Supplementary Material

Appendix A. Model Details

A1. Model Equations

We develop a susceptible-exposed-infectious-removed (SEIR) model to characterize the evolution of COVID-19 across age and risk groups in Japan. We consider five age groups in the model: children in age 0–19, adults in age 20–39, adults in age 40–59, the elderly in age 60–79, and the oldest in age 80+. Later in the rollout simulation, we combine age 20–39 and 40–59 into one age group following policies in Japan and other countries where young adults (age 20-59) are treated as a single age group apart from children, the elderly, and the oldest. In addition to age, individuals further differ by their risk status, and high-risk individuals have at least one medical condition listed as a risk factor for COVID-19.[1] We assume that one individual in each age-risk group was infected with SARS-CoV-2 on February 1, 2020, the model's start date.

Figure A1 illustrates the SEIR model. Infected individuals first enter an incubation period (E). At rate σ, they become infectious, and a fraction ρ_{ar} of infectious individuals is admitted to hospitals due to severe symptoms (H). The admission rate ρ_{ar} differs by age a and risk status r. Infectious individuals without severe symptoms enter self-quarantine (Q) at probability ω, and those not in quarantine (at home or in a hospital), denoted by A, transmit the virus through contact. Infectious individuals with severe symptoms recover (R) at rate γ_H, and those without severe symptoms recover (R) at rate γ_A. Severe cases may transition to the deceased state (D) at rate m_{ar}.

[1] The Ministry of Health, Labour and Welfare of Japan determines the risk factors for COVID-19. The list of high-risk conditions is available at https://www.mhlw.go.jp/content/000759274.pdf (accessed 24 October 2021)

Let $c_{aa'}$ be the number of contacts an individual of age a has with those of age a'. β_a is the susceptibility of individuals of age a. The susceptible population S_{ar} depends on the following equation:

$$\dot{S}_{ar} = -\beta_a S_{ar} \sum_{a'} c_{aa'} \left(\frac{A_{a'}}{N_{a'}}\right),$$

where $N_{a'}$ is the number of individuals of age a' and $\frac{A_{a'}}{N_{a'}}$ is the share of age group a' who are infectious and not in quarantine. We similarly derive the dynamics for the other components as follows:

$$\dot{E}_{ar} = \beta_a S_{ar} \sum_{a'} c_{aa'} \left(\frac{A_{a'}}{N_{a'}}\right) - \sigma E_{ar},$$

$$\dot{H}_{ar} = \sigma p_{ar} E_{ar} - \gamma_H H_{ar} - m_{ar} H_{ar},$$

$$\dot{D}_{ar} = m_{ar} H_{ar},$$

$$\dot{A}_{ar} = \sigma(1 - p_{ar})(1 - \omega) E_{ar} - \gamma_A A_{ar},$$

$$\dot{Q}_{ar} = \sigma(1 - p_{ar})\omega E_{ar} - \gamma_A Q_{ar}, \text{ and}$$

$$\dot{R}_{ar} = \gamma_A (A_{ar} + Q_{ar}) + \gamma_H H_{ar}.$$

We calibrate the model to match the weekly deaths by age group as published by the National Institute of Population and Social Security Research.[2] We use population surveillance data from Stokes et al. [1] to calibrate the share of infectious individuals with severe cases, p_{ar}. Next, we describe the model calibration.

[2] The data are available at http://www.ipss.go.jp/projects/j/choju/covid19/index-en.asp (accessed 24 October 2021)

A2. Model Parameters

We calibrate several parameters from the literature. According to surveillance data in the US [1], high-risk individuals with chronic conditions are six times more at risk of hospitalization due to COVID-19. We use detailed hospitalization rates across risk statuses and age groups to quantify the severe case rate p_{ar} in our model. We assume an incubation period $1/\sigma = 5$ and an infectious period $1/\gamma_A = 5$, both based on Kissler et al. [3]. We assume a recovery rate for hospitalized cases $\gamma_H = 1/12$ from Sanche et al. [2]. We use Ibuka et al. [4] for the contact matrix by age group in Japan.

