

Staggered Rollout for Innovation Adoption

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LACEA-LAMES 2023

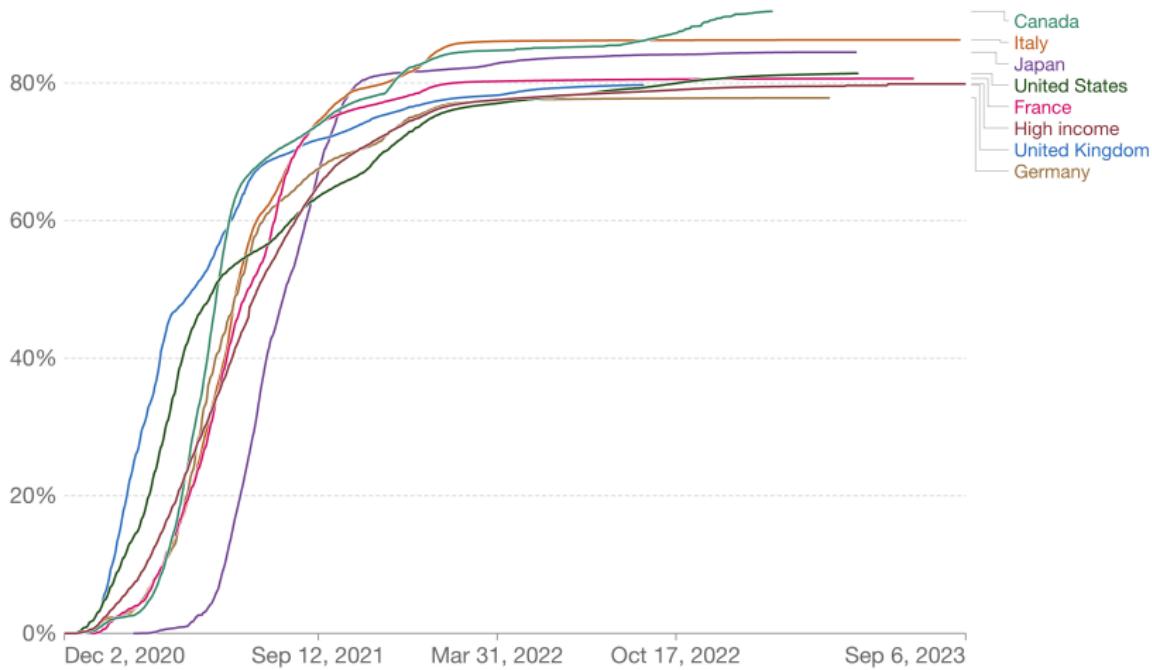
November 17, 2023



Share of Vaccinated Initially Increased Convexly

Share of people who received at least one dose of COVID-19 vaccine
Total number of people who received at least one vaccine dose, divided by the total population of the country.

Our World
in Data



Source: Official data collated by Our World in Data

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A Ubiquitous Curve

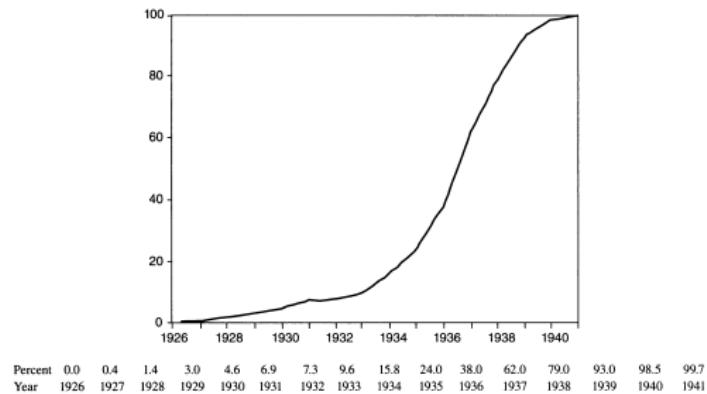


FIGURE 5. PERCENT OF ADOPTERS OF HYBRID CORN IN TWO IOWA COMMUNITIES, 1926–1941
(From Ryan and Gross 1943, Figure 4)

"The S-curve of diffusion is so ubiquitous that students of diffusion often expect every innovation to be adopted over time in an S-shaped pattern"-
Rogers Everett (2003)

Bariatric surgeries (Buchwald and Oien, 2009; Buchwald and Oien, 2013), **microwave ovens** (Wiersema and Buzzell, 1979; Guenthner et al., 1991)

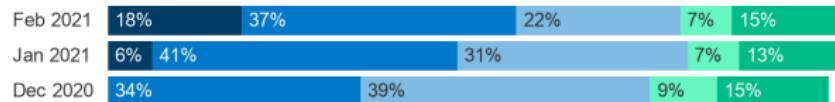
Choosing to Wait and See

Figure 1

Share Who Report Getting COVID-19 Vaccine Grows; Share Wanting To "Wait And See" Shrinks

Have you personally received at least one dose of the COVID-19 vaccine, or not? When an FDA authorized vaccine for COVID-19 is available to you for free, do you think you will...?

■ Already vaccinated ■ Get it as soon as you can ■ Wait and see how it's working
■ Get it only if required ■ Definitely not get it



NOTE: December 2020 survey did not have an option for respondents to indicate they had already been vaccinated. See topline for full question wording.

