Intervention options and testing needs for long-term suppression of COVID-19 transmission

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Aims: examine strategies which allow social distancing to be relaxed, school closure to be ended, but keep transmission suppressed (i.e. keep incidence of deaths, ICU cases substantially below current peak).

Policies examined:

- Assume policy switch in the last week in May (except schools, in some scenarios).
- Continued case isolation in the home (90% compliance), household quarantine (75% compliance).
- Whole population reduced social distancing (work contacts at 75% of normal, social at **40%** of normal).
- Age-targeted social distancing – households with no-one <45 as normal, those with people >45 have 75% reduction in social and work contacts, children in such households do not go to school
- Schools reopening after May half-term, or in September.
- Reactive school closure for 2 weeks when a case is detected in a pupil or staff member.
- Tracing of contacts of symptomatic index case (manual and/or app-based).

Transmission/infectiousness scenarios

In addition to the Default scenario used in prior modelling, we examine three other scenarios for sensitivity analysis:

- *PreSymp* – higher level of presymptomatic transmission (1.5 days, 1/3 of all transmission).
- *MoreSocial* – lower level of household (27%) and school/workplace transmission (27%), more in other social contexts. PreSymp infectiousness scenario also assumed.
- *LoKids* – higher asymptomatic fraction overall (50%+) and children less susceptible (0-5 – 70%; 5-10 – 80%; 10-15 – 90%, >15 – 100%) and symptomatic susceptible (0-5 – 20%; 5-10 – 30%; 10-15 – 40%, >15 – 50%). This scenario also has an IFR reduced by ¼.

Other

- R_0 values of 2.8, 3 and 3.2 examined
- Contact tracing modelling tuned to give a mean of ~20 contacts per index case (excl. household).
- Contacts distributed between general social mixing and schools/workplaces.
- Household members assumed to be contacts.
- Age dependent severity included, fitted to UK data.
- OFCOM data used to parameterise smartphone ownership (~65% in whole population, assuming <16s are not app users).

Results

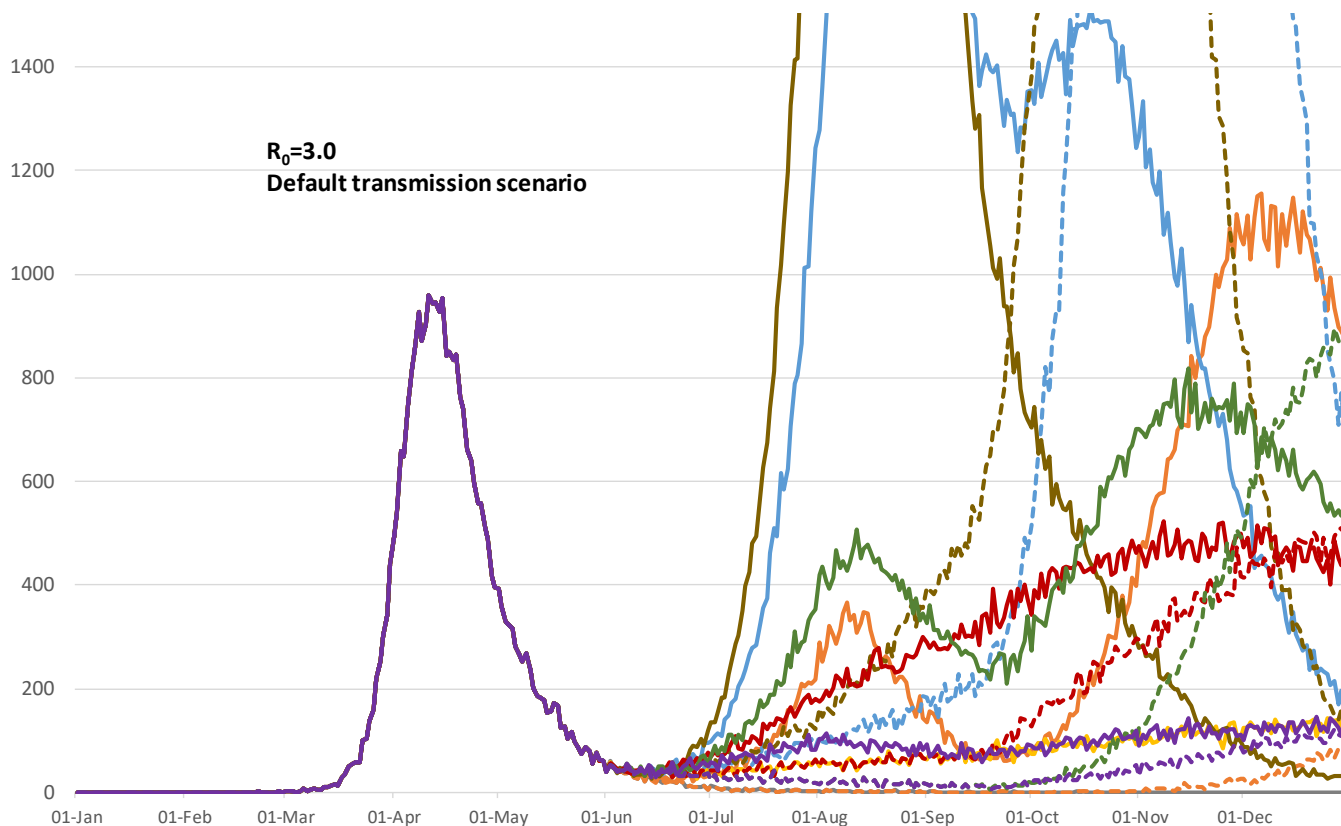Figure 1 shows illustrative dynamics for the policy options explored, Figure 2 shows the reproduction number (R) over time for those policies, while Tables 1-3 show predicted COVID-19 deaths, cases and contacts traced for policies involving schools reopening in June versus September. Tables 4-6 show COVID-19 related NHS demand (ICU and general ward admissions and maximum bed occupancy). All results are for GB.

