Governing the Resource
Scarcity-Induced Institutional Change

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Motivation

- Variety of institutions for natural resource management
  - Open access;
  - Common property;
  - Private property, state property, …

  … across resources and over time
- Given the costs of institutional change and resource governance, how do resource institutions change over time?

Changes in resource institution: examples

- Enclosure of open/common fields in England (McCloskey 1976, Allen 1982, …)
- Groundwater use in Southern California: from open access to restricted access (Ostrom 1965)
- Use of forest land (*Iriaichi*) in rural villages in Japan: from commons to private (McKean 1986)
- Lobster fisheries in Maine (Acheson 1988): from open access in colonial periods to group ("gangs") management / from food for servants to gourmet food

Analyzing institutional change

- Classical conjecture: Institution changes when benefits exceed costs (Demsetz)
  - "Montagne Indians asserted private property over beaver as scarcity and price increased"
- Formalization
  - Optimal timing of property-right enforcement (Anderson and Hill 1990, Lueck 1992)
    - One-time, fixed cost of adopting institution
    - no endogenous resource depletion
  - Optimal steady-state institution: open access, common property, vs private property (Copeland and Taylor 2009)
    - Variable cost of enforcement
    - Dynamic framework with resource dynamics

Our approach

- Apply a dynamic model of renewable resource management with
  - Fixed and variable costs of governance (restricting harvest below open access level);
  - Endogenous timing of switching from open access to governance.

- Q. Is it optimal to switch from open access to property-right regimes given the costs of adopting and maintaining them?
- Q. If so, what is the optimal timing of switching institutions?

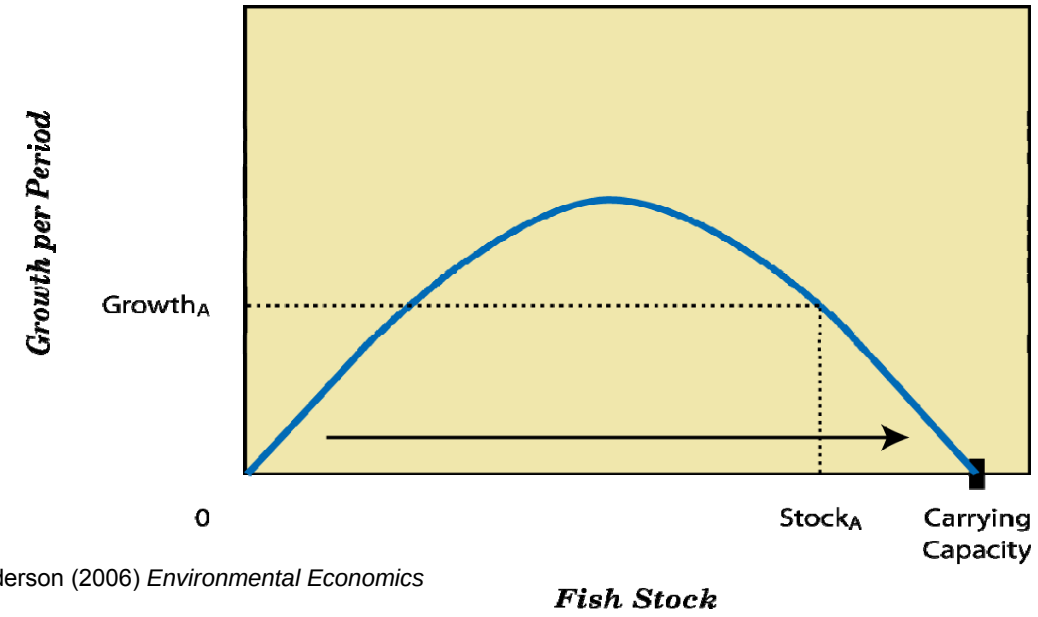
Assumption 1: Resource dynamics

- **Logistic growth function:** $F(S_t) = \frac{dS_t}{dt} = rS_t\left(1 - \frac{S_t}{K}\right)$

  where *r*: intrinsic rate of resource growth,

  S: resource stock level,

  K: carrying capacity



From Anderson (2006) *Environmental Economics*

Assumption 2: Net benefits of resource extraction

Net benefits at time t = $px_t - c(S_t)x_t$

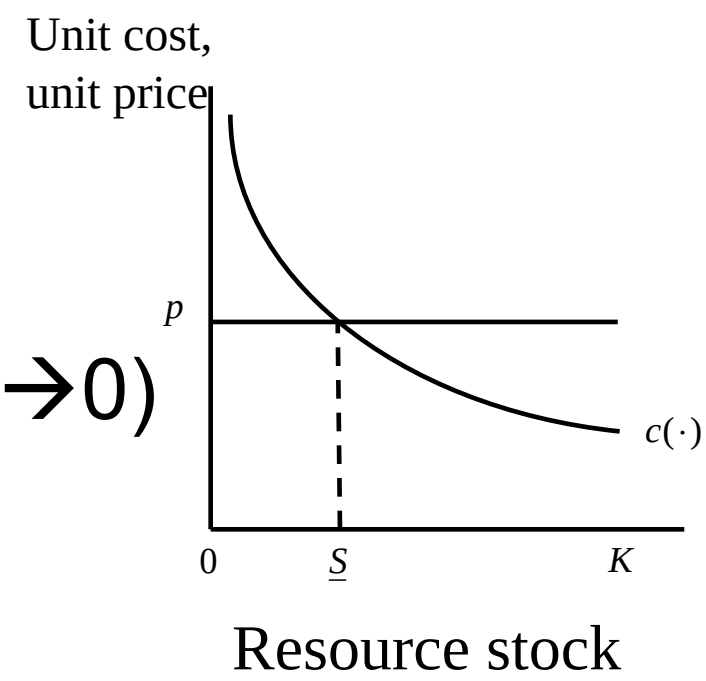
(rents from harvesting)

x_t: harvest in time t,

p: price of harvest,

c: unit harvesting cost

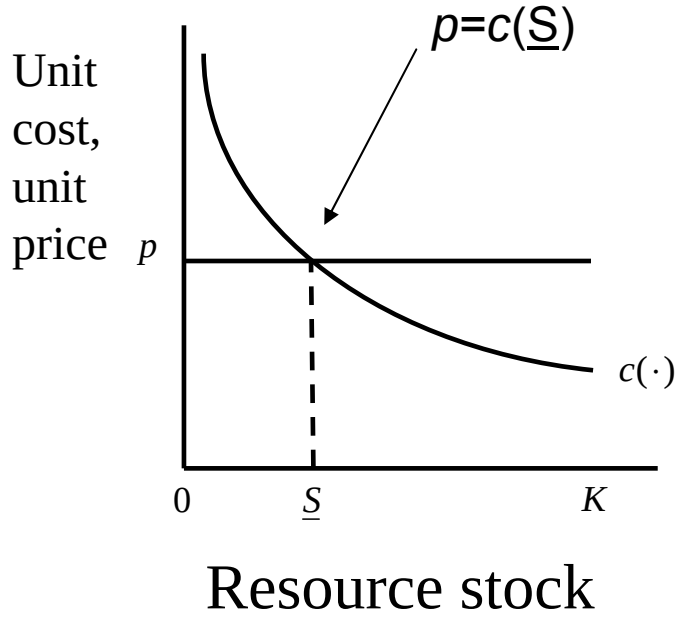
(c'<0,c''>0, c(S)→∞ as S→0)



