The Hammer and The Dance:

Equilibrium and Optimal Policy During a Pandemic Crisis

Toulouse School of Economics Macro Group
(T. Assenza, F. Collard, M. Dupaigne, P. Fève, C. Hellwig, S. Kankanamge, N. Werquin)

Covid, Search and Matching, Chicago, 05/28/2020

- 2 Specific features/challenges related to COVID-19:
  1. **Fast propagation:** short horizon between infection and recovery/death
  2. **Asymptomatic transmissions:** large fraction of transmissions/infections go undetected

Economic Policy During a Pandemic Crisis

- 2 Specific features/challenges related to COVID-19:
  1. **Fast propagation:** short horizon between infection and recovery/death
  2. **Asymptomatic transmissions:** large fraction of transmissions/infections go undetected
- Dynamic model linking economic interactions and infection risks
  → study trade-offs between
    1. mortality costs induced by pandemic
    2. adverse economic costs of policy interventions
- Keep it at a fairly high level of generality

Economic Policy During a Pandemic Crisis

- Equilibrium and Central Planner's allocations → "*The Hammer and The Dance*"

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    - **The Hammer:** Strong initial lockdown to bring infections under control
    - **The Dance:** Slow gradual deconfinement towards herd immunity

Economic Policy During a Pandemic Crisis

- Equilibrium and Central Planner's allocations → "*The Hammer and The Dance*"
  - The Hammer: Strong initial lockdown to bring infections under control
  - The Dance: Slow gradual deconfinement towards herd immunity
- Results = interplay between static and dynamic externalities
  1. Static: instantaneous economic and infection risk spill-overs
  2. Dynamic: linked to dynamic immunization and infection externalities
     - Long-run: Strong infection externalities → Excess mortality in equilibrium
     - Short-run: Strong immunization externalities → too strong/weak equil. lockdown depending on welfare cost of initial infection peak

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- Kaplan, Moll and Violante; Bethune and Korinek; Atkeson; Chang and Velasco; Garibaldi, Moen and Pissarides; Gonzalez-Eiras and Niepelt; Jones, Philippon and Venkateswaran; Krueger, Uhlig and Xie; Toxvaerd; Ritschl; Abaluck, Chevalier, Christakis, Forman, Kaplan, Ko and Vermund; Glover, Heathcote, Krueger and Ríos-Rull; Greenstone and Nigam; Cleevely, Susskind, Vines, Vines and Wills; Beck and Wagner; Rowthorn; von Thadden; Beenstock and Dai; Avery, Bossert, Clark, Ellison and Ellison; Berger, Herkenhoff and Mongey; Maloney and Taskin; Zhixian and Meissner; Victoria, Menzio and Wiczer, Forslid and Herzing, Moser and Yared, Hornstein, Bodenstein, Corsetti and Guerrieri, Deb, Furceri, Ostry and Tawk, **and many others...**
- Too numerous to mention

The Model

Time is discrete,
Perfect foresight
Measure Λ_t of Agents

Actions: $x \in \mathcal{X} \subseteq \mathbb{R}^k$
$\mathcal{X}$ Compact, Convex

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Instantaneous Payoffs:
$U(x, X) \in [\underline{V}, \overline{V}],\ \overline{V} > \underline{V} \geqslant 0$

Assumption:
$\exists X^\star \in \mathcal{X},\ U(X^\star, X^\star) = \overline{V}$

→ Equilibrium Efficiency
(2^{nd} Welfare Thm)

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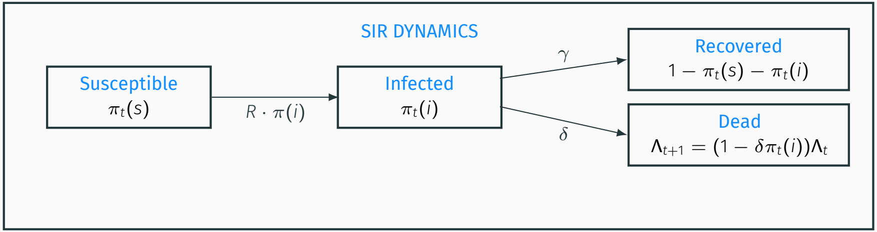

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Susceptible $\pi_t(s)$ → $R \cdot \pi(i)$ → Infected $\pi_t(i)$

Infected → γ → Recovered $1 - \pi_t(s) - \pi_t(i)$

Infected → δ → Dead $\Lambda_{t+1} = (1 - \delta\pi_t(i))\Lambda_t$

Assumption (Asymptomatic Transmission)
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Dynamic Game Payoffs

$$(1-\beta)\sum_{t=0}^{\infty} \beta^t \Lambda(x^{t-1}, X^{t-1}) U(x^{t-1}, X^{t-1})$$

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   (i) Static part: which sectors to open or close?

   - Align private and social MRS btw economic activity and infection risks to the shadow price.

   (ii) Dynamic part: timing of interventions?

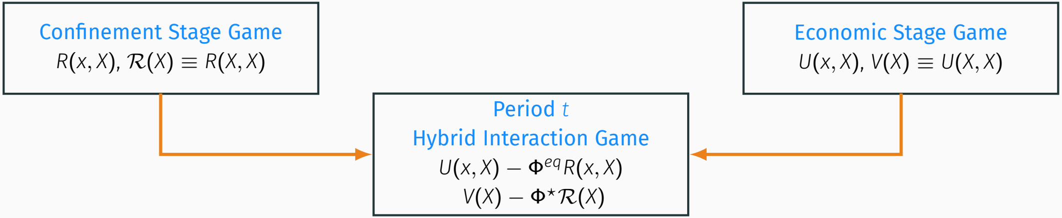
   - The dynamics of the shadow price of infection risks dictate the timing

Static Interaction Game

Confinement Stage Game
$R(x, X)$, $\mathcal{R}(X) \equiv R(X, X)$

Economic Stage Game
$U(x, X)$, $V(X) \equiv U(X, X)$

Static Interaction Game



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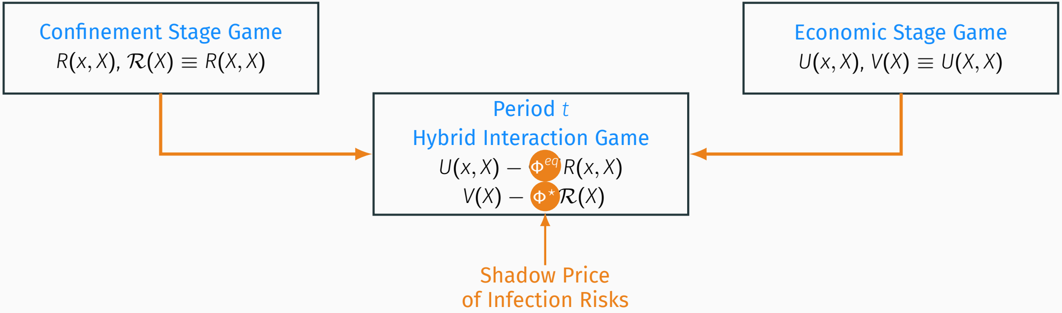

