DATA SOURCES
Appendix Table 1 shows key model input parameters, values, distribution type, and sources. All costs, clinical probabilities, and durations were age-specific when available and come from scientific literature or nationally representative data sources. The probability of an infected individual being a given age was based on the age-distribution of cases in the U.S. and age-specific COVID-19 data are specific to the U.S. context as of March 16, 2020. We report all costs in 2020 values, converting all past and future values to net present value using a 3% discount rate. We parameterized seeding SARS-CoV-2-infected persons into the population for a given $R_0$ such that simulated cases reflected case data reported as of March 24, 2020.

MODEL PARAMETERIZATION
We parameterized the number of individuals starting in the $I_a$ state and $I_s$ state on day one (i.e., coronavirus seed) SARS-CoV2-infected persons into the population for a given $R_0$ such that simulated cases reflected case data reported as of March 24, 2020. This date was the last date for which data was available at the time of model calibration. When the asymptomatic individuals were half as infectious as symptomatic individuals, for an $R_0$ of 2.5, this was equivalent to 400 symptomatic cases and 87 asymptomatic cases; for an $R_0$ of 3.5 this was 50 symptomatic cases and 11 asymptomatic cases. When the probability of asymptomatic infection was 35% and asymptomatic individuals were as infectious as symptomatic individuals (i.e., relative infectiousness of asymptomatic infection 100%), for an $R_0$ of 2.5, this was equivalent to 250 symptomatic cases and 134 asymptomatic cases; for an $R_0$ of 3.5 this was 26 symptomatic cases and 14 asymptomatic cases. All of these parameterizations have a ratio of symptomatic to asymptomatic persons based on the probability of having symptoms.
Appendix
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Appendix Figure 1. Model structure A) transmission and B) clinical pathway of COVID-19 cases.

A.

1. Susceptible (S)
   - susceptible\(^{-}\)vaccination coverage
   - Exposed (E)
     - Infectious: Asymptomatic (la)
       - 1/duration infectiousness
     - Infectious: Symptomatic (lb)
       - 1/duration infectiousness
   - Recovered/Immune (R)

B.

Severe Disease Outcomes
- Severe Pneumonia
  - ICU Admission
  - ARDS\(^{-}\)
  - No ICU Admission
    - Survive
    - Die
- Severe Non-pneumonia
  - ICU Admission
  - ARDS\(^{-}\)
  - No ICU Admission
    - Survive
    - Die

Ambulatory Care
- Infectious: Symptomatic (a)
  - Telephone Consult
  - Hospitalized\(^{+}\)
    - Survive
    - Die
  - Not Hospitalized
    - Survive
    - Die

Hospitalized\(^{+}\)

VE = vaccine efficacy; it is turned on/off in either or both of these places in the model, depending on scenario
\(\beta\) = symptomatic beta
\(\beta_{I}\) = asymptomatic beta
\(\gamma\) = viral shedding, depending on scenario
#Any individual in the population could be vaccinated, however the vaccine had no impact on those already infected and/or exposed

\(^{+}\) Person starts with mild infection
\(^{*}\) Person progresses to severe disease requiring hospitalization
\(^{*}\) ARDS = acute respiratory distress syndrome, with or without sepsis

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### Appendix Table 1. Model Parameter Inputs, Values, and Sources