SOURCE: KFF COVID-19 Vaccine Monitor (Feb. 15-Feb. 23, 2021)

KFF COVID-19
Vaccine Monitor

- Informational free-riding by a significant portion of the population
- Ryan and Gross (1943) - “adoption of neighbors” is the **main** reported factor determining take up of hybrid corn

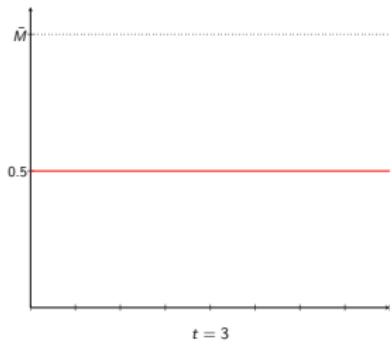
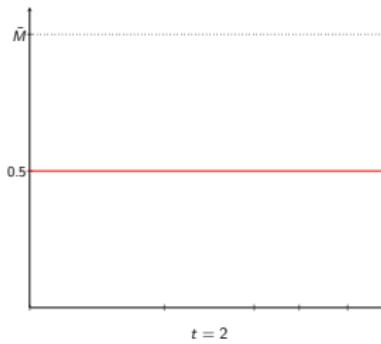
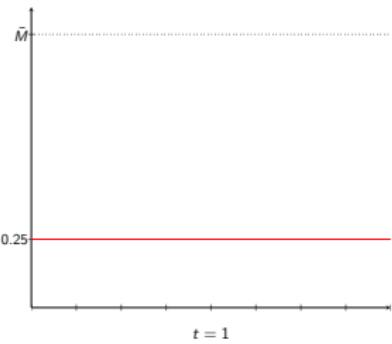
How does a principal who cannot
force adoption, nor make
transfers, induce earlier adoption?

One idea is to create
artificial scarcity

Simple Example

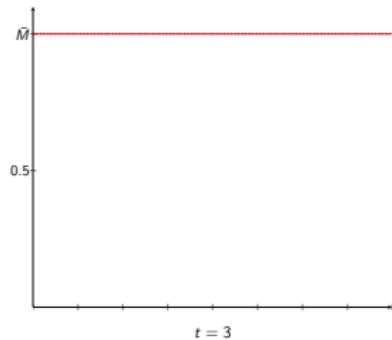
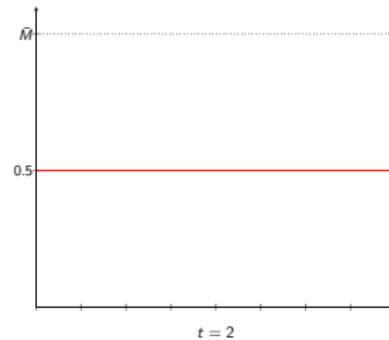
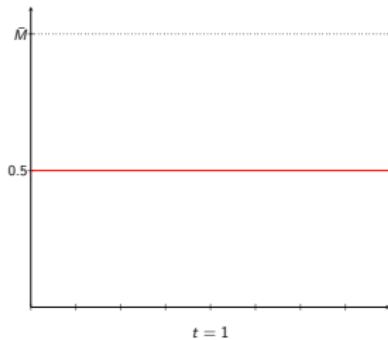
- Owner wants to release a new rideshare app
- She needs to reach a certain critical mass of adoption $\bar{M} < 1$
- Half the potential market is high value if the product is good, half wants to see some information first
- Information depends on take-up of others, and is revealed over time.
- There are three periods $t = 1, 2, 3$
- Owner can commit to a supply plan

Simple Example - Free Supply



Half the optimists would prefer adopting at $t = 2$!

Simple Example - Supply Restriction



Without that option, they prefer adopting at $t = 1$ and therefore pessimists are convinced by $t = 3$.

Model Outline

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- Take-up decision is **irreversible**
- Single principal wants to encourage earlier adoption and can control only supply path

Outline of Results

- Heterogeneity in valuation types is **enough** for S-shaped adoption (no need to add myopic types or adoption restrictions)
- Imposing artificial scarcity on path is profitable, with “**batched**” release
- The number of batches is **small**
- I study how the optimal supply is affected by the distribution of types

Model

- Continuum of individuals with finite set of types $v \in V$ and $\eta(V) = 1$. ► Heterogeneous Beliefs

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- Common payoff of -1 if $\omega = B$
- For $v \in V$, payoff is $v > 0$ in the good state.
- Principal's payoff is 1 if the target is hit, 0 otherwise. ► Critical Mass
- Therefore, the principal maximizes $e^{-rt} \text{Prob}(M_t = \bar{M})$. ► Objective

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- Can be relaxed to allow for **both** types of news, as long as the arrival rate of good news is lower.
- Bad news is fitting for many cases, as medical innovations and those with high switching costs

▶ Example

Belief Updating

- Absent signal realizations, agents become more **optimistic**

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- Absent signal realizations, agents become more **optimistic**
- Important to note that learning is sensitive only to the “area” below the stock of adopters, not the whole path:

$$\mu_t = \frac{\mu_0}{\mu_0 + (1 - \mu_0)e^{-\beta \int_0^t M_s ds}}$$

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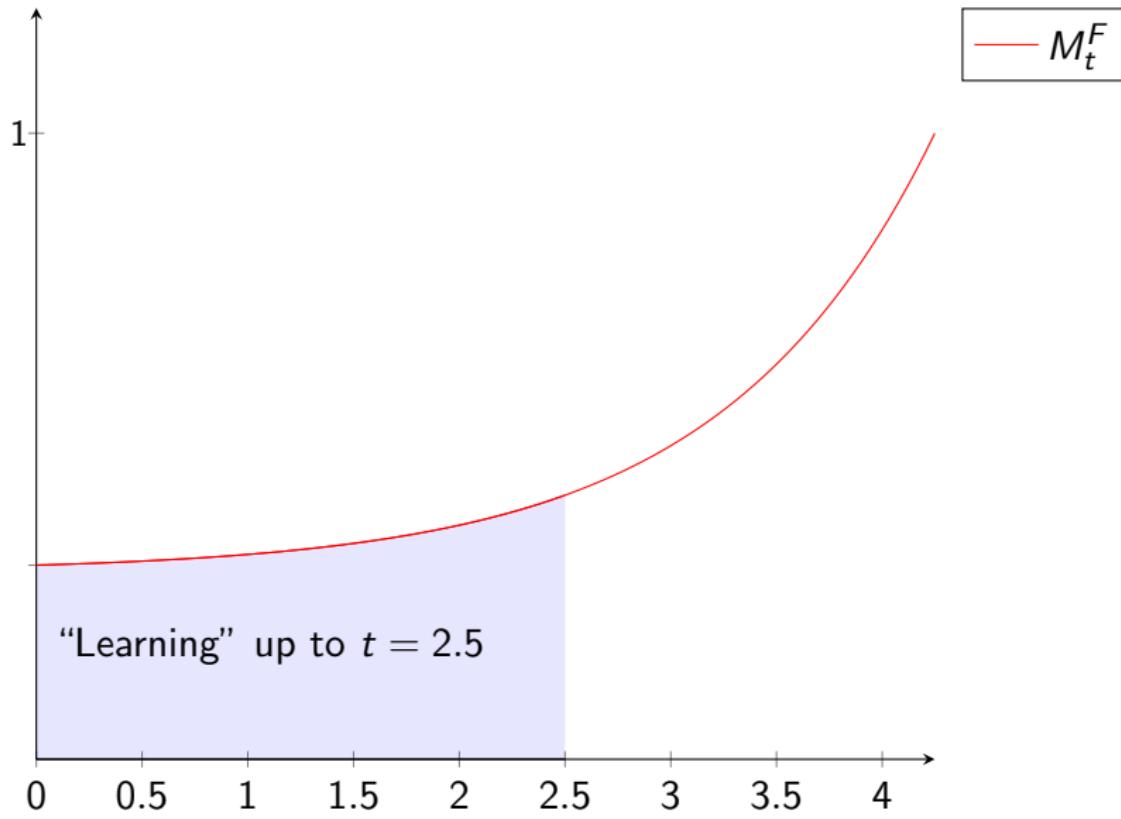
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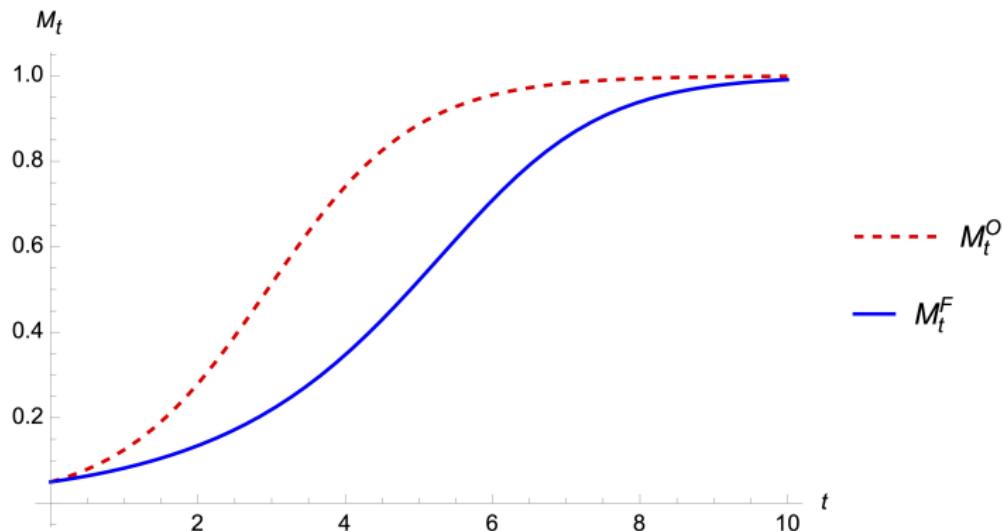
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Graphical Representation - Free Supply



S-shaped Adoption for $V \rightarrow \text{Uniform}$



Contribution: replicate S-shaped adoption curve without restrictions on adoption or myopic players.

Myopic Take-up Paths

- Suppose that individuals take up as soon as it is **myopically** profitable:

$$v_0^M \mu_0 - (1 - \mu_0) = 0$$

$$v_t^M \mu_t - (1 - \mu_t) = 0$$

Myopic Take-up Paths

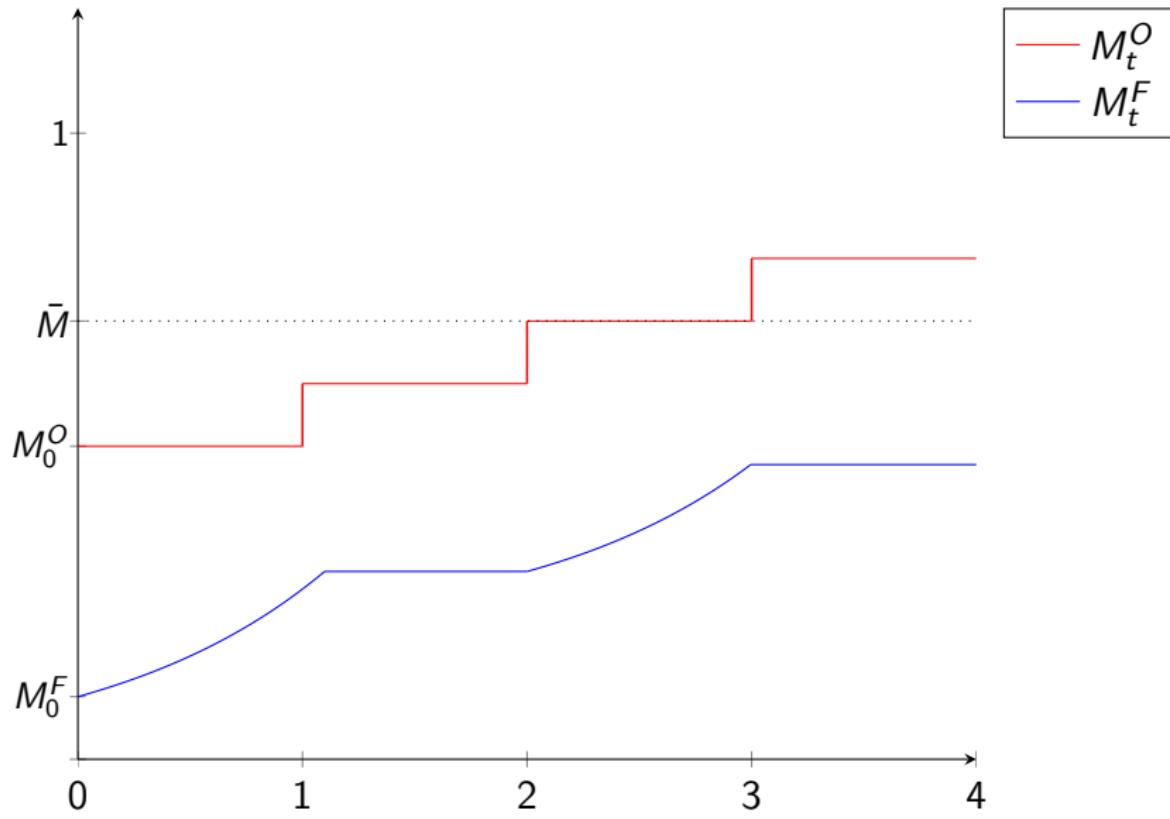
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- Denote that unique take-up path by $\{M_t^O\}$.

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- If demand is higher than available supply, a uniformly at random chosen set of agents is served
- Product is durable: whatever is unclaimed is available
- Fitting assumption for settings in which supply cannot be **fully** controlled by producer (usual with durable goods sold by third parties)

One Type

- Suppose that $V = \{v\}$
- If initial belief μ_0 is too low, $M_t^E = 0$ for every t

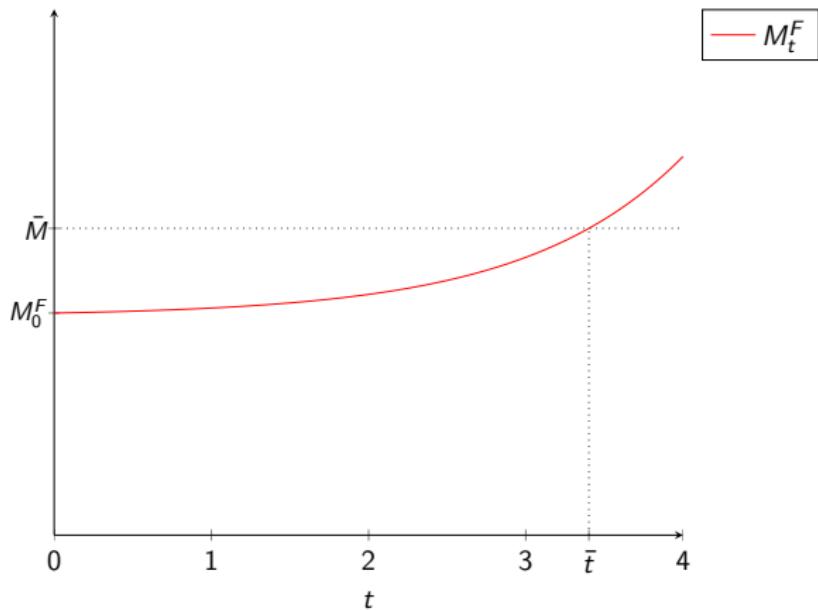
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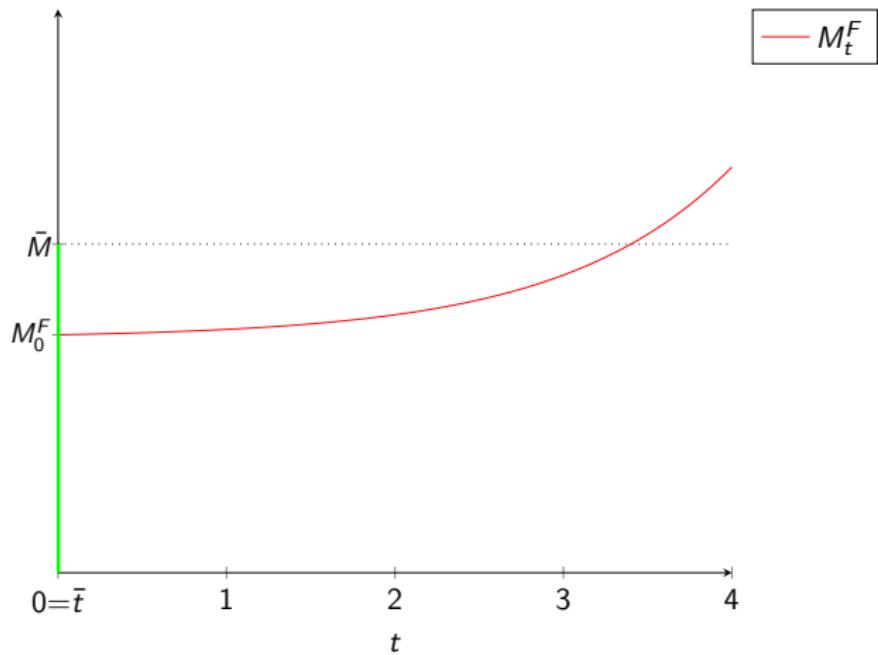
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- If initial belief μ_0 is too high, $M_t^E = 1$ for every t
- Otherwise, we have **partial** take-up up to a point in time