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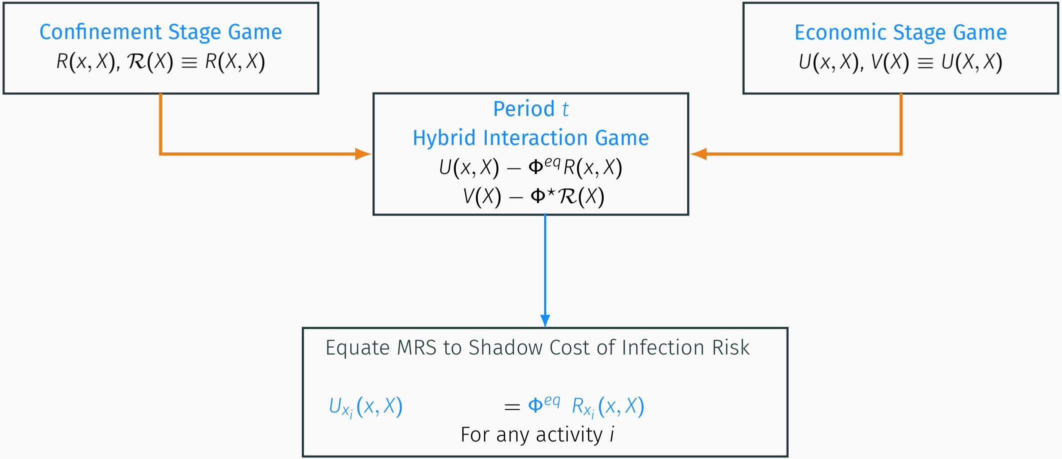

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Economic Stage Game

$U(x, X)$, $V(X) \equiv U(X, X)$

Period t
Hybrid Interaction Game

$U(x, X) - \Phi^{eq} R(x, X)$

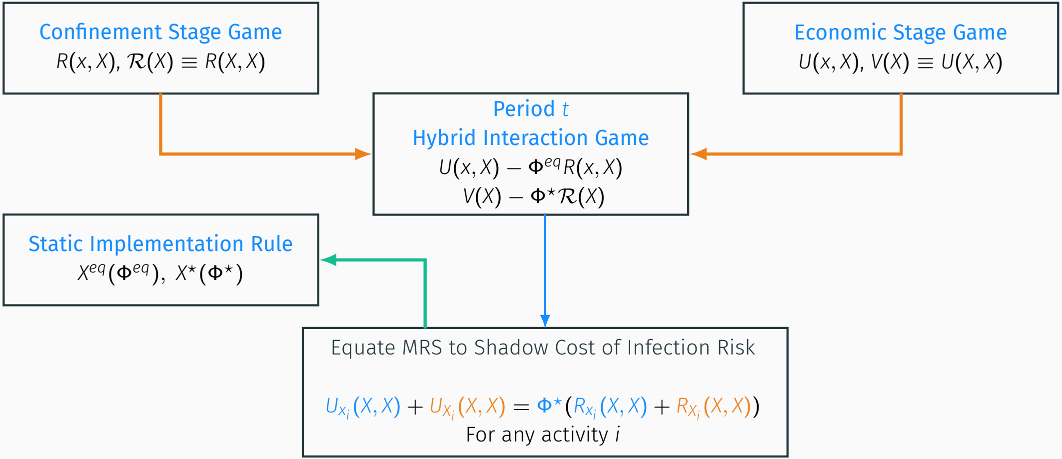
$V(X) - \Phi^{\star} \mathcal{R}(X)$

Equate MRS to Shadow Cost of Infection Risk

$$U_{x_i}(X, X) + U_{X_i}(X, X) = \Phi^{\star}\left(R_{x_i}(X, X) + R_{X_i}(X, X)\right)$$

For any activity i

Static Interaction Game



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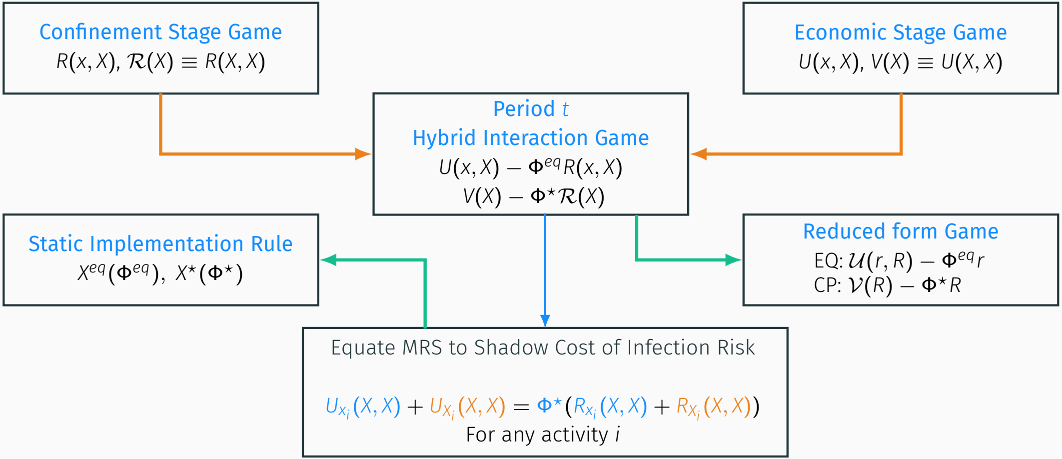
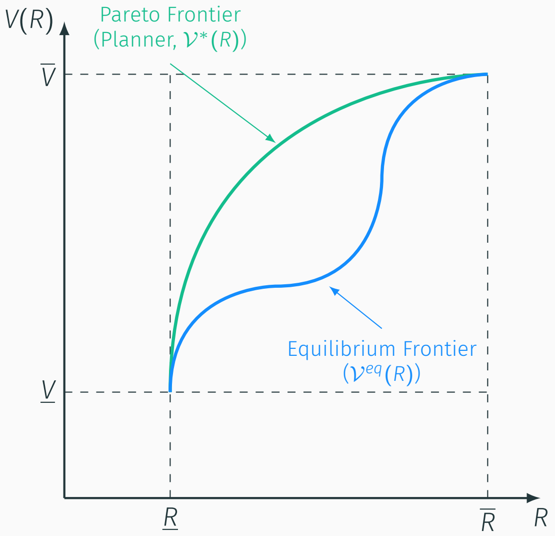
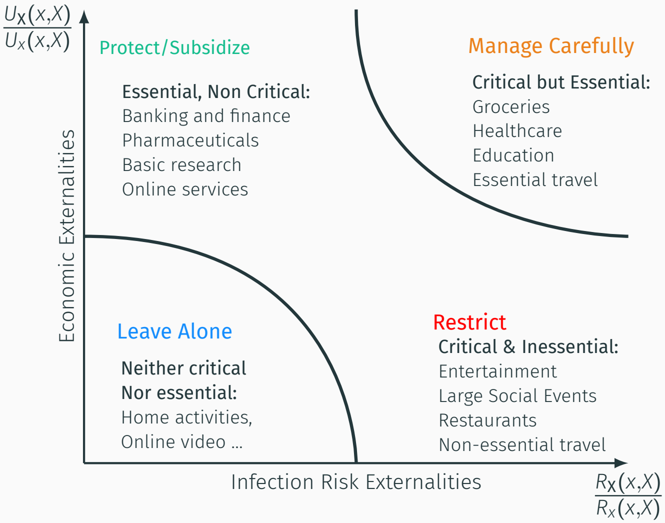


Equilibrium and Pareto Frontiers



Static Efficiency Conditions → Optimal Policy

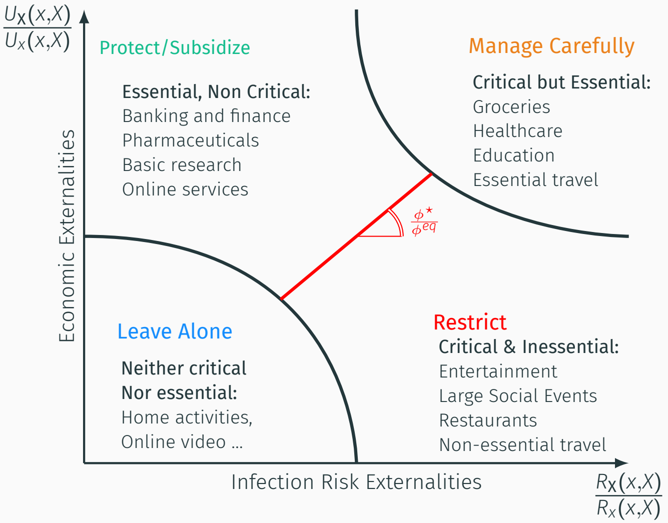


Static Efficiency Conditions → Optimal Policy

- Focus policy on sectors with large absolute spill-overs
- Protect/subsidize sectors if

