Proactive Resilient Healthcare Supply Chain Development
(INFORMS 2021, INSEAD, IIM, Beijing JTU, Michigan, Carnegie Mellon, Maryland)

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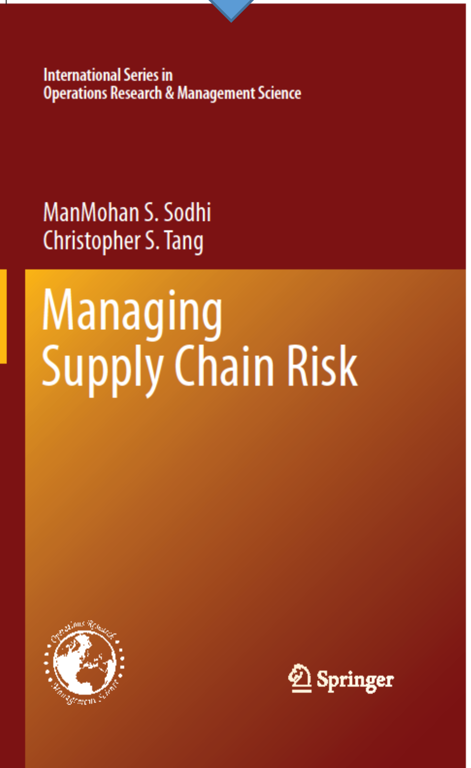
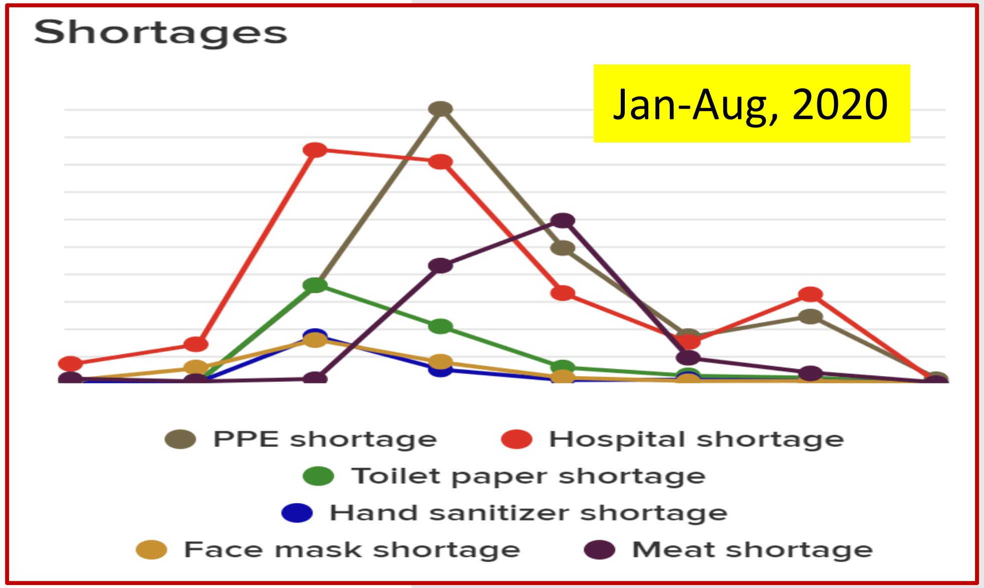
Identify, Evaluate, Mitigate, Respond



My Life as a Supply Chain Researcher

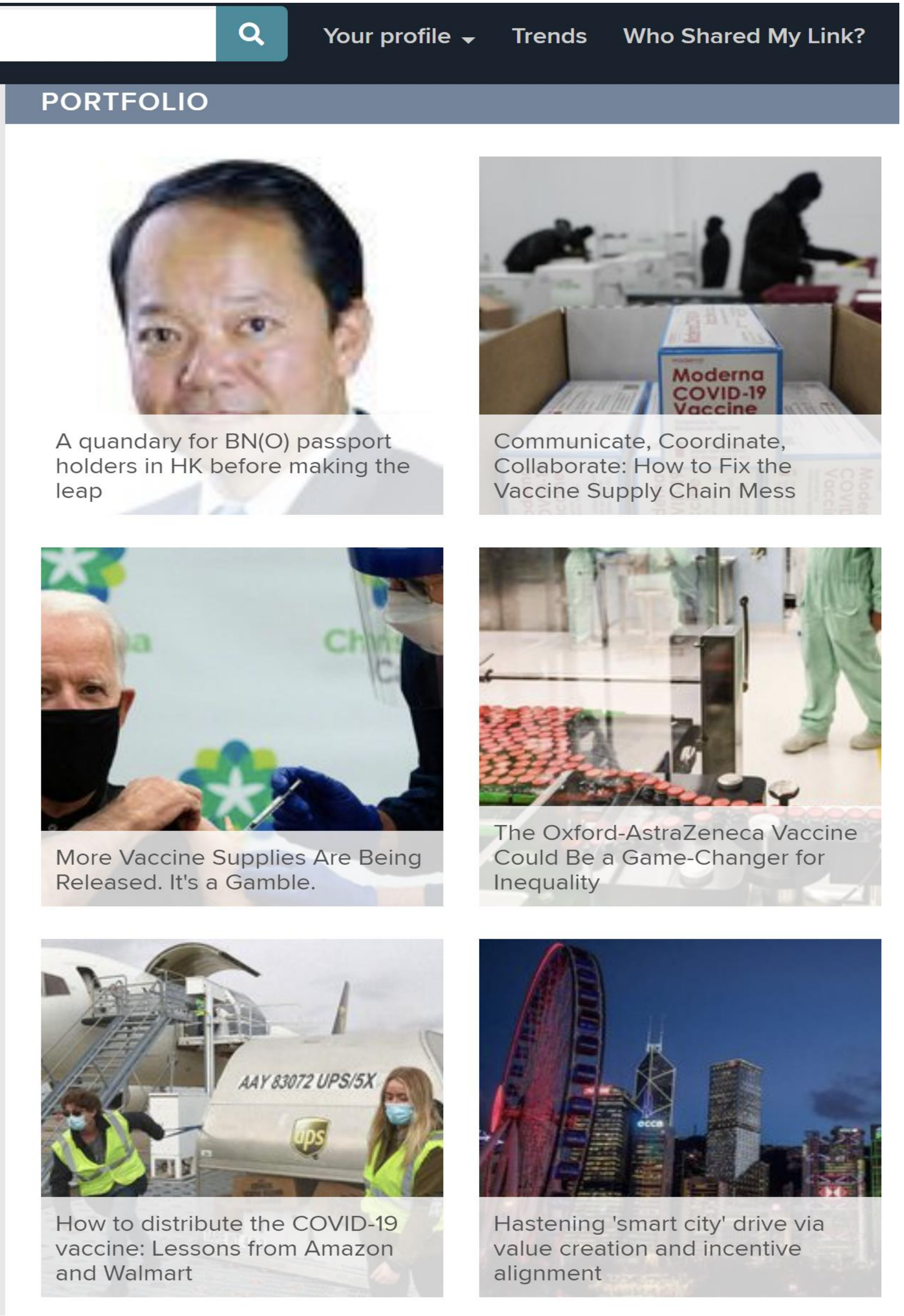
The loneliest guy in town.
Dependable Maytag washers last longer than any other brand.
Maytag washers need fewer repairs and cost less
to service than any other brand.

WORK IS CRAZY THIS TIME
OF YEAR!



Shortages
Jan-Aug, 2020
PPE shortage
Hospital shortage
Toilet paper shortage
Hand sanitizer shortage
Face mask shortage
Meat shortage

LOS ANGELES
ASIA BUSINESS REPORT
Global chip shortage
US has three of the top semiconductor equipment companies
BBC WORLD NEWS



MUCK RACK
Search for people, articles, outlets
Your profile
Trends
Who Shared My Link?
PORTFOLIO
A quandary for BN(O) passport holders in HK before making the leap
Communicate, Coordinate, Collaborate: How to Fix the Vaccine Supply Chain Mess
More Vaccine Supplies Are Being Released. It's a Gamble.
The Oxford-AstraZeneca Vaccine Could Be a Game-Changer for Inequality
How to distribute the COVID-19 vaccine: Lessons from Amazon and Walmart
Hastening 'smart city' drive via value creation and incentive alignment

Four Healthcare Supply Chain Challenges amid Pandemic

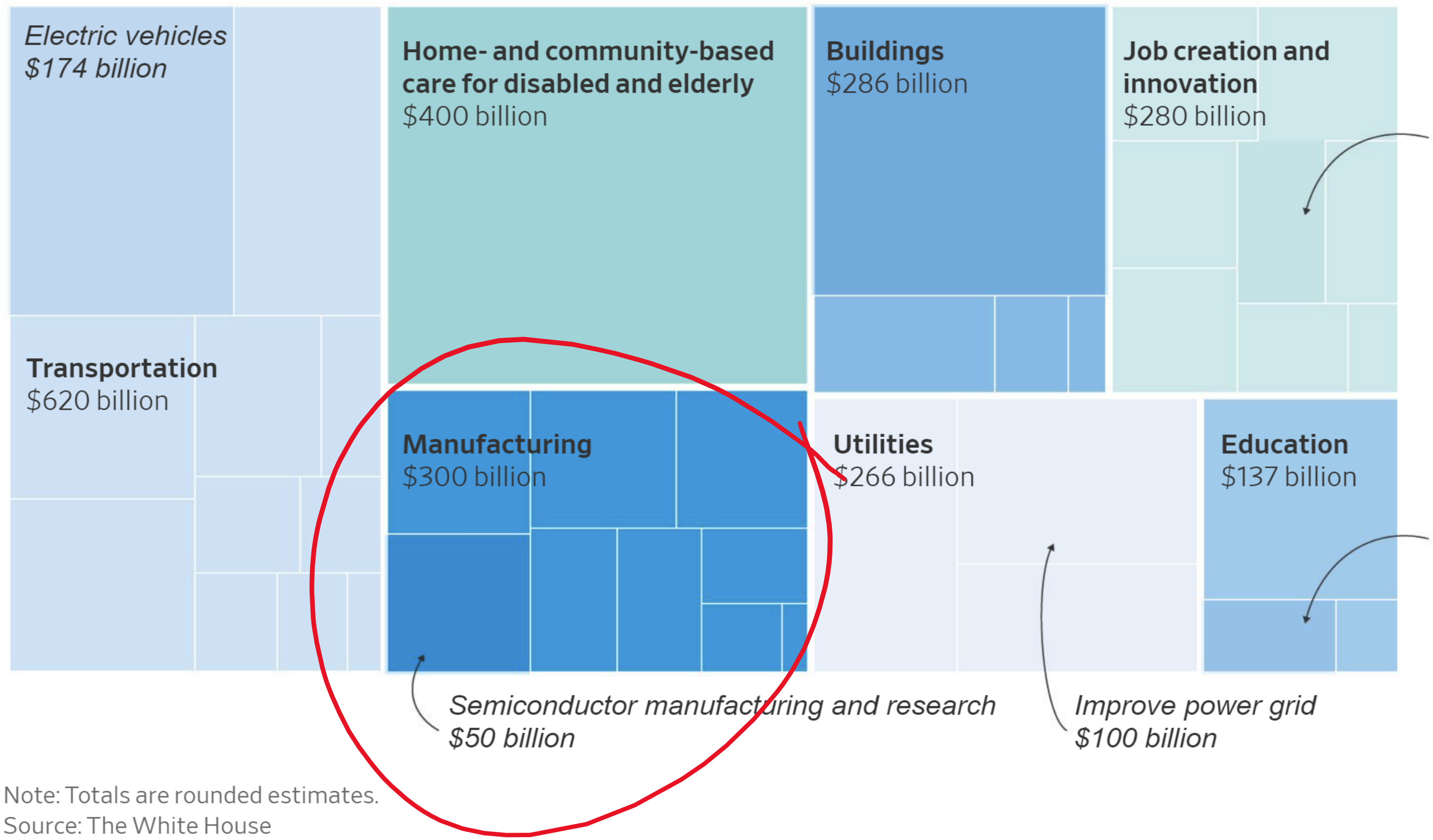
1. PPE Shortages
2. National stockpile allocation (with private information)
3. Warp Speed COVID Vaccine Development
4. Efficient Vaccine distribution

Need Innovative healthcare supply chain solutions

Overcoming challenge # 1: PPE Shortages

Reshoring via Biden's Build Back Better!