One Type Graphical Representation



Convex Adoption: to keep indifference for more optimistic agents, only the promise of **greater learning** can delay adoption.

One Type Graphical Representation - Supply Restriction



All equilibria with free-riding **unravel!**

One-Type Optimal Plan

Theorem

With one type, the principal can supply $S_0 = 1 - \epsilon$ and get immediate adoption at time 0

Supply Restrictions Are Beneficial

Theorem

There is always a supply plan inducing an adoption path preferred by the principal to free supply

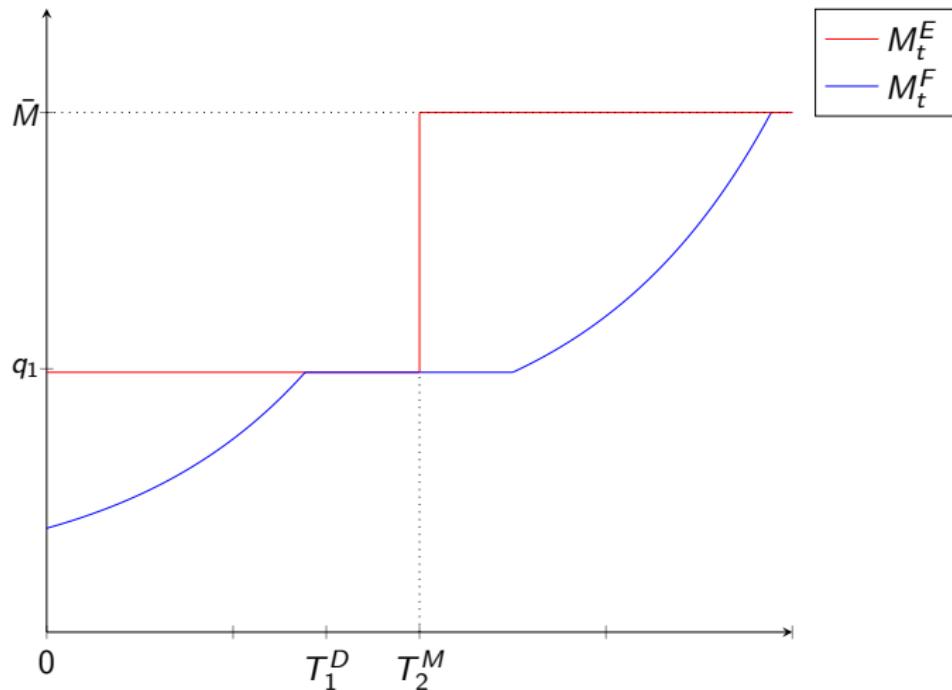
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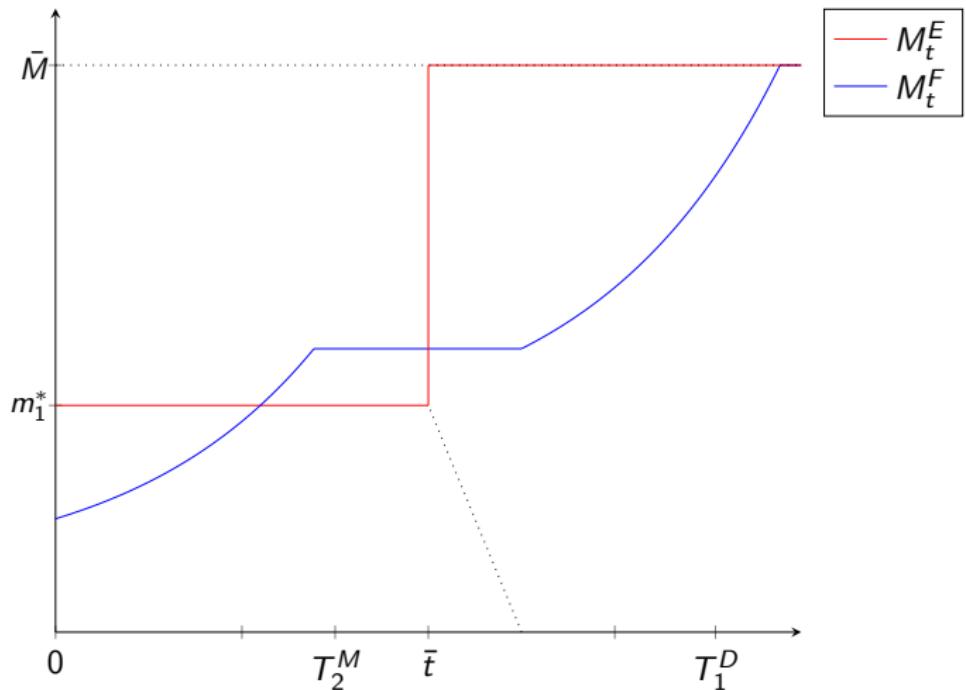
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By serving $S_0 = \bar{M} < 1$, last type will adopt myopically.