We obtain the population size by age group in Japan from the Population Census. High-risk individuals are those with at least one medical condition listed as a risk factor for COVID-19. Based on this definition, we obtain the share of high-risk individuals by age group from the Comprehensive Survey of Living Conditions, a survey of population health and income. We calibrate the mortality rate m_{ar}based on the COVID-19 Registry Study [5], a survey of COVID-19 cases in health facilities in Japan. The survey provides summary statistics on the number of deceased and recovered cases by age and risk status,[3] and we infer the mortality rate m_{ar} from the statistics. Specifically, the deceased share d_{ar} observed for hospitalized cases in age a and risk r equals $d_{ar} = \frac{m_{ar}}{m_{ar} + \gamma_H}$, the relative exit rate to the recovered (R) and the deceased (D) states. We then solve for m_{ar} based on the relation.

[3] The summary statistics are available at https://www.niid.go.jp/niid/ja/diseases/ka/corona-virus/2019-ncov/2488-idsc/iasr-news/10080-491p03.html

We estimate the susceptibility β_a matching model predicted deaths with weekly data by age group in Japan. Given the calibrated values of hospitalization p_{ar} and mortality rate m_{ar}, deaths from COVID-19 are informed by the virus transmission pattern given by contact and susceptibility across age groups. To account for time-varying factors affecting contact, we adjust β_a by a multiplier τ_t that differs each quarter in 2020–2021. The adjustment coincides with the onset of the two state-of-emergencies in Japan: the first beginning in the second quarter of 2020 (April 7, 2020), and the second beginning in the first quarter of 2021 (January 7, 2021). The second half of 2020 saw sustained easing of travel restrictions and surges of infections in the fourth quarter.[4] These seasonal differences and changes from policies are captured in the quarterly adjustment on contact. In addition, we estimate a fixed quarantine rate ω over the sample period.

We estimate the age-specific susceptibility $\boldsymbol{\beta_a}$ for 5 age groups, quarterly adjusters $\boldsymbol{\tau_t}$, and the self-quarantine rate ω using a least squares loss function minimizing the prediction errors of deaths by age groups. The least squares criterion is commonly used to fit deterministic transmission models of diseases [6-10]. In particular, we adopt the following loss function

$$\min_{\boldsymbol{\theta}} \sum_{a,t} \left(\boldsymbol{D}_{at}^{\boldsymbol{\theta}} - \boldsymbol{D}_{at}\right)^2,$$

where $\boldsymbol{D}_{at}^{\boldsymbol{\theta}}$ is the model predicted death count by time t in age group a, and parameter $\boldsymbol{\theta} = (\boldsymbol{\beta_a}, \boldsymbol{\tau_t}, \omega)$ is a 10*1 vector of parameters. We solve the minimizing problem using a Nelder-Mead Simplex algorithm from the NLopt package on PYTHON version 3.8. We find that 68% of infectious individuals are self-quarantined, and the seasonal adjusters indicate substantial contact

[4] A summary of COVID-19 developments in Japan can be found at https://english.kyodonews.net/news/2021/04/29b154a681ba-chronology-of-major-events-related-to-coronavirus-and-japan.html (accessed July 2022).

reductions following the onset of state-of-emergencies in the second quarter of 2020 and the first quarter of 2021. Our susceptibility estimates indicate higher susceptibility for adults compared to children and especially high susceptibility among the oldest elderly, similar to the age pattern identified in the literature [11]. Table A1 lists the model parameters, values, and the sources of calibration.

Table A1. Model Parameters

Parameter	Name	Description and Value	Source
p_{ar}	Probability of severe cases by age-risk groups	Low risk: [0.027, 0.036, 0.079, 0.186, 0.301] High risk: [0.166, 0.217, 0.338, 0.563, 0.623]	Stokes et al. [1]
m_{ar}	Mortality rate of hospitalized cases	Low risk: [0.000083, 0.000083, 0.000083, 0.002, 0.012] for age groups 0–19, 20–39, 40–59, 60–79, 80+ High risk: [0.00084, 0.00084, 0.00084, 0.007, 0.021] for age groups 0-19, 20-39, 40-59, 60-79, 80+	Calibrated from the deceased share of hospitalized cases by age and risk status based on summary statistics published at https://www.niid.go.jp/niid/ja/diseases/ka/corona-virus/2019-ncov/2488-idsc/iasr-news/10080-491p03.html
β_a	Susceptibility by age group	[6.16e-07, 0.058, 0.18, 0.12, 0.26] for age groups 0–19, 20–39, 40–59, 60–79, 80+	Fitted from weekly death data by age group

