From Node to Network: Weaving A Global Perspective on Efficacy and Costs of Non-Pharmaceutical Interventions

Appendix I: Parameter Definitions, Values, and Sources

Age Groups and Population [1]

Age Group	Age Range	Population
1	0-9	714531
2	10-19	735014
3	20-29	732106
4	30-39	766250
5	40-49	671303
6	50-59	727131
7	60-69	692621
8	70-79	410576
9	80+	237629

Mixing Matrix among Age Groups [1]

	age_grp1	age_grp2	age_grp3	age_grp4	age_grp5	age_grp6	age_grp7	age_grp8	age_grp9
age_grp1	5.0419522	1.314893	0.8163274	1.90919	0.9785968	0.8442709	0.5391928	0.2264935	0.11093732
age_grp2	1.2782502	11.7172604	1.7593806	1.4899821	1.9836308	1.3483093	0.4390597	0.3486255	0.1713126
age_grp3	0.7967305	1.7663691	5.707739	2.5269865	1.9021941	1.7096585	0.5009915	0.1699075	0.08345381
age_grp4	1.7803268	1.4292433	2.4143843	4.3844776	2.5746557	1.7383824	0.7585293	0.2819625	0.13920869
age_grp5	1.0416127	2.1718902	2.0744845	2.938807	3.7304134	2.1595466	0.6837456	0.450897	0.21924813
age_grp6	0.8296411	1.3629266	1.7213559	1.8319059	1.9937399	2.82	0.807549	0.3002753	0.14737179
age_grp7	0.5562494	0.4659331	0.5295521	0.8391647	0.6627007	0.8477853	1.4179561	0.3694232	0.18029206
age_grp8	0.3941697	0.6241101	0.3029654	0.5262211	0.7372289	0.5317882	0.6231982	0.5062382	0.29299541
age_grp9	0.3335795	0.5298897	0.257111	0.4488874	0.619377	0.4509491	0.5255001	0.5062382	0.29299541

Initial # of Cases at Each Compartment by Age Group [1]

	age_grp1	age_grp2	age_grp3	age_grp4	age_grp5	age_grp6	age_grp7	age_grp8	age_grp9
I	0	5	53	41	25	44	22	11	0
H	0	0	0	4	7	4	5	1	5
ICU	0	0	0	1	3	0	1	0	1
D	0	0	0	0	0	0	0	0	0
R	0	0	0	0	0	0	0	0	0

beta[1]**:** Probability that contact with an infectious person result in an infection [1]

n_days_incubation: average time in day from being exposed to virus to becoming infected.[1][13][15]

n_days_infectious: average time in day from symptom onset to hospital [1][16]

Variant	**beta**	**n_days_incubatio**	**n_days_infectious**
Original	0.0295	5.2	7.8
Delta	0.0358	3.7	8.5
Early Omicron	0.0812	3.2	6.5
Late Omicron	0.1031	4.2	6.5

Length of stay (day) in hospital.[1][17]

Age Group	Original	Delta	Early Omicron	Late Omicron
1	11	3.6	2.16	2.05
2	11	3.6	2.16	2.05
3	11	3.6	2.16	2.05
4	11	3.6	2.16	2.05
5	11	5.78	3.93	2.92
6	11	5.78	3.93	2.92
7	11	5.78	3.93	2.92
8	11	12.31	7.61	6.02
9	11	12.31	7.61	6.02

Length of stay (day) in ICU.[1][17]

Age Group	Original	Delta	Early Omicron	Late Omicron
1	8	7.5	4.65	3.93
2	8	7.5	4.65	3.93
3	8	7.5	4.65	3.93
4	8	7.5	4.65	3.93
5	8	9.44	5.67	4.3
6	8	9.44	5.67	4.3
7	8	9.44	5.67	4.3
8	8	8.94	5.63	4.36
9	8	8.94	5.63	4.36

[1] Beta of the original virus is calibrated against real observed data via simulation as describe in [1]. The value of beta for other variants is calibrated in the same way.

prop_hosp[2]**:** proportion of symptomatic infections being hospitalized [1][4][19].

