Simulating Epidemic Outcomes under Different Occupancy and Rollback Policies

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Purpose: To analyze potential COVID-19 epidemic outcomes in New York City under different reopening occupancy guidelines and rollback strategies.

Schedule of three phase-in and occupancy policies:

Four phases are included in the phased reopening plan, see details for industries in each phase here: https://forward.ny.gov/reopening-new-york-city

Policy 1: Based on New York State Guidance, assume all industries when allowed to reopen, cap at 50% occupancy; schools are 100% open.

Date	Note	Ph1 industries	Ph2 industries	Ph3 industries	Ph4 industries
6/8/20	phase 1	50% open, retail curbside only	Closed	Closed	Closed
6/22/20	phase 2	50% open	50% open	Closed	Closed
7/6/20	phase 3	50% open	50% open	50% open	Closed
7/20/20	phase 4, schools closed	50% open	50% open	50% open	50% open
9/7/20	phase 4, schools open	50% open	50% open	50% open	50% open, schools: 100%
12/23/20	phase 4, school break	50% open	50% open	50% open	50% open, schools: 100%
1/8/21	phase 4, schools open	50% open	50% open	50% open	50% open, schools: 100%

Policy 2: Based on New York State Guidance, assume all industries when allowed to reopen, cap at 50% occupancy; schools are also capped at 50%

Date	Note	Ph1 industries	Ph2 industries	Ph3 industries	Ph4 industries
6/8/20	phase 1	50% open, retail curbside only	Closed	Closed	Closed
6/22/20	phase 2	50% open	50% open	Closed	Closed
7/6/20	phase 3	50% open	50% open	50% open	Closed
7/20/20	phase 4, schools closed	50% open	50% open	50% open	50% open
9/7/20	phase 4, schools open	50% open	50% open	50% open	50% open, schools: 50%
12/23/20	phase 4, school break	50% open	50% open	50% open	50% open, schools: 50%
1/8/21	phase 4, schools open	50% open	50% open	50% open	50% open, schools: 50%

Policy 3: Based on New York State Guidance, assume Phase 1-3 industries when allowed to reopen, cap at 50% occupancy; For Phase 4, schools are 100% open, others are capped at 25%

Date	Note	Ph1 industries	Ph2 industries	Ph3 industries	Ph4 industries
6/8/20	phase 1	50% open, retail curbside only	Closed	Closed	Closed
6/22/20	phase 2	50% open	50% open	Closed	Closed
7/6/20	phase 3	50% open	50% open	50% open	Closed
7/20/20	phase 4, schools closed	50% open	50% open	50% open	25% open
9/7/20	phase 4, schools open	50% open	50% open	50% open	25% open, schools: 100%
12/23/20	phase 4, school break	50% open	50% open	50% open	25% open, schools: 100%
1/8/21	phase 4, schools open	50% open	50% open	50% open	25% open, schools: 100%

Rollback settings:

1) Fixed re-opening schedule as shown above *without rollback* for each policy

2) Re-opening schedule as shown above but *with adaptive PAUSE*: full PAUSE if at higher level of hospitalizations.

Rules for PAUSE: if hospitalizations exceed threshold 2, PAUSE; if hospitalizations remain below threshold 1 for 2 weeks, reopen per schedule.

Hospitalization thresholds:

Threshold 1: three consecutive days with COVID-like ED admissions above 200% of baseline ED pneumonia admissions as seen in prior years for corresponding period.

Threshold 2: three consecutive days with COVID-like ED admissions above 250% of baseline ED pneumonia admissions as seen in prior years for corresponding period.