Harvest under open access

- Maximum harvest rate: $\overline{x}$ (> MSY)
- Given stock level S, harvest under open access is

$$x_{oa}(S) = \begin{cases} 0 & if\ S < \underline{S}; \\ F(S) & if\ S = \underline{S}; \\ \overline{x} & if\ S > \underline{S}. \end{cases}$$



Costs of Constitutional Governance

- **Fixed (C≥0) at time *T* when adopting governance**
  - **Constitutional design (harvesting rules, procedures for decisions, monitoring, sanctions)**
  - **Infrastructure (fence, weapons, cameras)**
- **Variable:** $g(x_{oa} - x_t)$ **beginning at *T* where *g* ≥ 0**
  - **Monitoring**
  - **Operation and maintenance**
  - **Conflict resolution**

Second best problem

(with endogenous timing of institutional change)

$$\max_{x,T} \underbrace{\int_0^T e^{-\rho t}[p - c(S_t)]x_{oa}dt}_{\text{PV under open access/ pre-governance}} - \underbrace{e^{-\rho T}C}_{\text{PV of investment to start governance}} + \underbrace{\int_T^\infty e^{-\rho t}\left[\{p - c(S_t)\}\, x_t - g(x_{oa} - x_t)\right] dt}_{\text{PV of rents under governance}}$$

$$\text{s.t.} \quad S_t = \begin{cases} F(S_t) - x_{oa} & \text{for } 0 \leq t \leq T; \\ F(S_t) - x_t & \text{for } t > T, \end{cases}$$

$$0 \leq x_t \leq x_{oa,t} \quad \text{for all } t, \qquad \text{given } S_0.$$

(Linear control problem with regime switching)

Properties of the solution

- If *C* and/or *g* are large enough, never switch to governance
- Upon switching from open access to governance, the Most Rapid Approach Path to the steady state is optimal
- Steady state S* given by the singular solution

$$-c'(S^*)F(S^*)-[\rho-F'(S^*)][p+g-c(S^*)]=0.$$

With zero investment cost (C=0): To govern or not?

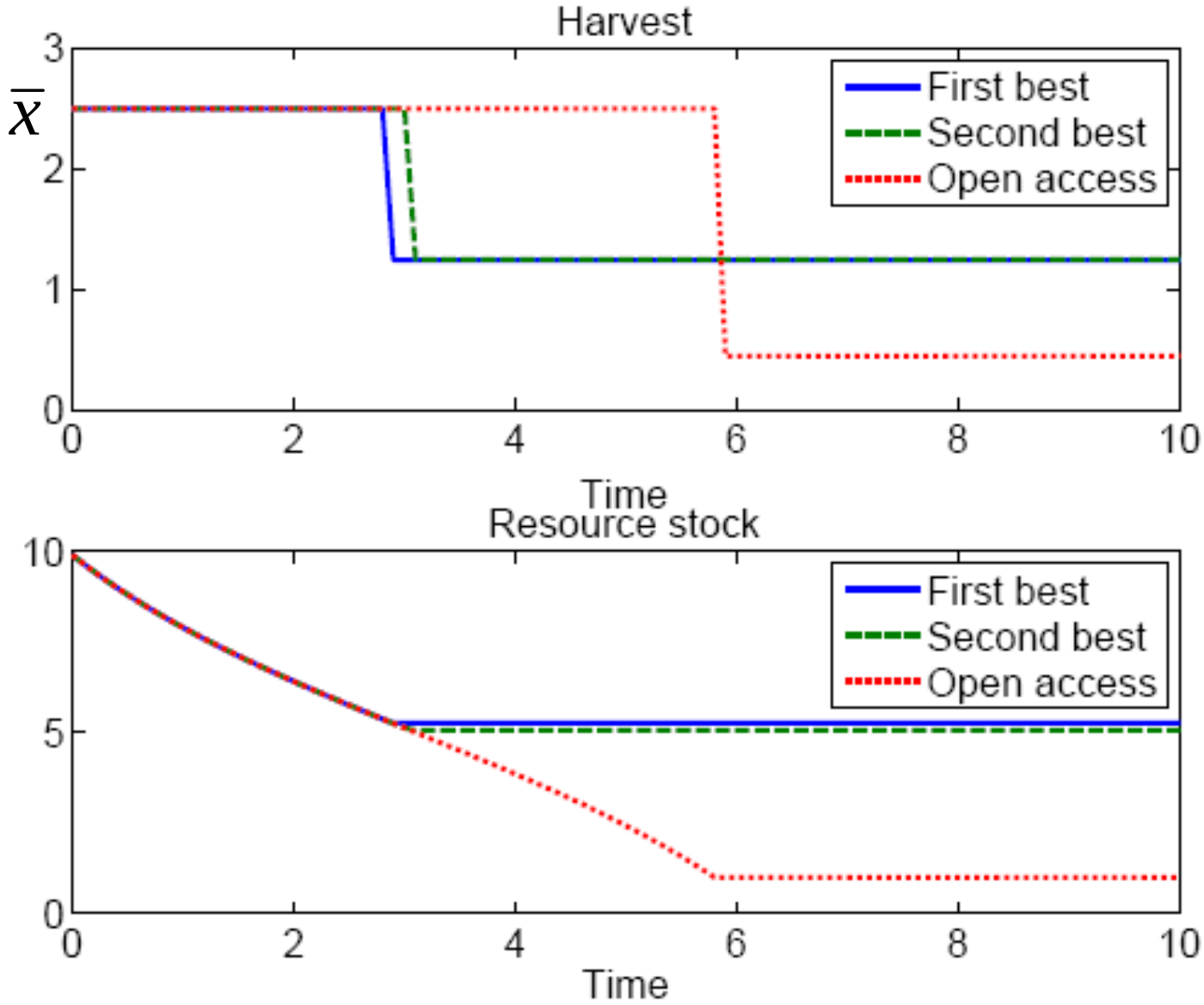
Given $S_0 > S^*$, two options:

1. No governance ($T^* = \infty$)—allow open access at all *t:* $x_{oa} = \overline{\chi}$ until stock reaches $\underline{S}$; $x_{oa} = F(\underline{S})$ thereafter
2. Governance ($T^* < \infty$)—MRAP to S^*.

   Allow open access until stock reaches S^*, then choose $x^* = F(S^*)$;

- Choose the one with higher PV
- The realized stock path is monotonic in either case ($dS/dt < 0$ for all *t* until steady state).