Conclusions

- For any of the current measures to be relaxed, something additional will need to be substituted to maintain control of transmission. We predict that either opening schools or relaxing social distancing (or both) on their own will lead to a resurgence and a second wave eventually larger than the first (Figure 1).

- Fundamentally, the challenge is that to control transmission, interventions need to block ~67% of transmission. Current measures are estimated to block a little under 80% (current R of 0.6-0.7). Any replacement strategy can only increase R by 0.4 (13%). Figure 2 illustrates R over time for different strategies (note that the R for lockdown slightly increases over time due to gradual concentration of transmission in low compliance subgroups of the population as case numbers drop).

- Three additional measures are considered here: contact tracing (of 80% of contacts of symptomatic cases), reactive school closure (closing individual schools for 2 weeks if a case is detected in a pupil or staff member), and age targeted social distancing (anyone living in a household with someone >45 does not attend school, reduces social and work contacts by 75%).

- Age-targeted social distancing has insufficient effectiveness to prevent the very large epidemic in the <45s causing substantial deaths (>100k) in the >45s.

- High compliance case isolation and household quarantine will be essential to maintain control of transmission – likely aided by mass testing.

- Rapid (<2 days) contact tracing and isolation of 80% of contacts in the home likely essential. More sensitivity analysis to timing of tracing will be undertaken, but the scope for long delays is limited.

- Reactive school closure or a comparable locally targeted social distancing measure will likely be essential to maintain control of transmission.

- Combining case isolation, household quarantine, tracing and isolation of 80% of contacts and reactive school closure is predicted to be able to maintain control of transmission and allow schools to reopen and a reduced level (but not zero) of social distancing. This strategy gives a value of R very close to 1 (Figure 2).

- App-based contact tracing might cover a little under half of the contact tracing required.

- The most successful policy not requiring isolation outside the home or quarantine of contacts of contacts combines case isolation, household quarantine, reduced social distancing (see above), isolation of 80% of contacts and reactive school closure. Incidence (deaths, cases hospitalisations) are lower still with greater social distancing. The level of reduced social distancing modelled here is the minimum required to keep R~1 in the absence of local reactive social distancing policies.

- This policy option is predicted to keep COVID-19 deaths to between 9 and 36 thousand between June and December inclusive if schools reopen in September, and to between 19 and 52 thousand if schools reopen in June (last 2 rows of Table 1). The difference is due to the effect of blanket school closure reducing cases still further from June to September.