For each policy, we simulate epidemic outcomes per the following settings:

1. Seasonality:
    1) Assume same seasonality as observed for OC43 (a beta-coronavirus, in the same genus as SARS-CoV-2).
    2) Assume no seasonality

2. Immunity: assumed ~3 years (range: 2.5 – 3.5 years); close to estimate for human endemic coronavirus combined (our estimate based on NYC data; unpublished)

3. Mobility: Estimated per categories of industries allowed to open in months (data from Safegraph.com) per the specified occupancy (Tables above)

4. Transmission rate/infectious period – representing level of infection control via precautionary measures (e.g. mask wearing, test & trace, disinfection, etc.). Of note, estimated transmission rate and infectious period decreased substantially from March 1 to June 6 (model training period), suggesting effectiveness of precautionary measures, in addition to reduction in mobility.
    1) "As Is" scenario: we project changes in transmission rate and infectious period based on the mobility estimates and model parameter estimates from March 1 – the most recent week, 2020. In addition, we in part account for potential reduction in transmission due to preventive measures (e.g. mask wearing).
    2) "10% reduction in transmission" scenario: 10% reduction in the transmission rate with respect to the projected estimates per the "As Is" scenario. This is possible with enhanced public health interventions (e.g. the contact tracing program and onsite preventive measures).
    3) "25% reduction in transmission" scenario: 25% reduction in the transmission rate with respect to the projected estimates per the "As Is" scenario. This is possible with enhanced public health interventions (e.g. the contact tracing program and onsite preventive measures).
    4) "10% increase in transmission" scenario: 10% increase in the transmission rate with respect to the projected estimates per the "As Is" scenario. This is possible if the preventive measures implemented during ~April – May are relaxed.
    5) "25% increase in transmission" scenario: 25% increase in the transmission rate with respect to the projected estimates per the "As Is" scenario. This is possible if the preventive measures implemented during ~April – May are relaxed.

5. Re-introduction of infection (i.e. seeding) from outside: 1 per 30 days per uhf

Modeling: A network SEIRS (susceptible-exposed-infectious-recovered-susceptible) model was trained on case and mortality data from the week of 3/1/20 to the week of 6/21/20 (the most recent week). From the week of 6/28/20 to the week of 5/23/21 (i.e., for ~1 year), the model was integrated stochastically using state variables estimated for the most recent week and corresponding parameter settings under each policy and scenario. Each simulation (500 ensemble members) was repeated 10 times and aggregated for the summary.

Some observations:

1) Impact of occupancy restrictions:
   a. Compared to Policy 1 (Schools fully open), reducing school capacity to 50% (Policy 2) would substantially reduce transmission (10-40% reductions in total number of infections; Figs 1-2).
   b. Compared to Policy 1, keeping schools 100% open but capping other phase 4 industries at 25% capacity (Policy 3) would also substantially reduce transmission (6-33% reductions in total number of infections; Figs 1-2).
   c. Limitations: While simulations show Policies 2 and 3 would result in similar levels of transmission reduction, our analyses were based entirely on changes in population mobility and did not account for potential increased transmission in school settings, although other phase 4 industries may share similar super-spreading nature.

2) Impact of adaptive rollback:
   a. For most occupancy and transmission scenarios except for the "25% reduction in transmission" scenario, PAUSE would be needed to avoid overwhelming the healthcare systems (i.e., exceeding the hospitalization threshold; Figs 3-4).
   b. When enacted, adaptive rollback with PAUSE would reduce COVID burden by 16-49%, compared to no rollback (Fig 3).

3) Under Policy #2 (cap all industries including schools at 50% capacity) with adaptive PAUSE:
   a. Under the "As Is" transmission scenario, 11.7% (IQR: 2.9 – 22.8%) of the population would be infected and there would be 35.8 K (IQR: 8.9 K – 74.0 K) hospitalizations and 14.5 K (IQR: 3.6 K – 28.6 K) deaths tallied over ~1 year (6/28/2020 – 5/31/21). The number of weeks needed to be on PAUSE would be 2 weeks starting early Dec 2020 (Weeks of 12/6 and 12/13).
   b. Under the "10% transmission reduction" scenario (note: early data from contact tracing suggested a ~5-10% reduction), 7.6% (IQR: 1.3 – 18.3%) of the population would be infected and there would be 23.6 K (IQR: 4.1 K – 58.3 K) hospitalizations and 9.7 K (IQR: 1.7 K – 23.6 K) deaths tallied over ~1 year (present – 5/31/21). The number of weeks needed to be on PAUSE would be 3 weeks in the winter during the holiday season starting the Week of 12/27/20 (Table 1).