Bang-Bang Path to Steady State
when C=0, S_0=K



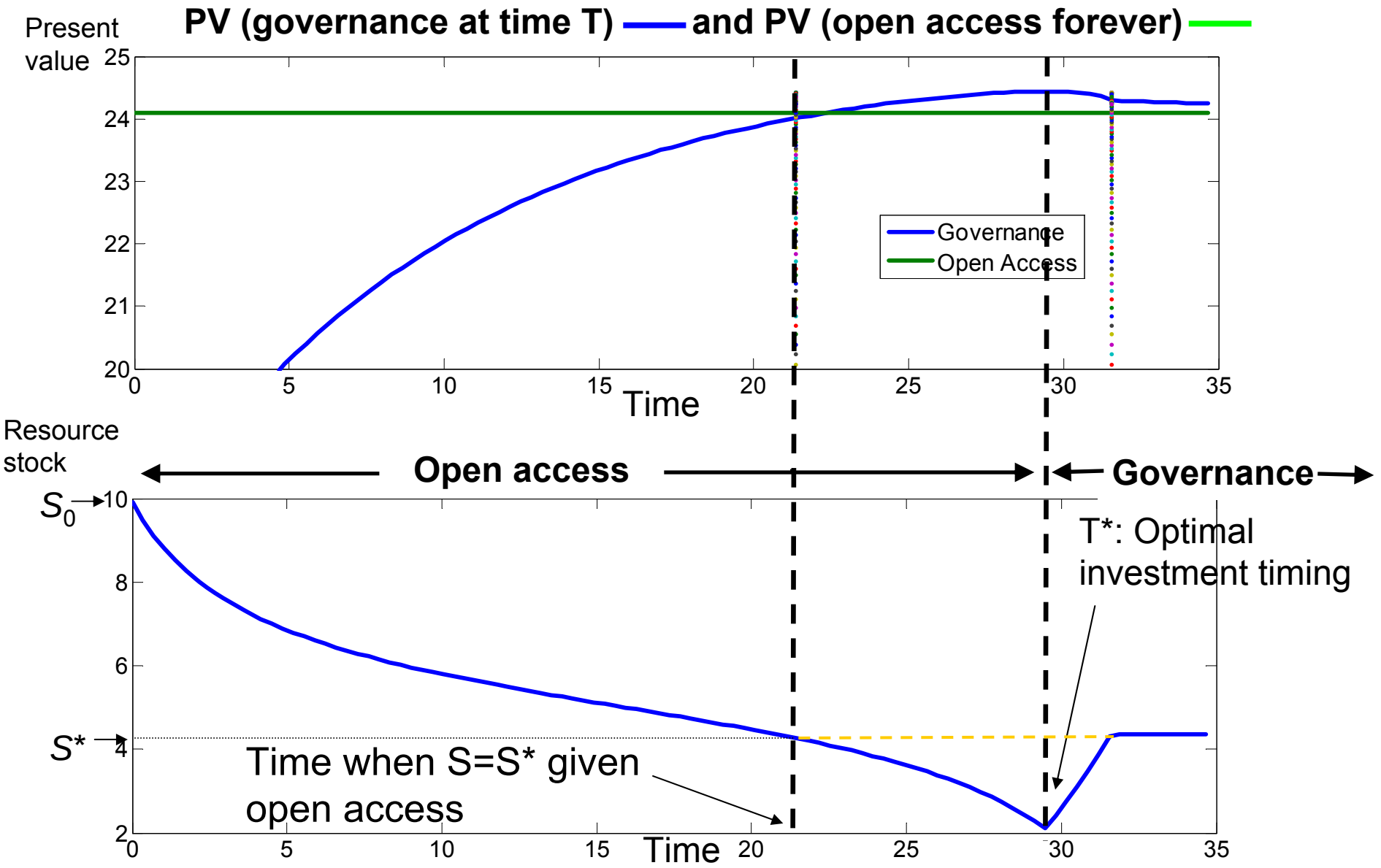
Overshooting given $C>0$

Proposition

Suppose $S_0>S^*$. Governance is the second best with C small enough. With such C>0, governance allows open access until the stock falls below S, and then restrict harvest so that the stock builds up to the steady state.*

→ The realized stock path is non-monotonic: $dS/dt<0$ first, then $dS/dt>0$ until steady state