$c_{aa'}$	Contact matrix	Number of contacts between an average person in age group a and persons in age group a'	Ibuka et al. [4]
τ_t	Seasonal adjustments	Differs each quarter in 2020–2021, applied to the contact matrix to capture multiple state-of-emergency issuances and seasonal patterns [0.42, 0.47, 0.63, 0.45] from the second quarter of 2020 onward	Fitted from weekly death data by age group
ω	Self-quarantine rate	Share of infectious individuals without severe symptoms entering self-quarantine 0.68	Estimated from weekly death data by age group
$1/\sigma$	Incubation period	Period in which infectious individuals are not yet infectious, assumed to be 5 days	Kissler et al. [3]
γ_H	Recovery rate of severe cases	Rate at which hospitalized patients recover, assumed to be 1/12	Sanche et al. [2]

γ_A	Recovery rate of non-severe cases	Rate at which infectious individuals without severe symptoms recover, assumed to be 1/5	Kissler et al. [3]
pop_{ar}	Population by age-risk group	Low risk: [15.59, 24.31, 26.16, 17.78, 7.1] millions in age groups 0–19, 20–39, 40–59, 60–79, 80+ High risk: [1.27, 2.48, 8.60, 14.26, 4.41] millions in age groups 0–19, 20–39, 40–59, 60–79, 80+	Population estimates by age and risk status from the Population Census and the Comprehensive Survey of Living Conditions; high-risk individuals have at least one medical condition listed as a risk factor for COVID-19

Table A1 summarizes the model parameters, values, and their sources. We estimate virus transmission including age-specific susceptibility, seasonal adjusters, and the self-quarantine rate from weekly death counts by age group in Japan. The remaining parameters are calibrated from external sources.

A3. Virus transmissibility R_0

Based on the next generation matrix [12,13], virus transmission among infected individuals can be written as follows

$$\dot{\boldsymbol{\mathcal{X}}} = \boldsymbol{\mathcal{F}} - \boldsymbol{\mathcal{V}},$$

where

$$\boldsymbol{\mathcal{X}} = \begin{bmatrix} \mathbf{E} \\ \mathbf{A} \\ \mathbf{Q} \\ \mathbf{H} \end{bmatrix}, \qquad \boldsymbol{\mathcal{F}} = \begin{bmatrix} \mathbf{U} \\ \mathbf{0} \\ \mathbf{0} \\ \mathbf{0} \end{bmatrix}, \qquad \boldsymbol{\mathcal{V}} = \begin{bmatrix} \sigma\mathbf{E} \\ \gamma_A\mathbf{A} - \sigma(1-\omega)(\mathbf{1}-\mathbf{p}) \otimes \mathbf{E} \\ \gamma_A\mathbf{Q} - \sigma\omega(\mathbf{1}-\mathbf{p}) \otimes \mathbf{E} \\ (\gamma_H\mathbf{1} + \mathbf{m}) \otimes \mathbf{H} - \sigma\mathbf{p} \otimes \mathbf{E} \end{bmatrix}.$$

In detail, $\mathbf{E} = [E_{00}, E_{01}, E_{10}, E_{11}, \dots, E_{40}, E_{41}]$ is a $10 * 1$ vector stacking exposed individuals by age and risk status. Likewise, **H**, **A**, and **Q** stack the hospitalized, asymptomatic, and the self-quarantine population by age-risk. **m** and **p** stack the transition probabilities to mortality and severe cases, respectively. $\otimes$ gives the element-wise product of matrices, and $\mathbf{1}$ and $\mathbf{0}$ are vectors of 1's and 0's, respectively.

In a fully susceptible population, transmission occurs through $\mathbf{U} = \boldsymbol{\rho} \otimes \mathbf{B}$ where $\boldsymbol{\rho} = [\rho_{00}, \rho_{01}, \dots, \rho_{40}, \rho_{41}]$ is the population share by age-risk and **B** denotes the contact-based infection rate. Because contact and susceptibility β do not differ by risk given age, each element occurs twice in **B** with the i-th element given by $B_i = \beta_{\lfloor \frac{i-1}{2} \rfloor} \sum_{k=0}^{4} c_{\lfloor \frac{i-1}{2} \rfloor k} (A_{k0} + A_{k1})$ and $\lfloor \cdot \rfloor$ is the floor operator.