Breakdown of Biden's infrastructure plan



Note: Totals are rounded estimates.
Source: The White House

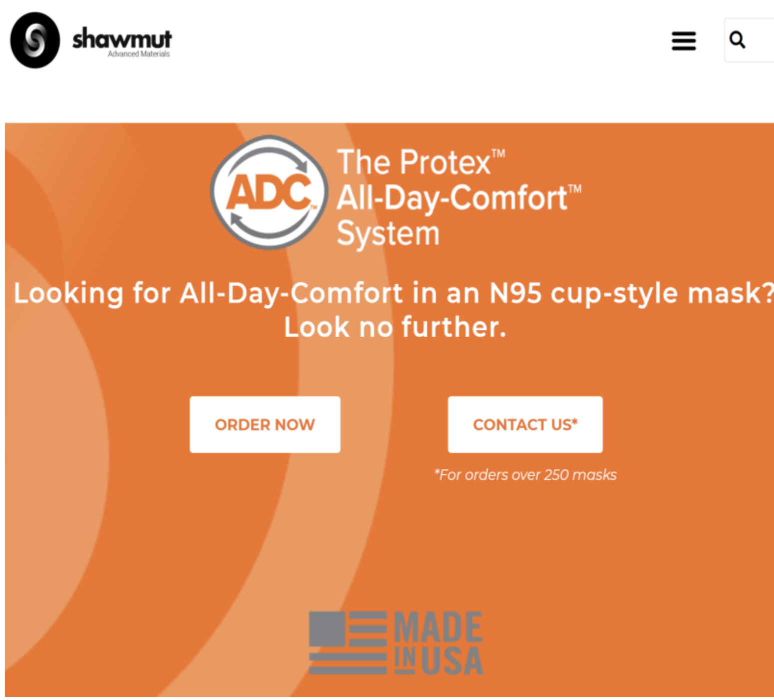
BIDEN HARRIS

4 areas: semiconductor, EV battery + minerals, Pharmaceuticals, API

THE BIDEN PLAN TO REBUILD U.S. SUPPLY CHAINS AND ENSURE THE U.S. DOES NOT FACE FUTURE SHORTAGES OF CRITICAL EQUIPMENT

But Reshoring is hard to do….. The Odyssey in 2020

- Shawmut, an advanced textiles producer in MA, tried to produce hospital gowns and N95 masks in 2020
  - 3-5 months to source, import, and adapt materials and melt-blown equipment, etc.
- Hospital Gowns need 510(k) filing with FDA 90 days in advance before marketing
  - Cost $100,000 to prepare, 6+ months for approve
- N95 masks needs to pass NIOSH 's testing + approval
  - 81-page document to explain the process
  - Took months approved in Feb 2021
- Lessons:
  - Public-Private sector coordination is needed!
  - Need innovative ideas to develop resilient supply chains!
  - Need proactive collaborations!



Agenda: Innovative Ideas + Resilient Supply Chains

4 Challenges	Proposals: Resilient Supply Chains
PPE Shortages	A Resilient Supply "Ecosystem"
Stockpile allocation to different states (with private info)	An "Truth-Telling" Mechanism
Warp Speed COVID Vaccine Development	A "Parallel" Development Process + "Incentive Contracts"
Efficient Vaccine distribution	A "Dose-Stretching" Policy

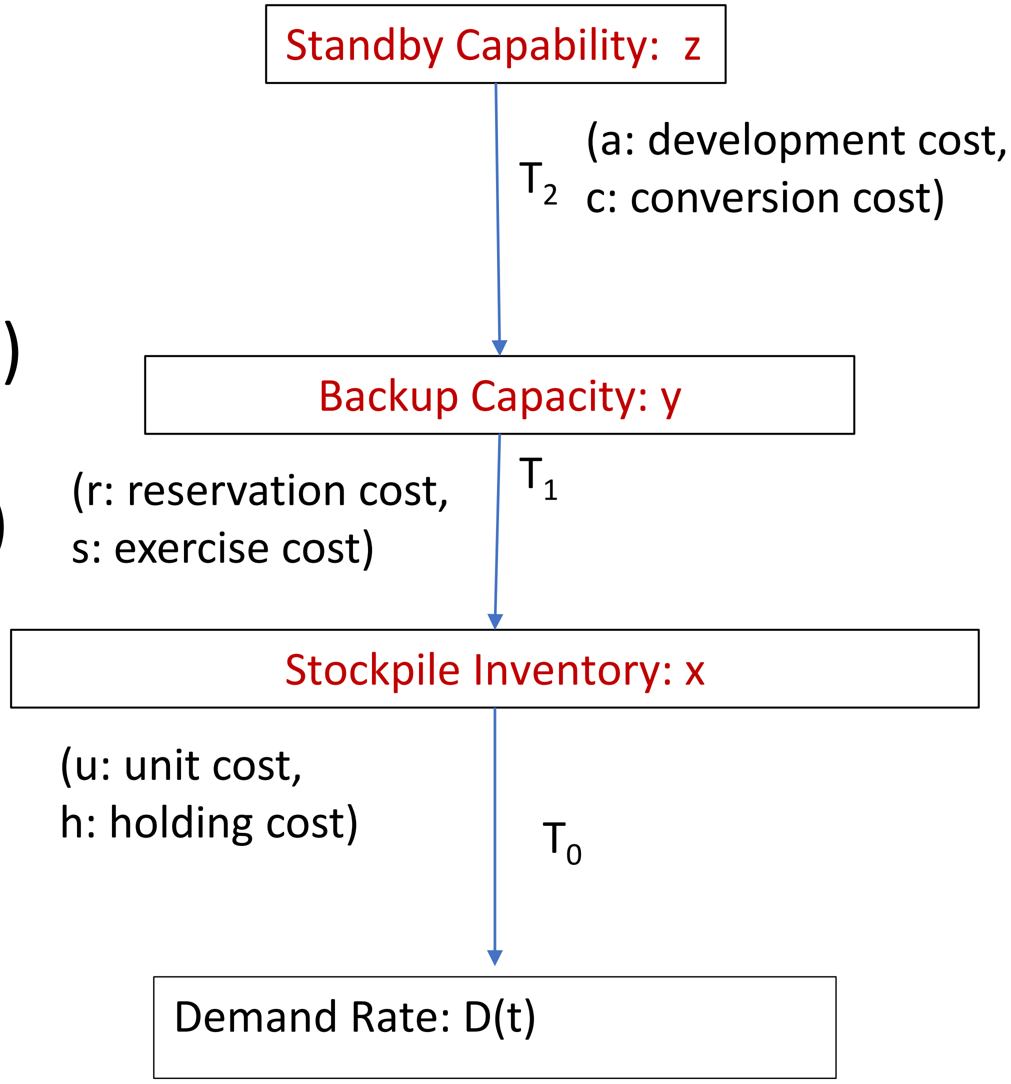
Proposal 1: A resilient supply ecosystem (Li, Sodhi, Tang, Yu (2021))

- A 3-tiered supply "ecosystem" (x, y, z):
  1. Stockpile inventory x : "on-demand"
  2. Backup capacity y : "on-reserve"
     (shift from global to domestic supply chains)
  3. Standby capability z : "on-alert"
     (convert capability to capacity: 3-D printing)

  Capability is necessary for future products

Need coordination and collaboration

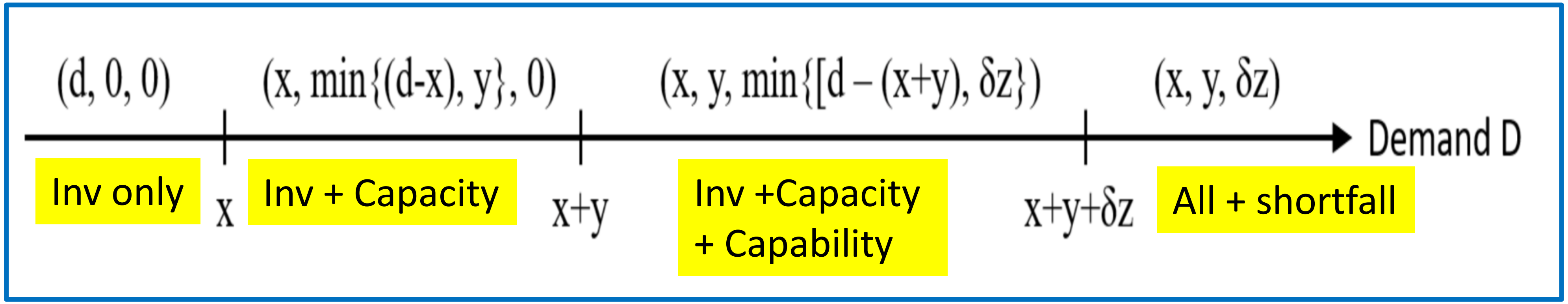
- US government, private corporations, universities – e.g., Consortium -- America Makes, Sematech, etc.