  Social MRS>Private MRS
- Restrict sectors if

  Social MRS<Private MRS
- Milder (stronger) intervention on sectors with small (large) absolute spill-overs



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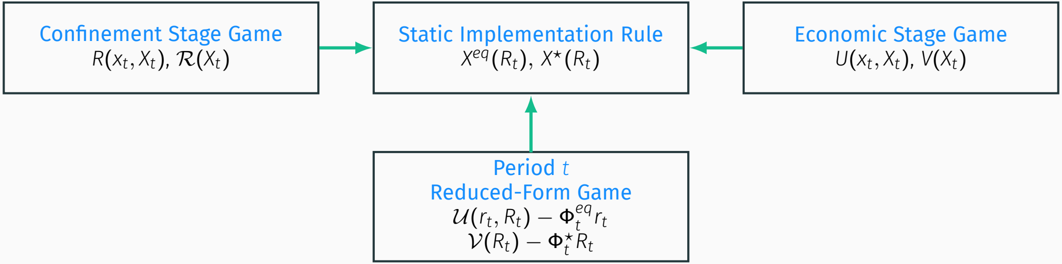

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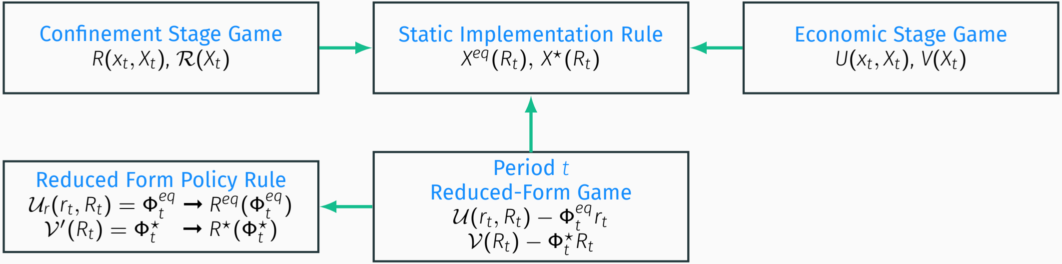

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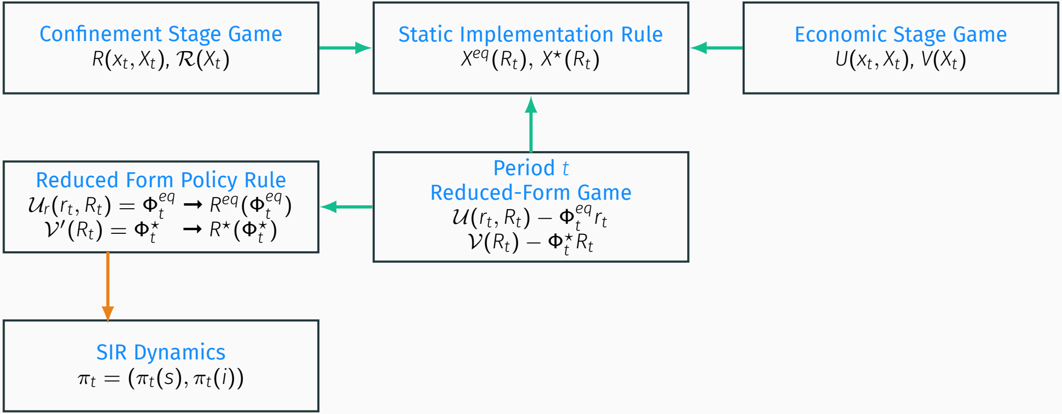

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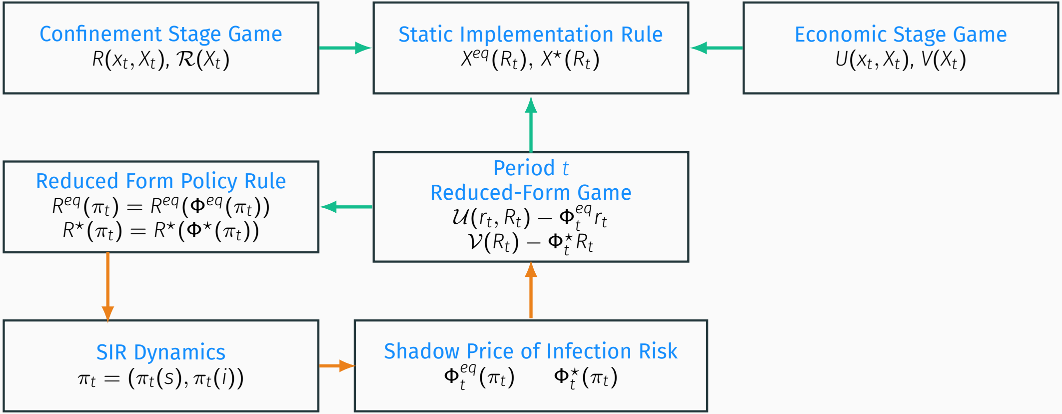

Dynamic Efficiency conditions

- Focus on reduced form trade-off between R and $\mathcal{V}$:

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- Social Marginal Value of Recovery $(i \to r)$

$$-\frac{\partial v(\pi)}{\partial \pi(i)} = v_r(\pi) - v_i(\pi) - \pi(s)\frac{\partial v_s(\pi)}{\partial \pi(i)} - \pi(i)\frac{\partial v_i(\pi)}{\partial \pi(i)} - (1 - \pi(s) - \pi(i))\frac{\partial v_r(\pi)}{\partial \pi(i)}$$

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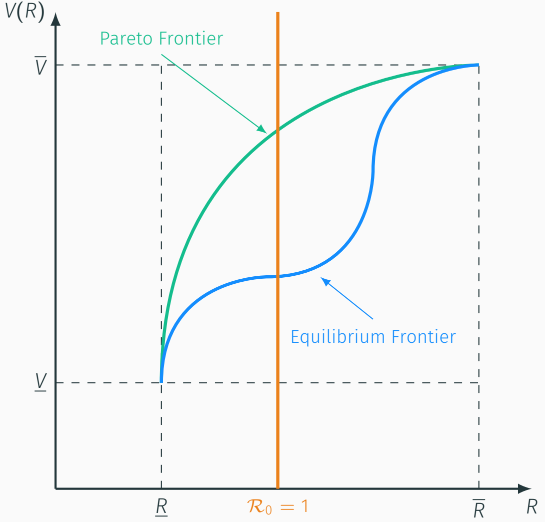
A useful limit case: Instantaneous propagation ($\beta \to 1$)



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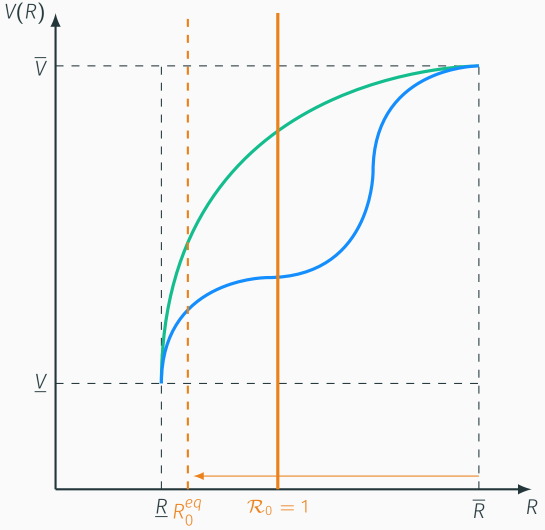