Two Types - Case 1



Two Types - Case 2



Optimality of “Simple” Supply Plans

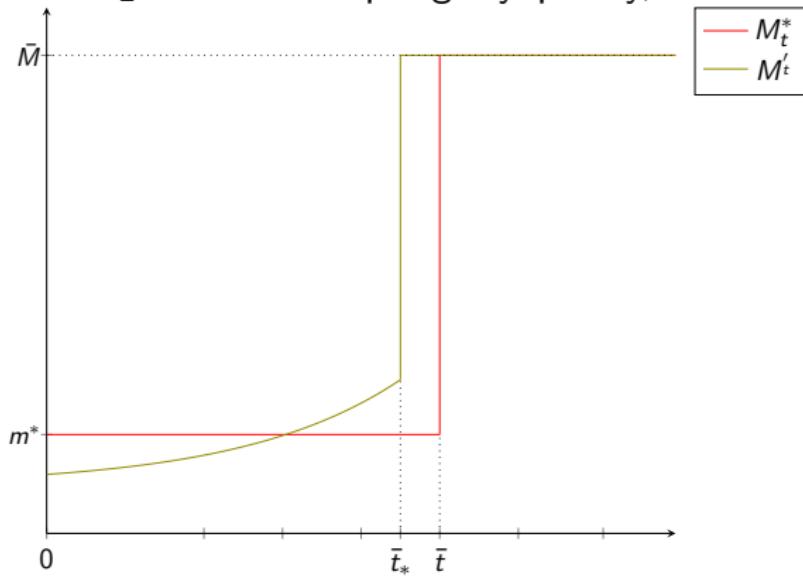
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- Then v_2 must be adopting myopically, at the final moment \bar{t}_*

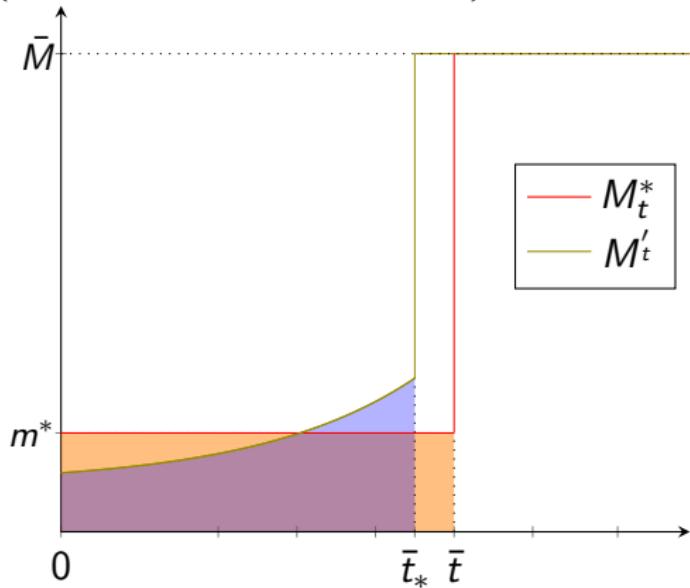
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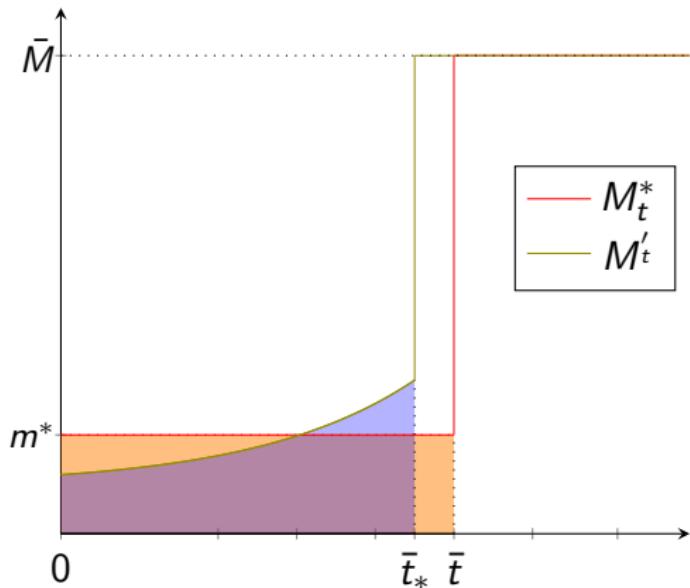
Optimality of “Simple” Supply Plans

- So the same “learning” is happening at the earlier point in time \bar{t}_* .
(Blue Area=Orange Area)



Optimality of “Simple” Supply Plans

- But then $\bar{t}_* \succ^{v_1} 0$ for v_1 types, and none would adopt at 0.
- Therefore M'_t is not equilibrium



