What level of ICU occupancy should trigger additional mitigations?

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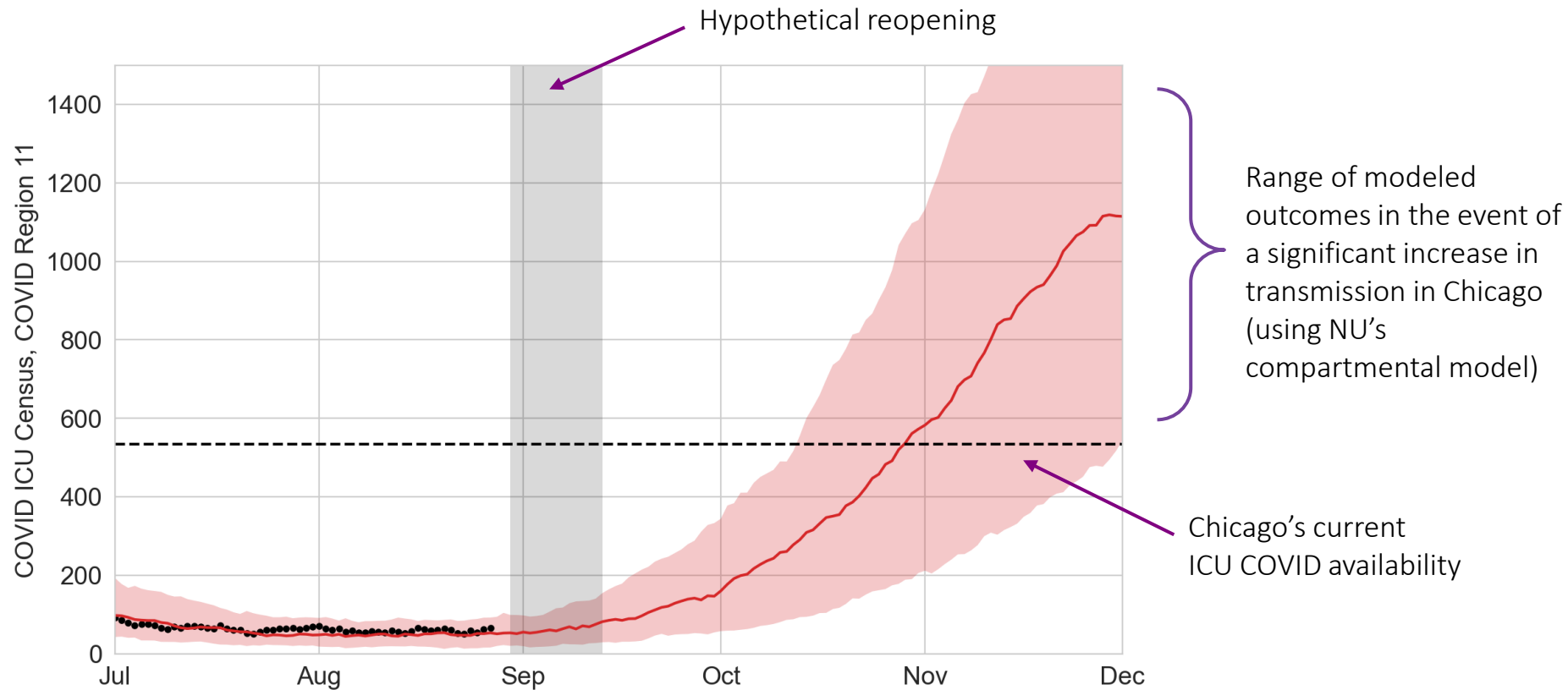Is 75% of available ICU capacity a good trigger for imposing mitigations?

If not, what is a good trigger threshold?

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Rephrased…

How does the ICU occupancy threshold for imposing new mitigation depend on:

- How fast transmission is increasing
- How fast we can act
- How strong the mitigation is
- COVID Region
- Acceptable risk of overflowing 100% capacity

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If transmission increases too much, ICU and hospital bed capacities could be threatened

Hypothetical reopening

Range of modeled outcomes in the event of a significant increase in transmission in Chicago (using NU's compartmental model)

Chicago's current ICU COVID availability

COVID ICU Census, COVID Region 11

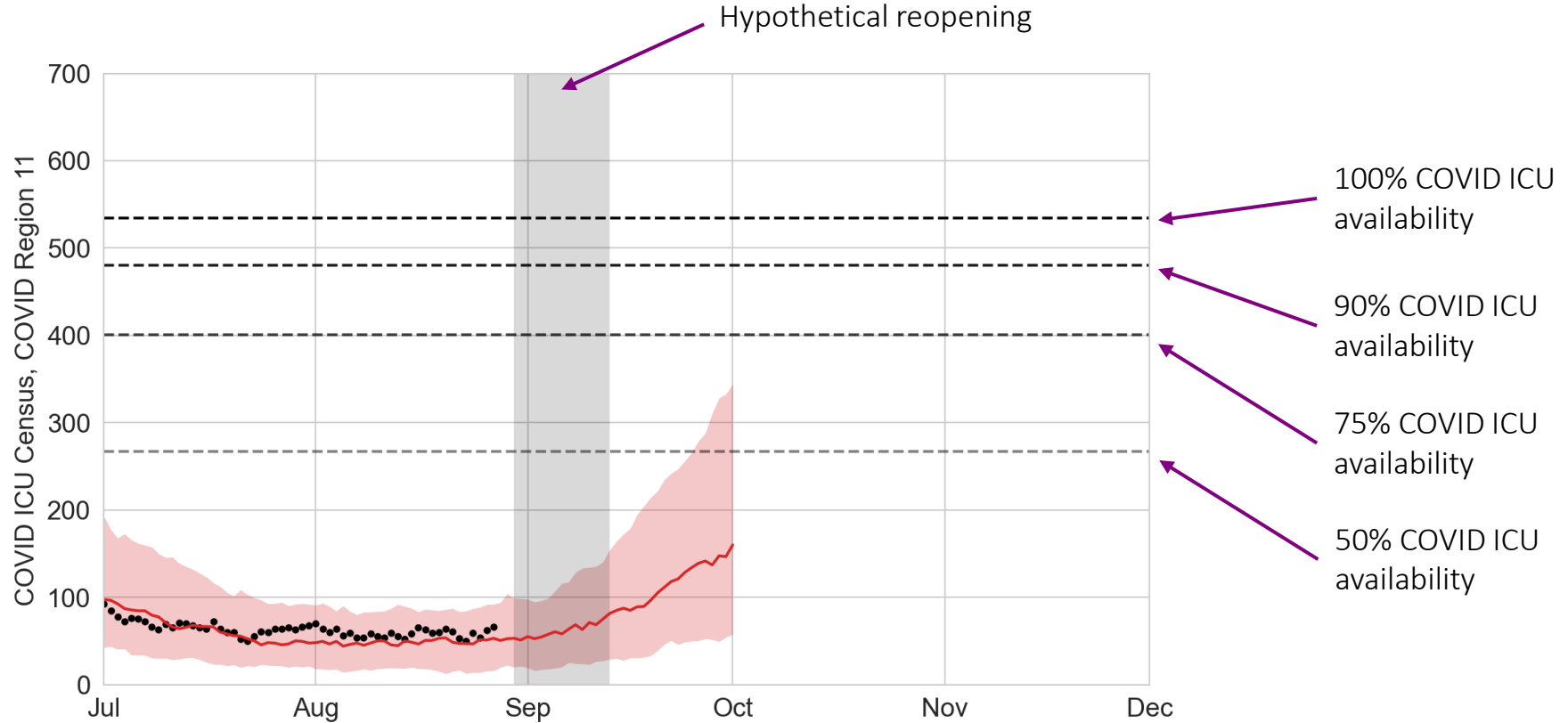**Data source:** EMResource

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Note:

We will use "reopening" to describe increases in transmission after September 1, but seasonal effects could also contribute to increased transmission even if social behavior has not changed.