Age Group	Original	Delta	Early Omicron	Late Omicron
1	0.001897	0.011817	0.017857	0.014341
2	0.008181	0.012365	0.018246	0.014497
3	0.020353	0.027201	0.02518	0.01343
4	0.033977	0.047903	0.03247	0.017375
5	0.044731	0.075586	0.038167	0.017927
6	0.052879	0.132985	0.072905	0.030495
7	0.061984	0.178475	0.132374	0.055011
8	0.077175	0.318927	0.307759	0.162225
9	0.103218	0.335122	0.298065	0.153329

prop_ICU: proportion of hospitalized cases requiring ventilation [1][2][5].

Age Group	Original	Delta	Early Omicron	Late Omicron
1	0.1304	0.184	0.104	0.133
2	0.1196	0.184	0.104	0.133
3	0.1351	0.133	0.095	0.133
4	0.1711	0.133	0.095	0.133
5	0.2219	0.133	0.095	0.133
6	0.2719	0.195	0.147	0.133
7	0.2962	0.195	0.147	0.133
8	0.2703	0.195	0.147	0.133
9	0.1877	0.195	0.147	0.133

prob_hosp_die: proportion of hospitalized people (not in ICU) who are dead. [1][5]

Age Group	Original	Delta	Early Omicron	Late Omicron
1	2.86E-09	0.002154123	0.002209432	0.004292663
2	0.00000276	0.010164278	0.007456533	0.004344504
3	0.0003	0.015341463	0.018082399	0.004513429
4	0.0043	0.025759802	0.026351095	0.008162853
5	0.0186	0.029716482	0.029555624	0.010117337
6	0.0365	0.0478921	0.049572678	0.018590686
7	0.0538	0.05726723	0.062785501	0.023786588
8	0.0957	0.065939583	0.069873163	0.025930409
9	0.2874	0.068967868	0.080591234	0.032168615

[2] the values for the original virus mean are provided in [1];
the values for the other variants are computed as: hospital week_age_num / cases_week_age_num

prob_icu_death: proportion of people who are hospitalized and in the ICU die [1][5]

Age Group	Original	Delta	Early Omicron	Late Omicron
1	0.0005	0.020576836	0.014426697	0.037397842
2	0.0424	0.097092245	0.048688138	0.037849477
3	0.1002	0.146546275	0.118070745	0.03932116
4	0.1738	0.246065389	0.172061982	0.071115074
5	0.2633	0.283860786	0.192986255	0.088142618
6	0.3686	0.457479769	0.323689514	0.16196275
7	0.4897	0.547033838	0.409963896	0.20722964
8	0.6267	0.629874757	0.456243459	0.225906689
9	0.7795	0.658801854	0.52622812	0.280254168

prob_inf_die[3]**:** the proportion of people who are symptomatic and do not get hospitalized but die, i.e., die at home. [4][19]

Age Group	Original	Delta	Early Omicron	Late Omicron
1	0.08930854	5.48E-05	3.62E-05	1.26E-05
2	0.26353432	1.13E-05	0	0
3	0.15794502	4.91E-05	0	5.94E-06
4	0.15717893	0.000208452	0	6.25E-06
5	0.14297132	0.002216614	3.80E-05	0.000186606
6	0.11012012	0.003032728	0.000201257	0.000647975
7	0.04463342	0.004408981	0.000283792	0.00098789
8	0.02264691	0.014736735	0.002833539	0.00629969
9	0.01166143	0.048008964	0.012737161	0.017147367

[3] It is calculated as follows (e.g. delta):
delta_cases_home_die_week_age_group_num = delta_death_week_age_group_num...
-delta_hospital_week_age_group_num .* repmat((1-delta_prop_ICU).',size(delta_hospital_week_age_group_num,1),1) .* repmat(delta_prob_hosp_die.', size(delta_hospital_week_age_group_num,1),1)...
-delta_hospital_week_age_group_num .* repmat(delta_prop_ICU.', size(delta_hospital_week_age_group_num,1), 1) .* repmat(delta_prob_icu_die.',size(delta_hospital_week_age_group_num,1),1)

Appendix II: Parameter Values in Table 3

Table 3 Estimated Values of Major Parameter by COVID-19 Variants

COVID-19 variant	R_0	Rate of Hospitalized $P_{H,v}$	Rate of ICU $P_{ICU,v}$	Rate of Death $P_{D,v}$
Initial	3.87	0.0353	0.2301	0.0153
Delta	5.08	0.0796	0.1765	0.0123
Early Omicron	9.5	0.0683	0.1331	0.0053
Late Omicron	13.3	0.0377	0.1330	0.0028