Simple Plans

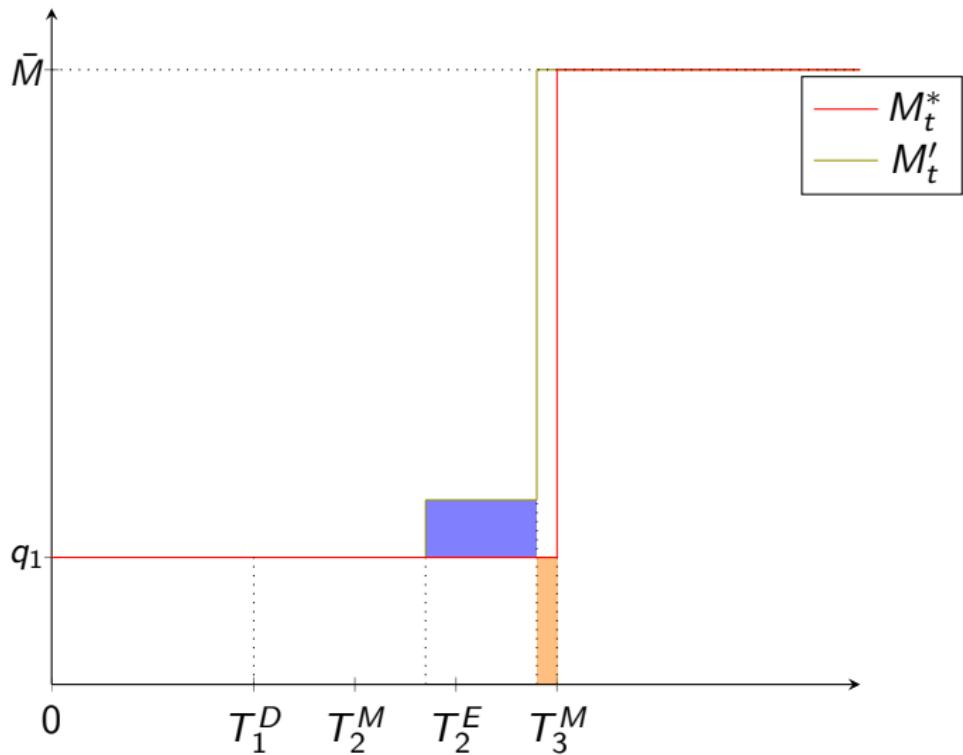
Definition

A **simple supply plan** consists of at most as many batches as types and induces immediate exhaustion.

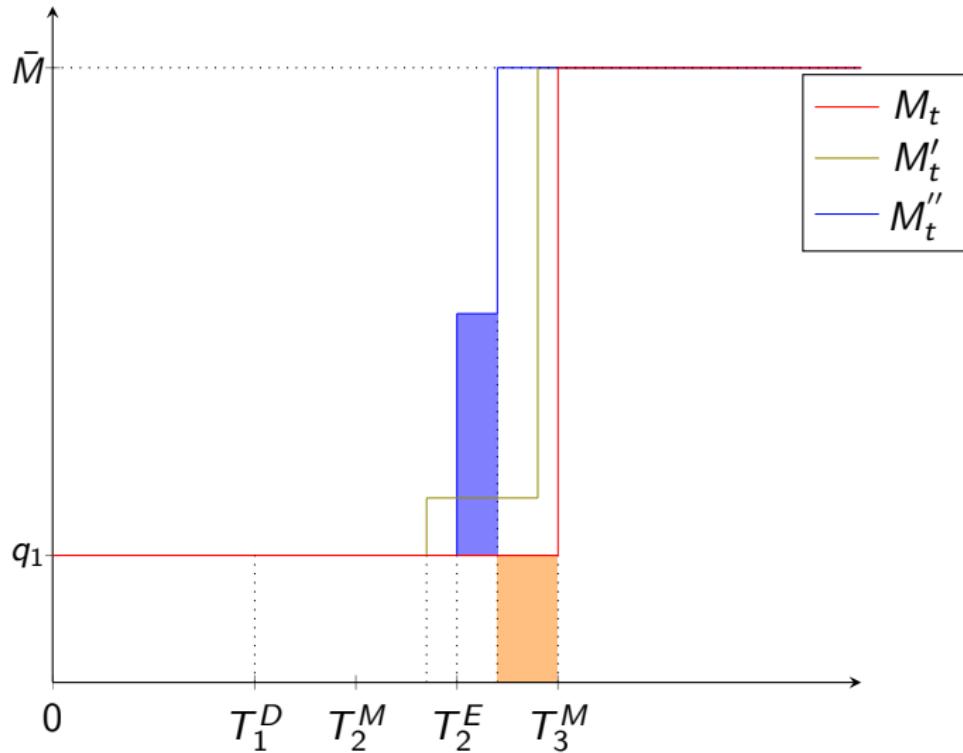
Theorem

It is without loss of generality to focus on simple supply plans.

Three Types - Mid-Batch



Three Types - Mid-Batch



Extensions and Discussion

- Two regions differently connected ($\beta_1 > \beta_2$) - preference for the more connected along the way, skeptics in both should adopt **simultaneously** . ▶ Two Regions
- Two products ex-ante equal - may or may not improve principal's payoff, as scarcity is **hampered**. ▶ Two Products
- Social Welfare - high types are **equally** well-off, mid-types may or may not be better-off, and low-types are **worse-off** , when comparing to free-supply equilibrium ▶ Social Welfare

Conclusion

- Can replicate **S-shaped** adoption without imposing myopic agents or take-up restrictions
- **Consumer competition** leads to immediate take-up at the unique equilibrium.
- Batching can make lower types adopt faster through earlier take-up of **higher types** .
- Trade-off between earlier or higher adoption from mid-types must favor the **latter**
- Benefits of batching may **compensate** those of having multiple products

Thank you!

Please send feedback to:
ricardo_fonseca@brown.edu

Appendix

Heterogeneous Valuations vs Beliefs

- Instead of heterogeneous valuations, heterogeneity in beliefs may be seen as more fitting in many cases
- The model is a more tractable version of one in which agents have homogeneous adoption benefits but different priors.
- For each value set $V = \{v_1, v_2, v_3, \dots, v_N\}$ and common belief μ_t , we can associate an analogous model with $V = \{v\}$ and $\mu_0 = (\mu_0^1, \mu_0^2, \mu_0^3, \dots, \mu_0^N)$.
- What matters is the **threshold** belief for adoption $\bar{\mu}^i$ for a $i \in \{1, \dots, N\}$.