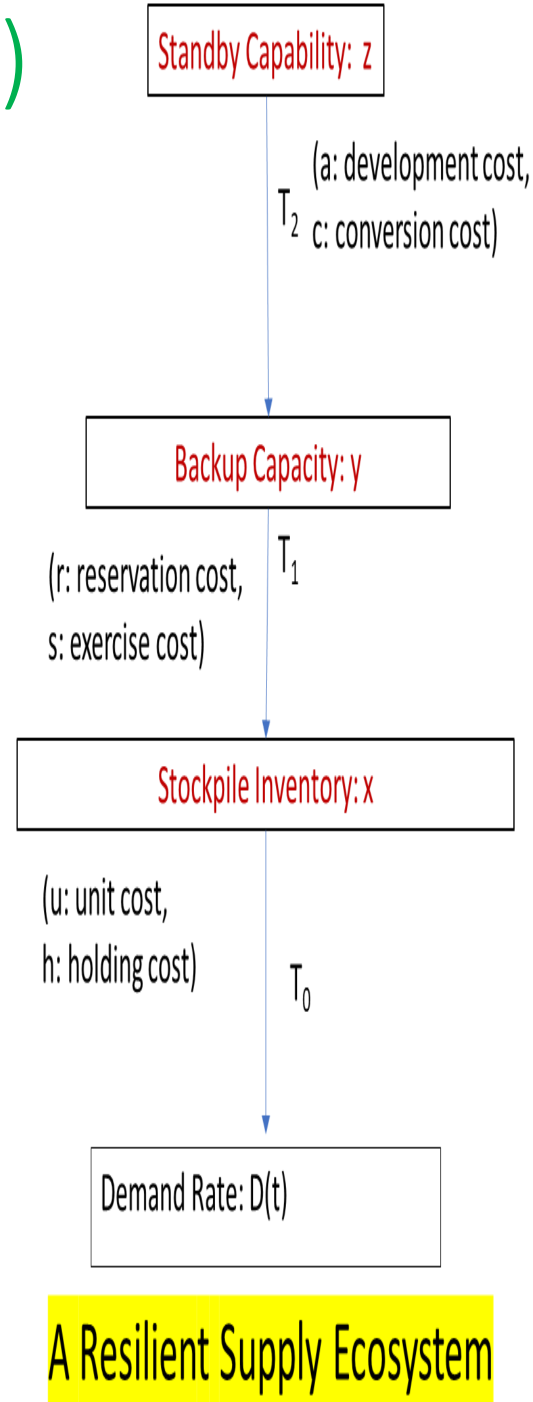
A 3-tiered Resilient Supply Ecosystem

Proposal 1: A resilient supply ecosystem (x, y, z)

1. Assume D(t) is Exponentially distributed with rate λ
2. Stockpile Inventory x (u: unit cost, h: holding cost)
3. Backup capacity y (r: reservation cost, s: exercise cost)
4. Standby capability z (a: development cost, c: conversion cost) + conversion yield = δ w.p. θ (= 0, w.p. (1-θ))
5. Stockout penalty p, and deployment time is instantaneous



Question: what is (x*, y*, z*) that minimizes the total expected cost? When to develop capability z* > 0?



Optimal x*, y*, and z*

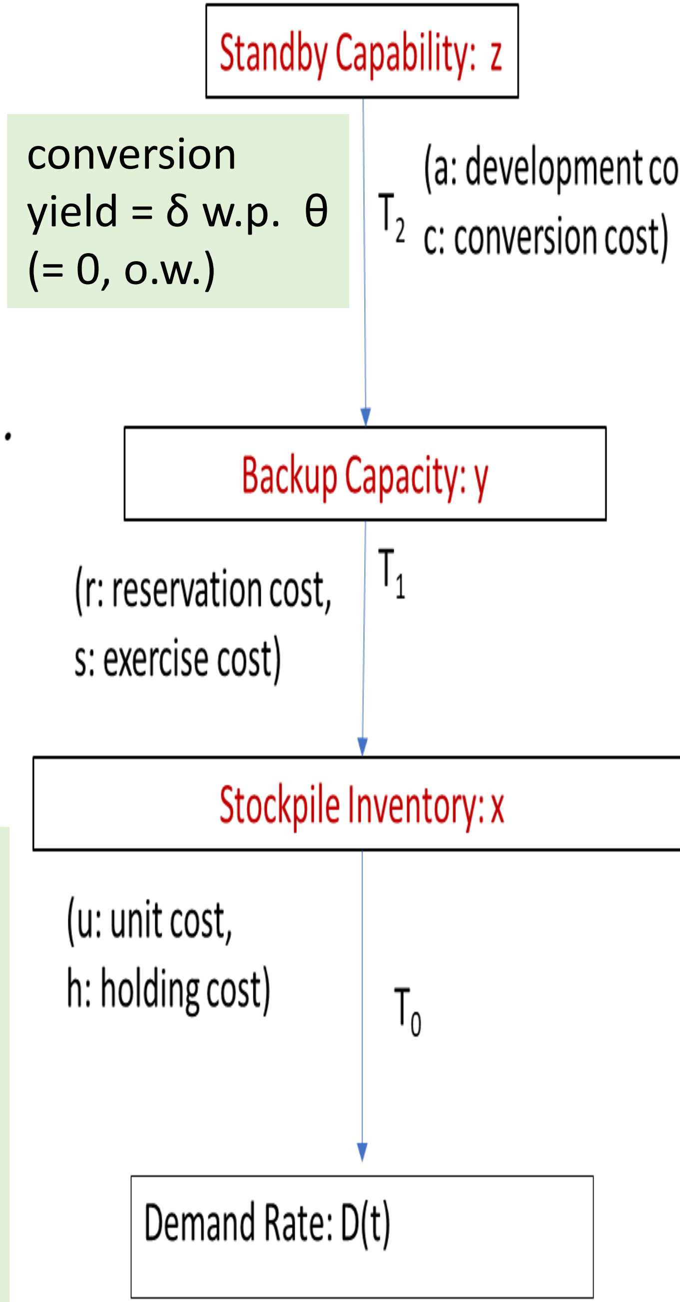
1. *The optimal stockpile inventory* $\hat{x} = \frac{1}{\lambda} \cdot ln(\frac{h/2+s}{u+h-r})$.

2. *The optimal backup capacity* $\hat{y} = \frac{1}{\lambda} \cdot ln\left(\delta_h \cdot \frac{(u+h-r)}{(h/2+s)} \cdot \frac{[(c-s)+(1-\theta)(p-c)]}{(r\delta_h-a)}\right)$.

3. *The optimal standby capability* $\hat{z} = \frac{1}{\lambda\delta_h} \cdot ln\left(\frac{\theta(p-c)(r\delta_h-a)}{a[(c-s)+(1-\theta)(p-c)]}\right)$.

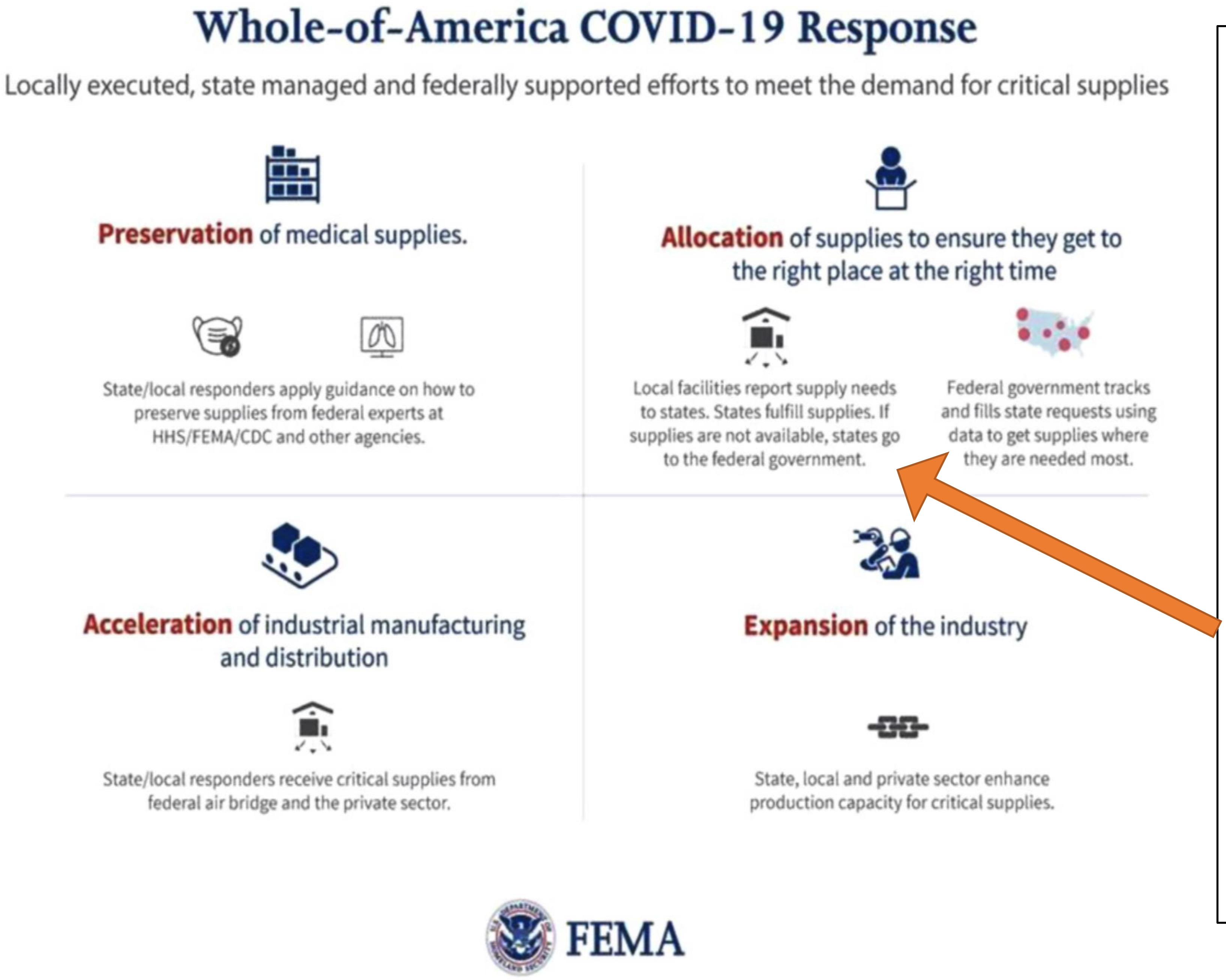
Also, $\hat{z} > 0$ *if and only if* $a < r\delta_h$ *and* $c < p\left(1 - a(1-\frac{s}{p})/\theta r\delta_h\right)$.