The model doesn't care *why* transmission has increased, only that it has, so we are bundling all these effects together into "reopening".

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What if we reintroduced mitigation measures to reduce transmission once a given threshold level of ICU availability is reached? Could we prevent ICU overflow?
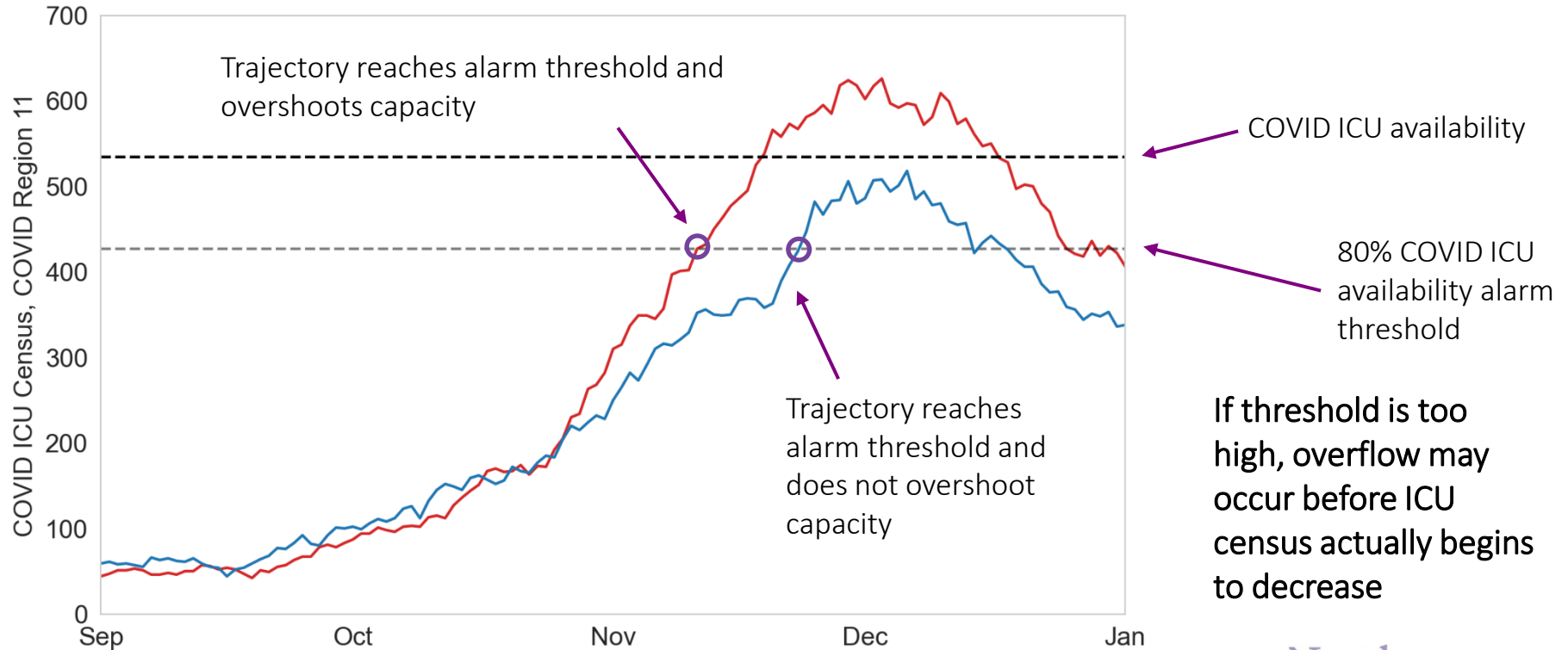

Data source: EMResource

Can we design "rollback thresholds" in COVID ICU census for each COVID region such that ICU overflow is reliably averted?

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Our procedure:

1. Choose a reopening level for each region that represents a **realistic worst-case scenario**

2. Choose a alarm threshold for ICU census (e.g. 80% of ICU availability)

3. Run many simulations in which, if the alarm threshold is met, transmission returns to its previous minimum level (i.e. early-June transmission levels)

4. Based on these simulations, calculate the probability that ICU overflow occurs still occurs despite the alarm

5. Repeat for other alarm thresholds (e.g. 40% of ICU availability, 50% of ICU availability, etc.)

Risk Tolerance Curve
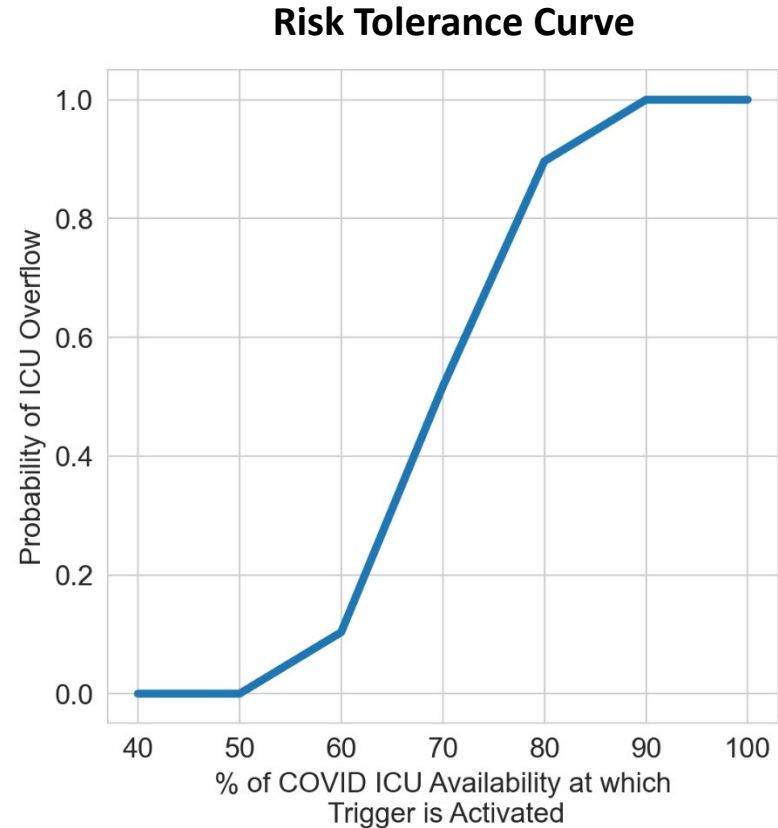
Why can't we roll back transmission just before we break ICU capacity? It takes some time for a fall in transmission to be reflected in ICU census, and ICU census may overshoot capacity in the intervening time

Trajectory reaches alarm threshold and overshoots capacity

COVID ICU availability

80% COVID ICU availability alarm threshold

Trajectory reaches alarm threshold and does not overshoot capacity

If threshold is too high, overflow may occur before ICU census actually begins to decrease