Optimal overshooting given $C>0$



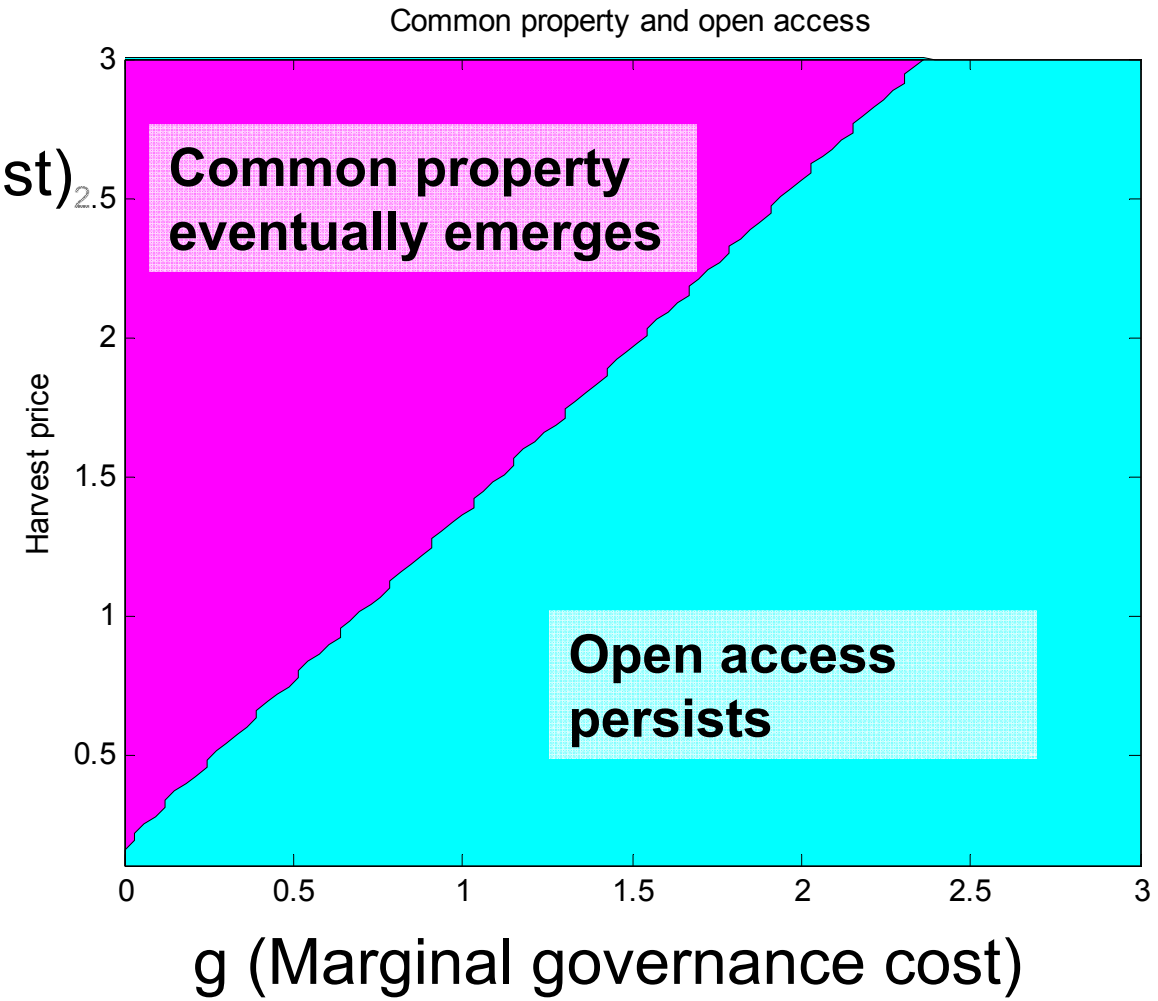
Common and Private Property

- Switching from open access to common/private property
  - Is switching efficient?
  - Optimal timing?
- With gov cost $e^{-\rho T}C + \int_T^{\infty} e^{-\rho t} g(x_{oa,t} - x_t)dt$,

  assume:
  - Common property: C=0, g>0
  - Private property: C>0, g=0

Open access vs Common Property
(Starting at stock above Steady State)

P
(Price of harvest)

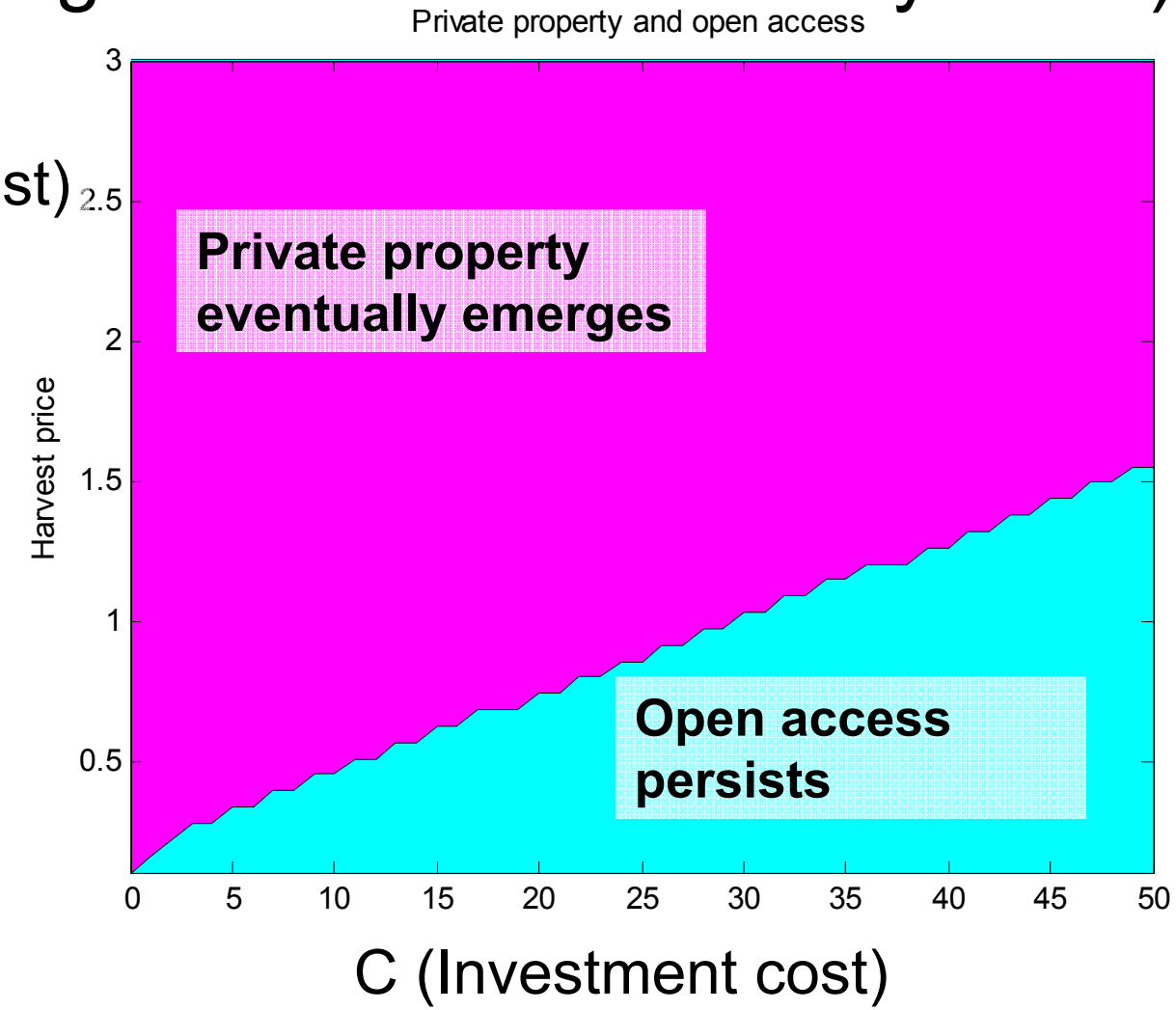


g (Marginal governance cost)

Open access vs Private Property

(Starting at stock above Steady State)

P
(Price of harvest)