The Jacobian matrix of $\boldsymbol{\mathcal{V}}$ is given by

$$\mathbf{V} = \begin{bmatrix} \sigma\boldsymbol{\Lambda}_{\mathbf{1}} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ -\sigma(1-\omega)\boldsymbol{\Lambda}_{\mathbf{1-p}} & \gamma_A\boldsymbol{\Lambda}_{\mathbf{1}} & \mathbf{0} & \mathbf{0} \\ -\sigma\omega\boldsymbol{\Lambda}_{\mathbf{1-p}} & \mathbf{0} & \gamma_A\boldsymbol{\Lambda}_{\mathbf{1}} & \mathbf{0} \\ -\sigma\boldsymbol{\Lambda}_{\mathbf{p}} & \mathbf{0} & \mathbf{0} & \boldsymbol{\Lambda}_{\gamma_H\mathbf{1}+\mathbf{m}} \end{bmatrix},$$

where $\boldsymbol{\Lambda}_{\mathbf{p}}$ is a diagonal matrix with the diagonal elements given by the vector **p**. The inverse is

$$\mathbf{V^{-1}} = \begin{bmatrix} \sigma^{-1}\boldsymbol{\Lambda}_{\mathbf{1}} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \gamma_A^{-1}(1-\omega)\boldsymbol{\Lambda}_{\mathbf{1-p}} & \gamma_A^{-1}\boldsymbol{\Lambda}_{\mathbf{1}} & \mathbf{0} & \mathbf{0} \\ \gamma_A^{-1}\omega\boldsymbol{\Lambda}_{\mathbf{1-p}} & \mathbf{0} & \gamma_A^{-1}\boldsymbol{\Lambda}_{\mathbf{1}} & \mathbf{0} \\ \boldsymbol{\Lambda}_{\mathbf{p}\oslash(\gamma_H\mathbf{1}+\mathbf{m})} & \mathbf{0} & \mathbf{0} & \boldsymbol{\Lambda}_{\mathbf{1}\oslash(\gamma_H\mathbf{1}+\mathbf{m})} \end{bmatrix},$$

where $\oslash$ gives the element-wise division of matrices.

The Jacobian matrix of $\boldsymbol{\mathcal{F}}$ is $\mathbf{F} = \begin{bmatrix} \mathbf{0} & \mathbf{F_{12}} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} \end{bmatrix}$ where $\mathbf{F_{12}} = \boldsymbol{\rho}\mathbf{1}' \otimes \boldsymbol{\beta}\mathbf{1}' \otimes \boldsymbol{\mathcal{C}}$, and $\boldsymbol{\mathcal{C}}$ is the contact matrix expanded by risk status given age, so that the ij-th element is $c_{\lfloor \frac{i-1}{2} \rfloor \lfloor \frac{j-1}{2} \rfloor}$.

R_0 is the spectral radius of matrix $\mathbf{FV^{-1}}$, or the magnitude of its largest eigenvalue. It follows from previous steps that $\mathbf{FV^{-1}} = \begin{bmatrix} \gamma_A^{-1}(1-\omega)\mathbf{F_{12}} \otimes \mathbf{\Lambda_{1-p}} & \gamma_A^{-1}\mathbf{F_{12}} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} \end{bmatrix}$. The spectral radius of $\mathbf{FV^{-1}}$ is equivalent to that of the reduced matrix $\widehat{\mathbf{FV^{-1}}} = \begin{bmatrix} \gamma_A^{-1}(1-\omega)\mathbf{F_{12}} \otimes \mathbf{\Lambda_{1-p}} & \gamma_A^{-1}\mathbf{F_{12}} \\ \mathbf{0} & \mathbf{0} \end{bmatrix}$.

We quantify matrix $\widehat{\mathbf{FV^{-1}}}$ plugging in the parameter values in Table A1. The implied virus transmissibility from the matrix gives $R_0 = 1.7$. Since estimates of R_0 differ across contexts and virus transmissibility itself varies over time, we consider a wide range of R_0, between 1.5 and 3.0, in our simulations of the rollout.