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Why use a "realistic worst-case scenario" to design our thresholds? A rapidly-increasing ICU census would be more difficult to "turn around" than a slowly-increasing ICU census
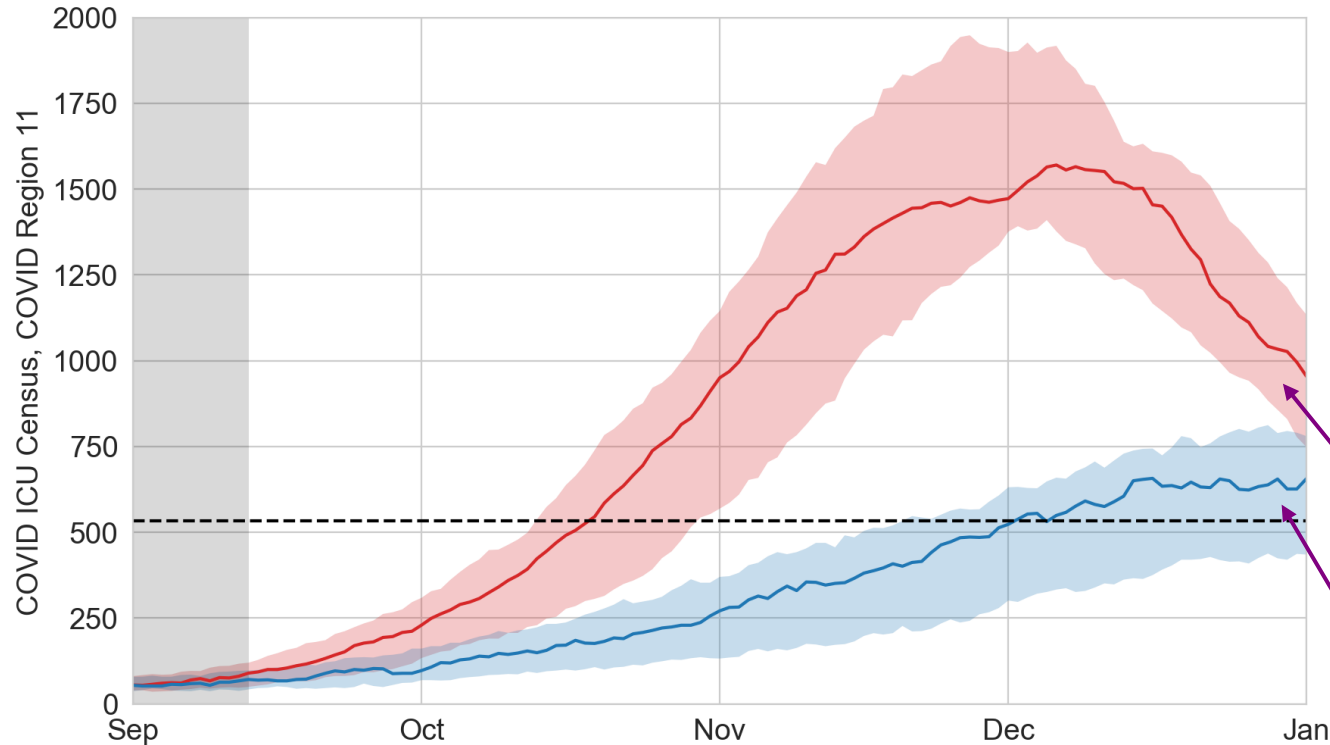
If we design an alarm threshold off of a scenario with slower reopening, our threshold may be insufficient to prevent overflow in the event of a more rapid increase in transmission

Hypothetical "hard" reopening
(all trajectories exceed ICU capacity by Dec 31)

Hypothetical "soft" reopening
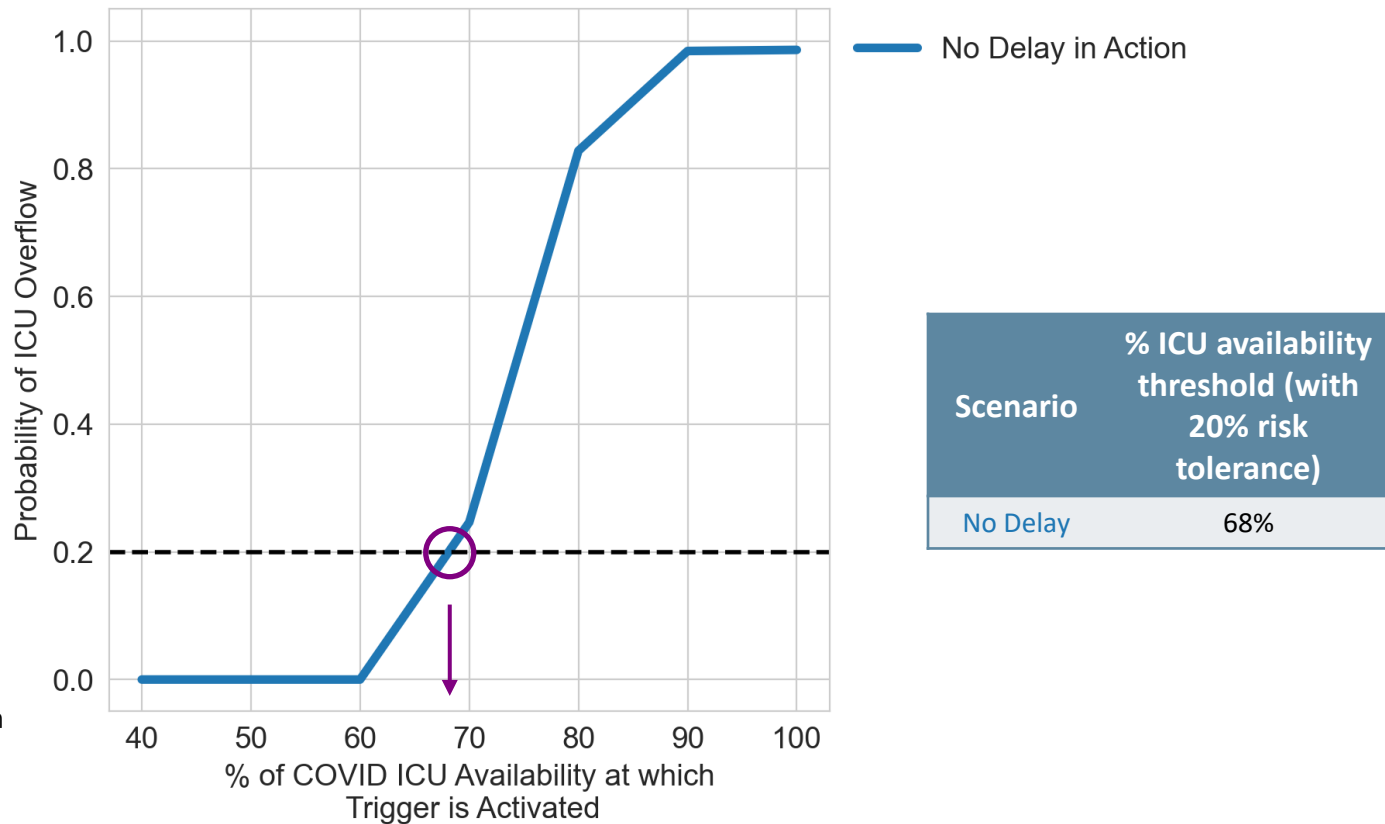*(some trajectories exceed ICU capacity by Dec 31)*

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What is the shape of the risk tolerance curve if we suppose that there is **no delay** between the alarm being pulled and when mitigation measures take effect?