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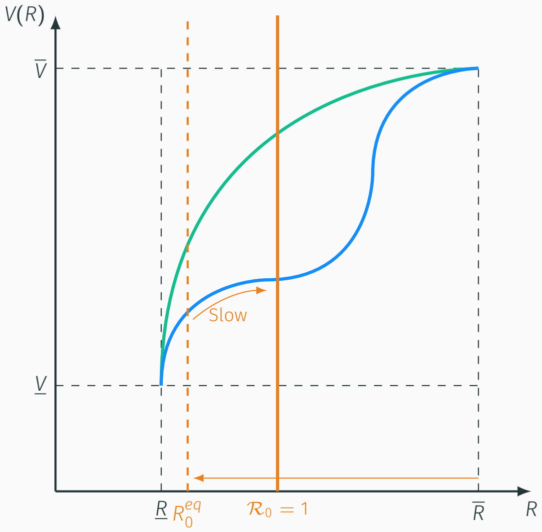
  - **Dance:** keep $\pi_t(i)$ within $(0,\eta)$ until herd immunity is reached ➞ very slow $(\pi_t(s))$



A useful limit case: Instantaneous propagation ($\beta \to 1$)

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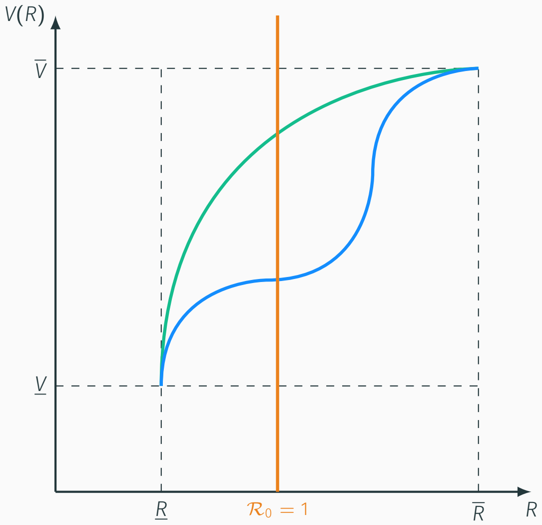

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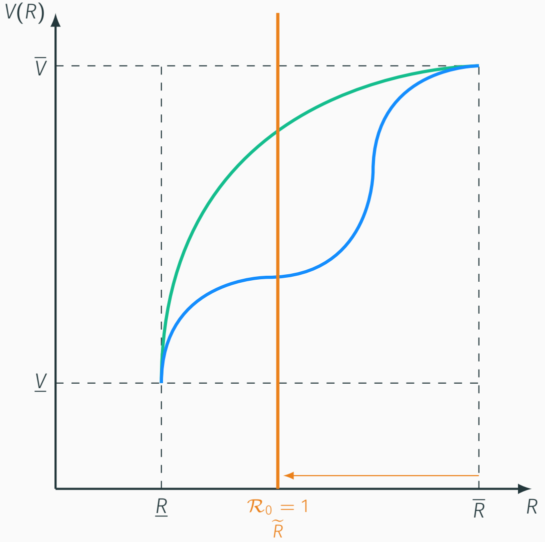

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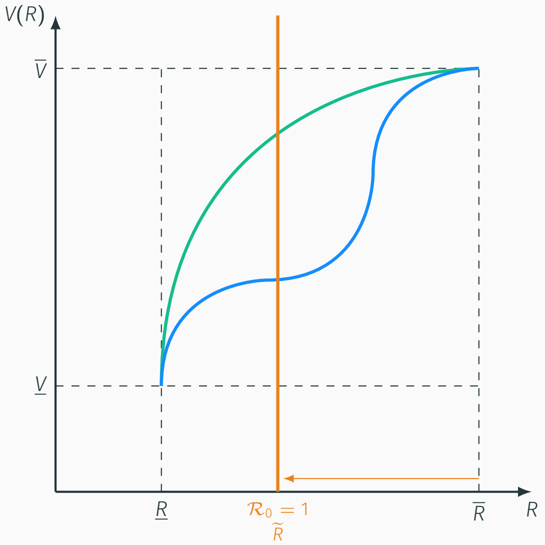
- **SR: Immunization externality:** hold-out motive that inefficiently slows the propagation
- **LR: infection externality:** agents exit confinement too fast, relative to the CP ➞ increases LR mortality.



Proposition

Start from an (arbitrarily) small, positive fraction $\pi_0(i) > 0$ of infected agents in the population, the sequential planner's solution and equilibrium $\{R_t^*, \pi_t^*\}$ and $\{R_t^{eq}, \pi_t^{eq}\}$ both satisfy:

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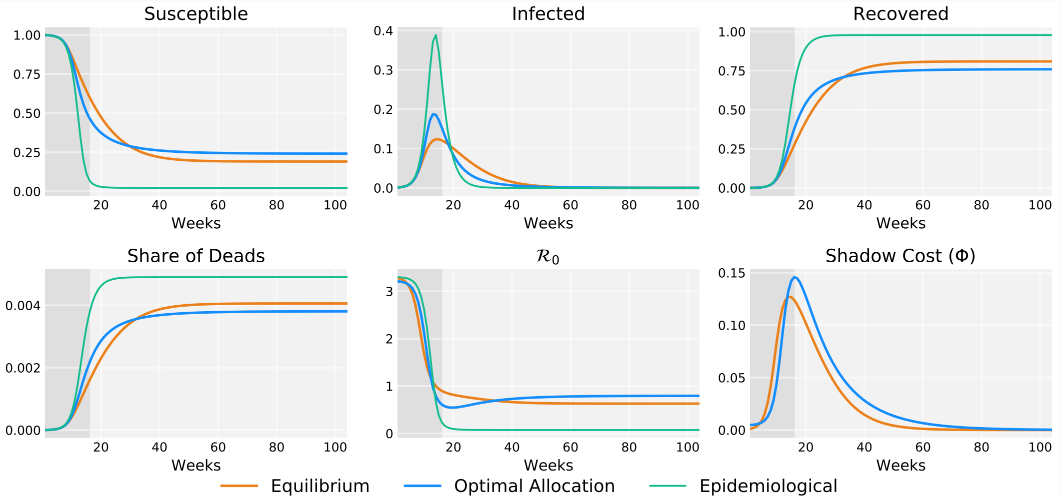
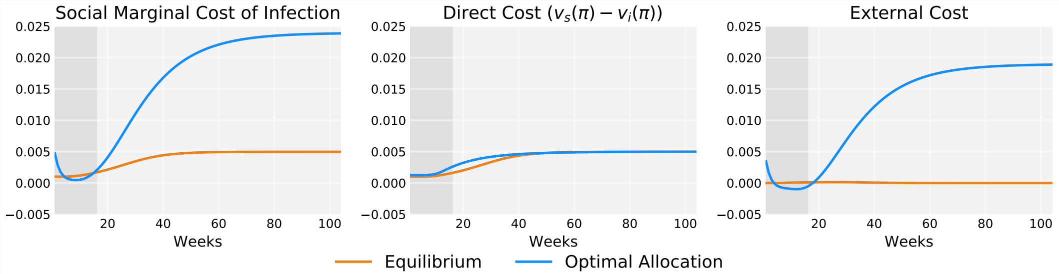
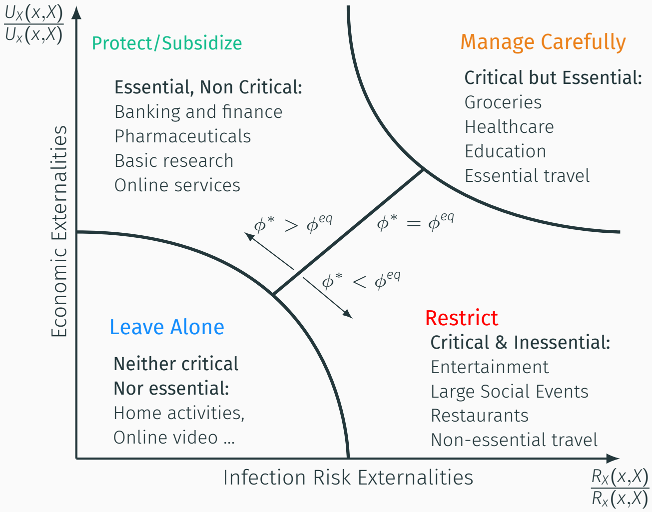
1. **Flatten the Curve (Short Run):** Starting from R_0^* and R_0^{eq} arbitrarily close to $\overline{R}$, both policy sequences are initially decreasing to "flatten the curve" and delay infections → The Hammer phase
2. **Herd Immunity (Long-run):** In the long run, R_t^* and R_t^{eq} converge to $\overline{R}$, and the economy returns to the pre-pandemic equilibrium in a state of herd immunity → The Dance phase



