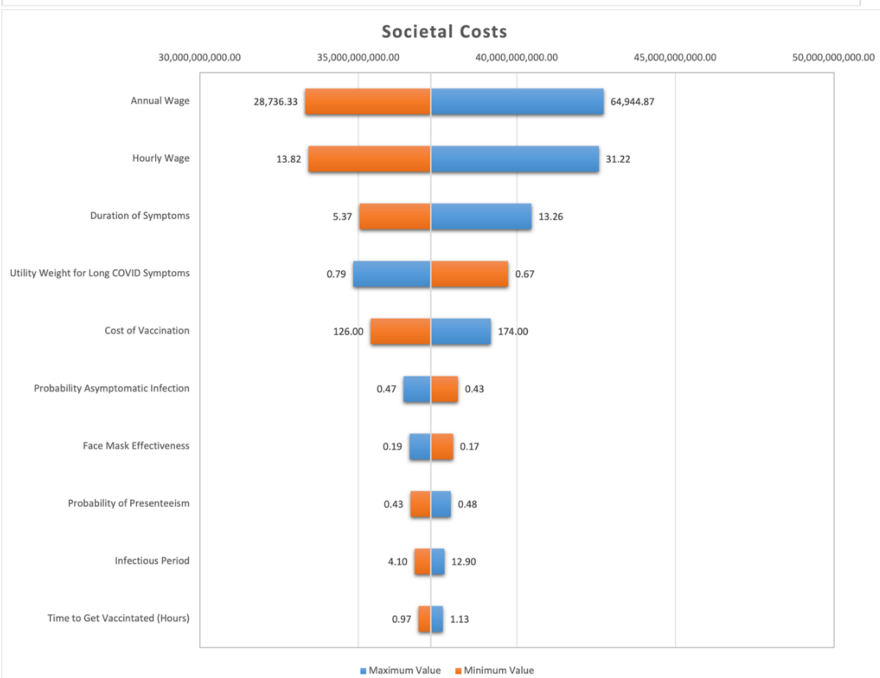


Appendix Figure 4. Impact of key parameters on A) SARS-CoV-2 cases, B) COVID-19 associated deaths, and C) direct medical costs when using face masks. The x-axis shows the magnitude of the impact when parameters are varied to their minimum and maximum values. The vertical line at zero indicates the point at which all variables on the y-axis are held at their midpoint value. The width of the bar shows the range of the impact each parameter had when varied from its minimum value to its maximum value.



Appendix Figure 5. Impact of model input parameters (Appendix Table 1) on total SARS-CoV-2 infections and total societal costs with a vaccine that prevents infection (70% vaccine efficacy) and severe disease and maintaining face mask use when achieving an 80% vaccination coverage level and protection onset occurs by March 1, 2022 with an R_0 of 5. The x-axis shows the magnitude of the impact when parameters are varied to the minimum and maximum ends of their ranges; midpoint line on the x-axis indicates the point for the target result at which all variables on the y-axis are held at their midpoint values. The width of the bar shows the range of impact that each parameter had when varied from its minimum to maximum value. To note, plots of total cases only include those parameters that affect this number (e.g., costs of hospitalization, etc. are not included) while plots of costs only include the top 10 parameters that impacted this value, which account for 99.9% of variation.





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