- This policy option will require a maximum of 15 and 30 thousand cases per day to be tested (last two rows of Table 2).

- If contacts as well as cases are to be tested, this might require a maximum of 200 and 500 thousand contacts to be tested per day for the optimal policy option, depending on the transmission scenario.

- The ratio of contacts needing to be traced per case is highest for low incidence scenarios (we assume ~20 per case here) but reduces for higher incidence scenarios as infections are socially clustered and often shared by multiple index cases.

- The three alternative transmission scenarios explored in addition to the default scenario are all generally more difficult to control – due to a higher proportion of either presymptomatic or asymptomatic transmission, or because school closure (complete or reactive) has a lower effect.

- We will continue to explore other policy combinations, notably geographically localised intensification of social distancing in response to epidemiological triggers, periodic social distancing (e.g. only opening leisure venues at weekends), and partial re-opening of schools (e.g. primary schools only).

Figure 1: Daily deaths through time for policies examined, default scenario

R_0=3.0
Default transmission scenario

—— Lockdown continued

—— Schools reopen in June, other measures continue

- - - Schools reopen in September, other measures continue

—— Relaxed social distancing from late May, other measures (incl school closure continue)

—— Relaxed social distancing from late May, schools reopen in June, other measures continue

- - - Relaxed social distancing from late May, schools reopen in September, other measures continue

—— Age targeted social distancing from late May, schools reopen in June, other measures continue

- - - Age targeted social distancing from late May, schools reopen in September, other measures continue

—— Relaxed social distancing from late May, schools reopen in June, reactive school closure from then, other measures continue

- - - Relaxed social distancing from late May, schools reopen in September, reactive school closure from then, other measures continue

—— Relaxed social distancing from late May, schools reopen in June, contact tracing of 80% of contacts of symptomatic cases, other measures continue

- - - Relaxed social distancing from late May, schools reopen in September, contact tracing of 80% of contacts of symptomatic cases, other measures continue

—— Relaxed social distancing from late May, schools reopen in June, reactive school closure from then, contact tracing of 80% of contacts of symptomatic cases, other measures continue

- - - Relaxed social distancing from late May, schools reopen in September, reactive school closure from then, contact tracing of 80% of contacts of symptomatic cases, other measures continue

Figure 2: Reproduction number, R, through time for policies examined, default scenario. The value for the continued lockdown scenario eventually becomes erratic due to very low case numbers and random effects

R₀=3.0
Default transmission scenario

—— Lockdown continued

—— Schools reopen in June, other measures continue

---- Schools reopen in September, other measures continue

—— Relaxed social distancing from late May, other measures (incl school closure continue)

—— Relaxed social distancing from late May, schools reopen in June, other measures continue