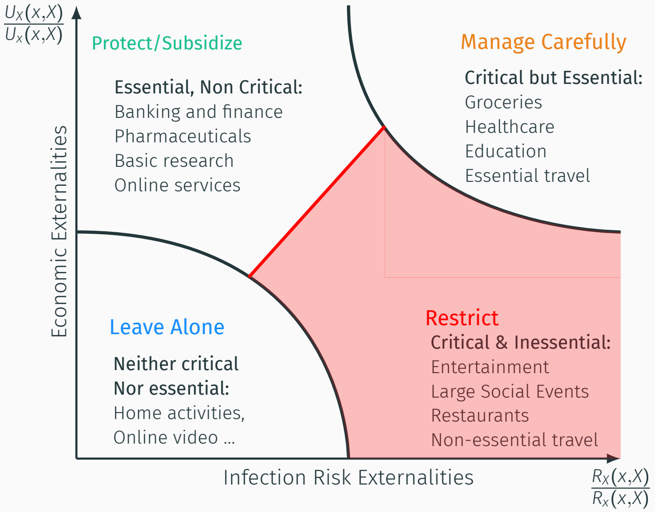
Pareto Frontier

Externalities

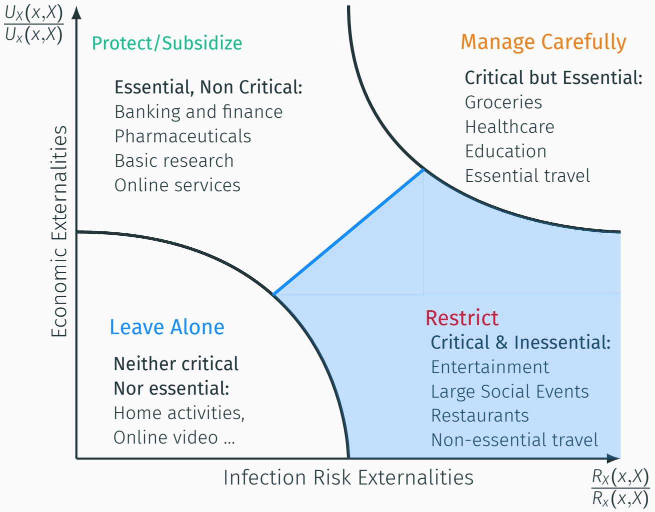



$\frac{U_X(x,X)}{U_x(x,X)}$
Economic Externalities
Protect/Subsidize
Essential, Non Critical:
Banking and finance
Pharmaceuticals
Basic research
Online services
Manage Carefully
Critical but Essential:
Groceries
Healthcare
Education
Essential travel
$\phi^* > \phi^{eq}$
$\phi^* = \phi^{eq}$
$\phi^* < \phi^{eq}$
Leave Alone
Neither critical
Nor essential:
Home activities,
Online video ...
Restrict
Critical & Inessential:
Entertainment
Large Social Events
Restaurants
Non-essential travel
Infection Risk Externalities
$\frac{R_X(x,X)}{R_x(x,X)}$

Policy Dynamics



Policy Dynamics



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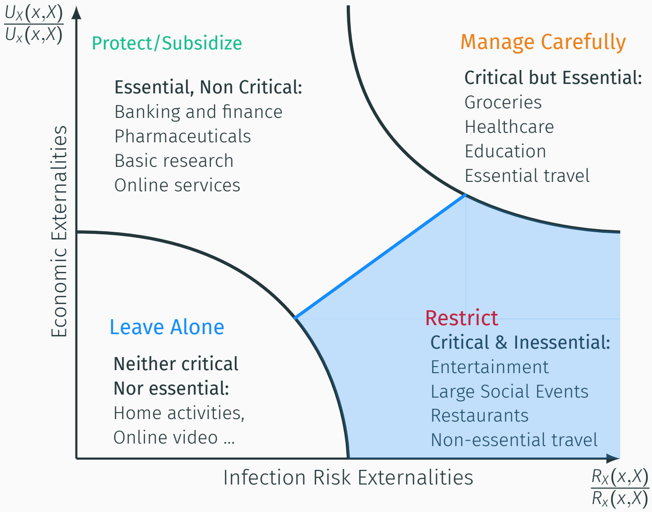
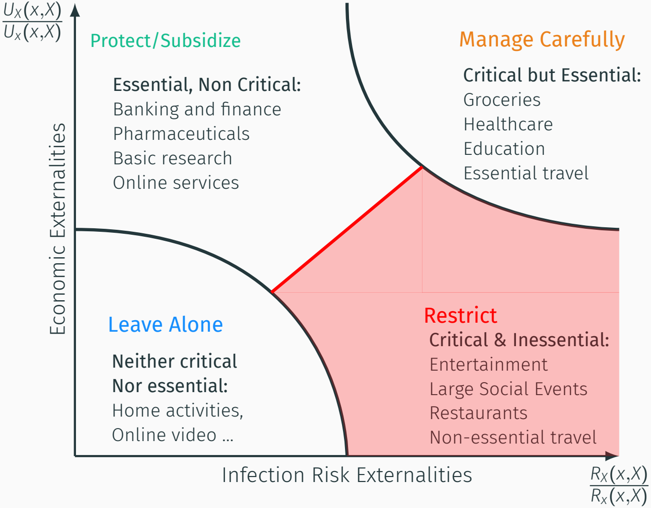


Policy Dynamics



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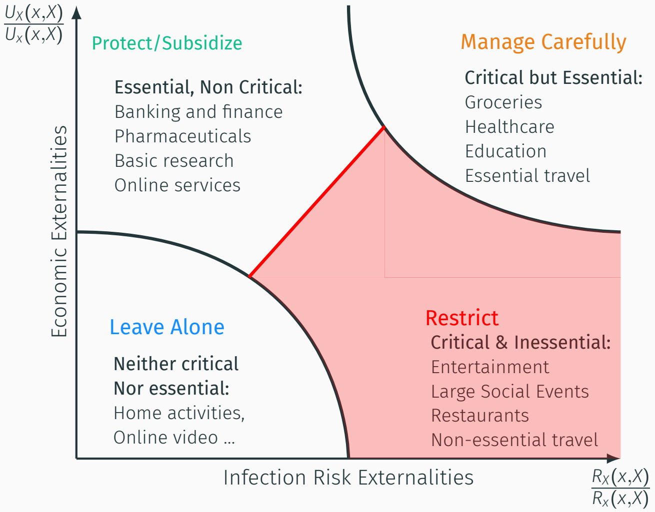

Extensions

- Additional Externalities
  - Static Externalities ▸ Show
  - Congestion Externalities ▸ Show
  - Hope for vaccine and cure ▸ Show
  - Transitory immunization ▸ Show
- Shifts in Pareto and Equilibrium Frontiers
  - Face Masks ▸ Show
  - Testing and contact tracing ▸ Show

Concluding Remarks

- Dynamic model integrating economic interactions and infection risk

- Fast Propagation → **Hammer and Dance** Dynamics
- Highlight the role of static and dynamic externalities

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- Dynamic model integrating economic interactions and infection risk

- Fast Propagation → **Hammer and Dance** Dynamics
- Highlight the role of static and dynamic externalities

- **Clear policy implications:**
  - **The hammer:**
    - Early, decisive action is warranted if saves lives in LR.
    - If only delays infections in SR → just lengthens the recovery and inflicts higher economic costs
  - **The dance:** Optimal deconfinement
    - Keeps the pandemic's transmission rate close 1.