| Parameter                                      | Distribution type | Mean or median | SE or range       | Source |
|------------------------------------------------|-------------------|----------------|-------------------|--------|
| **SARS-CoV-2 transmission**                    |                   |                |                   |        |
| Latent period (days)                           | Triangular        | 5.2            | 4.1–7.0           | 3      |
| Infectious period (days)                       | Uniform           | 3–14           |                   | 4-7    |
| **Costs (2020 US$)**                           |                   |                |                   |        |
| Annual wages (all occupations)                 | Beta pert         | 40,993         | 21,950–104,403a   | 8      |
| Ambulatory care visit                          | Uniform           |                | 110.43–148.33     | 9      |
| **Over the counter medications, daily**        |                   |                |                   |        |
| 0–12 years old                                 | Gamma             | 3.87           | 2.10              | 10     |
| ≥13 years old                                  | Gamma             | 0.46           | 0.17              | 10     |
| **Hospitalization for pneumonia**              |                   |                |                   |        |
| 0–17 years old                                 | Gamma             | 12,502.30      | 1,508.04          | 11     |
| 18–44 years old                                | Gamma             | 10,627.15      | 1,045.06          | 11     |
| 45–64 years old                                | Gamma             | 13,718.14      | 1,238.76          | 11     |
| 65–84 years old                                | Gamma             | 12,264.39      | 478.40            | 11     |
| ≥85 years old                                  | Gamma             | 10,982.73      | 518.29            | 11     |
| **Hospitalization for severe non-pneumonia (all ages)** | Gamma           | 6,886.53       | 1,182.99          | 11     |
| **Hospitalization for sepsis**                 |                   |                |                   |        |
| 0–17 years old                                 | Gamma             | 22,694.30      | 1,861.33          | 11     |
| 18–44 years old                                | Gamma             | 43,778.39      | 5,382.40          | 11     |
| 45–64 years old                                | Gamma             | 38,734.24      | 2,725.10          | 11     |
| 65–84 years old                                | Gamma             | 30,308.29      | 1,367.91          | 11     |
| ≥85 years old                                  | Gamma             | 22,694.30      | 1,861.33          | 11     |
| **Hospitalization for acute respiratory distress syndrome (ARDS)** | Gamma | 42,350.58 | 4,198.97 | 11 |
| 0–17 years old                                 | Gamma             | 26,210.96      | 1,558.61          | 11     |
| 45–64 years old                                | Gamma             | 19,863.98      | 453.92            | 11     |
| 65–84 years old                                | Gamma             | 18,718.55      | 335.69            | 11     |
| ≥85 years old                                  | Gamma             | 16,559.75      | 754.12            | 11     |
| **Probabilities**                              |                   |                |                   |        |
| Asymptomatic infection                         | Beta              | 0.179          | 0.155 - 0.202     | 12     |
| Relative infectiousness of asymptomatic infection| Point estimate | 0.5            |                   | Assumption²,13 |
| Missing work/school                            | Point estimate    | 1.0            |                   | Assumption |
| Ambulatory care                                |                   |                |                   |        |
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| Age-group | Beta | Point estimate | 14 |
|-----------|------|----------------|----|
| 0–4 years old | 0.455 | 0.098 | 14 |
| 5–17 years old | 0.318 | 0.061 | 14 |
| 18–64 years old | 0.313 | 0.014 | 14 |
| ≥65 years old | 0.62 | 0.027 | 14 |

Probability of hospitalization, given infection

| Age-group | Point estimate | 1 |
|-----------|----------------|----|
| 0–19 years old | 0.016 | 1 |
| 20–44 years old | 0.143 | 1 |
| 45–64 years old | 0.208 | 1 |
| 65–84 years old | 0.292 | 1 |
| ≥85 years old | 0.313 | 1 |

Probability of intensive care unit (ICU) admission

| Age-group | Point estimate | 1 |
|-----------|----------------|----|
| 0–19 years old | 0.0 | 1 |
| 20–44 years old | 0.1399 | 1 |
| 45–64 years old | 0.2422 | 1 |
| 65–84 years old | 0.3048 | 1 |
| ≥85 years old | 0.2013 | 1 |

Probability of mortality

| Age-group | Point estimate | 1 |
|-----------|----------------|----|
| 0–19 years old | 0.0 | 1 |
| 20–44 years old | 0.007 | 1 |
| 45–64 years old | 0.0456 | 1 |
| 65–84 years old | 0.1109 | 1 |
| ≥85 years old | 0.3323 | 1 |

Pneumonia, given hospitalization

| Beta | Point estimate | 15 |
|------|----------------|----|
| 0.79 | 0.711–0.869 | 15 |

ARDS, requiring ventilator use

| Beta | Point estimate | 16,17 |
|------|----------------|------|
| 0.73 | 0.1697 | 16,17 |

Age-group, given infection

| Age-group | Point estimate | 1 |
|-----------|----------------|----|
| 0–19 years old | 0.0502 | 1 |
| 20–44 years old | 0.2879 | 1 |
| 45–64 years old | 0.3503 | 1 |
| 65–84 years old | 0.2528 | 1 |
| ≥85 years old | 0.0588 | 1 |