Table 1. Comparing different **occupancy/rollback policies**. Summary results assuming 3-yr immunity and OC43 seasonality, including total infections (% population), total hospitalizations, and total deaths. Numbers are median (and interquartile range) summed over ~1 year (6/28/20 – 5/31/21).

schedule	scenario	measure	sch 100%, others 50%	all 50%	sch 100%, other ph4 25%
Fixed	As Is	Infections (%)	22.7 (9.6, 34.1)	18.8 (6.9, 29.7)	20.1 (7.6, 31.3)
Fixed	10% redn in TX	Infections (%)	12.3 (3, 24.1)	9 (1.7, 19.9)	9.8 (1.9, 21.2)
Fixed	25% redn in TX	Infections (%)	2.9 (0.4, 10.6)	1.9 (0.3, 7.4)	2 (0.3, 7.9)
Fixed	10% incr in TX	Infections (%)	31.7 (17.4, 42.7)	27.6 (14.1, 38.3)	29.1 (15.2, 40)
Fixed	25% incr in TX	Infections (%)	40.2 (24.5, 51.2)	36 (20.7, 47)	37.8 (22.1, 48.8)
Fixed	As Is	Hospitalizations	67264 (28522, 113893)	55917 (20967, 98134)	59677 (23011, 103677)
Fixed	10% redn in TX	Hospitalizations	37451 (9284, 77208)	27703 (5513, 63381)	29978 (6141, 67592)
Fixed	25% redn in TX	Hospitalizations	9236 (1363, 33747)	5953 (866, 23614)	6310 (906, 25341)
Fixed	10% incr in TX	Hospitalizations	93799 (49504, 147208)	81499 (40780, 130840)	85947 (43768, 137056)
Fixed	25% incr in TX	Hospitalizations	119481 (68148, 178690)	106851 (58366, 162934)	111927 (61859, 169484)
Fixed	As Is	Deaths	29622 (13010, 44264)	24457 (9425, 38484)	26182 (10373, 40626)
Fixed	10% redn in TX	Deaths	16415 (4083, 31629)	11966 (2387, 26092)	13052 (2691, 27869)
Fixed	25% redn in TX	Deaths	3852 (626, 13878)	2452 (416, 9715)	2606 (440, 10438)
Fixed	10% incr in TX	Deaths	40820 (22940, 55472)	35433 (18670, 49480)	37430 (20158, 51763)
Fixed	25% incr in TX	Deaths	51340 (31258, 66528)	45690 (26456, 60846)	48008 (28261, 63214)
Adept	As Is	Infections (%)	13.6 (3.7, 25.2)	11.7 (2.9, 22.8)	12.3 (3.1, 23.6)
Adept	10% redn in TX	Infections (%)	8.9 (1.7, 20.1)	7.6 (1.3, 18.3)	7.8 (1.3, 18.8)
Adept	25% redn in TX	Infections (%)	3.1 (0.5, 10.7)	2.2 (0.3, 7.8)	2.3 (0.3, 8.3)
Adept	10% incr in TX	Infections (%)	17.5 (6.1, 29.7)	15.2 (4.8, 27.1)	15.8 (5.2, 27.6)
Adept	25% incr in TX	Infections (%)	21 (8.6, 32.8)	18.4 (6.8, 30.7)	19.3 (7.3, 31.5)
Adept	As Is	Hospitalizations	41221 (11318, 82327)	35831 (8939, 74036)	37385 (9570, 76752)
Adept	10% redn in TX	Hospitalizations	27505 (5179, 64405)	23588 (4053, 58352)	24127 (4052, 60120)
Adept	25% redn in TX	Hospitalizations	9655 (1575, 34263)	6806 (1104, 24945)	7165 (1156, 26639)
Adept	10% incr in TX	Hospitalizations	52756 (17891, 98070)	46071 (14241, 89083)	47768 (15396, 90962)
Adept	25% incr in TX	Hospitalizations	62996 (24812, 109485)	55702 (19865, 101616)	58081 (21415, 104408)
Adept	As Is	Deaths	16897 (4698, 31840)	14456 (3619, 28596)	15097 (3851, 29608)
Adept	10% redn in TX	Deaths	11358 (2183, 25771)	9707 (1693, 23629)	9961 (1700, 24235)
Adept	25% redn in TX	Deaths	4040 (698, 14103)	2828 (516, 10273)	2987 (531, 10963)
Adept	10% incr in TX	Deaths	21466 (7314, 37514)	18774 (5851, 34327)	19573 (6398, 35049)
Adept	25% incr in TX	Deaths	25675 (10041, 41441)	22517 (8006, 38744)	23467 (8594, 39679)
Adept	As Is	Weeks on PAUSE	4	2	3
Adept	10% redn in TX	Weeks on PAUSE	3	3	1
Adept	25% redn in TX	Weeks on PAUSE	0	0	0
Adept	10% incr in TX	Weeks on PAUSE	11	10	10
Adept	25% incr in TX	Weeks on PAUSE	13	13	12