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For COVID Region 11 (Chicago), a 75% ICU availability alarm threshold prevents ICU overflow ~50% of the time **when there is no delay in action**
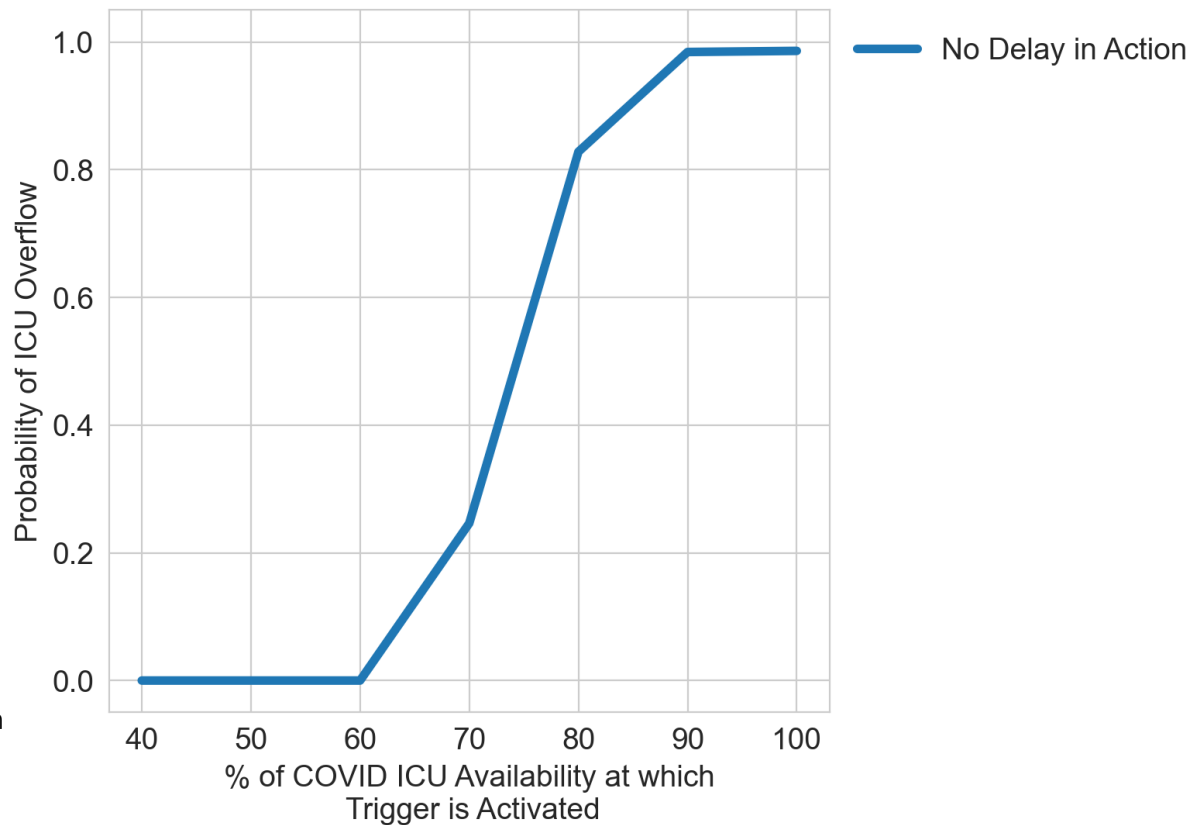
Hard reopen
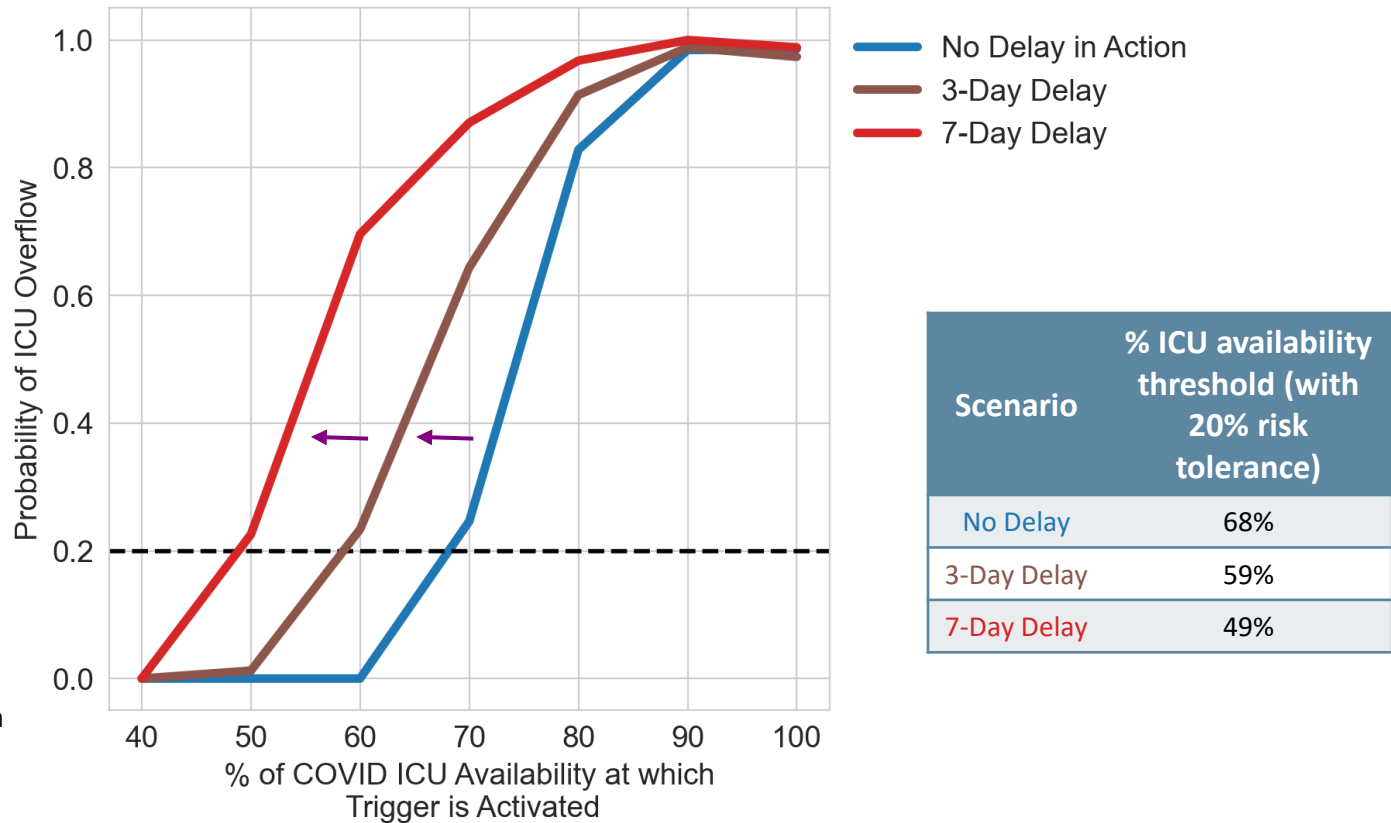Return to June transmission
No delay

Tolerating a 20% risk of ICU capacity overflow, a realistic worst-case scenario with **no delay in action** would require a 68% COVID ICU availability alarm threshold

Hard reopen
Return to June transmission
No delay

Scenario	% ICU availability threshold (with 20% risk tolerance)
No Delay	68%

How does the shape of the risk tolerance curve change if we suppose that there is **some delay** between the alarm being pulled and when mitigation measures take effect?

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Under the assumption that there will be **some delay** between the alarm and mitigation measures taking effect, **lower** thresholds are necessary to prevent overflow

Hard reopen
Return to June transmission
Variable delay

Scenario	% ICU availability threshold (with 20% risk tolerance)
No Delay	68%
3-Day Delay	59%
7-Day Delay	49%

What if, instead of returning to early-June transmission levels, **we return to early-August transmission levels** when the alarm is pulled?