A4. Vaccine Rollout

We consider two protective effects of vaccines. For infectious individuals, vaccines reduce the probability of severe cases by a certain percent Δp. For susceptible individuals, vaccines reduce the infectivity of the virus as well as the transmissibility from an infected contact, both by the percent Δe. We use Δp to parametrize the vaccine efficacy against severe cases and use Δe to indicate efficacy against infection. Let subscript v denote vaccinated individuals and subscript n denote unvaccinated individuals. Virus transmission then follows:

$$\dot{S}_{arv} = -(1-\Delta e)\beta_a S_{arv} \sum_{a'} c_{aa'} \left(\frac{A_{a'n} + (1-\Delta e)\, A_{a'v}}{N_{a'}}\right),$$

$$\dot{S}_{arn} = -\beta_a S_{arn} \sum_{a'} c_{aa'} \left(\frac{A_{a'n} + (1-\Delta e)\, A_{a'v}}{N_{a'}}\right),$$

$$\dot{E}_{arv} = (1-\Delta e)\beta_a S_{arv} \sum_{a'} c_{aa'} \left(\frac{A_{a'n} + (1-\Delta e)\, A_{a'v}}{N_{a'}}\right) - \sigma E_{arv},$$

$$\dot{E}_{arn} = \beta_a S_{arn} \sum_{a'} c_{aa'} \left(\frac{A_{a'n} + (1-\Delta e)\, A_{a'v}}{N_{a'}}\right) - \sigma E_{arn},$$

$$\dot{H}_{arv} = \sigma(1-\Delta p) p_{ar} E_{arv} - \gamma_H H_{arv} - m_{ar} H_{arv},$$

$$\dot{H}_{arn} = \sigma p_{ar} E_{arn} - \gamma_H H_{arn} - m_{ar} H_{arn},$$

$$\dot{D}_{arv} = m_{ar} H_{arv},$$

$$\dot{D}_{arn} = m_{ar} H_{arn},$$

$$\dot{A}_{arv} = \sigma(1-(1-\Delta p) p_{ar})(1-\omega) E_{arv} - \gamma_A A_{arv},$$

$$\dot{A}_{arn} = \sigma(1-p_{ar})(1-\omega) E_{arn} - \gamma_A A_{arn},$$

$$\dot{Q}_{arv} = \sigma(1-\Delta p) p_{ar} \omega A_{arv} - \gamma_A Q_{arv},$$

$$\dot{Q}_{arn} = \sigma p_{ar} \omega A_{arn} - \gamma_A Q_{arn},$$

$$\dot{R}_{arv} = \gamma_A (A_{arv} + Q_{arv}) + \gamma_H H_{arv}, \text{ and}$$

$$\dot{R}_{arn} = \gamma_A (A_{arn} + Q_{arn}) + \gamma_H H_{arn},$$

where vaccines reduce infectivity through $(1-\Delta e)\beta_a$ and reduce transmissibility from a vaccinated contact through $\frac{(1-\Delta e)\, A_{a'v}}{N_{a'}}$. The reduced transmissibility also benefits unvaccinated

individuals (subscript n) in contacts, but the benefits of reducing infectivity and severe cases are specific to vaccinated individuals.

To model the rollout, we move a fixed number of unvaccinated individuals to the vaccinated counterparts each day and update the equations daily. In the three-stage rollout, multiple age-risk groups can be targeted at the same stage and the daily quota of vaccines is evenly distributed across eligible individuals without further differentiation between groups. The transition between stages is triggered by hitting the target coverage rate in the current stage. We solve for optimal targeting strategies through an exhaustive search over all possible allocations of age-risk groups to rollout stages. We also consider simpler strategies targeting either the elderly or high-risk individuals to understand when it matters the most to pursue optimal targeting in the rollout.

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Supplementary Figures: Captions and Legends

Supplementary Figure A1. SEIR transmission model of COVID-19
Figure A1 illustrates the transmission patterns of COVID-19. Susceptible individuals transition to the exposed state after infection. Infectious individuals with severe symptoms are treated under medical quarantine in hospitals. A fraction of non-severe cases self-quarantine and those not in medical or self-quarantine transmit the virus through contact. The details of the model estimation are provided in Appendix A1.

Supplementary Figure B1. Optimal targeting of age-risk groups to minimize deaths, vaccination speed = 0.3% daily, R_0 ranges from 1.5 to 3.0 during the rollout
Each row of a matrix indicates the optimal targeting of age-risk groups across three rollout stages (indicated by color), given the target coverage rate on the y-axis. The header of the matrix shows the reduction in infection and severe cases conferred by the vaccine. The x-axis indicates the population groups by age (20-year bands) and risk status. For instance, low-risk adults aged 20–59 are labeled "20–59l" and high-risk young adults are labeled "20–59h."