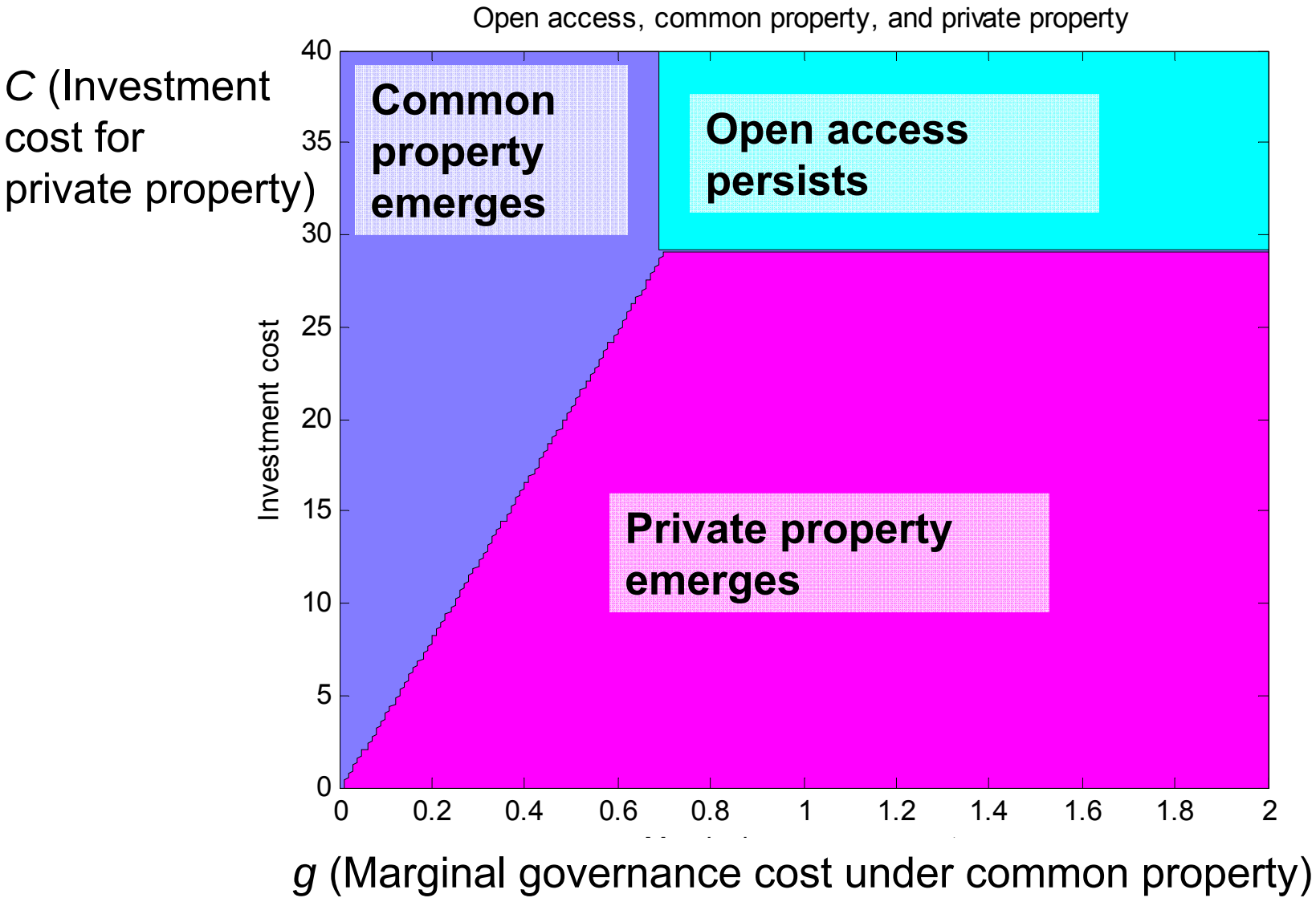
Optimal timing of institutional change

- Optimal switching time is later if harvest price is larger (steady state stock is smaller)
- (Common property) Switching is delayed if marginal governance cost *g* is larger; with *g* large enough, open access is second best
- (Private property) Switching is delayed if investment cost *C* is larger; with *C* sufficiently large, switching never occurs

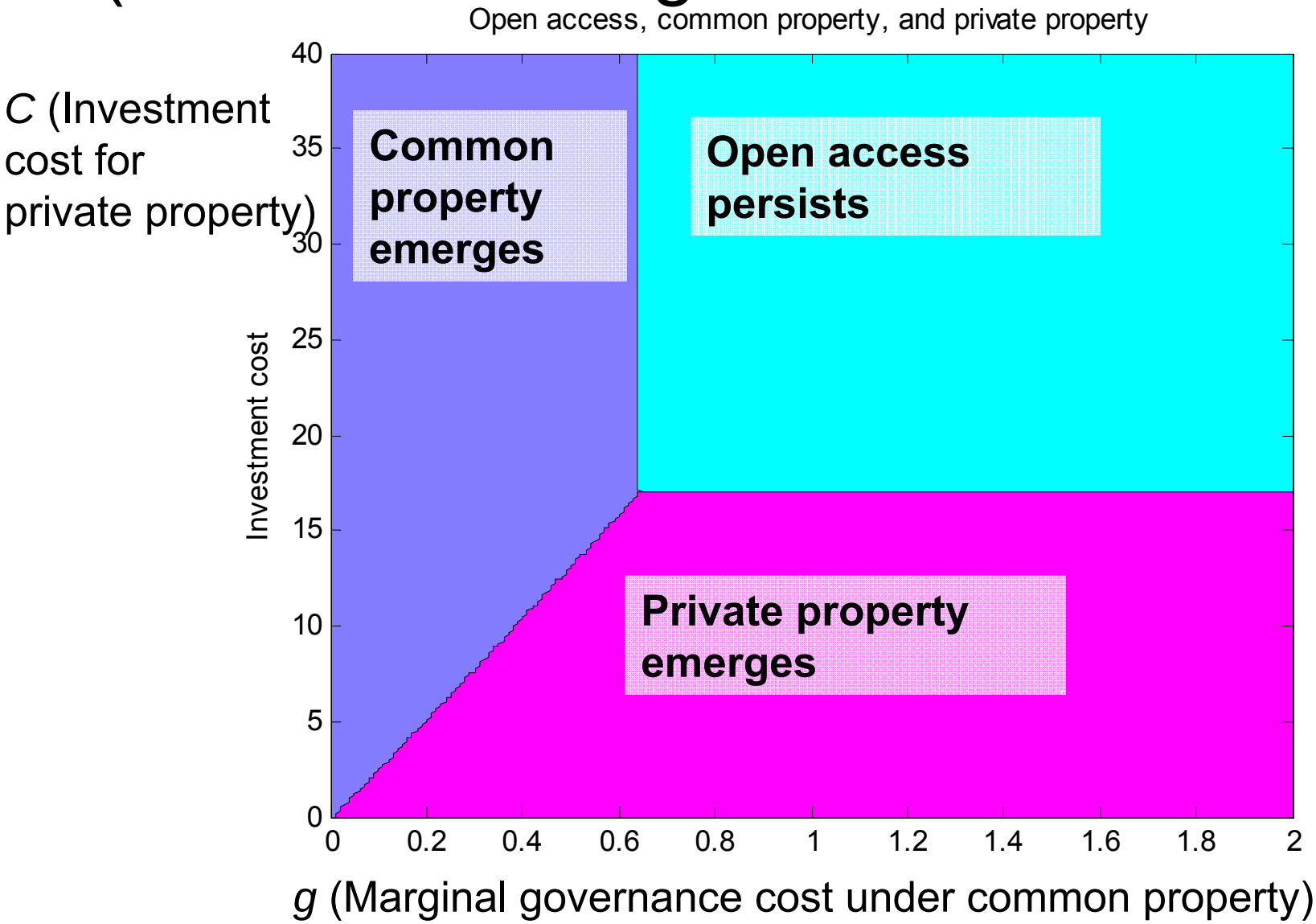
OA, Common Property, and Private Property

- So far, pairwise comparison
- Which of the three regimes is the most preferred?

Second best institutions



Second best institutions (when resource growth rate is lower)



Summary so far

- Open access is the second best when stock is large; switching to governance can be the second best as stock decreases
- Switching to governance with a fixed cost implies non-monotonic resource transition
- With stock-dependent harvest costs, second-best steady-state stock always less than first-best.