→ Policy must control the epidemic, not the other way around.

THANK YOU!

SIR Dynamics

- Λ_t is the mass of agents
- Susceptible: $S_t = \pi_t(s)\Lambda_t$, Infected: $I_t = \pi_t(i)\Lambda_t$, Recovered: $R_t = \pi_t(r)\Lambda_t$

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$$S_{t+1} = S_t - R_t S_t$$
$$I_{t+1} = R_t S_t + (1 - \gamma - \delta) I_t$$
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where $R_t = R(x_t, X_t)\pi_t(i)$.

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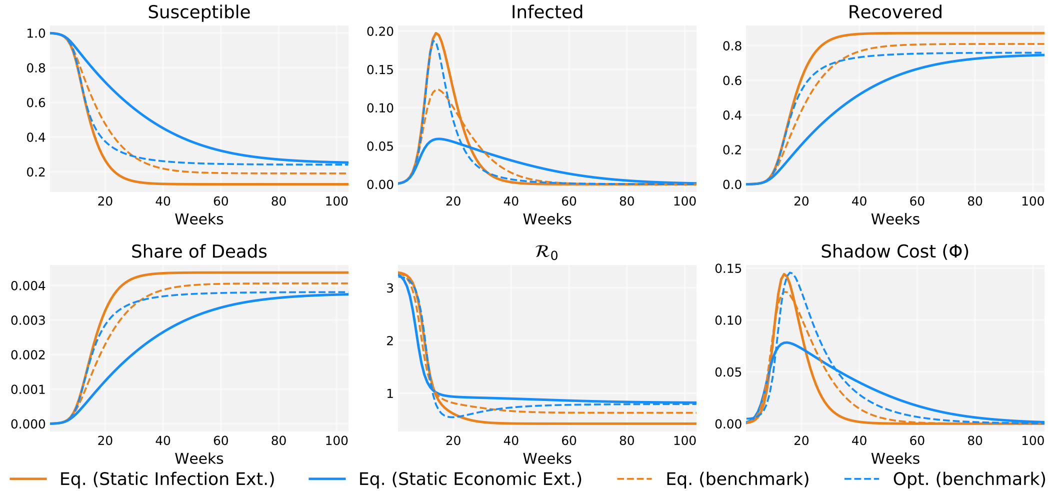
  where $R_t = R(x_t, X_t)\pi_t(i)$.
- Dynamics of population: $\Lambda_{t+1} = (1-\delta\pi_t(i))\Lambda_t$. Dividing the previous system by Λ_t

$$\pi^k_{t+1}(s) = \frac{\pi^k_t(s) - r_t\pi^k_t(s)\pi_t(i)}{1-\delta\pi^k_t(i)}$$
$$\pi^k_{t+1}(i) = \frac{\pi^k_t(i) + r_t\pi^k_t(s)\pi_t(i) - \gamma\pi^k_t(i) - \delta\pi^k_t(i)}{1-\delta\pi^k_t(i)}$$
$$\pi^k_{t+1}(r) = \frac{\pi^k_t(r) + \gamma\pi^k_t(i)}{1-\delta\pi^k_t(i)}$$

Back

Extensions: Static Externalities)



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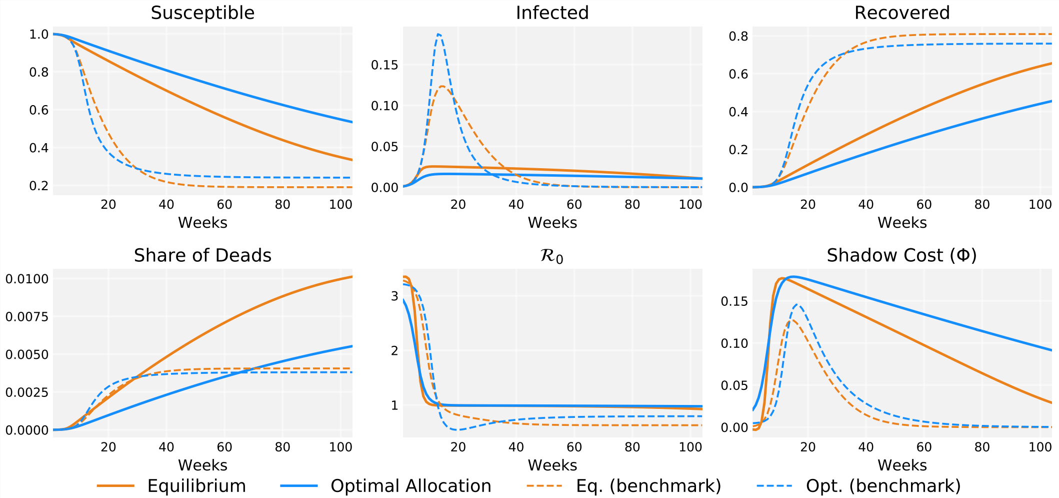
Extensions: Congestion Externalities

- Congestion of the medical sector: death probability is an increasing and convex function of share of infected
- **Equilibrium:**
  - Stronger hammer to avoid infection and face a higher risk of death
  - But do not understand the congestion → not strong enough, larger death toll
- **Planner:**
  - Much higher shadow cost of infection due to infection externality

  → Stronger Hammer to delay infection and save lives by avoiding congestion

Back

Extensions: Congestion Externalities



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Extensions: Hopes for Vaccines and Cures

- Probability that all susceptible are moved to recovery state in each period
- Comes too late for those who are infected
- **Equilibrium:**
  - The private benefits of a vaccine are remote

  → No significant change in behavior.
- **Planner:**
  - Very high initial shadow cost of infection

  → Strong Hammer to delay infection and save lives while waiting for vaccine
- Depends very much on expected time to a vaccine/cure.