Supplementary Figure B2. Optimal targeting of age-risk groups to minimize severe cases, vaccination speed = 0.3% daily, R_0 ranges from 1.5 to 3.0 during the rollout
Each row of a matrix indicates the optimal targeting of age-risk groups across three rollout stages (indicated by color), given the target coverage rate on the y-axis. The header of the matrix shows the reduction in infection and severe cases conferred by the vaccine. The x-axis indicates the population groups by age (20-year bands) and risk status. For instance, low-risk adults aged 20–59 are labeled "20–59l" and high-risk young adults are labeled "20–59h."

Supplementary Figure B3. Optimal targeting of age-risk groups to minimize cases, vaccination speed = 0.3% daily, R_0 ranges from 1.5 to 3.0 during the rollout
Each row of a matrix indicates the optimal targeting of age-risk groups across three rollout stages (indicated by color), given the target coverage rate on the y-axis. The header of the matrix shows the reduction in infection and severe cases conferred by the vaccine. The x-axis indicates the population groups by age (20-year bands) and risk status. For instance, low-risk adults aged 20–59 are labeled "20–59l" and high-risk young adults are labeled "20–59h."

Supplementary Figure B4. Optimal targeting of age-risk groups to minimize deaths, vaccination speed = 0.3% daily, R_0 ranges from 1.7 to 2.7 during the rollout, first case on January 1, 2020
Each row of a matrix indicates the optimal targeting of age-risk groups across three rollout stages (indicated by color), given the target coverage rate on the y-axis. The header of the matrix shows the reduction in infection and severe cases conferred by the vaccine. The x-axis indicates the population groups by age (20-year bands) and risk status. For instance, low-risk adults aged 20–59 are labeled "20–59l" and high-risk young adults are labeled "20–59h."

Supplementary Figure B5. Optimal targeting of age-risk groups to minimize severe cases, vaccination speed = 0.3% daily, R_0 ranges from 1.7 to 2.7 during the rollout, first case on January 1, 2020
Each row of a matrix indicates the optimal targeting of age-risk groups across three rollout stages (indicated by color), given the target coverage rate on the y-axis. The header of the matrix shows the reduction in infection and severe cases conferred by the vaccine. The x-axis indicates the population groups by age (20-year bands) and risk status. For instance, low-risk adults aged 20–59 are labeled "20–59l" and high-risk young adults are labeled "20–59h."

Supplementary Figure B6. Optimal targeting of age-risk groups to minimize cases, vaccination speed = 0.3% daily, R_0 ranges from 1.7 to 2.7 during the rollout, first case on January 1, 2020
Each row of a matrix indicates the optimal targeting of age-risk groups across three rollout stages (indicated by color), given the target coverage rate on the y-axis. The header of the matrix shows the reduction in infection and severe cases conferred by the vaccine. The x-axis indicates the population groups by age (20-year bands) and risk status. For instance, low-risk adults aged 20–59 are labeled "20–59l" and high-risk young adults are labeled "20–59h."

Supplementary Figure B7. Optimal targeting of age-risk groups to minimize deaths, vaccination speed = 0.3% daily, R_0 ranges from 1.7 to 2.7 during the rollout, first case on January 16, 2020
Each row of a matrix indicates the optimal targeting of age-risk groups across three rollout stages (indicated by color), given the target coverage rate on the y-axis. The header of the matrix shows the reduction in infection and severe cases conferred by the vaccine. The x-axis indicates the population groups by age (20-year bands) and risk status. For instance, low-risk adults aged 20–59 are labeled "20–59l" and high-risk young adults are labeled "20–59h."

Supplementary Figure B8. Optimal targeting of age-risk groups to minimize severe cases, vaccination speed = 0.3% daily, R_0 ranges from 1.7 to 2.7 during the rollout, first case on January 16, 2020
Each row of a matrix indicates the optimal targeting of age-risk groups across three rollout stages (indicated by color), given the target coverage rate on the y-axis. The header of the matrix shows the reduction in infection and severe cases conferred by the vaccine. The x-axis indicates the population groups by age (20-year bands) and risk status. For instance, low-risk adults aged 20–59 are labeled "20–59l" and high-risk young adults are labeled "20–59h."

Supplementary Figure B9. Optimal targeting of age-risk groups to minimize cases, vaccination speed = 0.3% daily, R_0 ranges from 1.7 to 2.7 during the rollout, first case on January 16, 2020
Each row of a matrix indicates the optimal targeting of age-risk groups across three rollout stages (indicated by color), given the target coverage rate on the y-axis. The header of the matrix shows the reduction in infection and severe cases conferred by the vaccine. The x-axis indicates the population groups by age (20-year bands) and risk status. For instance, low-risk adults aged 20–59 are labeled "20–59l" and high-risk young adults are labeled "20–59h."