Fig 1. Comparing cumulative epidemic outcomes under *different* ***occupancy policies (all without rollback)***. Boxplots show the distribution of simulated total number of infections (row 1), hospitalizations (row 2), or deaths (row 3), summed over the week of 6/28/20 – the week of 5/31/21 (1 year). Policy option is indicated by color: Policy 1 (50% cap; schools: 100%) in orange, Policy 2 (50% cap for all) in blue, and Policy 3 (50% cap for phases 1-3; schools: 100% and 25% cap for other phase 4 industries) in green. Each policy was simulated under 5 scenarios (labeled on the x-axis). Numbers in percentage indicate the relative changes compared to policy 1 (positive numbers indicate increases and negative indicate decreases). Columns show results under different *seasonality* assumptions (left: seasonality assumed; right: no seasonality)

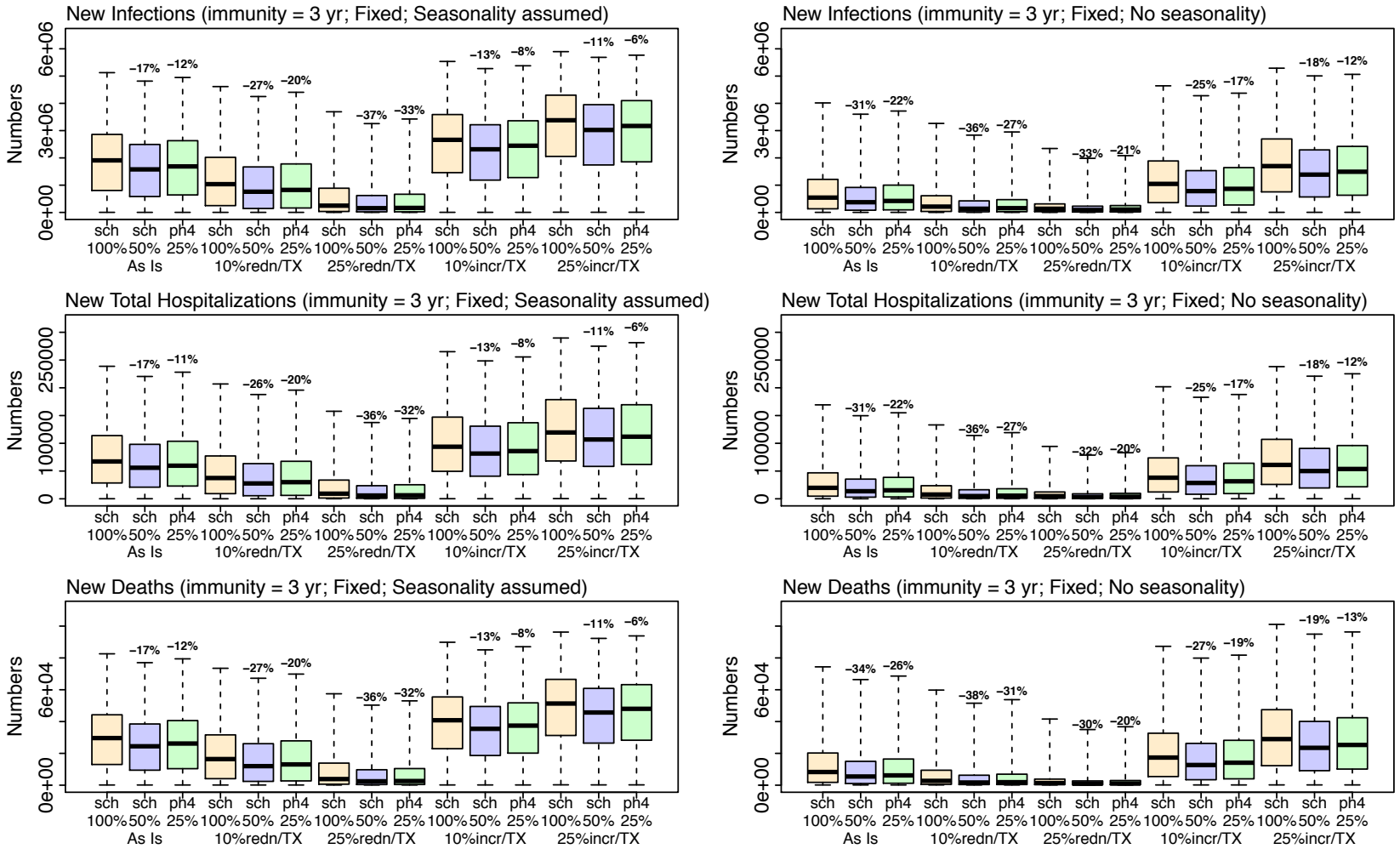

Fig 2. Comparing epidemic trajectories under different ***occupancy policies without rollback*** (# infections are shown here; for more epidemic outcomes, see other plots in pdf). Solid lines show median of simulated *weekly* number of infections. Policy option is indicated by color: Policy 1 (50% cap; schools: 100%) in orange, Policy 2 (50% cap for all) in blue, and Policy 3 (50% cap for phases 1-3; schools: 100% and 25% cap for other phase 4 industries) in green. Transmission scenarios are as labeled in the panel titles. For clarity, interquartile ranges are not shown (see details in excel spreadsheets). These simulations assumed 3-year immunity and human coronavirus OC43 seasonality for SARS-CoV-2.