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If we assume that mitigation measures are not as strong at reducing transmission (reduction to early-August levels instead of early-June levels), **even lower thresholds are necessary to prevent overflow**

High Reduction in Transmission, No Delay

Low Reduction in Transmission, No Delay
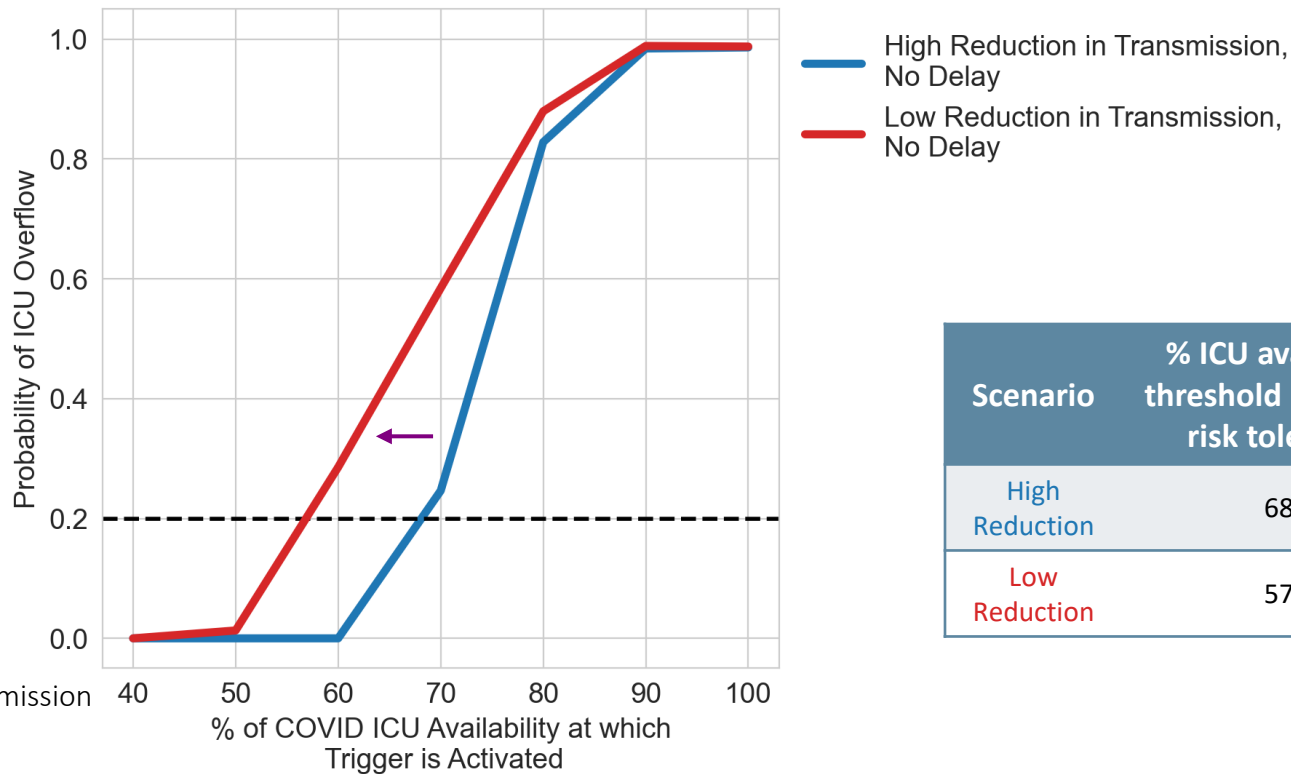
Hard reopen
Return to Aug transmission
No delay

Scenario	% ICU availability threshold (with 20% risk tolerance)
High Reduction	68%
Low Reduction	57%

What if we choose a less rapid reopening scenario?

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If we choose a softer reopening scenario (only 50% of trajectories exceed ICU capacity by Dec 31st), thresholds for action don't need to be as low because overall probability of ICU overflow decreases

Variable reopen
Return to June transmission
No delay
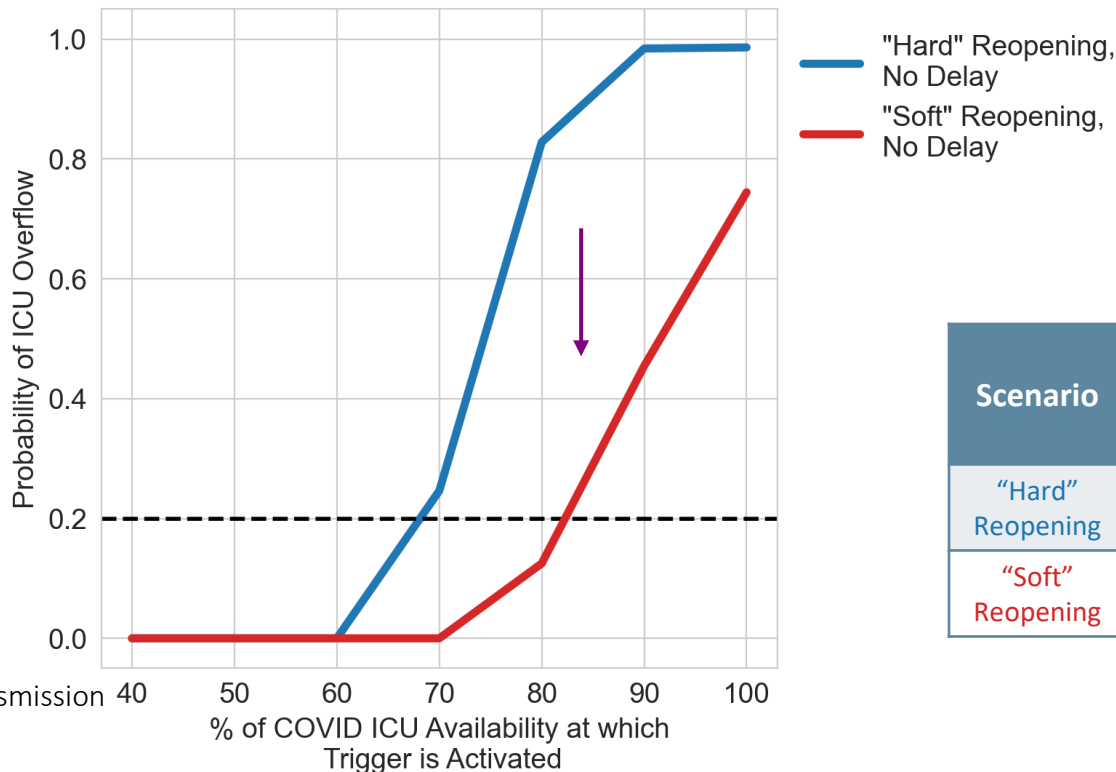
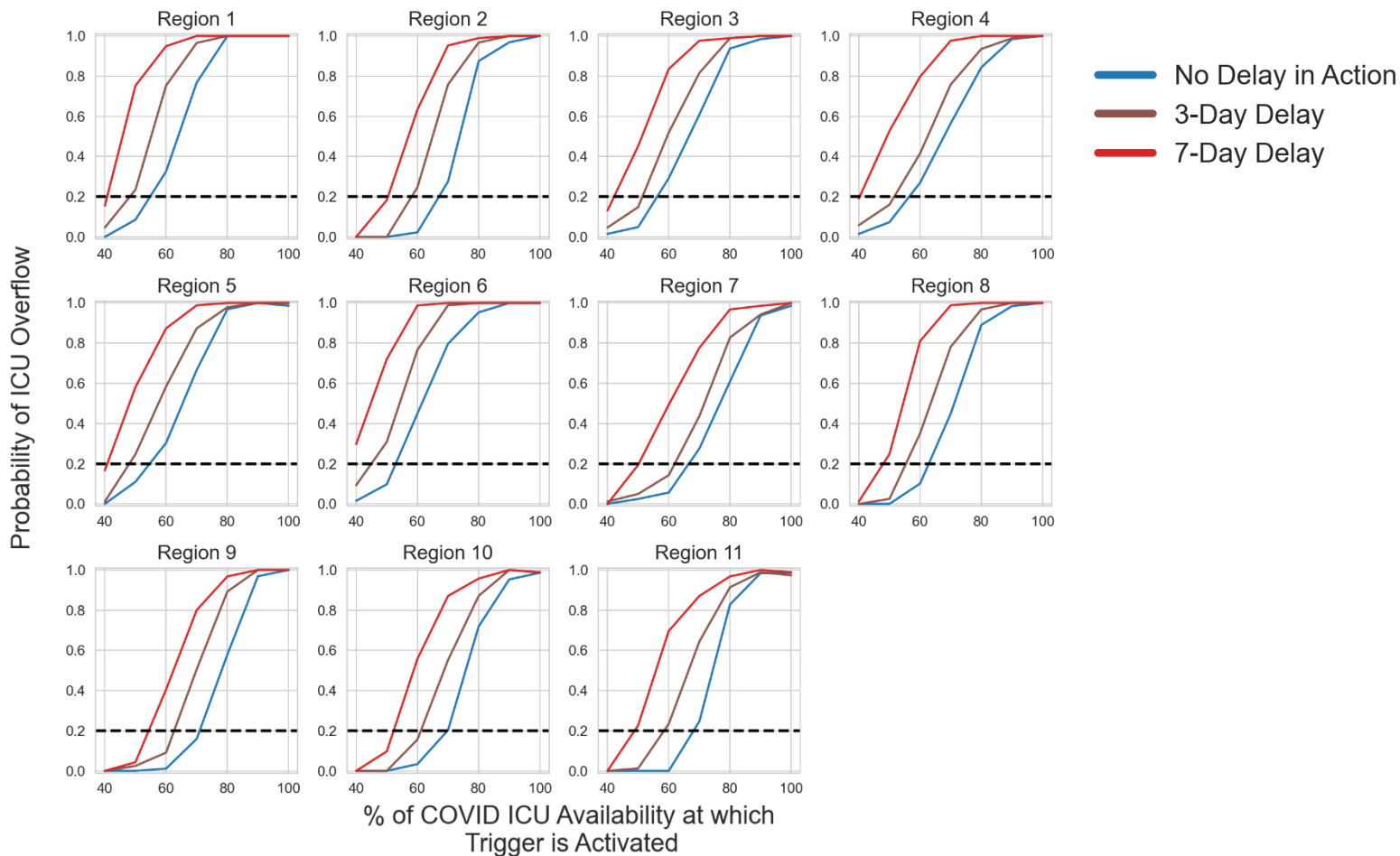| Scenario	% ICU availability threshold (with 20% risk tolerance)
"Hard" Reopening	68%
"Soft" Reopening	82%