Supplementary Figure B10. Improvements in outcomes under optimal targeting of age-risk groups over the current policy, low virus transmissibility scenarios (R_0 ranges from 1.5 to 2.0 during the rollout)
Each matrix shows the percent reduction in outcomes when the rollout optimally targets age-risk groups given the R_0 and vaccination speed on the x-axis and the target coverage rate on the y-axis. The denominator of the percent reduction is the outcome of the current policy in Japan, which targets the elderly in the first stage followed by high-risk individuals in the second stage. On the x-axis, a fast rollout vaccinates 0.5% of the population daily, and a slow rollout 0.3% daily. The header of the matrix indicates vaccine efficacy in reducing infections and severe cases.

Supplementary Figure B11. Improvements in outcomes under optimal targeting of age-risk groups over simple rollouts targeting the elderly, R_0 ranges from 1.7 to 2.7 during the rollout
Each matrix shows the percent reduction in outcomes when the rollout optimally targets age-risk groups given the R_0 and vaccination speed on the x-axis and the target coverage rate on the y-axis. The denominator of the percent reduction is the outcome of the rollout targeting the elderly. On the x-axis, a fast rollout vaccinates 0.5% of the population daily, and a slow rollout vaccinates 0.3% daily. The header of the matrix indicates vaccine efficacy in reducing infections and severe cases.

Supplementary Figure B12. Improvements in outcomes under optimal targeting of age-risk groups over simple rollouts targeting high-risk individuals, R_0 ranges from 1.7 to 2.7 during the rollout
Each matrix shows the percent reduction in outcomes when the rollout optimally targets age-risk groups given the R_0 and vaccination speed on the x-axis and the target coverage rate on the y-axis. The denominator of the percent reduction is the outcome of the rollout targeting high-risk individuals. On the x-axis, a fast rollout vaccinates 0.5% of the population daily, and a slow rollout vaccinates 0.3% daily. The header of the matrix indicates vaccine efficacy in reducing infections and severe cases.

Supplementary Figure B13. Improvements in outcomes under optimal targeting of age-risk groups over simple rollouts targeting the elderly, low virus transmissibility scenarios (R_0 ranges from 1.5 to 2.0 during the rollout)
Each matrix shows the percent reduction in outcomes when the rollout optimally targets age-risk groups given the R_0 and vaccination speed on the x-axis and the target coverage rate on the y-axis. The denominator of the percent reduction is the outcome of the rollout targeting the elderly. On the x-axis, a fast rollout vaccinates 0.5% of the population daily, and a slow rollout vaccinates 0.3% daily. The header of the matrix indicates vaccine efficacy in reducing infections and severe cases.

Supplementary Figure B14. Improvements in outcomes under optimal targeting of age-risk groups over simple rollouts targeting high-risk individuals, low virus transmissibility scenarios (R_0 ranges from 1.5 to 2.0 during the rollout)
Each matrix shows the percent reduction in outcomes when the rollout optimally targets age-risk groups given the R_0 and vaccination speed on the x-axis and the target coverage rate on the y-axis. The denominator of the percent reduction is the outcome of the rollout targeting high-risk individuals. On the x-axis, a fast rollout vaccinates 0.5% of the population daily, and a slow rollout vaccinates 0.3% daily. The header of the matrix indicates vaccine efficacy in reducing infections and severe cases.

Supplementary Figure B15. Trade-offs between policy objectives under optimal targeting of age-risk groups, low virus transmissibility scenarios (R_0 ranges from 1.5 to 2.0 during the rollout)
Each matrix shows the percent increase in outcomes when targeting in the rollout is optimized for an alternative outcome of interest. Panel A shows the percent increase in deaths when the rollout minimizes severe cases rather than deaths. Panels B and C show the percent increase in deaths and severe cases, respectively, when the rollout minimizes cases. The denominator in the percent increase is the outcome when the rollout is optimized for an alternative outcome given the R_0 and vaccination speed on the x-axis and the target coverage rate on the y-axis. On the x-axis, a fast rollout vaccinates 0.5% of the population daily, and a slow rollout vaccinates 0.3% daily. The header of the matrix indicates vaccine efficacy in reducing infections and severe cases.