◀ back

Principal's Objective

- Principal wants adoption **regardless** of the state
- Although this is standard for a profit-maximizing firm, the public health motivating scenario requires some words:
 - ① For vaccines, there is an externality effect: a social planner could want to see high vaccination even if for substantial part costs are higher than benefits (low risk, etc)
 - ② With myopia to reaching target, social planner with better knowledge of the state of the world would also prefer scarcity.

◀ back

Critical Mass

- The idea of a point in which adopting an innovation becomes self-sustaining is highlighted in the literature.
 - If the objective is to reach this mass fast (due to exogenous factors or competitor arrival), the model discussed can help shed light on how to face it.

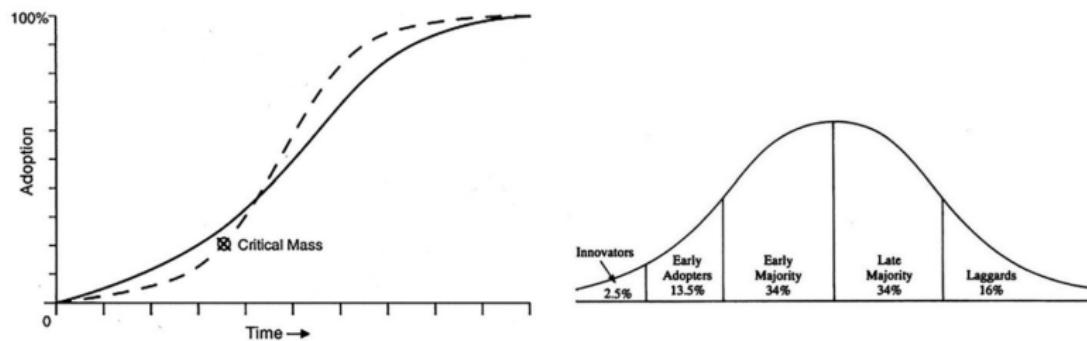
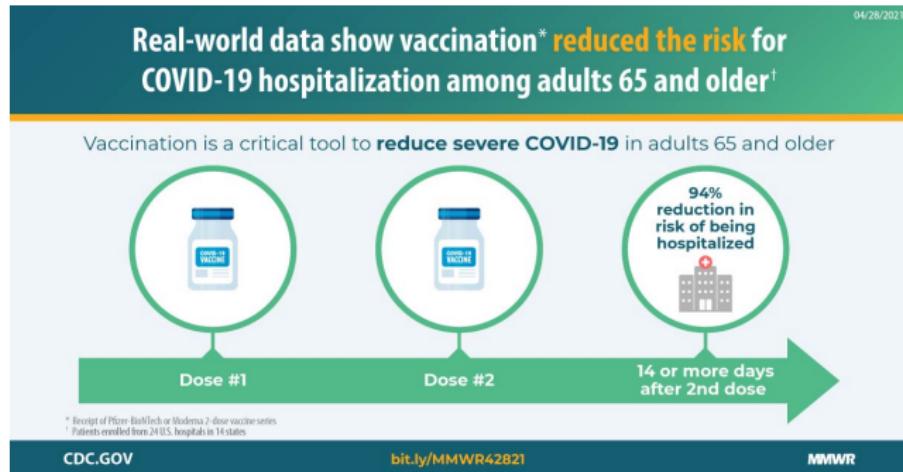


Figure 1. Rogers' S-shaped diffusion curve and adopter categorisation (taken from Rogers 2003, 344; 281).

Bad News

- Pfizer vaccine was advertised as having 95% effectiveness and mild side effects.



- In general, if innovations have to be tested before being released, only good outliers are released to the public; news can only **harm** perception.

Two Regions

- There are two regions A_1 and A_2 with equal types distributions
- Region A_i has arrival rate of news β_i
- $\beta_1 > \beta_2$, so that news from Region 1 are more salient
- Any realization is observable by all regions
- If all types must be served, the last for each must adopt myopically
- As belief is common, they must pick-up at the same final moment

◀ back

Two Products

- Two products that can independently be good or bad (state space now $\{G, B\} \times \{G, B\}$)
- Releasing equal amounts of the two goods is the best option for hedging whenever using both matters
- Suppose that we have two types, and \bar{t} is the same with the two batches. Then all hedging gains are there and having both products released is beneficial.
- Work again with two types, but assume now that time to reach myopic target for low-type v_2 doubles. Together with the fact that now the last batch scarcity play cannot be done, we must be **worse-off** with two batches.

◀ back

Social Welfare

- As all v_1 type agents are indifferent between picking up at time 0 and any other moment in which they pick up in equilibrium, **no welfare gains** for them.
- All type v_3 agents are picking up myopically. With free-supply, they would get a positive payoff. Therefore they are **worse-off**.
- Finally, the situation of the v_2 types depends. The fact that v_1 types is taking up earlier is beneficial for them, but the fact that they may be forced to pick up with v_3 types might decrease welfare. So signal is **uncertain**

◀ back

Discussion - Ethical Concerns

- Restricting the supply of vaccines raises ethical concerns
- Three points:
 - ① The effect of availability on take-up is worth modeling and understanding
 - ② As Wood and Schulman (2021) points out, one can leverage perceived scarcity
 - ③ If adoption is already close to the target, a case can be made for restrictions