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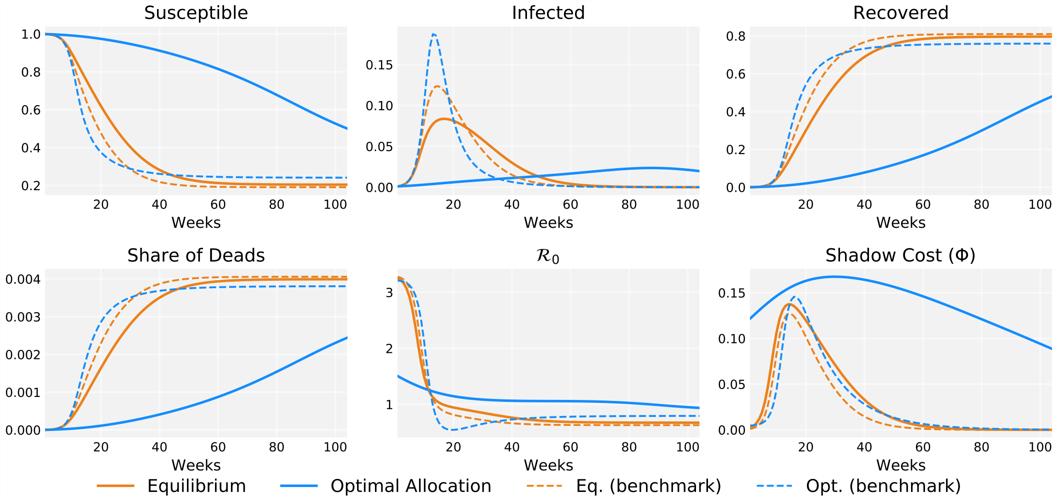
Extensions: Hopes for Vaccines and Cures (1 Year)



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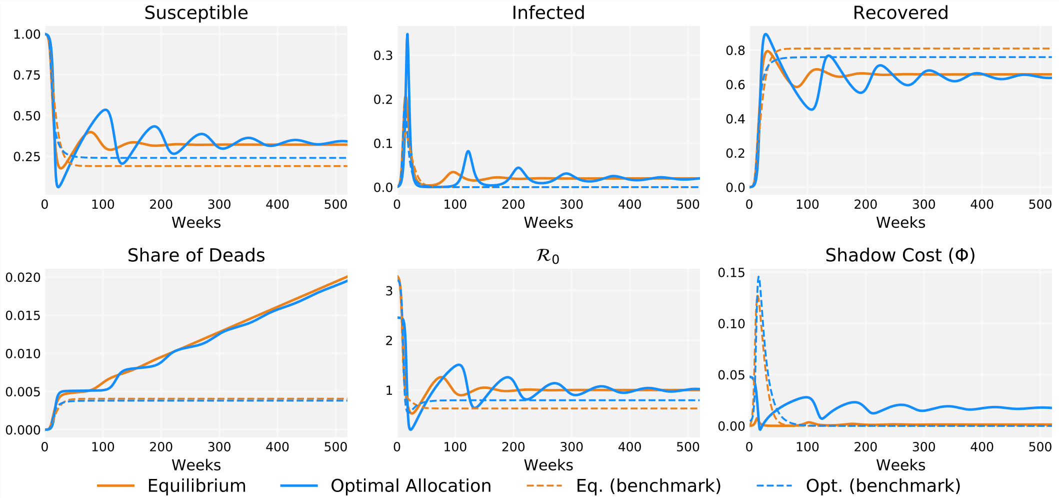
Extensions: Transitory Immunity (1 Year)



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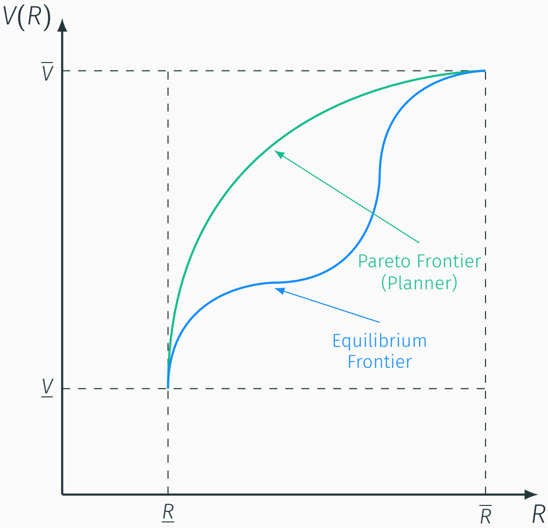
Extensions: Face Masks

- Wearing face mask does not affect utility but lowers infection risk.
- Costly to produce masks



Back

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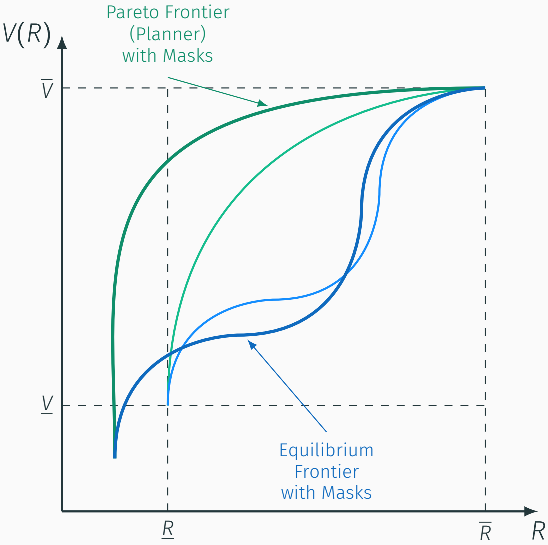

▶ Back

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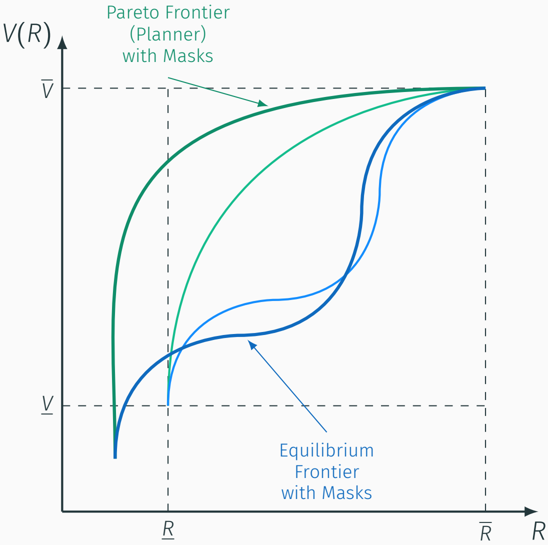
→ Gives the option to push infection risk below $\underline{R}$ → Faster control of epidemics



▸ Back

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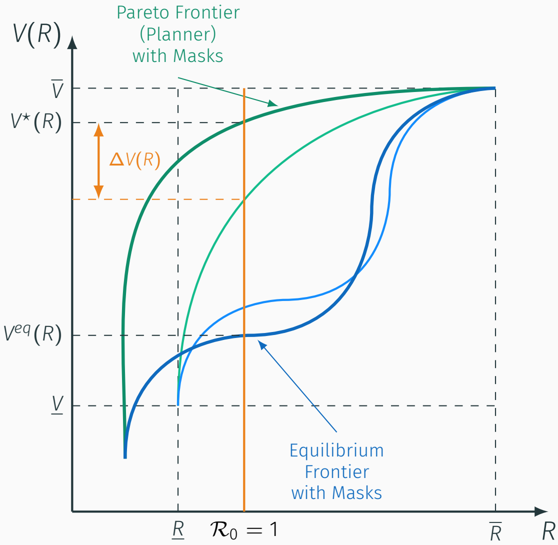
→ Relaxes the Pareto frontier to achieve higher utility during the dance phase.

- Lowers consumption losses.