However, lower thresholds are still necessary if we assume some delay will occur between hitting the threshold and taking action
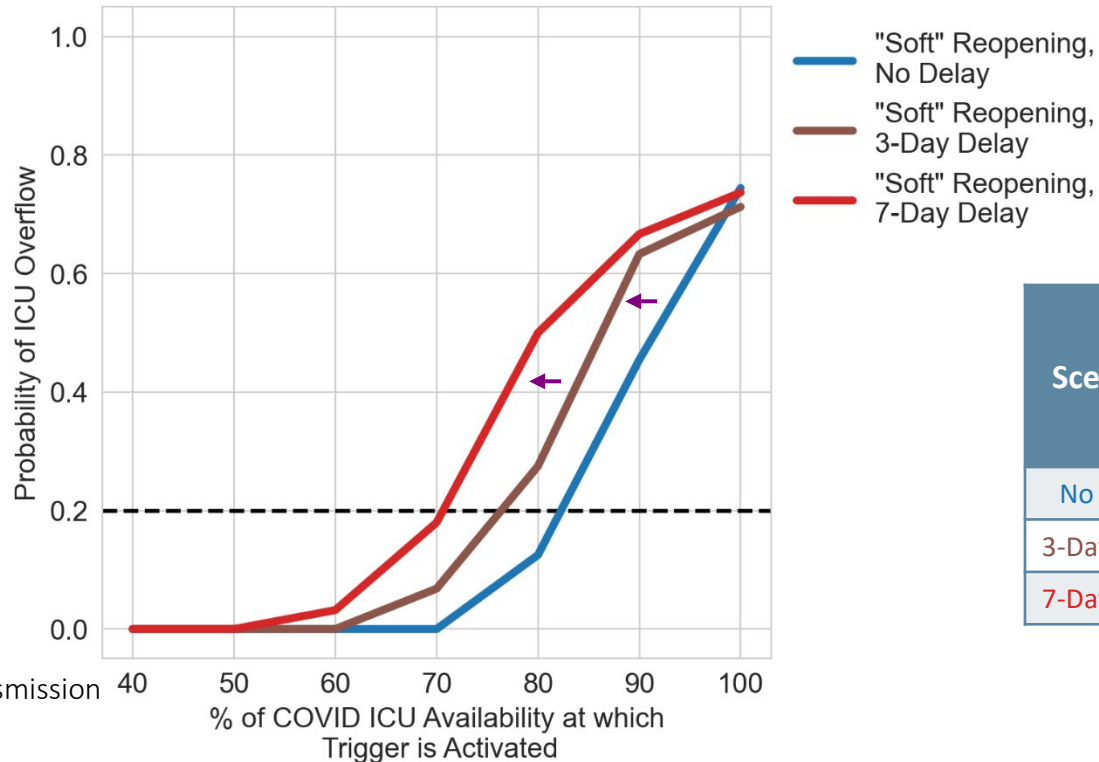
Scenario	% ICU availability threshold (with 20% risk tolerance)
No Delay	82%
3-Day Delay	76%
7-Day Delay	70%

Soft reopen
Return to June transmission
Variable delay

Each region requires different alarm thresholds

No Delay in Action
3-Day Delay
7-Day Delay

Probability of ICU Overflow

% of COVID ICU Availability at which Trigger is Activated

Hard reopen
Return to June
transmission
Variable delay

Thresholds for action, per Covid Region, at 20% risk tolerance for exceeding 100% ICU capacity

Scenario					% ICU availability threshold to trigger mitigation, by COVID Region										
	Reopen strength	Return level	Delay to act	Risk	1	2	3	4	5	6	7	8	9	10	11
A	Hard	June	0 days	20%	55	67	56	56	55	53	66	63	72	70	68
B	Hard	Aug	0	20%	50	43	<40	<40	<40	<40	<40	55	65	60	56
C	Hard	June	3	20%	47	58	51	52	48	45	62	55	62	61	57
D	Hard	June	7	20%	41	50	42	40	41	<40	50	47	54	52	49
E	Soft	June	0	20%	75	78	84	82	77	70	77	85	78	85	83
F	Soft	Aug	0	20%	71	62	55	60	50	<40	51	81	74	80	75
G	Soft	June	3	20%	70	73	79	77	74	64	74	82	73	80	76
H	Soft	June	7	20%	62	68	73	73	70	61	68	75	67	74	71

*We picked 20% risk tolerance for this example table but have model outputs for the entire range of risk.

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Preliminary Conclusions

- Under a worst-case scenario, a 75% ICU availability alarm threshold would be **insufficient in every region** to reliably prevent capacity overflow

- **Lag time** between trigger and mitigation measures taking effect should **always** be considered when designing alarm thresholds

- **How quickly transmission is increasing** has a HUGE impact on where thresholds for action lie. Reliable measurement of trends in transmission is KEY. Our current data is insufficient for estimating these trends because it is biased, noisy, and lagged. Sentinel surveillance is necessary to address these issues and give us the information we need to make good decisions.