Summary (2)

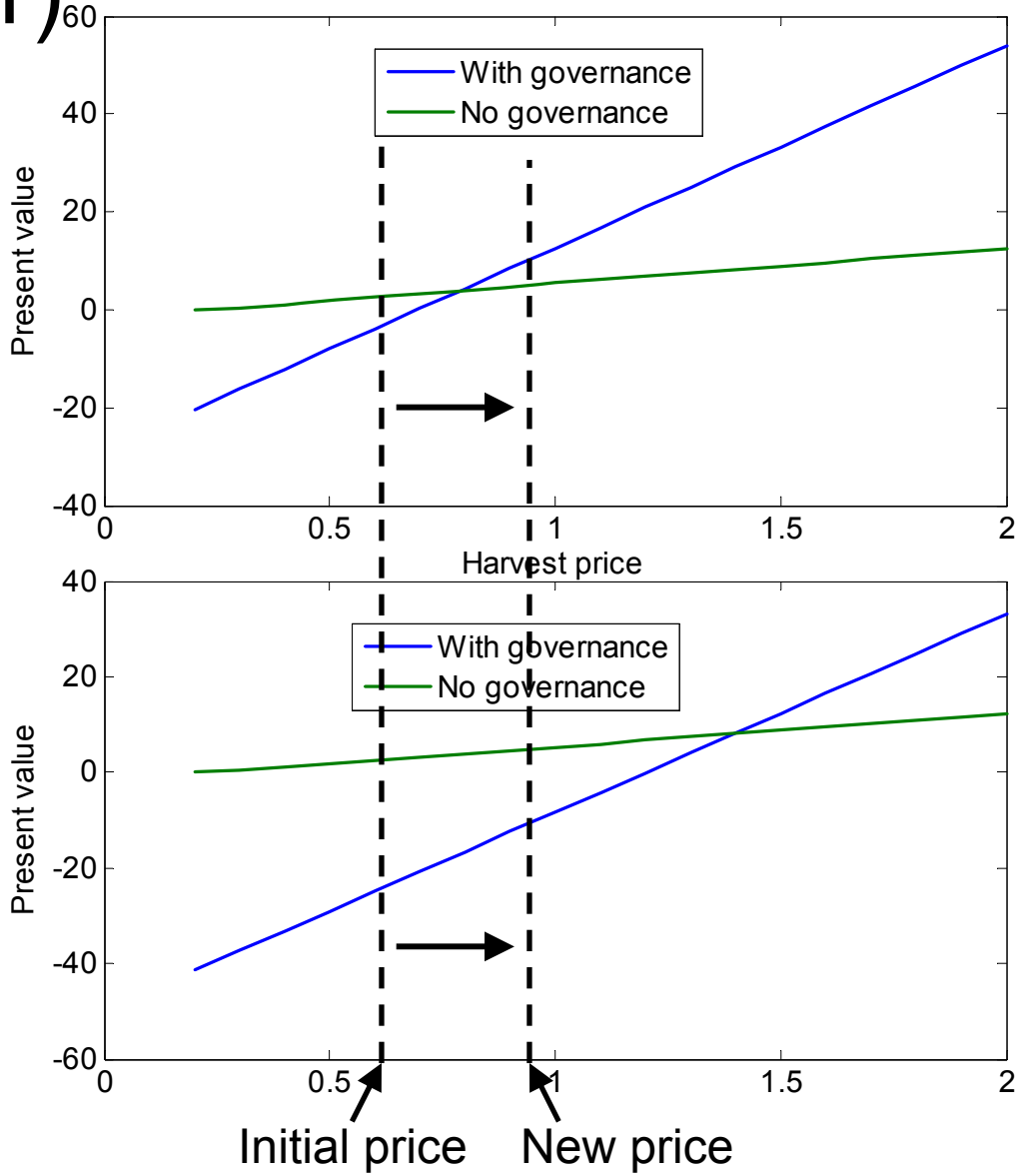
- For high governance costs it takes a higher-price/later-switch-point to switch to any governance.
- Relative costs determine the ranking of private vs common property

Effects of harvest price shock (Demsetz, Taylor)

Beaver (OA→Gov)

(Lower governance cost For beaver)

Bison (OA→OA)



Similar results when price is endogenous (with downward-sloping demand)

- With governance costs, open access can be the second best when the resource is plentiful. As resource scarcity increases, the second best may involve governance and diverge from open access
- With governance costs high enough, open access is the second best at all resource stock levels.

Summary

- A framework to analyze institutional change of a resource over time as well as difference in steady-state institutions for different resources

Plan ahead:

- How does switching from OA to CP and then to PP occur as price changes?
- What if *g* is large? (CP is skipped?) *C* is large? (PP will never be adopted?)

(End of the slides)

Title photo from *The Economist* Aug 19 2004

Extension

- So far, price is fixed
- Results carry over to the case with endogenous price (downward-sloping demand curve):

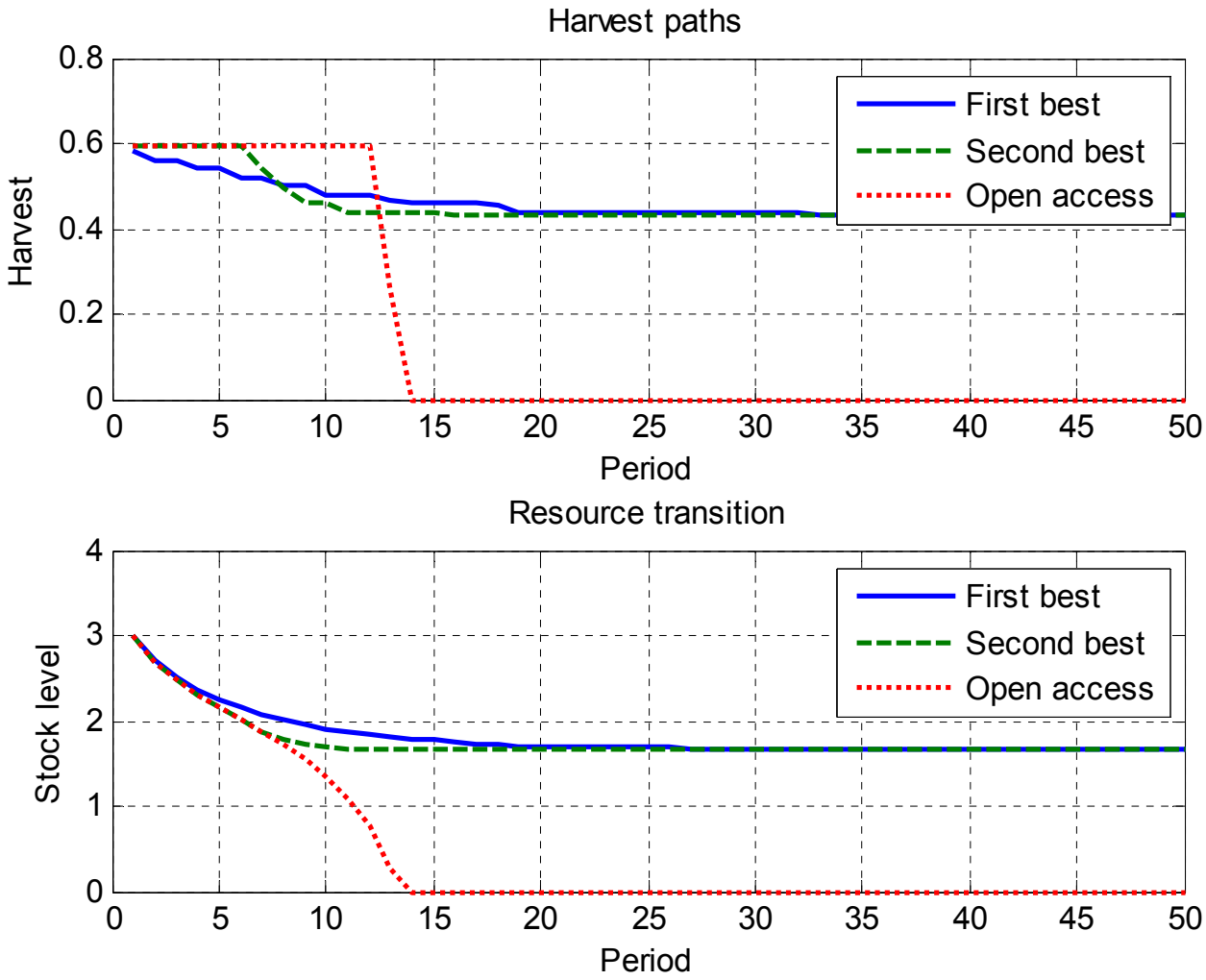
$$\max_x \int_0^\infty e^{-\rho t} \left[\int_0^{x_t} P(\omega) d\omega - c(S_t) x_t - g(x_{oa}(S_t) - x_t) \right] dt$$