Durations (days)

| Ambulatory care | Triangular | 0.5 | 3–17 | 6,18,19 |
| Duration of symptoms with mild illness | 7 | 3–17 | 6,18,19 |
| Duration of symptoms prior to hospital admission | Triangular | 7 | 3–9 | 16,20 |

Hospitalization for pneumonia

| Age-group | Gamma | 11 |
|-----------|-------|----|
| 0–17 years old | 4.7 | 0.4 | 11 |
| 18–44 years old | 4.3 | 0.4 | 11 |
| 45–64 years old | 5.1 | 0.2 | 11 |
| 65–84 years old | 5.5 | 0.2 | 11 |
| Age Group          | Parameter | Gamma Mean | SE Gamma | Notes |
|--------------------|-----------|------------|----------|-------|
| ≥85 years old      | Hospitalization for severe non-pneumonia (all ages) | Gamma | 5.0 | 0.2 | 11 |
| Hospitalization for sepsis | Gamma | 3.1 | 0.5 | 11 |
| 0–17 years old     | Hospitalization for acute respiratory distress syndrome (ARDS) | Gamma | 7.3 | 0.5 | 11 |
| 18–44 years old    | Hospitalization for acute respiratory distress syndrome (ARDS) | Gamma | 11.2 | 1.3 | 11 |
| 45–64 years old    | Hospitalization for acute respiratory distress syndrome (ARDS) | Gamma | 10.7 | 0.5 | 11 |
| 65–84 years old    | Hospitalization for acute respiratory distress syndrome (ARDS) | Gamma | 8.8 | 0.4 | 11 |
| ≥85 years old      | Hospitalization for acute respiratory distress syndrome (ARDS) | Gamma | 7.3 | 0.5 | 11 |

| Age Group          | Parameter | Gamma Mean | SE Gamma | Notes |
|--------------------|-----------|------------|----------|-------|
| 0–17 years old     | Hospitalization for acute respiratory distress syndrome (ARDS) | Gamma | 9.5 | 0.75 | 11 |
| 18–44 years old    | Hospitalization for acute respiratory distress syndrome (ARDS) | Gamma | 8.8 | 0.5 | 11 |
| 45–64 years old    | Hospitalization for acute respiratory distress syndrome (ARDS) | Gamma | 7.1 | 0.1 | 11 |
| 65–84 years old    | Hospitalization for acute respiratory distress syndrome (ARDS) | Gamma | 7.0 | 0.1 | 11 |
| ≥85 years old      | Hospitalization for acute respiratory distress syndrome (ARDS) | Gamma | 6.1 | 0.3 | 11 |

**Notes:**
- aValues are 95% CI.
- bAssumes 5 to 10 mg/kg orally every 6 to 8 hours as needed OR 10 to 15 mg/kg orally every 4 to 6 hours as needed.
- cAssumes 200 mg orally every 4 to 6 hours as needed.
- dUses ICD-10-CM code #J13 Pneumonia due to *Streptococcus pneumoniae*.
- eUses ICD-10-CM code #J11.89 Influenza due to unidentified influenza virus with other manifestations.
- fUses ICD-10-CM code #R65.21 Severe sepsis with septic shock.
- gData for age-group unavailable and uses lowest values of all age-groups as a proxy.
- hUses ICD-10-CM code #J96.22 Acute and chronic respiratory failure with hypercapnia for 18 years and older and ICD-10-CM code #J96.20 Acute and chronic respiratory failure, unspecified whether with hypoxia or hypercapnia for 0 to 17-year-olds.
- iValues account for the age-specific probability of infection.
- jValues are 10%–90%.
### Appendix Table 2. Number of Clinical Outcomes, Resource Use, and Costs Due to COVID-19 During the Course of an Epidemic When Vaccination Occurs When 0% of the Population Has Been Exposed to SARS-CoV-2 With a Vaccine That Prevents Infection, Varying With Vaccine Efficacy