Implications:
- Optimal inventory x* is linked with capacity decision only
- Optimal capacity y* is wedged between inventory and capability decision
- Optimal capability z* is connected to the capacity decision only
- Develop capability (z* > 0) only when the effective costs (development and conversion) are low enough



A Resilient Supply Ecosystem

Challenge # 2: Allocating critical supplies (with private information)



Process:

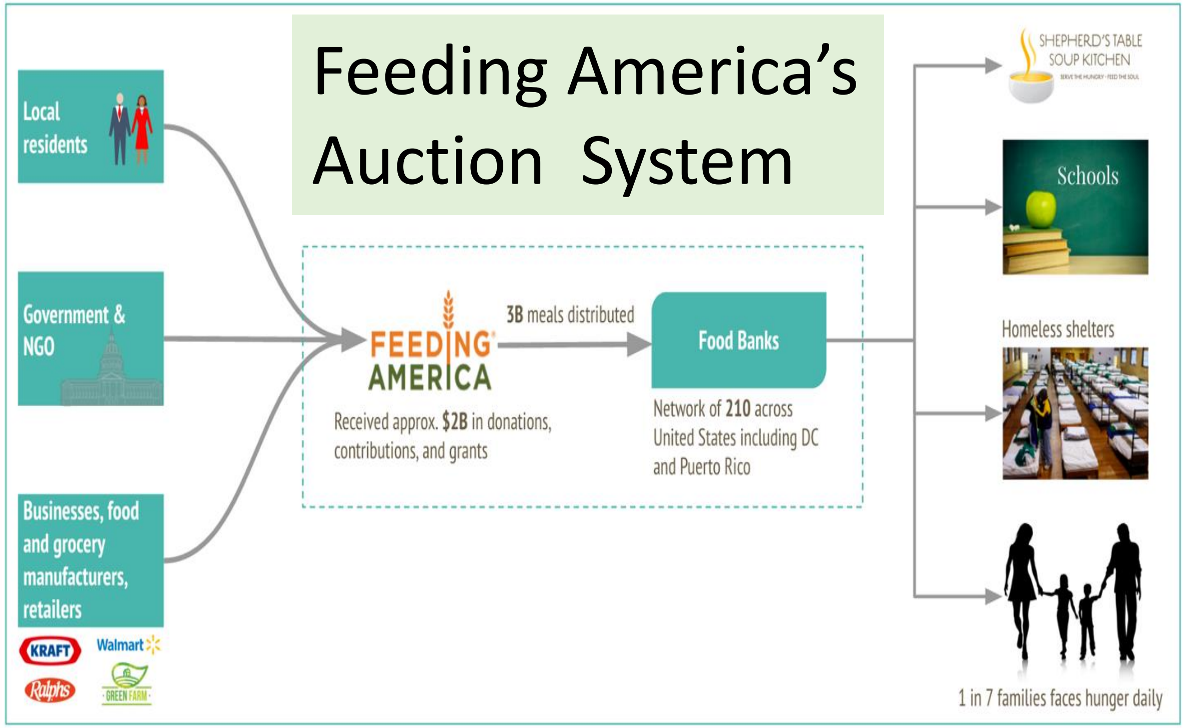
- States make request to Federal government
- Federal government allocates supplies

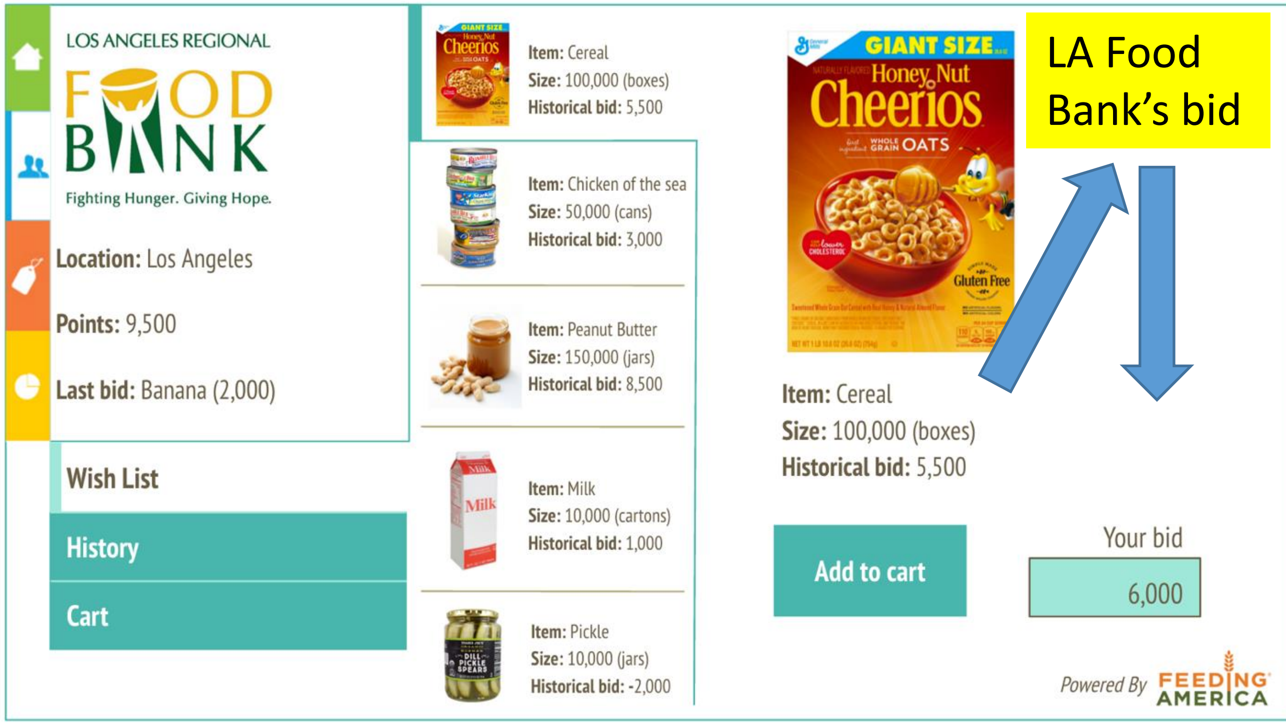
Challenges:

1. Decentralized Information – data reside at the State level
2. Decentralized control -- Fed sets policy, States executes

Proposal 2: A proactive truth-telling mechanism

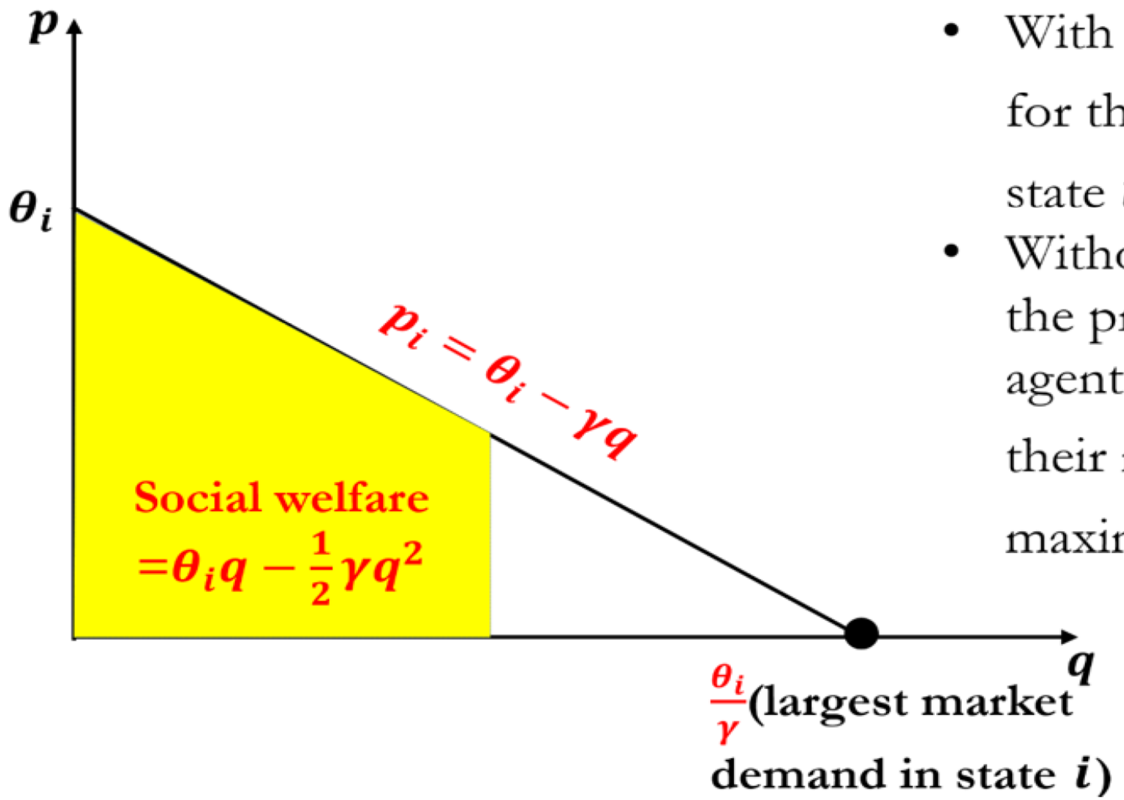
- T is the "points" to be paid by a state
  - Fed provides each state with a certain # of points (not $) -- to induce truth-telling
- q is the "allocation" to each state – receive less allocation with 0 point
  - Unlike the PPE bidding war in 2020 based on $ + winner takes all
- Need to find T and q (Fan, Chen, and Tang, 2021)





Proposal 2: A proactive truth telling mechanism and an efficient allocation plan (Fan, Chen and Tang (2021))

- Principal has Q units of a good (e.g., mask) for sale
- There are n agents, and marginal utility of an extra medical supply is: $p_i = \theta_i - \gamma q$
- $\theta \in [\underline{\theta}, \overline{\theta}]$ is the private information and follows CDF $F(\theta)$
- $\frac{\theta_i}{\gamma}$ is the largest demand of agent i

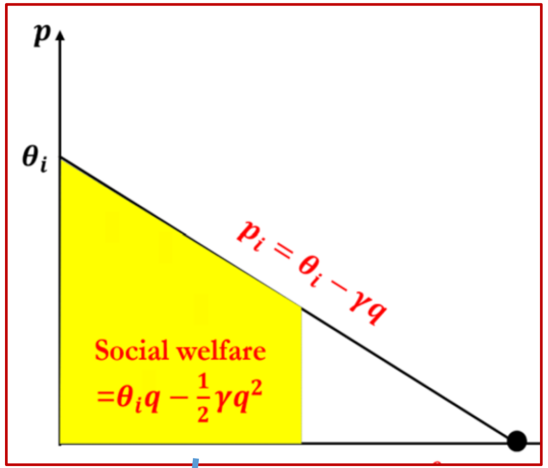


- With sufficient resource Q, the best strategy for the principal is to allocated $\frac{\theta_i}{\gamma}$ to each state i.
- Without sufficient resource, the question for the principal is how to allocate Q among n agents (who have private information about their market demand characterized by $\frac{\theta_i}{\gamma}$) to maximize the total social welfare:

Proposal 2: A proactive truth-telling mechanism (T, q)

- The principal proposes a menu of contract $\left(q(\theta_1, \theta_2, \ldots, \theta_n), T(\theta_1, \theta_2, \ldots, \theta_n)\right)$ which depends on agents' report $\theta_1, \theta_2, \ldots, \theta_n$
- $q = \{q_1, q_2, \ldots, q_3\}$ is the quantity allocated to agents
- $T = \{T_1, T_2, \ldots, T_n\}$ is the transfer paid by agents