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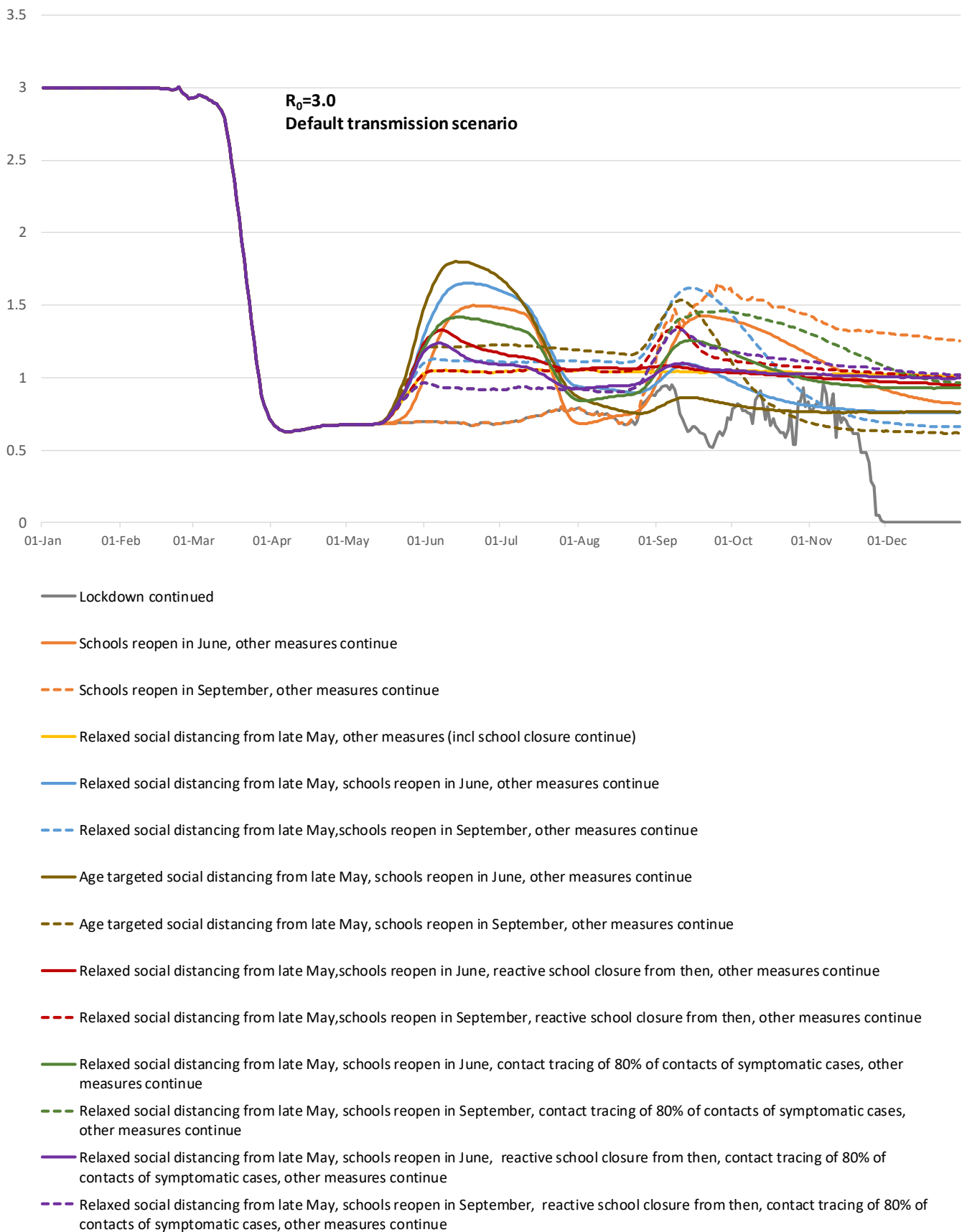
Table 1: COVID-19 deaths - maximum daily and total from June-December for different policy options, $R_0=3$. Empty cells imply a policy is not implemented. Symptomatic case isolation of 90% of cases is assumed in all scenarios.

Schools closure	Reactive school closure	Social distancing	Contact tracing coverage	Max daily deaths				Total deaths June-Dec			
				Default	PreSymp	MoreSocial	LowKids	Default	PreSymp	MoreSocial	LowKids
Shut	No	Full	0%	60	106	40	99	925	2501	556	2045
Open June	No	Full	0%	1157	2878	1185	1212	76294	116402	74074	80121
Open Sept	No	Full	0%	96	2204	40	912	2779	80393	966	23771
Shut	No	Reduced	0%	143	664	1023	401	16807	82207	93403	52478
Open June	No	Reduced	0%	2161	5784	3797	3664	203094	228496	241803	173278
Open Sept	No	Reduced	0%	4373	5047	5657	3561	237699	256960	296939	205020
Open June	No	Age>45	0%	3368	5359	5479	3648	179847	193163	218833	151728
Open Sept	No	Age>45	0%	3496	3386	3212	2292	189588	192646	219038	152869
Open June	Yes	Reduced	0%	522	1301	1645	924	63587	133649	164998	107607
Open Sept	Yes	Reduced	0%	511	1252	1662	903	38167	123917	139266	89391
Open June	No	Reduced	80%	817	1246	641	1361	84359	99755	70519	106457
Open Sept	No	Reduced	80%	894	1114	684	1289	35999	72358	41562	87763
Open June	Yes	Reduced	80%	145	248	217	362	19074	34681	28614	52000
Open Sept	Yes	Reduced	80%	121	230	231	379	8653	21929	16364	36269