| Scenario | Total SARS-CoV-2 cases (in millions) | Symptomatic cases (in millions) | Hospitalized cases (in millions) | Number of patients ventilated (in millions) | Deaths (in thousands) | Total beds days (in millions) | Ventilated days (in millions) | Direct medical costs (in billions) | Productivity losses (in billions) |
|----------|--------------------------------------|---------------------------------|----------------------------------|---------------------------------------------|----------------------|-----------------------------|-------------------------------|-------------------------------|-------------------------------|
|          | Median (95% CI)                      | Median (95% CI)                 | Median (95% CI)                  | Median (95% CI)                             | Median (95% CI)      | Median (95% CI)              | Median (95% CI)               | Median (95% CI)               | Median (95% CI)               |
| R₀ of 2.5|                                      |                                 |                                  |                                             |                      |                             |                               |                               |                               |
| No vaccine | 282.5 (280.7, 284.3)                | 232.1 (223.9, 240.0)            | 48.1 (46.4, 49.8)                | 8.5 (6.5, 9.7)                              | 4,160.9 (4,014.2, 4,302.0) | 267.2 (251.7, 282.6) | 68.0 (51.8, 77.9) | 883.5 (808.5, 980.8) | 2,796.4 (1,661.8, 4,515.5) |
| 60% vaccine efficacy, 75% coverage | 43.0 (7.1, 53.8)                    | 37.7 (6.2, 48.5)                | 7.8 (1.3, 10.0)                  | 1.3 (0.2, 1.9)                              | 675.9 (111.3, 869.0) | 43.3 (7.2, 56.1) | 10.5 (1.7, 15.1) | 225.2 (22.2, 183.9) | 62.5 (62.5, 771.4) |
| 70% vaccine efficacy, 75% coverage | 0.10 (0.04, 0.72)                   | 0.09 (0.03, 0.65)               | 0.02 (0.01, 0.1)                 | 0.003 (0.001, 0.02)                         | 1.63 (0.58, 11.6)    | 0.10 (0.04, 0.75) | 0.03 (0.01, 0.19) | 0.03 (0.12, 2.34) | 0.32 (0.32, 8.61) |
| 80% vaccine efficacy, 60% coverage | 27.1 (3.5, 45.8)                    | 22.6 (2.9, 39.4)                | 4.7 (0.6, 8.2)                   | 0.8 (0.1, 1.5)                              | 404.3 (51.3, 705.5)  | 25.9 (3.3, 45.8) | 6.5 (0.8, 11.9) | 81.2 (10.5, 147.5) | 239.0 (28.8, 604.0) |
| R₀ of 3.5|                                      |                                 |                                  |                                             |                      |                             |                               |                               |                               |
| No vaccine | 312.9 (311.9, 314.0)                | 257.1 (248.7, 264.8)            | 53.3 (51.6, 54.9)                | 9.5 (7.2, 10.7)                             | 4,608.3 (4,458.0, 4,747.6) | 296.0 (281.4, 312.1) | 76.2 (57.6, 85.7) | 978.9 (896.4, 1,082.3) | 3,141.3 (1,871.3, 5,059.2) |
| 80% vaccine efficacy, 75% coverage | 39.3 (5.6, 46.2)                    | 33.3 (4.7, 40.5)                | 6.9 (1.0, 8.4)                   | 1.1 (0.2, 1.6)                              | 596.7 (84.5, 726.9)   | 38.2 (5.4, 46.9) | 9.1 (1.4, 12.7) | 119.7 (17.2, 154.3) | 54.3 (54.3, 652.7) |
| 80% vaccine efficacy, 60% coverage | 110.9 (105.2, 119.3)                | 91.6 (86.9, 96.1)               | 19.0 (18.0, 19.9)                | 3.3 (2.6, 3.8)                              | 1,642.8 (1,558.7, 1,723.1) | 105.5 (98.2, 112.8) | 26.7 (20.3, 31.0) | 345.4 (311.2, 386.9) | 1,076.7 (644.0, 1,795.9) |
APPENDIX REFERENCES