The 'rate of hospitalized' $P_{H,v}$ represents the overall probability of getting hospitalized if infected with variant v. For the last three variants (rows), it is obtained by summing up patients across all age groups [4][19] and dividing it by the total number of infected cases during each week [4] [19] and averaging this rate over all the weeks when a certain variant is prevalent. That is,

$$P_{H,v} = \frac{1}{N_v}\sum_{n=1}^{N_v}\frac{\sum_{i=1}^{9} H_{v,i}^{(n)}}{\sum_{i=1}^{9} I_{v,i}^{(n)}}, \qquad v = 2,3,4,$$

where $H_{v,i}^{(n)}$ and $I_{v,i}^{(n)}$ are the number of hospitalized patients and infected cases in age group i during week n of the prevalence of the variant v. N_v is the total number of weeks a certain variant is prevalent.

The 'rate of ICU' P_{ICU} represents the overall probability of being admitted to ICU care if hospitalized. For the last three rows, it is obtained by multiplying the given ICU rate [2] with the hospitalized cases [4][19] in each age group first. Then summing across age groups then averaging over weeks spanned by a certain variant. That is,

$$P_{ICU,v} = \frac{1}{N_v}\sum_{n=1}^{N_v}\frac{\sum_{i=1}^{9}\left[H_{v,i}^{(n)} \times P_{ICU,i}\right]}{\sum_{i=1}^{9} H_{v,i}^{(n)}}, \qquad v = 2,3,4,$$

where $P_{ICU,i}$ is the probability of a hospitalized patient in age group i being admitted to ICU care.

The 'rate of death' $P_{D,v}$ represents the overall probability of death if infection is confirmed. For the last three rows, it is obtained by summing up deaths across all age groups [2] and dividing it by the total number of infected cases during each week [2] and averaging this rate over all the weeks when a certain variant is prevalent. That is,

$$P_{D,v} = \frac{1}{N_v}\sum_{n=1}^{N_v}\frac{\sum_{i=1}^{9} D_{v,i}^{(n)}}{\sum_{i=1}^{9} H_{v,i}^{(n)}}, \qquad v = 2,3,4.$$

The first row of the data for the initial variant in the table are obtained via simulation using the original data provided in [1]. More exactly, all the rates are calculated using the total number of deaths, ICU patients, hospitalized patients and infectious over all age groups spanning 365 days, which is sufficiently long to entail one complete wave of prevalence.

Data Sources:

[1] MODELING THE IMPACT OF SOCIAL DISTANCING MEASURES ON THE SPREAD OF SARS-CoV-2 IN MINNESOTA TECHNICAL DOCUMENTATION MODEL VERSION 3.0 (UPDATED MAY 13, 2020)
[2] https://www.cdc.gov/mmwr/volumes/71/wr/pdfs/mm7104e4-H.pdf (Table 2)
[3] Estimates of asymptomatic disease rates with COVID-19 -- the proportion who are infected but never manifest symptoms -- have ranged from about 25% to 40% throughout the pandemic, with a number of papers, including one in the Annals of Internal Medicine, coming in at about a third of cases....There are no data yet on whether Omicron's subvariants, such as BA.2 and BA.4 and BA.5, cause more asymptomatic infections. (https://www.medpagetoday.com/special-reports/exclusives/98632)
[4] https://covid.cdc.gov/covid-data-tracker/#new-hospital-admissions ---- CDC data tracker for cases, hospitals, and death
[5] https://www.cdc.gov/mmwr/volumes/71/wr/pdfs/mm7137a4-H.pdf
[6] https://pubmed.ncbi.nlm.nih.gov/34369565/
[7] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8992231/
[8] https://www.reuters.com/article/factcheck-omicron-reproduction-number/fact-check-no-evidence-omicron-ba-5-is-more-infectious-than-measles-or-is-the-most-infectious-virus-known-idUSL1N2YW1T0
[9] https://www.thehartford.com/insights/home-workplace-safety/virus-mutations-covid-19
[10] https://theconversation.com/how-contagious-is-delta-how-long-are-you-infectious-is-it-more-deadly-a-quick-guide-to-the-latest-science-165538
[11] https://wwwnc.cdc.gov/eid/article/29/3/22-1360-f1
[12] https://www.cdc.gov/coronavirus/2019-ncov/covid-data/covidview/past-reports/04222022.html
    BA1.1 BA2 is during February and March
[13] https://wwwnc.cdc.gov/eid/article/29/3/22-1360_article
    Incubation Period, distribution of Delta, BA.1 (i.e., early omicron) and BA.5 (i.e., late omicron)
[14] https://www.publichealthontario.ca/-/media/documents/ncov/covid-wwksf/2022/01/wwksf-omicron-communicability.pdf?sc_lang=en
[15] https://wwwnc.cdc.gov/eid/article/29/2/22-1243_article
[16] https://www.health.com/news/omicron-timeline
[17] https://bmcinfectdis.biomedcentral.com/articles/10.1186/s12879-022-07971-6
     length of hospital and ICU stay for delta, delta-omicron and omicron (Table 1)
[18] https://www.nature.com/articles/s41591-022-01887-z
     length of hospital stay distribution for BA.2 and BA.1 (Table 5i, 5j)
[19] Annual Estimates of the Resident Population by Single Year of Age and Sex for the United States: April 1, 2020 to July 1, 2021 (NC-EST2021-SYASEXN), Source: U.S. Census Bureau, Population Division, Release Date: June 2022