Table 2: Symptomatic COVID-19 cases requiring testing - maximum daily and total from June-December for different policy options, $R_0=3$

Schools closure	Reactive school closure	Social distancing	Contact tracing coverage	Max daily case testing (thousands)				Total cases June-Dec (thousands)			
				Default	PreSymp	MoreSocial	LowKids	Default	PreSymp	MoreSocial	LowKids
Shut	No	Full	0%	2	6	1	4	49	164	28	113
Open June	No	Full	0%	172	449	179	166	13026	16643	12488	10202
Open Sept	No	Full	0%	25	332	7	151	631	15696	164	4886
Shut	No	Reduced	0%	13	61	90	32	1750	8203	9379	4809
Open June	No	Reduced	0%	237	703	375	376	22472	25380	24157	16480
Open Sept	No	Reduced	0%	480	613	587	351	25662	27243	28349	18847
Open June	No	Age>45	0%	489	829	783	466	24541	26661	28013	18037
Open Sept	No	Age>45	0%	514	509	441	289	26174	26415	28205	18223
Open June	Yes	Reduced	0%	50	126	151	78	7030	13741	15761	9917
Open Sept	Yes	Reduced	0%	51	133	148	78	4543	12921	13984	8594
Open June	No	Reduced	80%	95	158	68	153	10943	12705	8606	11276
Open Sept	No	Reduced	80%	111	145	79	143	5952	10165	5759	10090
Open June	Yes	Reduced	80%	14	26	19	32	2223	4012	3157	5155
Open Sept	Yes	Reduced	80%	13	23	21	33	1067	2639	1928	3747

Table 3: Contacts requiring testing - maximum daily and total from June-December for different policy options, $R_0=3$

Schools closure	Reactive school closure	Social distancing	Contact tracing coverage	Max daily contacts to trace (thousands)				Total tracing June-Dec (thousands)			
				Default	PreSymp	MoreSocial	LowKids	Default	PreSymp	MoreSocial	LowKids
Shut	No	Full	0%	0	0	0	0	0	0	0	0
Open June	No	Full	0%	0	0	0	0	0	0	0	0
Open Sept	No	Full	0%	0	0	0	0	0	0	0	0
Shut	No	Reduced	0%	0	0	0	0	0	0	0	0
Open June	No	Reduced	0%	0	0	0	0	0	0	0	0
Open Sept	No	Reduced	0%	0	0	0	0	0	0	0	0
Open June	No	Age>45	0%	0	0	0	0	0	0	0	0
Open Sept	No	Age>45	0%	0	0	0	0	0	0	0	0
Open June	Yes	Reduced	0%	0	0	0	0	0	0	0	0
Open Sept	Yes	Reduced	0%	0	0	0	0	0	0	0	0
Open June	No	Reduced	80%	971	1391	1095	1351	126527	141083	154709	121171
Open Sept	No	Reduced	80%	1095	1291	1209	1235	66075	104964	97844	100760
Open June	Yes	Reduced	80%	220	399	472	467	34897	62279	75931	72495
Open Sept	Yes	Reduced	80%	208	357	493	456	17077	41878	47085	53689

Table 4: Maximum COVID-19 ICU and general bed occupancy between June and December for different policy options, $R_0=3$

Schools closure	Reactive school closure	Social distancing	Contact tracing coverage	Max ICU occupancy				Max general ward bed occupancy			
				Default	PreSymp	MoreSocial	LowKids	Default	PreSymp	MoreSocial	LowKids
Shut	No	Full	0%	200	460	140	340	1060	2380	750	1850
Open June	No	Full	0%	4930	12290	5010	5270	26100	64710	26640	27210
Open Sept	No	Full	0%	410	9490	140	4040	2300	50050	750	21550
Shut	No	Reduced	0%	580	2850	4260	1610	2970	13630	21010	8170
Open June	No	Reduced	0%	9210	25060	16260	15560	46580	124860	80530	78400
Open Sept	No	Reduced	0%	18130	21500	23410	15180	93160	107700	118330	76240
Open June	No	Age>45	0%	13840	22050	22630	14870	75460	118820	122930	81240
Open Sept	No	Age>45	0%	14120	13550	12720	9280	77920	73250	69570	50230
Open June	Yes	Reduced	0%	2140	5700	6990	3900	10840	27600	34570	19360
Open Sept	Yes	Reduced	0%	2180	5410	6850	3850	11020	26590	34650	18940
Open June	No	Reduced	80%	3280	5020	2470	5650	16970	26470	12980	29380
Open Sept	No	Reduced	80%	3670	4510	2800	5320	19560	24480	14690	27970
Open June	Yes	Reduced	80%	610	1020	860	1480	2970	5210	4320	7550
Open Sept	Yes	Reduced	80%	510	900	890	1530	2590	4610	4500	7660