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Appendix

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Most regions are not currently approaching alarm thresholds
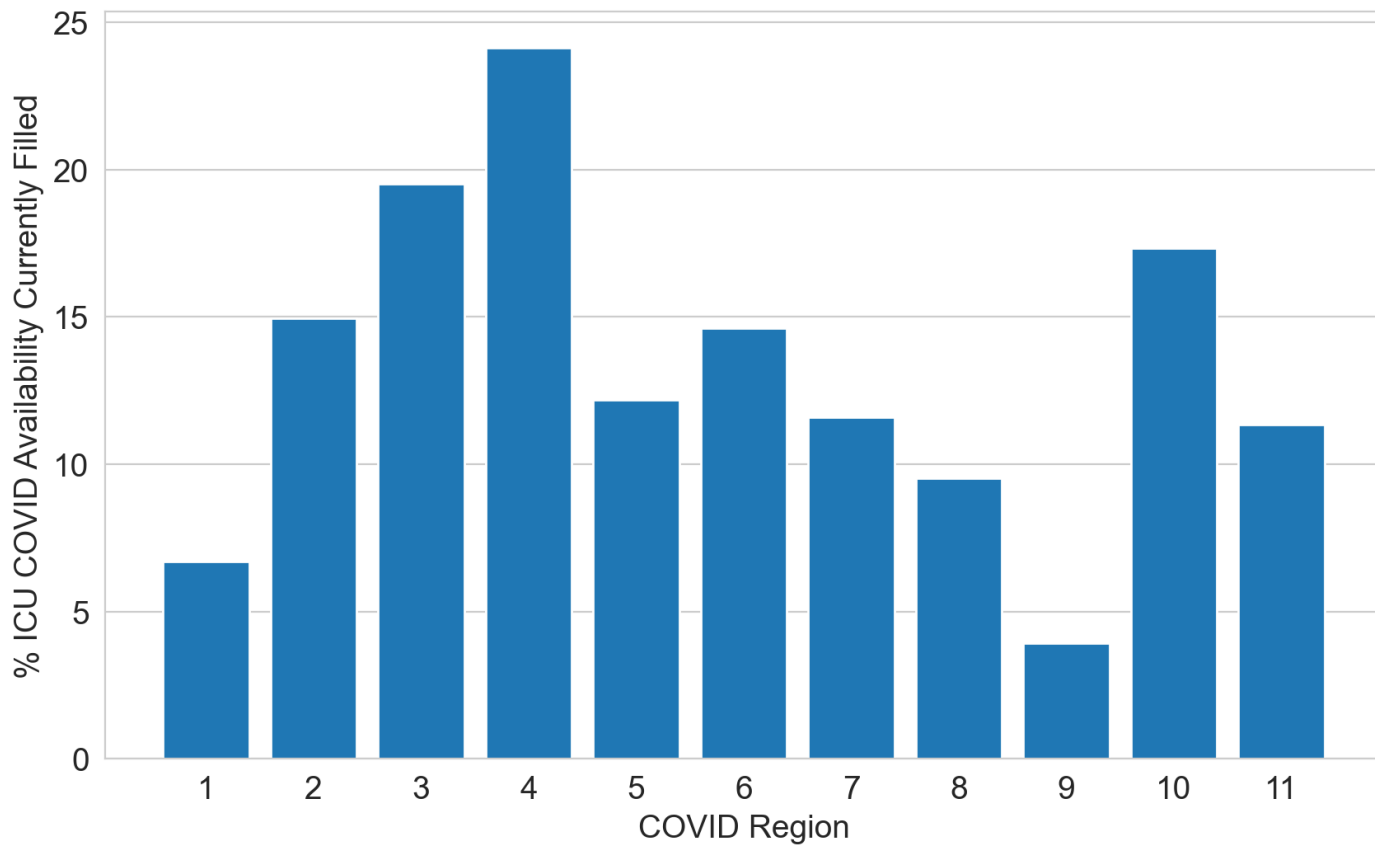
By simulating reopening scenarios, we can trigger a change in transmission if a given % of ICU beds filled reach a defined threshold
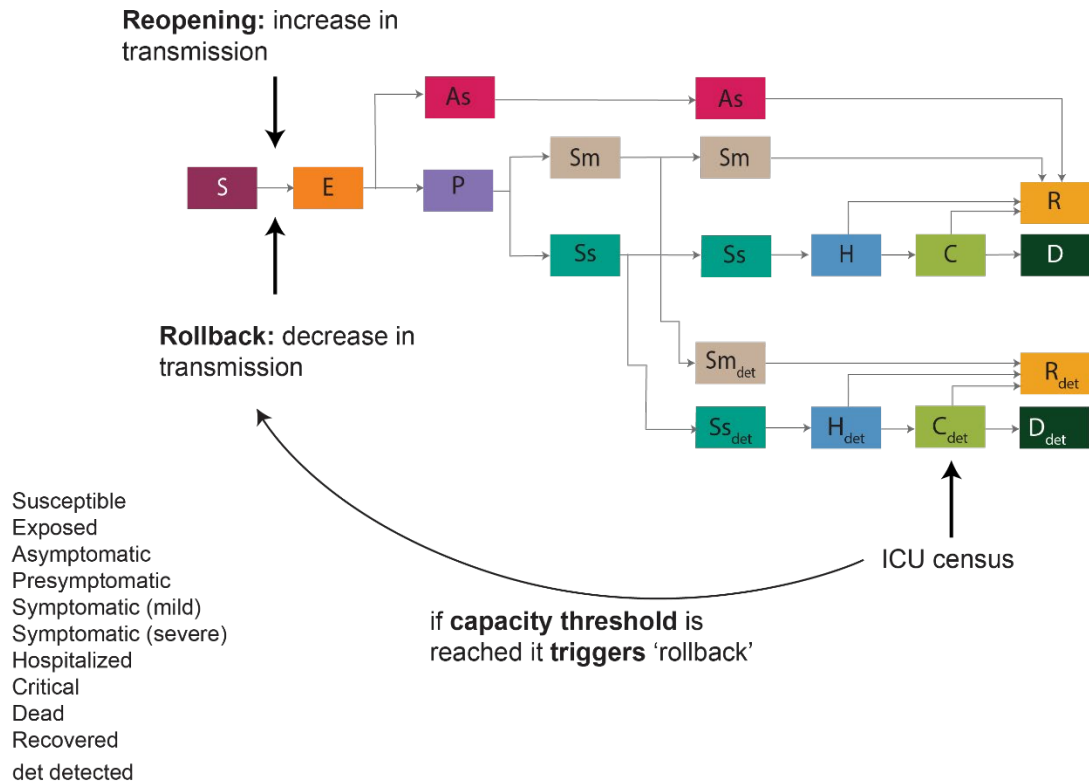
What does "hard" and "soft" reopening mean in terms of a quantity we can measure, like R_t?

COVID Region	% backsliding to March levels		Maximum R_t reached	
	hard reopening	soft reopening	hard reopening	soft reopening
1	16	9	1.26 (1.15 - 1.4)	1.16 (1.08 - 1.24)
2	8	4	1.2 (1.1 - 1.29)	1.12 (1.06 - 1.19)
3	19	5	1.22 (1.1 - 1.34)	1.09 (1.04 - 1.14)
4	12	4	1.22 (1.12 - 1.34)	1.09 (1.03 - 1.13)
5	15	5	1.25 (1.12 - 1.39)	1.12 (1.06 - 1.19)
6	13	4	1.24 (1.12 - 1.37)	1.13 (1.06 - 1.2)
7	7	4	1.18 (1.08 - 1.28)	1.11 (1.05 - 1.18)
8	8	4	1.23 (1.1 - 1.36)	1.12 (1.06 - 1.18)
9	10	8	1.21 (1.11 - 1.33)	1.15 (1.07 - 1.25)
10	9	5	1.19 (1.1 - 1.31)	1.12 (1.06 - 1.17)
11	8	5	1.24 (1.13 - 1.34)	1.16 (1.09 - 1.24)

"hard" = 100% of trajectories exceed ICU capacity by Dec 31 2020

"soft" = 50% of trajectories exceed ICU capacity by Dec 31 2020

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What does "hard" and "soft" reopening mean in terms of a quantity we can measure, like R_t?