1. Severe Outcomes Among Patients with Coronavirus Disease 2019 (COVID-19) — United States, February 12–March 16, 2020. MMWR Morb Mortal Wkly Rep. 2020;69(12):343–346. https://doi.org/10.15585/mmwr.mm6912e2.
2. CDC. COVID-19 Pandemic Planning Scenarios. https://www.cdc.gov/coronavirus/2019-ncov/hcp/planning-scenarios.html. Published May 20, 2020. Accessed June 1, 2020.
3. Li Q, Guan X, Wu P, et al. Early transmission dynamics in Wuhan, China, of novel coronavirus–infected pneumonia. N Engl J Med. 2020;382(13):1199–1207. https://doi.org/10.1056/nejmoa2001316.
4. Ling Y, Xu S, Lin Y, et al. The persistence and clearance of viral RNA in 2019 novel coronavirus disease survivors. Chin Med J (Engl). 2020;133(9):1039–1043. https://doi.org/10.1097/CM9.0000000000000774.
5. Wolfel R, Corman VM, Guggemos W, et al. Virological assessment of hospitalized patients with COVID-2019. Nature. 2020;581(7809):465–469. https://doi.org/10.1038/s41586-020-2196-x.
6. Chang, Mo G, Yuan X, et al. Time kinetics of viral clearance and resolution of symptoms in novel coronavirus infection. Am J Respir Crit Care Med. 2020;201(9):1150–1152. https://doi.org/10.1164/rccm.202003-0524le.
7. To KK, Tsang OT, Leung WS, et al. Temporal profiles of viral load in posterior oropharyngeal saliva samples and serum antibody responses during infection by SARS-CoV-2: an observational cohort study. Lancet Infect Dis. 2020;20(5):565–574. https://doi.org/10.1016/S1473-3099(20)30196-1.
8. Bureau of Labor Statistics. Occupational employment statistics: May 2018 national occupational employment and wage estimates, United States. https://www.bls.gov/oes/2018/may/oes_nat.htm. Published April 2, 2019. Accessed October 9, 2019.
9. Centers for Medicare & Medicaid Services. Physician Fee Schedule. https://www.cms.gov/apps/physician-fee-schedule/. Published 2020. Accessed April 13, 2020.
10. Walgreens Co. Price listing. https://www.walgreens.com. Published 2020. Accessed March 17, 2020.
11. HHS. HCUP facts and figures: statistics on hospital-based care in the United States. https://hcupnet.ahrq.gov/#setup. Published 2016. Accessed March 17, 2020.
12. Mizumoto K, Kagaya K, Zarebski A, Chowell G. Estimating the asymptomatic proportion of coronavirus disease 2019 (COVID-19) cases on board the Diamond Princess cruise ship, Yokohama, Japan, 2020. Euro Surveill. 2020;25(10):2000180. https://doi.org/10.2807/1560-7917.es.2020.25.10.2000180.
13. Ferguson N, Laydon D, Nedjati Gilani G, et al. Report 9: Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand. Imperial College London. https://www.imperial.ac.uk/media/imperial-college/medicine/sph/ide/gida-fellowships/Imperial-College-COVID19-NPI-modelling-16-03-2020.pdf. Published March 16, 2020. Accessed July 1, 2020.
14. Molinari N-AM, Ortega-Sanchez IR, Messonnier ML, et al. The annual impact of seasonal influenza in the US: measuring disease burden and costs. Vaccine. 2007;25(27):5086–5096. https://doi.org/10.1016/j.vaccine.2007.03.046.
15. Guan WJ, Ni ZY, Hu Y, et al. Clinical characteristics of coronavirus disease 2019 in China. *N Engl J Med*. 2020;382(18):1708–1720. https://doi.org/10.1056/nejmoa2002032.

16. Wang D, Hu B, Hu C, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China. *JAMA*. 2020;323(11):1061–1069. https://doi.org/10.1001/jama.2020.1585.

17. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet*. 2020;395(10223):497–506. https://doi.org/10.1016/s0140-6736(20)30183-5.

18. Arashiro T, Furukawa K, Nakamura A. COVID-19 in 2 persons with mild upper respiratory symptoms on a cruise ship, Japan. *Emerg Infect Dis*. 2020;26(6):1345–1348. https://doi.org/10.3201/eid2606.200452.

19. Duszynski T. What does it mean to ‘recover from coronavirus’? Here’s what you need to know. *Science Alert. Health*. April 11, 2020. https://www.sciencealert.com/this-is-what-it-means-to-recover-from-corona-and-what-you-can-do-after. Accessed July 1, 2020.

20. Garg S, Kim L, Whitaker M, et al. Hospitalization rates and characteristics of patients hospitalized with laboratory-confirmed coronavirus disease 2019 — COVID-NET, 14 states, March 1–30, 2020. *MMWR Morb Mortal Wkly Rep*. 2020;69(15):458–464. https://doi.org/10.15585/mmwr.mm6915e3.