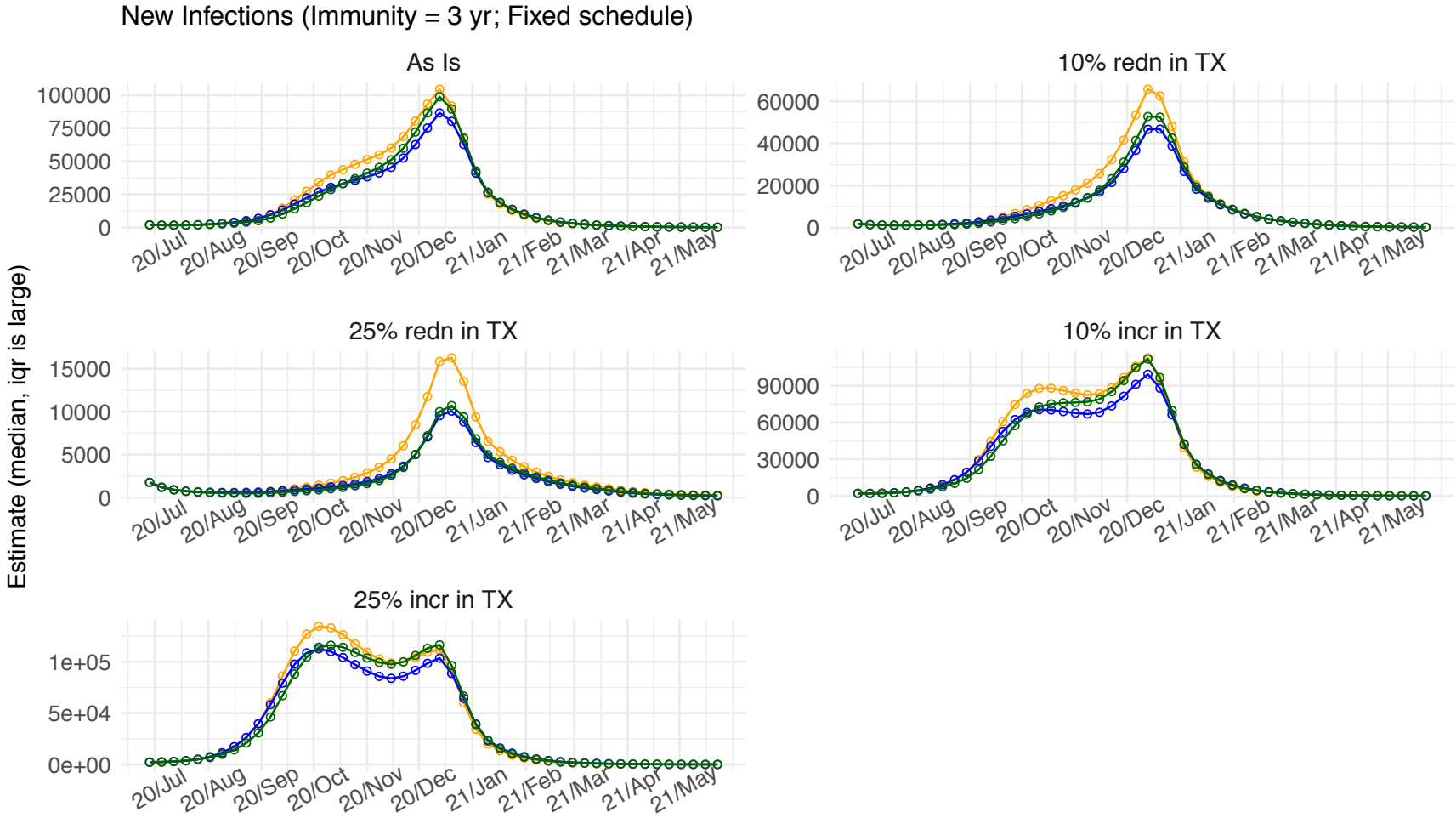

Fig 3. Comparing cumulative epidemic outcomes under *different* ***occupancy and rollback policies***. Boxplots show the distribution of simulated total number of infections (row 1), hospitalizations (row 2), or deaths (row 3), summed over the week of 6/28/20 – the week of 5/31/21 (1 year). Occupancy option is indicated by color: Policy 1 (50% cap; schools: 100%) in orange, Policy 2 (50% cap for all) in blue, and Policy 3 (50% cap for phases 1-3; schools: 100% and 25% cap for other phase 4 industries) in green. Rollback policy is indicated on the x-axis: 'fix' for no rollback and 'ada' for adaptive PAUSE. Each policy was simulated under 5 scenarios (labeled on the x-axis). Numbers in percentage indicate the relative changes compared to no rollback (positive numbers indicate increases and negative indicate decreases). Note under the '25% redn in TX' scenario, no PAUSE was needed; the (positive) percentages were due to model stochasticity and small numbers (see details in Table 1).