Table 5: COVID-19 hospital admissions - maximum daily and total from June-December for different policy options, $R_0=3$

Schools closure	Reactive school closure	Social distancing	Contact tracing coverage	Max daily hospital admissions				Total admissions June-Dec (thousands)			
				Default	PreSymp	MoreSocial	LowKids	Default	PreSymp	MoreSocial	LowKids
Shut	No	Full	0%	77	195	57	153	1.4	4.5	0.8	3.6
Open June	No	Full	0%	3084	8221	3199	3549	220.8	309	212.9	215.2
Open Sept	No	Full	0%	359	6059	93	2823	8.7	258	2.5	82.5
Shut	No	Reduced	0%	358	1671	2517	1004	44.1	210.4	248.3	136.2
Open June	No	Reduced	0%	5689	15345	9861	10007	521.8	583	609	440.5
Open Sept	No	Reduced	0%	11382	13385	14617	9319	613.4	651.4	742.5	518.8
Open June	No	Age>45	0%	9349	15043	15605	10103	476.1	510.5	570.8	398
Open Sept	No	Age>45	0%	9526	9286	8428	6142	500.2	506.7	572.2	400.8
Open June	Yes	Reduced	0%	1310	3304	4133	2309	170.6	342.1	421.6	276
Open Sept	Yes	Reduced	0%	1300	3297	4093	2267	106.9	321.3	366.9	234.4
Open June	No	Reduced	80%	2046	3290	1566	3647	228.6	263.1	188.2	277.6
Open Sept	No	Reduced	80%	2397	3034	1796	3417	110.8	201.1	118.2	237.4
Open June	Yes	Reduced	80%	354	625	525	927	50.6	90.6	76	135.3
Open Sept	Yes	Reduced	80%	318	578	541	917	23.6	58.3	45.4	97.1

Table 6: COVID-19 ICU admissions - maximum daily and total from June-December for different policy options, R_0=3

Schools closure	Reactive school closure	Social distancing	Contact tracing coverage	Max ICU daily admissions				Total ICU admissions June-Dec (thousands)			
				Default	PreSymp	MoreSocial	LowKids	Default	PreSymp	MoreSocial	LowKids
Shut	No	Full	0%	20	60	20	40	0.4	1.3	0.2	1
Open June	No	Full	0%	770	1950	810	850	52.4	76.6	50.7	53.5
Open Sept	No	Full	0%	80	1490	20	680	1.9	60.1	0.6	18.7
Shut	No	Reduced	0%	100	450	670	280	11.4	55.9	63.6	35.6
Open June	No	Reduced	0%	1480	3890	2550	2610	132.7	150.1	155.4	113.2
Open Sept	No	Reduced	0%	2860	3390	3660	2360	155	167.5	189.4	132.7
Open June	No	Age>45	0%	2180	3530	3610	2380	112	121.1	135.1	94.4
Open Sept	No	Age>45	0%	2220	2160	2030	1500	117.7	120.2	135.1	95
Open June	Yes	Reduced	0%	350	870	1100	610	43.8	90.3	109	71.3
Open Sept	Yes	Reduced	0%	360	850	1090	600	27	83.9	93.4	60.7
Open June	No	Reduced	80%	520	790	390	950	55.8	64.8	45.9	69.4
Open Sept	No	Reduced	80%	590	710	450	840	25.9	48.4	28.4	58.3
Open June	Yes	Reduced	80%	110	170	150	240	12.7	23	18.8	34.1
Open Sept	Yes	Reduced	80%	90	150	160	250	5.8	14.6	11	24.3