Θ (state's real need) is not known to the principal *(Fed)*



- Agent's expected utility of reporting x when his true type is θ_i is:

$$\pi_i(x, \theta_i) = \mathbb{E}_{\theta_{-i}}\left[\theta_i q_i(x, \theta_{-i}) - \frac{1}{2}\gamma q_i^2(x, \theta_{-i}) - T_i(x, \theta_{-i})\right]$$

- When reporting true type: $\pi_i(\theta_i) = \pi_i(\theta_i, \theta_i)$
- Allocation problem

(Max – social welfare)

$$\max_{\mathbf{q},\mathbf{T}} \quad \mathbb{E}_{\theta_i,\theta_{-i}}\left\{\sum_{i=1}^{n} w_i[\theta_i q_i(\theta_i, \theta_{-i}) - \frac{1}{2}\gamma q_i^2(\theta_i, \theta_{-i})]\right\} \quad (3)$$

$$s.t. \quad \pi_i(\theta_i, \theta_i) \geq \pi_i(x, \theta_i)\ \forall i, \forall x \quad (\text{IC})$$

$$\pi_i(\theta_i, \theta_i) \geq 0\ \forall i \quad (\text{IR})$$

$$\sum_{i=1}^{n} q_i \leq Q \quad (\text{Capacity Constraint})$$

w_i is the bargaining power of agent i due to political clout

Allocating scarce resources with private demand information $\frac{\theta_i}{\gamma}$: A mechanism design problem

- Closed formed expressions for q* and T*
- Allocation is "inefficient" when rationing is needed (i.e., when $Q < \sum \frac{\theta_i}{\gamma}$)
  - Agent with higher w_i will get more q_i*
- "Inefficiency" can be reduced when the principal cares about its own monetary benefits via w_0 by solving:

$$\max_{q_1, q_2, \ldots, q_n} \mathbb{E}_{\theta_i, \theta_{-i}} \left\{ \sum_{i=1}^{n} w_i [\theta_i q_i - \frac{1}{2} \gamma q_i^2] + w_0 \sum_{i=1}^{n} T_i \right\}$$

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s.t. $\pi_i(\theta_i, \theta_i) \geq \pi_i(x, \theta_i) \ \forall i, \forall x$

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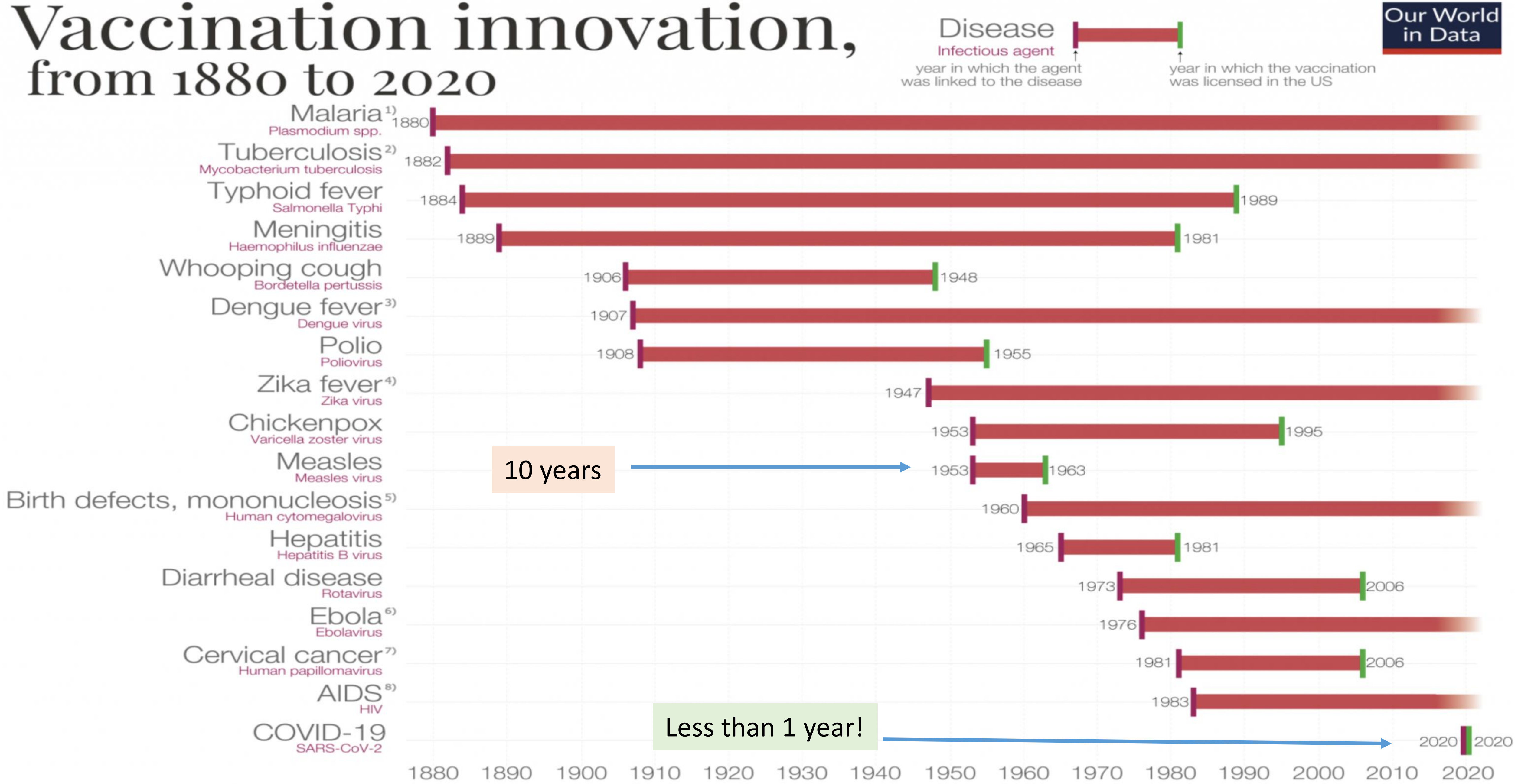
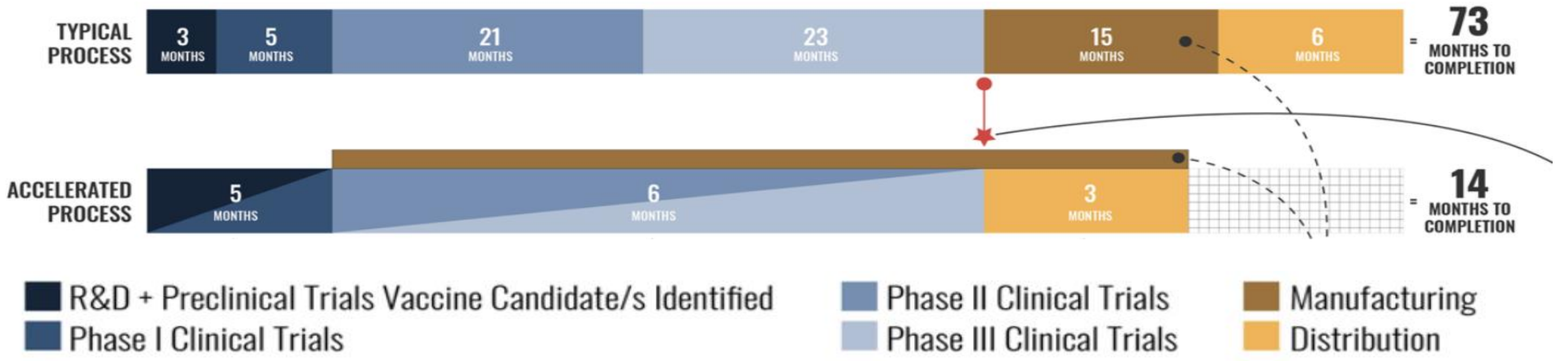
Challenge # 3: Warp Speed COVID Vaccine Development



Proposal 3: An incentive mechanism to support Warp Speed

- Typical "sequential (S)" vaccine development process takes a long time!
- Accelerated "concurrent (C)" vaccine development process (Warp Speed)
  - Phase II/III Clinical Trials and manufacturing are done in parallel
  - Firms may not participate: risky upfront mfring investment… vaccine may not work!
- Government offers contingent advance purchasing contracts as incentives for multiple firms to compete ….. **Will this be sufficient?**



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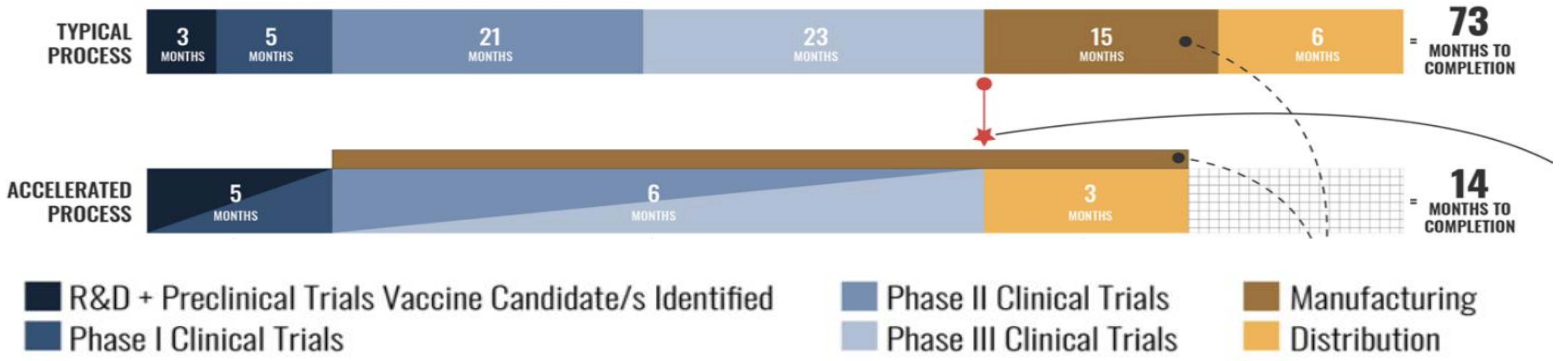
- For 2 firms, A and B with different uncertain efficacy, but e_A is stochastically higher than e_B. What is the development strategy in equilibrium?