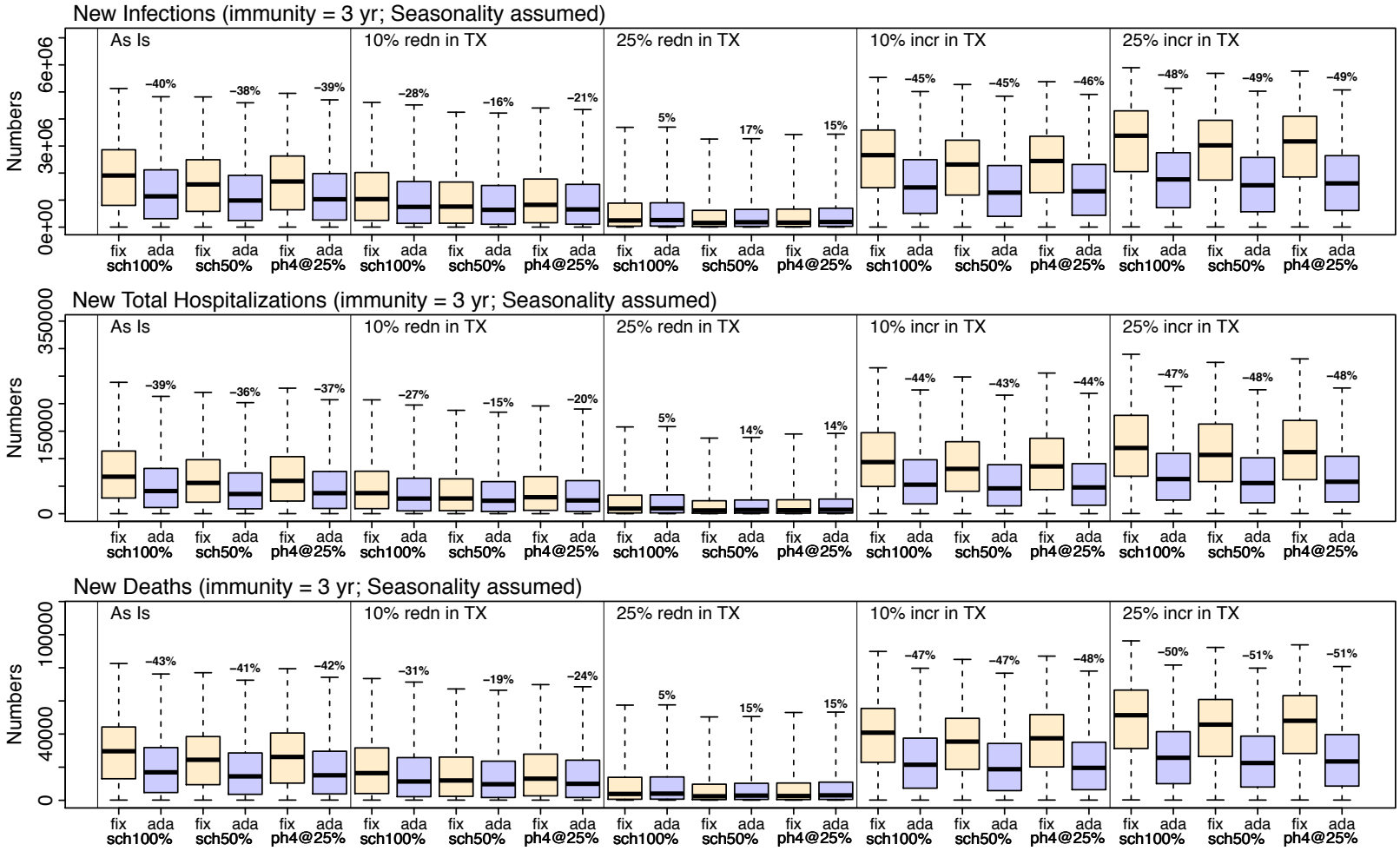

Fig 4. Comparing epidemic trajectories under different ***occupancy policies with adaptive PAUSE*** (# infections are shown here; for more epidemic outcomes, see other plots in pdf). Solid lines show median of simulated *weekly* number of infections. Policy option is indicated by color: Policy 1 (50% cap; schools: 100%) in orange, Policy 2 (50% cap for all) in blue, and Policy 3 (50% cap for phases 1-3; schools: 100% and 25% cap for other phase 4 industries) in green. Points show if a week is open as scheduled (open circle) or on PAUSE (filled circle). Transmission scenarios are as labeled in the panel titles. For clarity, interquartile ranges are not shown (see details in excel spreadsheets). These simulations assumed 3-year immunity and human coronavirus OC43 seasonality for SARS-CoV-2.