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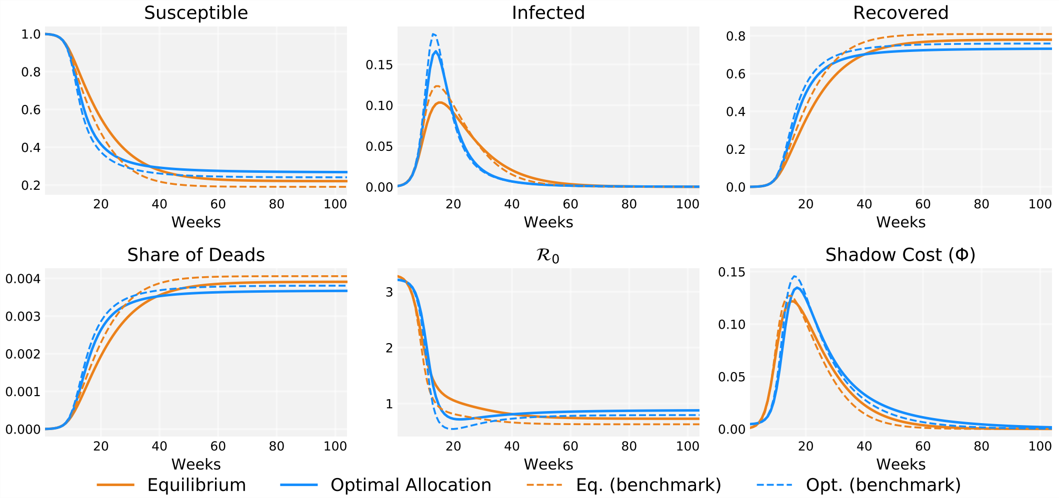

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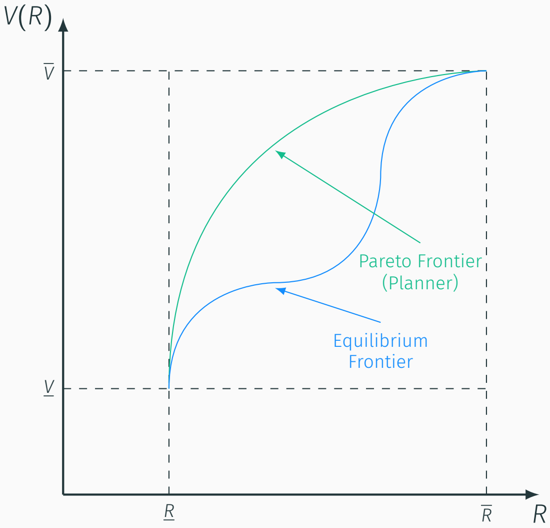
Extensions: Testing and Contact-Tracing

- test ➞ quarantine (temp. exit from game)
- Reduce undetected infections to $\pi(i)(1 - \mathbb{P}(\text{test}|i)$



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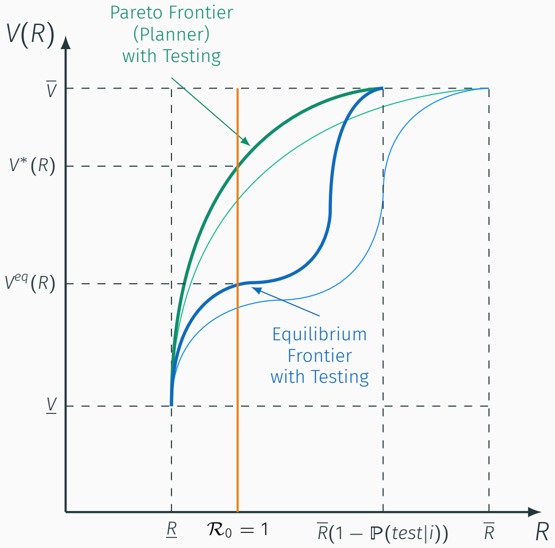
Extensions: Testing and Contact-Tracing

- test → quarantine (temp. exit from game)
- Reduce undetected infections to $\pi(i)(1 - \mathbb{P}(\text{test}|i)$

→ Improves static efficiency frontier (better control of infections)

→ But ≠ face masks as it lowers threshold level of recoveries for
  - herd immunity,
  - virus eradication,
  - elimination of economic restrictions.

- Shift $\overline{V}$ to the left.



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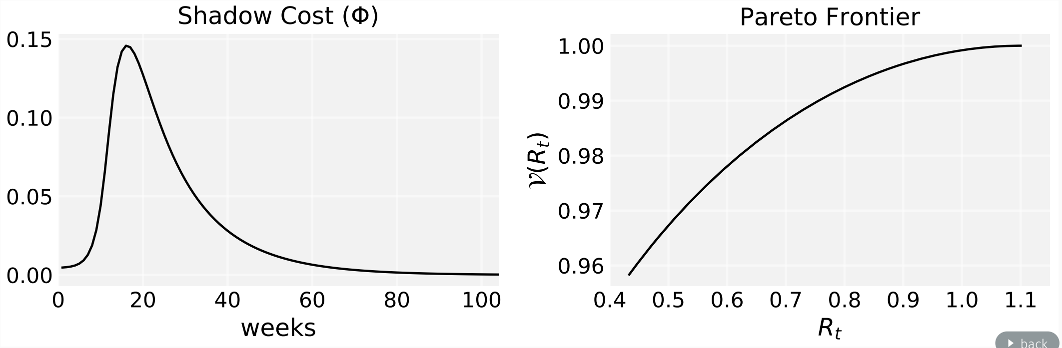
Dynamics along the Pareto Frontier



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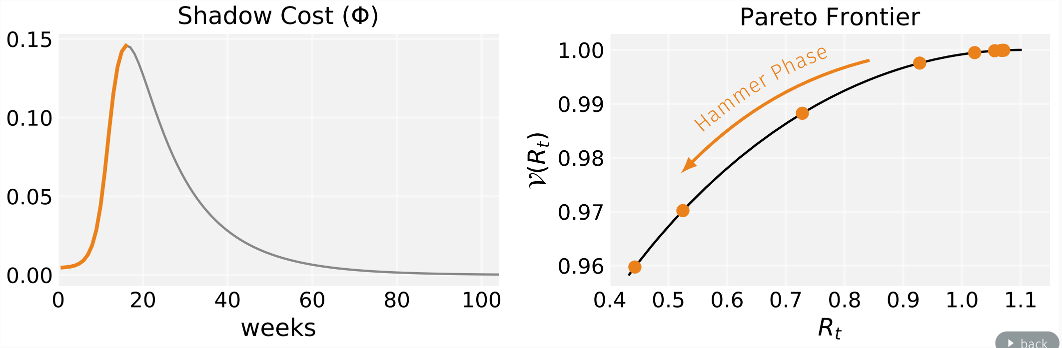

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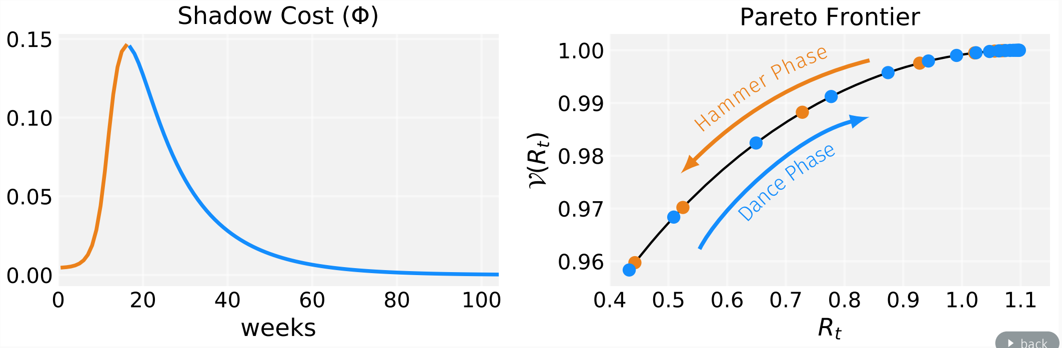

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Utility

- Individual utility function

$$\left(\frac{\mathcal{U}^{eq}(r,R)-\underline{V}}{\bar{V}-\underline{V}}\right)^2+\alpha\left(\frac{r-\bar{R}}{\bar{R}-\underline{R}}\right)^2+(1-\alpha)\left(\frac{R-\bar{R}}{\bar{R}-\underline{R}}\right)^2=1.$$

→ Leads to

$$\left(\frac{\mathcal{V}(R)-\underline{V}}{\bar{V}-\underline{V}}\right)^2+\left(\frac{R-\bar{R}}{\bar{R}-\underline{R}}\right)^2=1.$$

back