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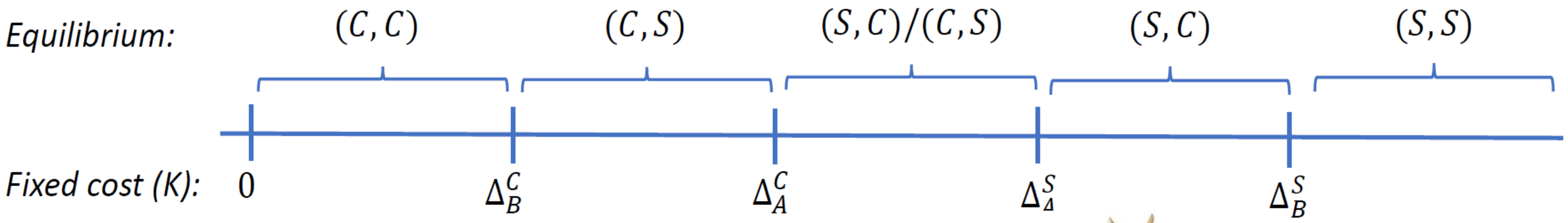
- For 2 firms, A and B with different uncertain efficacy, but e_A is stochastically higher than e_B. What is the development strategy in equilibrium?
- Preliminary results (Limon, Tang, and Tanisever, 2021): Depending on K, it is possible to have the hare to adopt S and yet the tortoise adopts C!



Proposal 3: An incentive mechanism to support Warp Speed

- Concurrent strategy (C) involves risky upfront mfring investment K, but vaccine may not be effective if its efficacy $e < \tau$.
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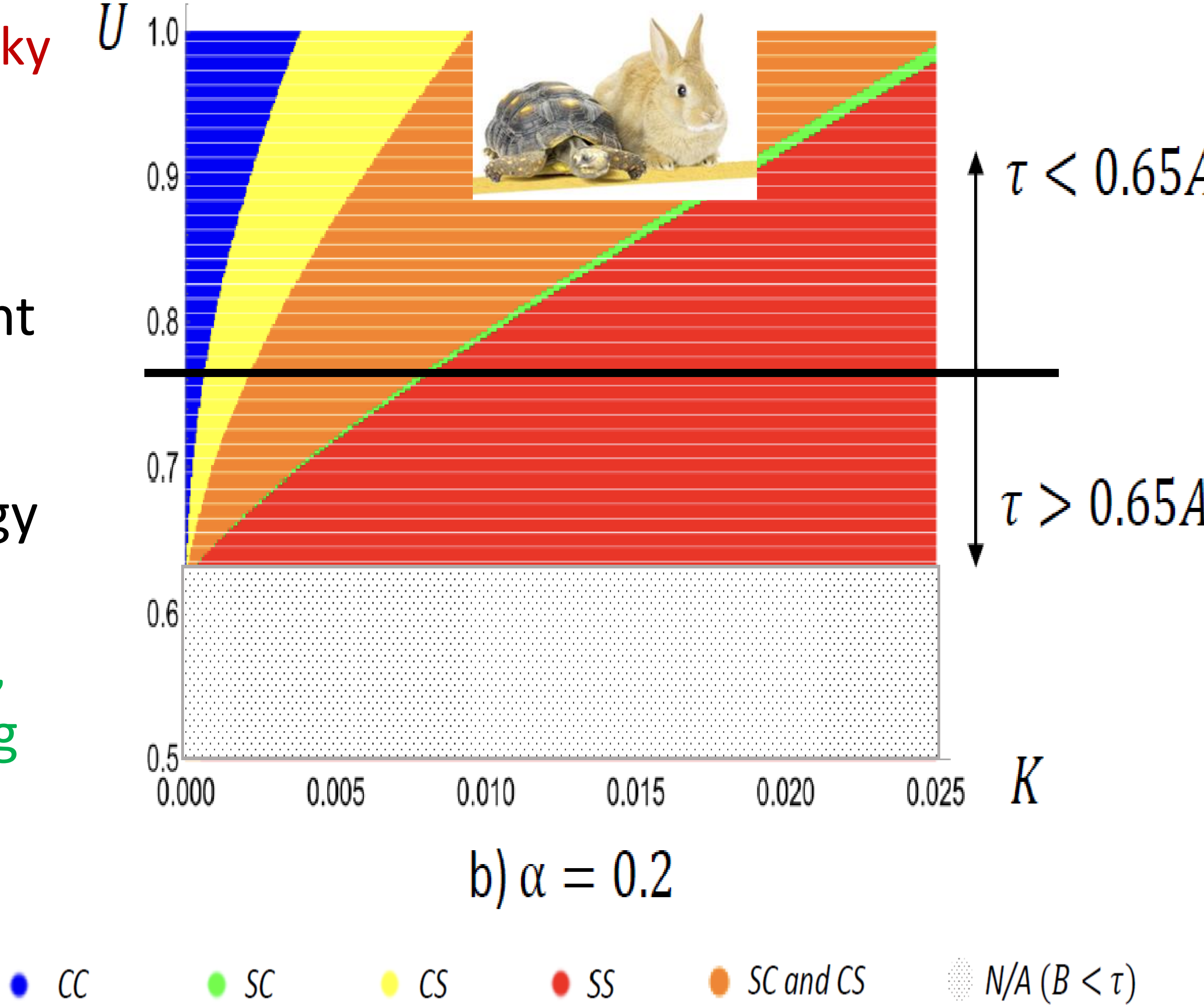
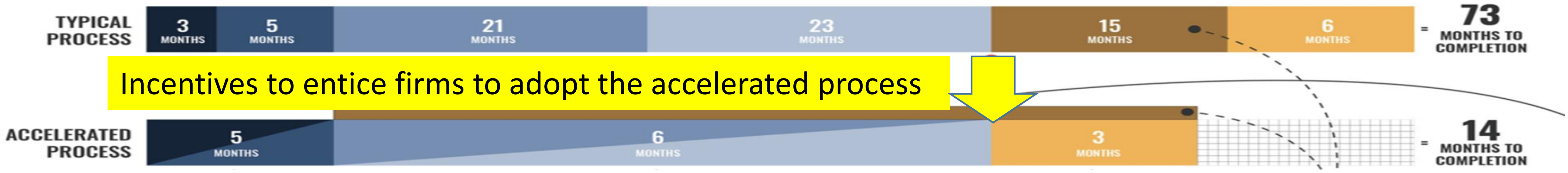


Proposal 3: An incentive mechanism to support Warp Speed



- Preliminary results (Limon, Tang, and Tanisever, 2021)
  - Contingent advance purchasing contracts can "nudge" some pharma (hares with high approval chance) to adopt the "accelerated" process
  - Extra subsidies are needed to encourage other pharma (tortoises with less promising vaccines) to adopt the "accelerated" process
- Implications: Incentives + subsidies are key!
- A new idea: Should competing pharma share production capacity for vaccine production "before" approval? (Dai & Tang, 2020)
  - Sanofi produces for Pfizer + Merck produces for J&J as an "afterthought"
  - Should firms establish "capacity sharing" agreements "before hand"?

Challenge # 4: efficient vaccine distribution mechanisms

- How to vaccinate as many as possible ASAP when:
  - both Pfizer and Moderna vaccines require 2 doses with 3-4 weeks apart
  - supply is limited (esp. in developing countries)

Pfizer

Ultra Cold* -50°C to -86°C
*** May 2021: Once thawed, can be stored for 1 month 2-8 °C

Two-dose Regimen
(3 weeks apart)

Efficacy Israel Lancet study:
75-85% after 1 dose**,
95% after both

moderna

Cold

-15°C to -30°C

Two-dose Regimen
(4 weeks apart)

Efficacy Clinical Trials:
95% after both

Johnson & Johnson

Chilled

+2°C to +10°C

One-dose Regimen
(One and Done!)

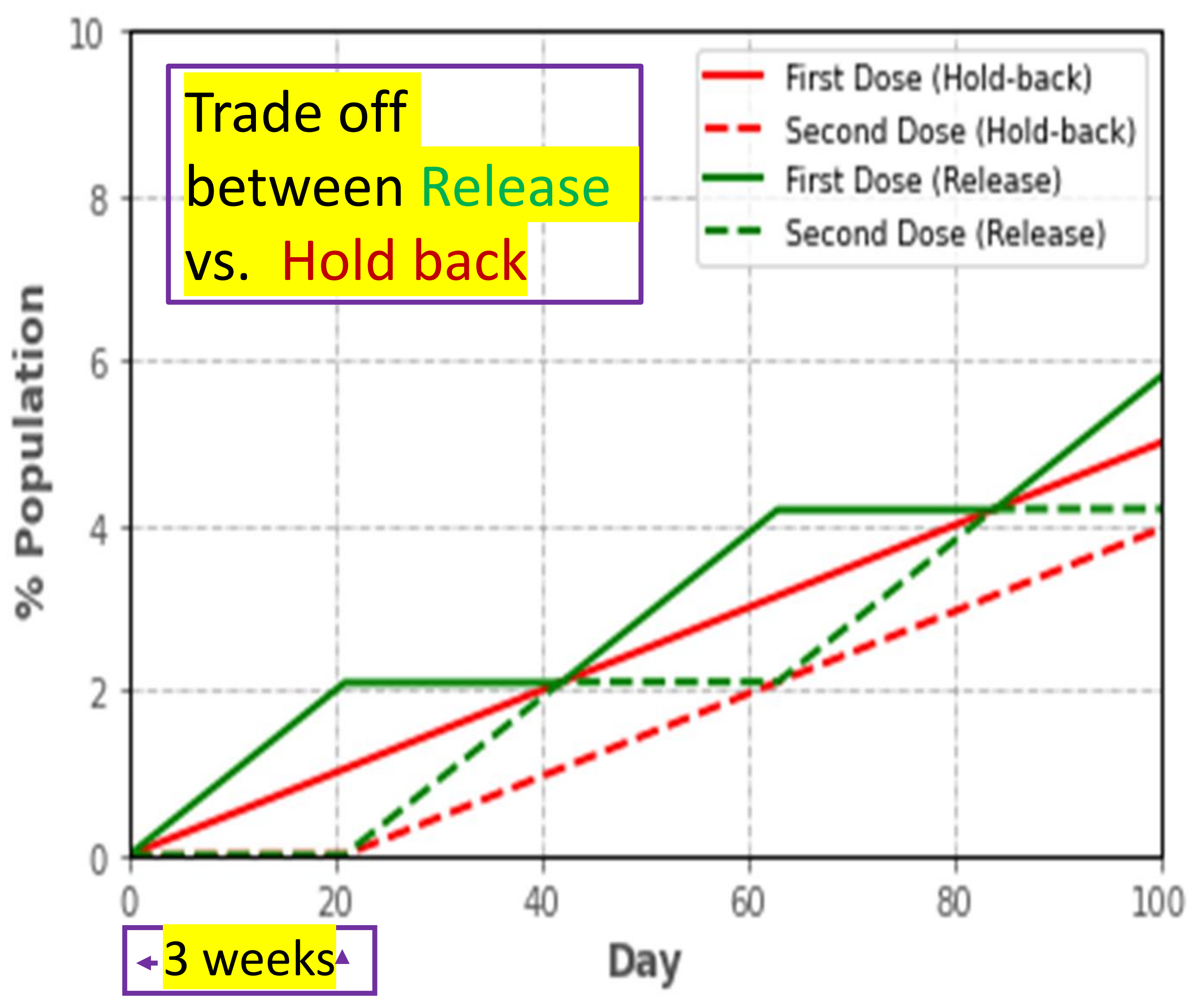
Efficacy Clinical Trials:
66% worldwide
72% USA