$$\text{s.t.} \quad \dot{S}_t = F(S_t) - x_t, \quad 0 \leq x_t \leq x_{oa}(S_t)$$

given $S_0 \approx K$.

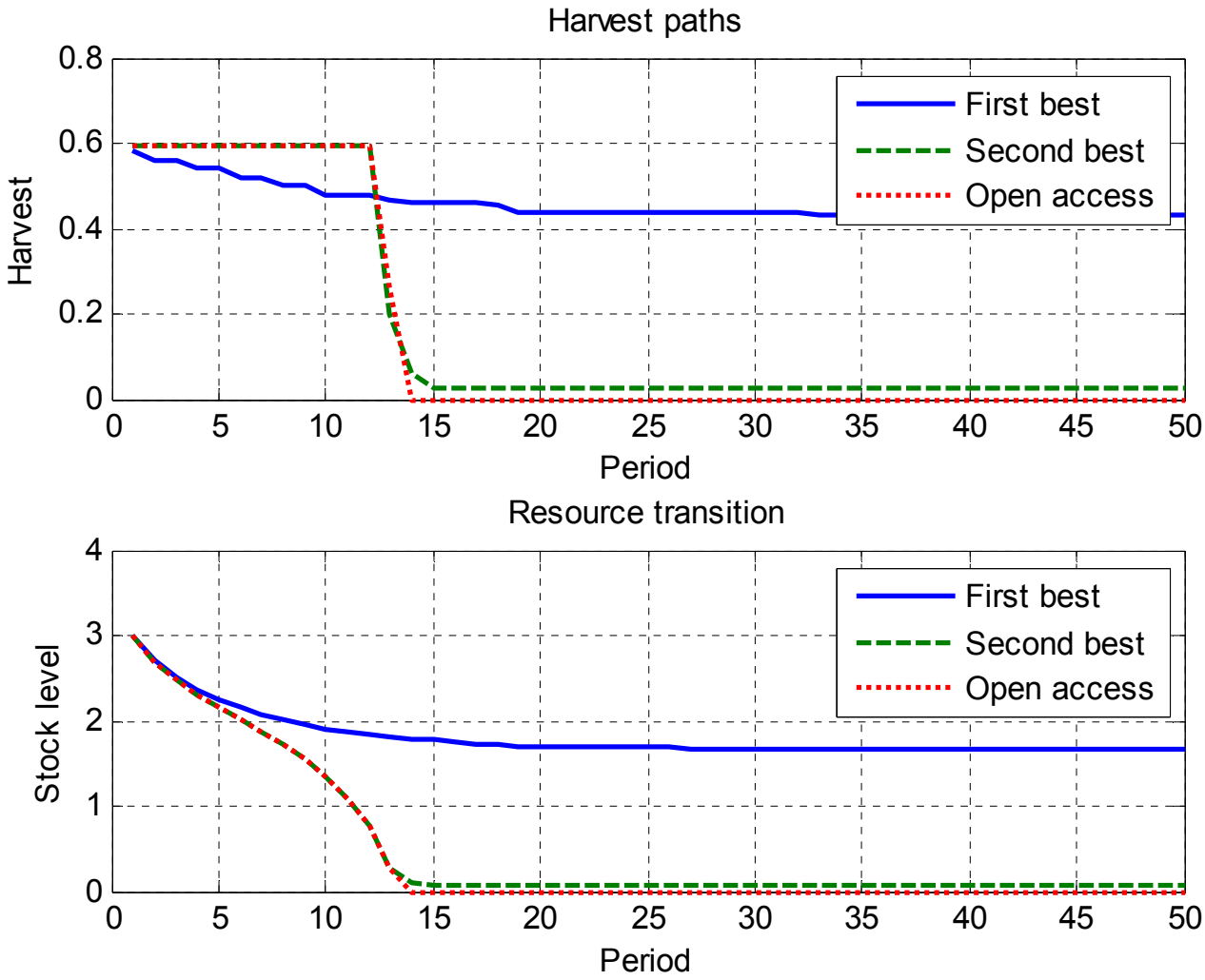
Case 1: Low governance cost

- Open access is second best when S is large
- Rent generated for smaller stock levels, converging to the first best steady state