"hard" = 100% of trajectories exceed ICU capacity by Dec 31 2020

"soft" = 50% of trajectories exceed ICU capacity by Dec 31 2020

hard reopening
soft reopening

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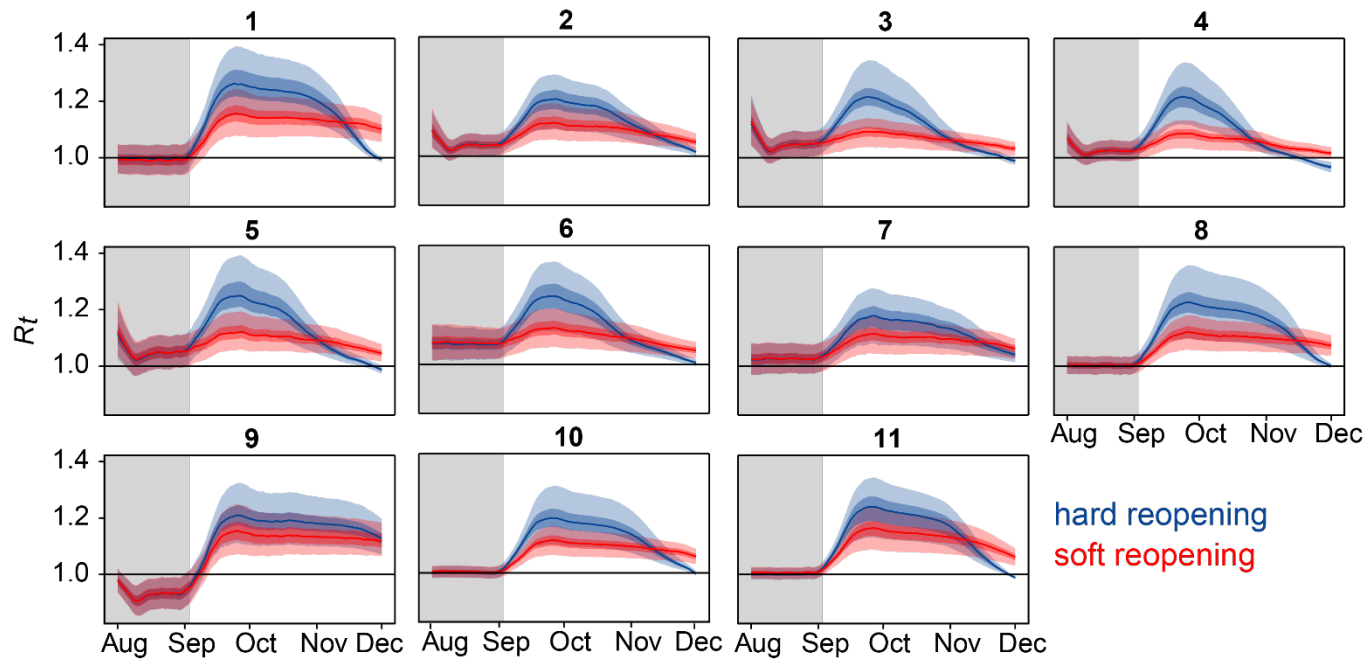
Responding to a "hard" reopen with weaker mitigation could mean overflow of ICU capacities even for very low occupancy triggers

Hard reopen

Return to August transmission

Variable delay
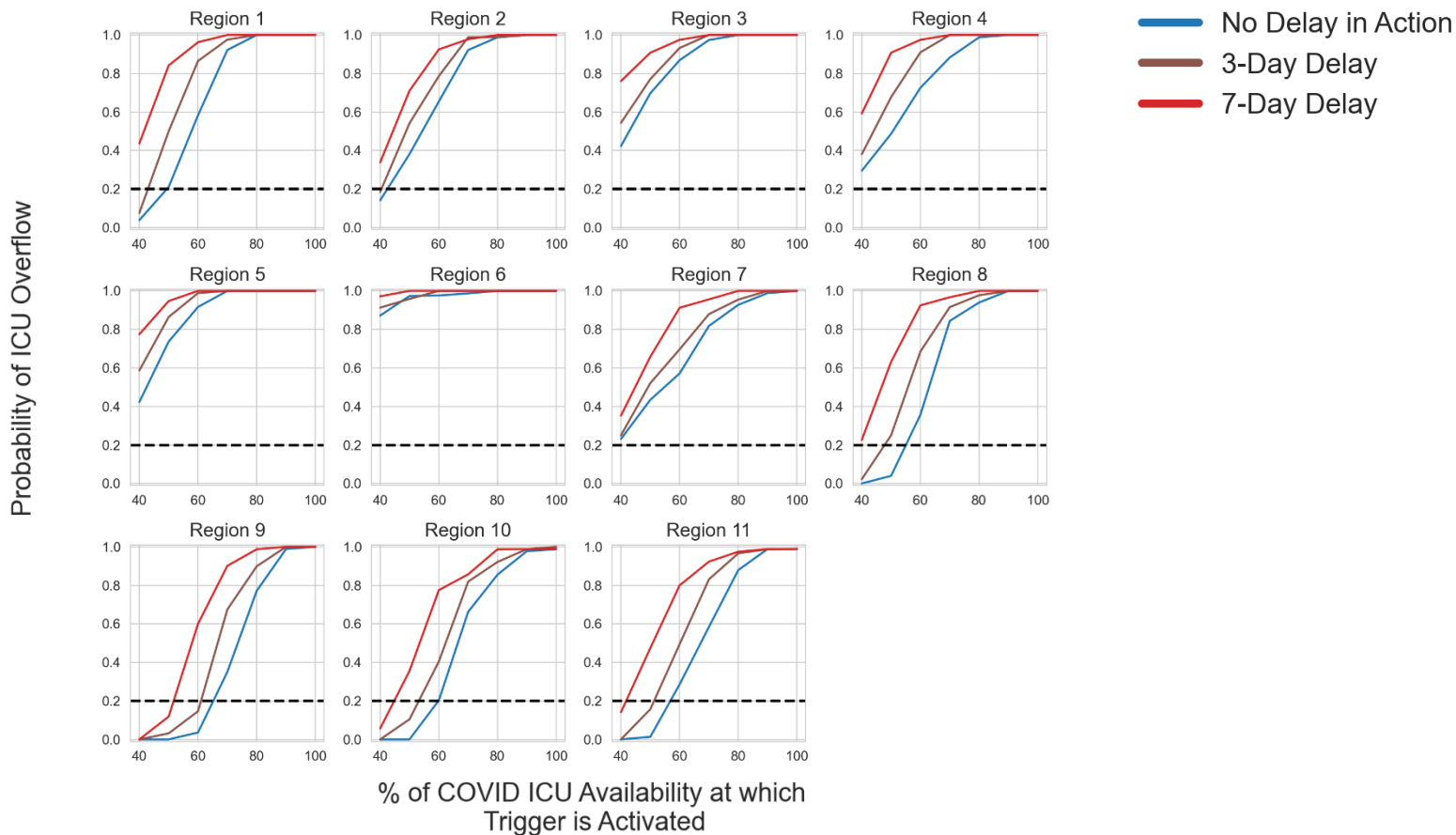
Choosing a less robust reopening shifts curves to the right, increasing necessary thresholds

Soft reopen

Return to June transmission

Variable delay