Proposal 4: Hold Back, Release, or Stretch? (Mak, Dai, Tang, 2021)

1. Hold back: Should you vaccinate 10 million people and hold back 10 million second doses?

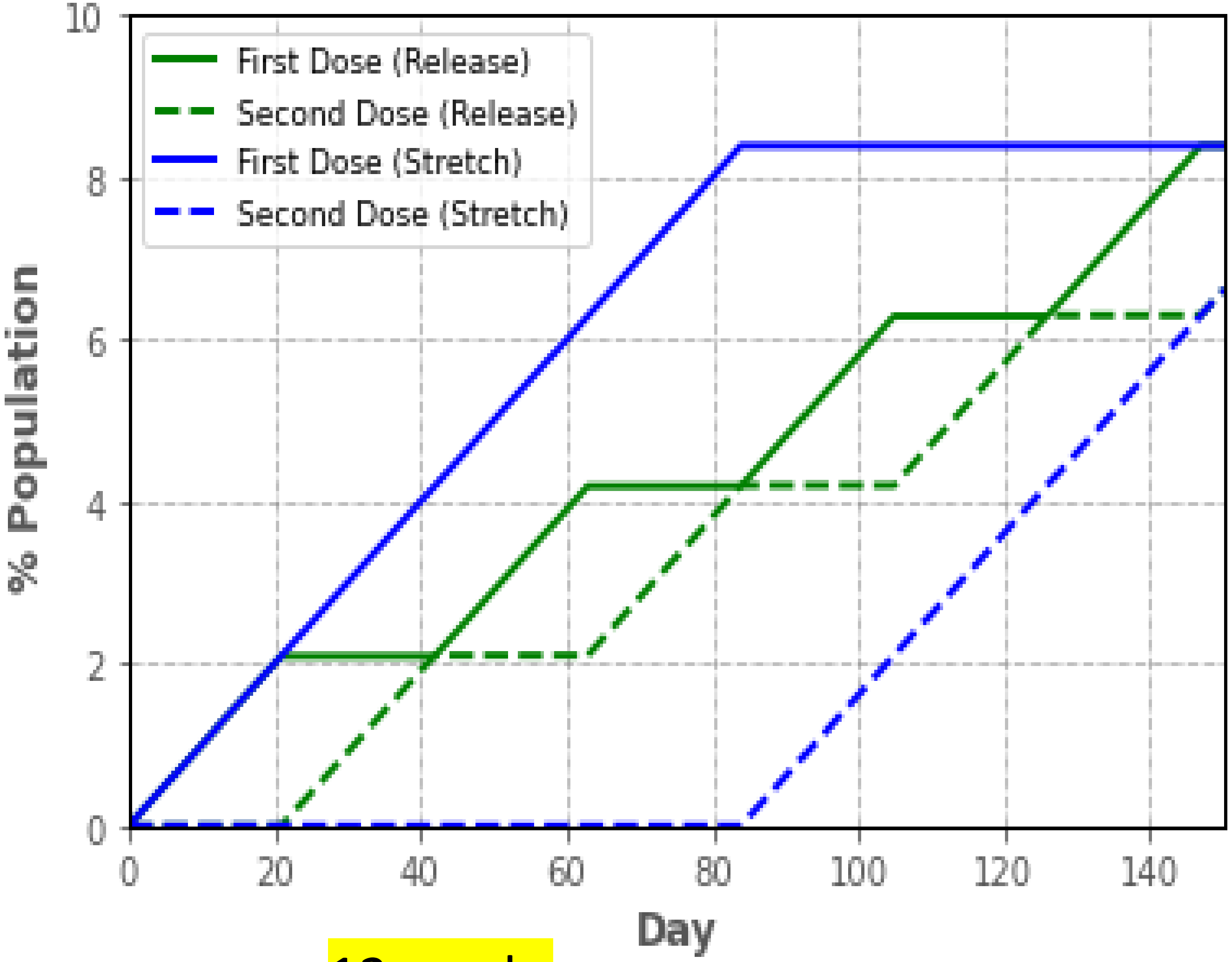
2. Release: Or maybe give all the doses to 20 million people, and use future supply to cover second doses?

3. Stretch: Stretch the lead-time between two doses to 12 weeks?

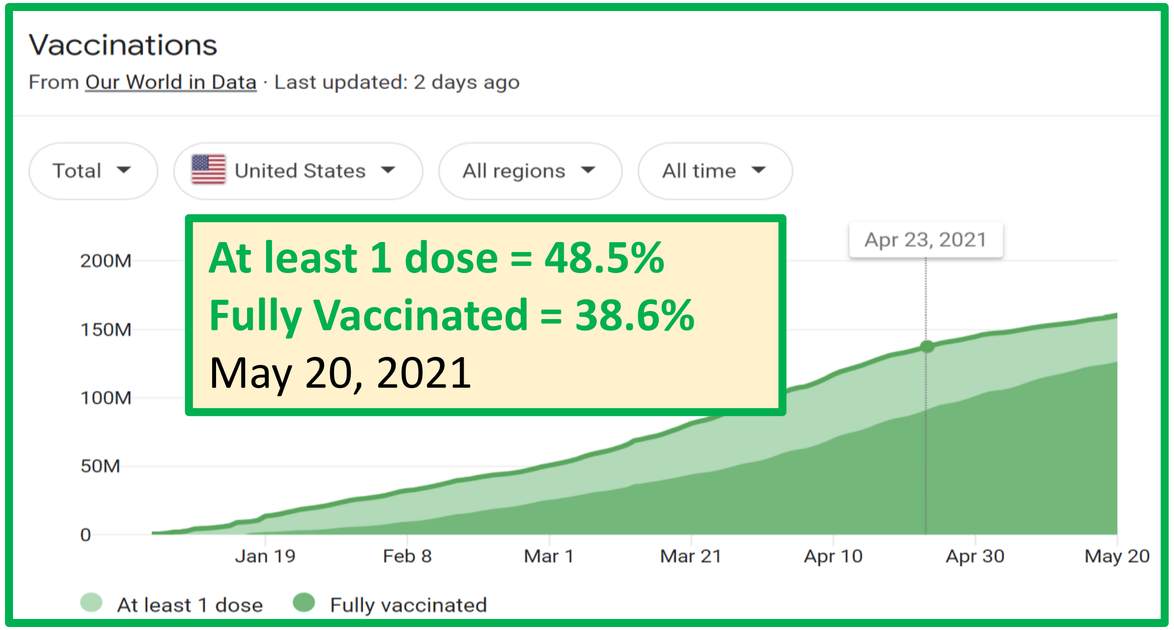


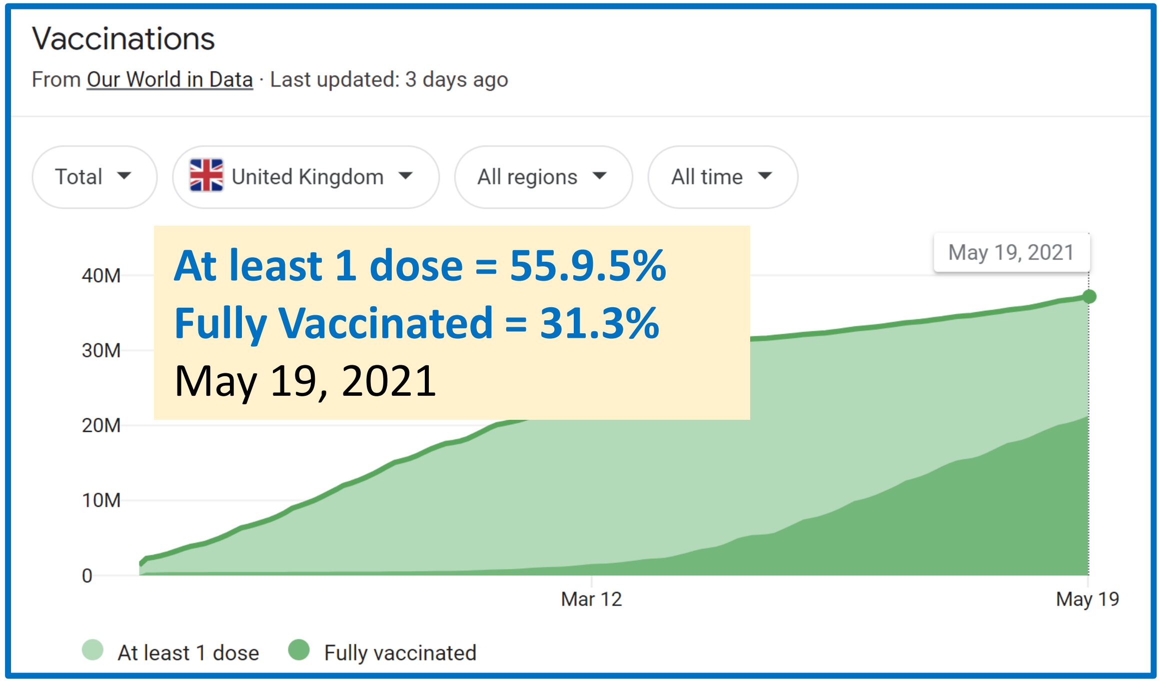
Proposal 4: Hold Back, Release, or Stretch? (Mak, Dai, Tang, 2021)