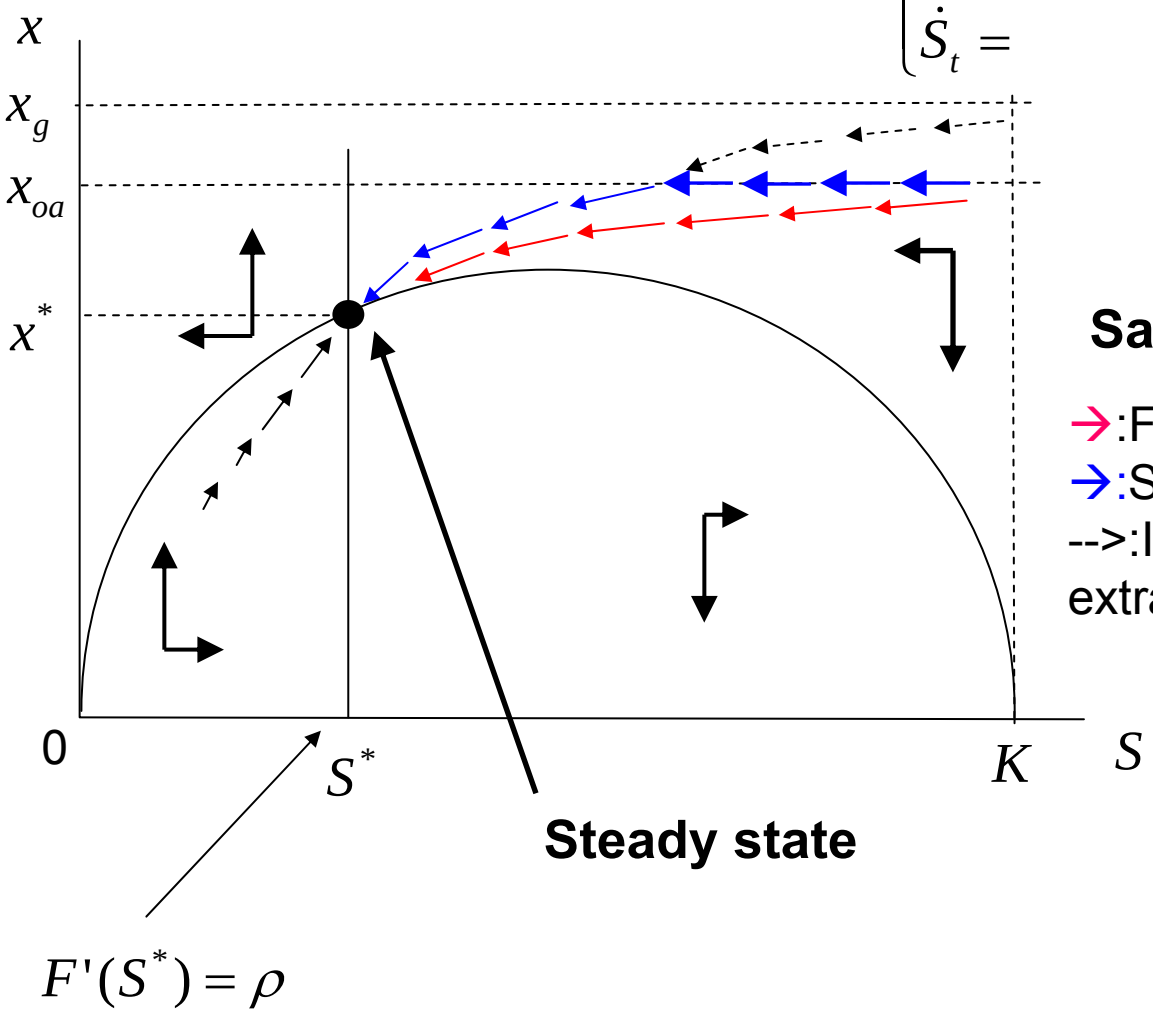
Case 2: High governance cost

- Second best coincides with open access



Open access may be the second best when stock is large

$$\begin{cases} \dot{x}_t = \dfrac{[P(x_t)-(c-g)][\rho - F'(S_t)]}{P'(x_t)}, \\ \dot{S}_t = F(S_t) - x_t. \end{cases}$$

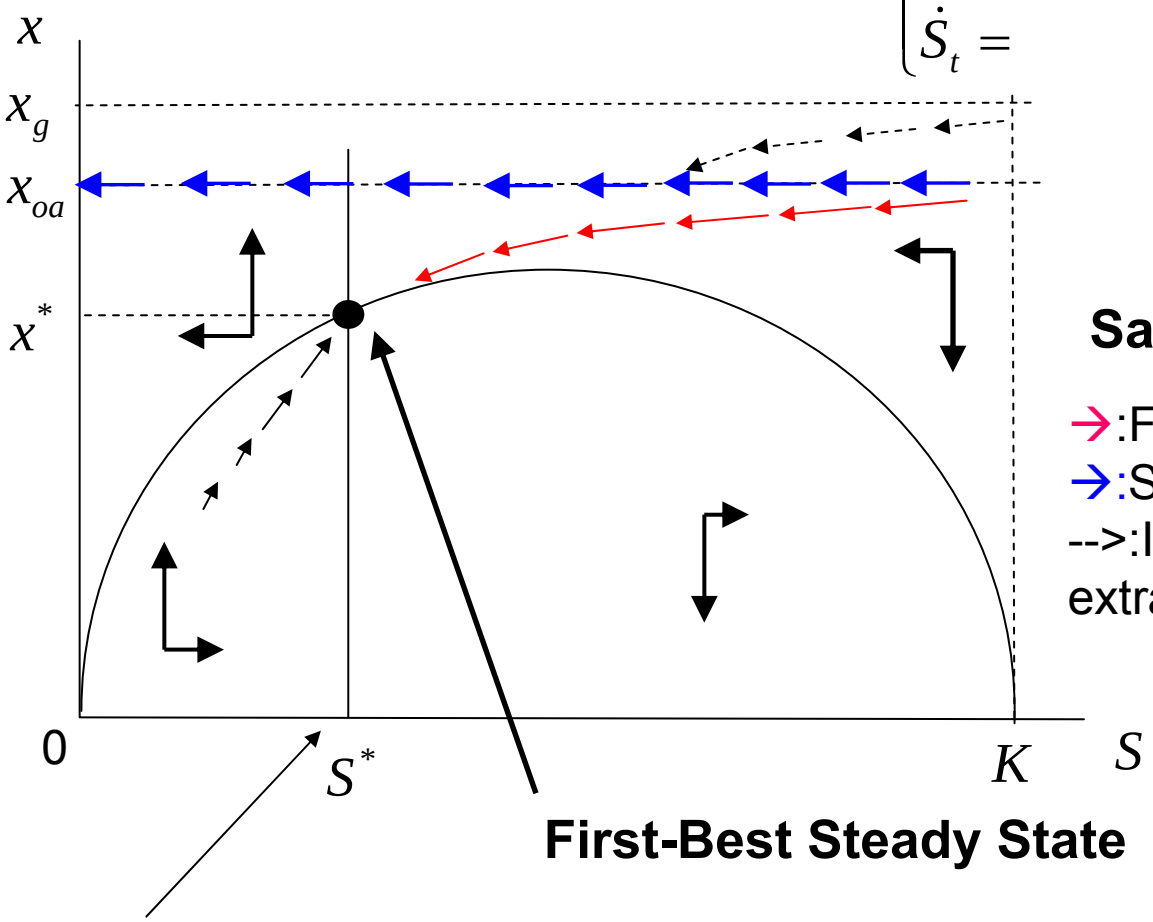


Saddle path:

→:First best (zero gov cost)
→:Second best with gov cost
-->:If c-g were the marginal extraction cost

Open access may be the second best all the way

$$\begin{cases} \dot{x}_t = \dfrac{[P(x_t)-(c-g)][\rho - F'(S_t)]}{P'(x_t)}, \\ \dot{S}_t = F(S_t) - x_t. \end{cases}$$



Saddle path:

→:First best (zero gov cost)
→:Second best with gov cost
-->:If c-g were the marginal extraction cost

First-Best Steady State

$F'(S^*) = \rho$

Second-Best Steady State