Appendix III: Test-Trace-Quarantine Policy

Figure A1 illustrates the peak number of ICU patients in a day and the total number of deaths within 365 days since the outbreak of the late Omicron variant, as the duration of the test-trace-quarantine policy increases. This policy is assumed to reduce contacts by 99% in the numerical experiment. Each line in Figure A1 corresponds to the day this policy is initiated. For simplicity, Figure A1 only plots a sample of initiation days.

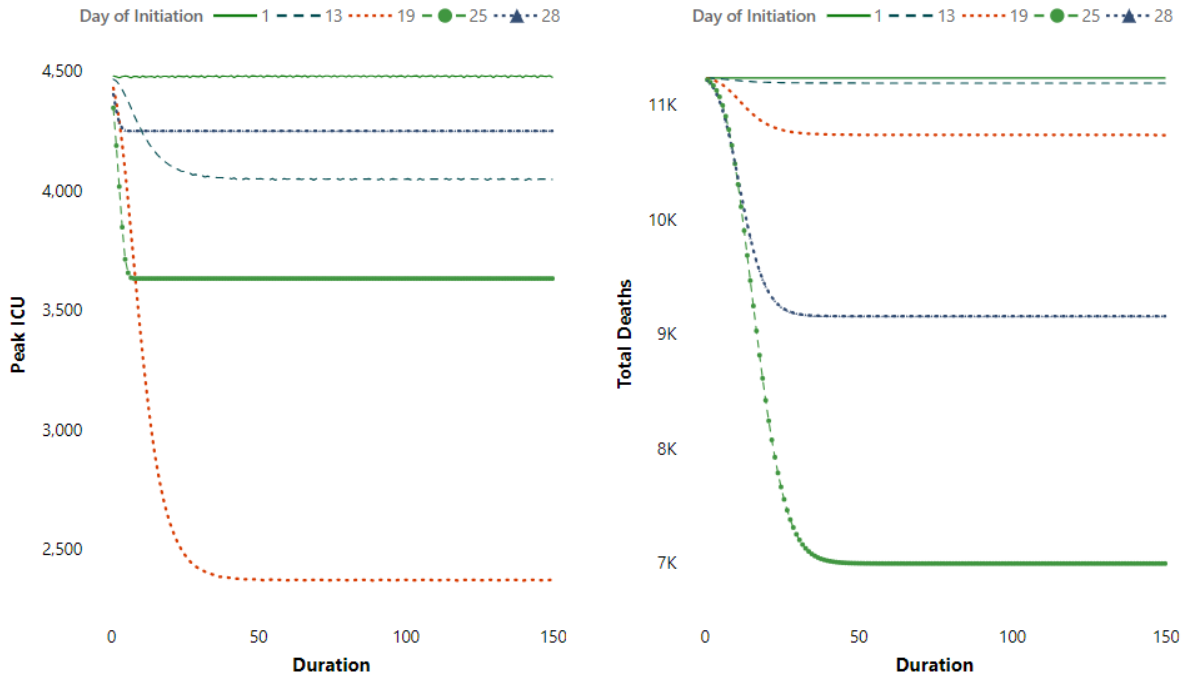

Figure A1 Peak ICU Occupancy and The Total Deaths using the Test-Trace-Quarantine Policy under the Late Omicron Strain