Trade off between: **Release** and **Stretch**



12 weeks





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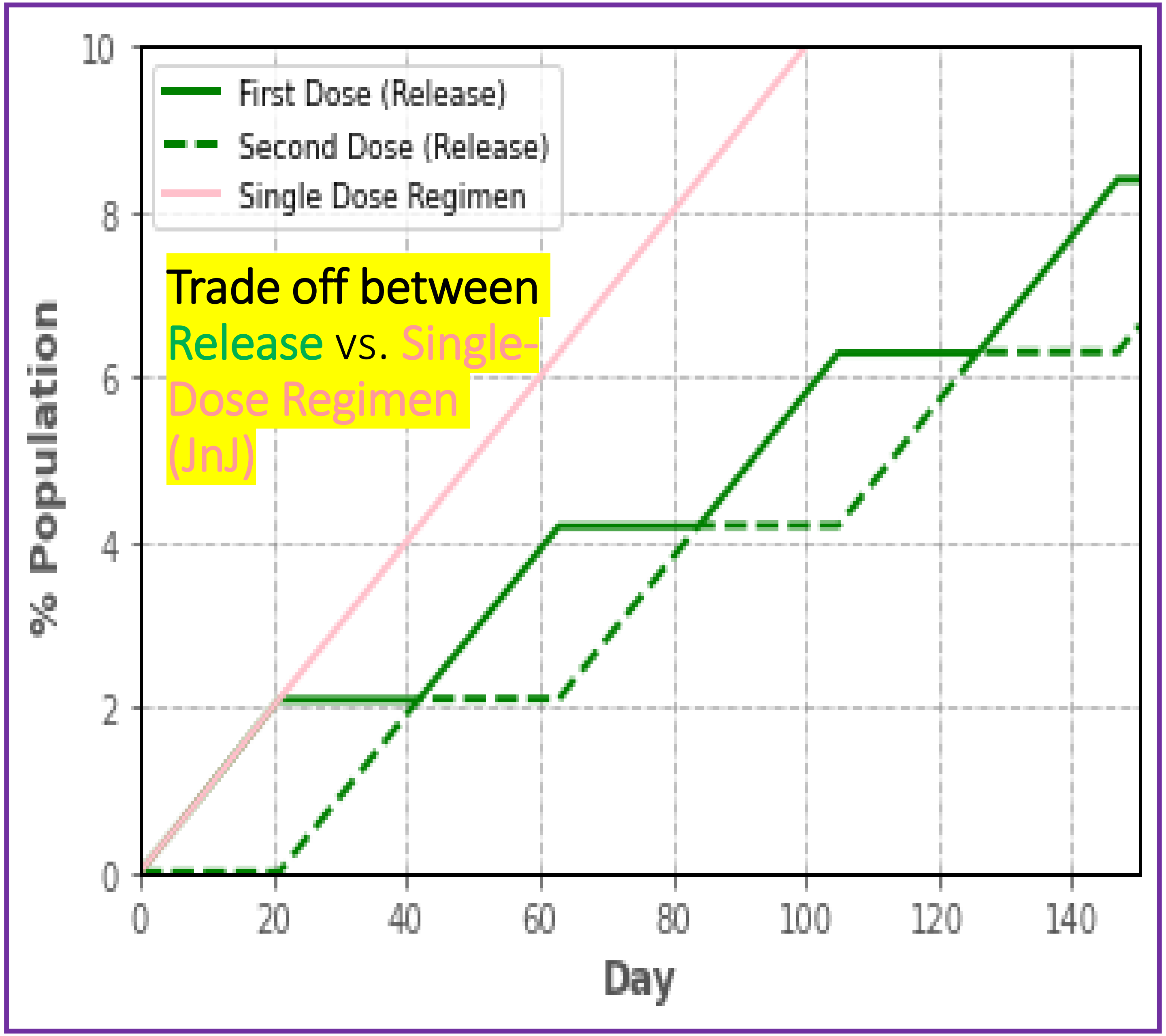


One and Done: Why People Are Eager for Johnson & Johnson's Vaccine

Johnson & Johnson's one-shot vaccine is allowing states to rethink distribution, even as health officials and experts worry some will view it as inferior.

BARRON'S

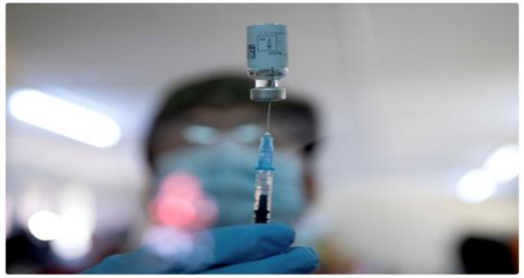
CORONAVIRUS

The Great Promise of a One-Dose Vaccine

COMMENTARY

By Tinglong Dai, Ho-Yin Mak, Christopher S. Tang

Updated Feb. 26, 2021 9:48 am ET / Original Feb. 26, 2021 9:40 am ET

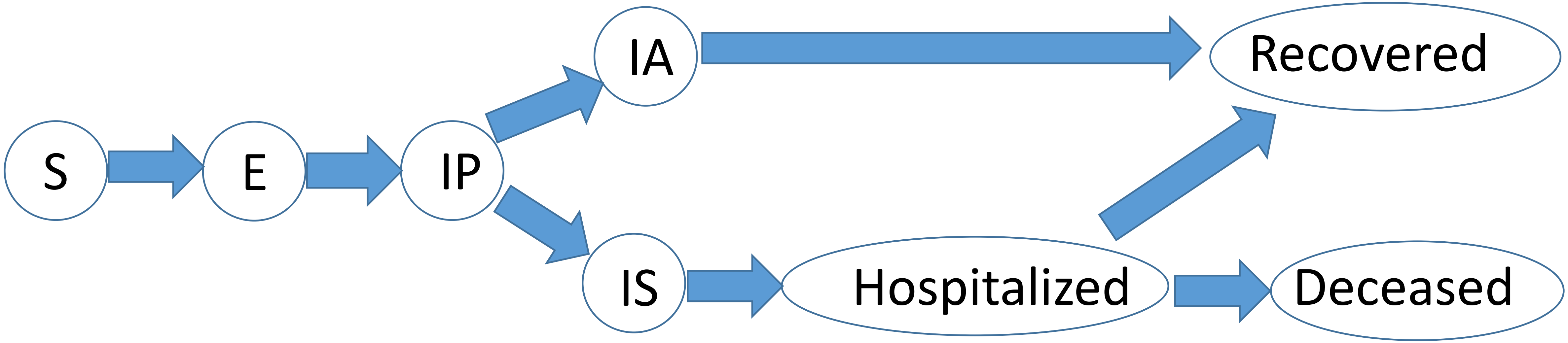


Get ready for one of these.
Phill Magakoe / AFP via Getty Images

The U.S. Food and Drug Administration's expert advisory committee is meeting today to discuss the emergency use authorization of Johnson & Johnson's Covid-19 vaccine. If authorized, it will be the first single-dose Covid-19 vaccine. Despite some confusing data about its efficacy compared with other vaccines, this new one-shot vaccine has the potential to substantially ease the logistical problems that we've seen to date. Healthcare systems, especially in the 130 countries that have yet to give out their first shots, should pay close attention. Americans should, too.

Comparison: Hold Back, Release, or Stretch? (Mak, Dai, Tang, 2021)

SEIR Model for one Risk Group with Pre-symptomatic/Asymptomatic/Symptomatic Infection who received k dose of vaccine, k = 0, 1, 2



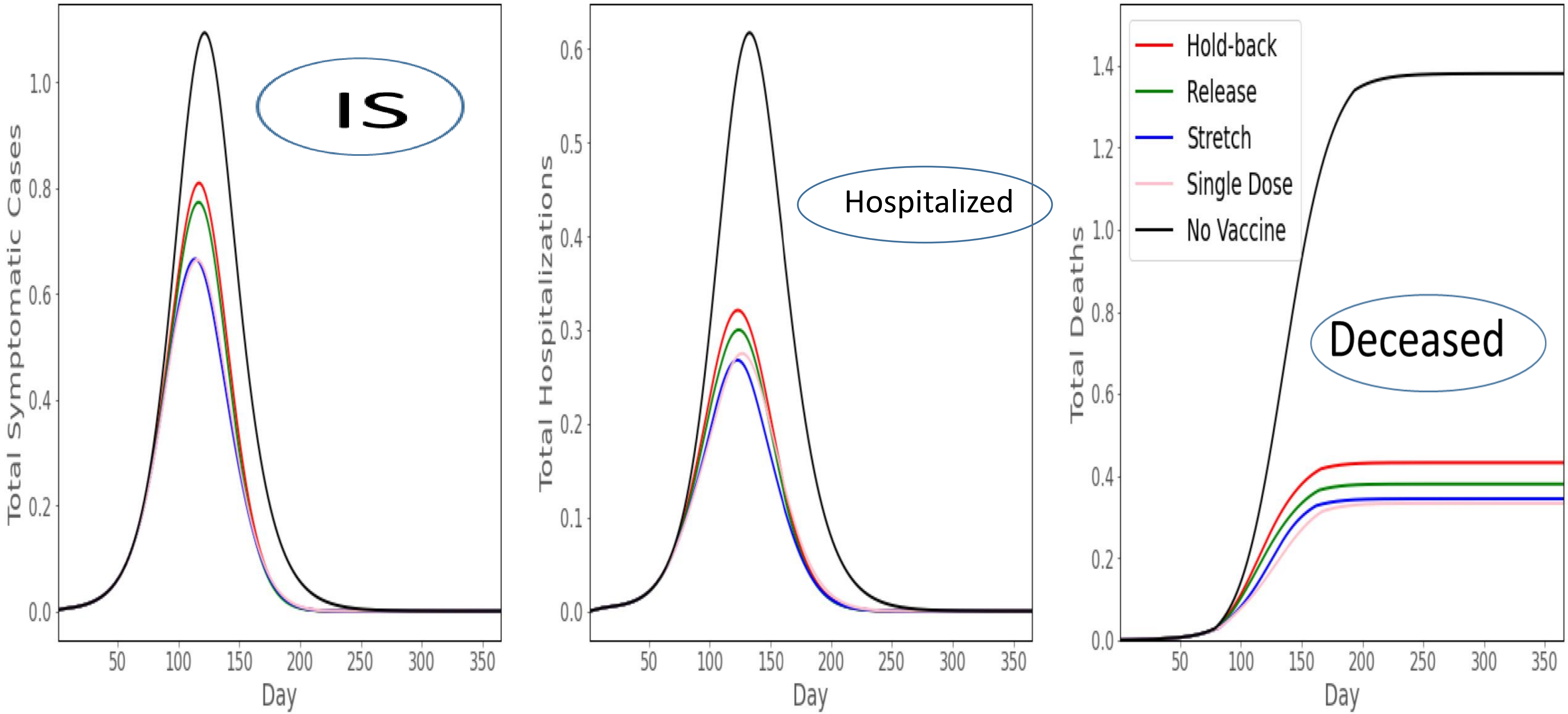
Model Calibration

High Risk Group = 65+ (13% of population), Low Risk Group = 65- (87% of population)

- # of contacts between groups (e.g., C(H,H) = 0.3, C(LL) = 0.84
- Transmission probability after vaccination (43% reduction after Pfizer vaccine – alpha variant)
- Duration at each state – e.g., Expose state = 4.6 days
- Efficacy of Pfizer after one- and two-dose (58%, 95%), and JnJ one dose efficacy (66%)

Proposal 4: Hold Back, Release, or Stretch? (Mak, Dai, Tang, 2021)

Simulation Results (SEIR model + high risk group has top priority for vaccine)



Conclusions: Four Healthcare Supply Chain Challenges

1. PPE Shortages
   * Supply Ecosystem (Inventory, Capacity & Capability)
2. National stockpile allocation (with private information)
   * Truth telling mechanism
3. Warp Speed COVID Vaccine Development
   * Concurrent development, contingent contracts, and subsidies
4. Efficient Vaccine distribution
   * Stretch the timing of the second dose


The New York Times

The World Needs Many More Coronavirus Vaccines

Wealthy nations have to step up.