Stationary Policies in the Control of Invasive Species

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Introduction

- Economists have 30 years experience studying agricultural pests
- Following Perrings, Williamson, Dalmazzone (2000) - explosion of research into the question of the economics of invasive species
- Questions that have emerged:
  - What are the linkages and the feedback loops between economic activity and the nuisance?
  - What are the consequences of the nuisance?
  - What are its population dynamics?
  - What is its spatial spread?
  - What strategies exist to direct at the problem?
  - What are the enormous uncertainties inherent in each of these?

Economic View

Problem:

- Invasive species may impact human welfare & these impacts may occur over time
- Policies in response tend to be costly
- There are then tradeoffs that must be assessed: Dynamic optimization allows a consideration of these tradeoffs but this may require a high degree of flexibility and responsiveness in management that may be beyond the means of resource managers

Outline:

- Management of an invasive species that is in the midst of a widespread dispersal
- Pertinent for current invasions
- Restate a complex stochastic process into deterministic terms
- Given complexity of problem look at use of stationary policies

Formulation of the Problem

$$p = N_I / N = \text{state variable, proportion of lakes invaded}$$

$$h = \text{control variable, control effort}$$

$$J[h] = \max_h \int_0^\infty e^{-rt} \left(\underbrace{w_U}_{\substack{\text{uninvaded}\\\text{value}}} - \underbrace{D(p)}_{\text{damages}} - \underbrace{C(h)}_{\text{costs of control}} \right) dt$$

$$s.t.$$

$$\underbrace{\frac{dp}{dt}}_{\substack{\text{rate of change}\\\text{of proportion of}\\\text{lakes invaded}}} = \underbrace{Ap(1-p)}_{\substack{\text{internal flow from}\\\text{lake to lake}\\\text{A=within system}\\\text{intensity of transport}}} + \underbrace{b(1-p)}_{\substack{\text{external flow to}\\\text{system}\\\text{b=background}\\\text{propagule pressure}}} - \underbrace{\frac{hp}{p+\alpha}}_{\substack{\text{rate of}\\\text{control}\\\text{from invaded}\\\text{lakes}}}$$

$$A > 0, \quad b > 0, \quad p(0) = p_0$$

Stationary Controls

$$J_A = \int_0^{\infty} e^{-rt} C\left(p(t), h(t)\right) dt \quad \textit{dynamic optimization}$$

$$J_B = \int_0^{\infty} e^{-rt} C\left(p_S, h_S\right) dt \quad \textit{static} \quad \textit{optimization}$$

Method (B):

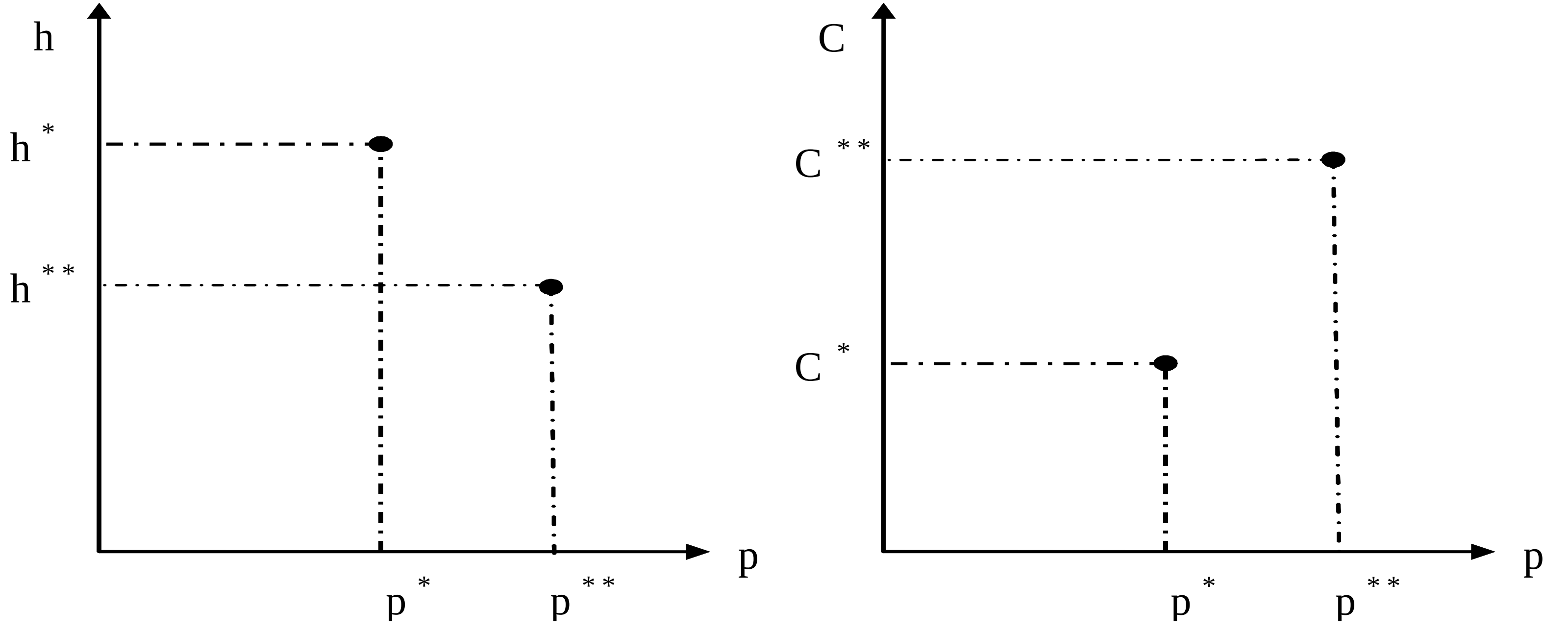
- obtain all possible steady states;
- calculate *C* for each steady state
- choose the one that provides the minimum *C*

➢ But: how far from optimal are these stationary policies?

Steady States – in General

$$J_A: \quad H = -C(p,h) + \mu F(p,h) \;\Rightarrow\; \underbrace{\left(p^{**}, \quad h^{**}\right)}_{\text{dynamic optimal}}$$

$$J_B: \quad \min_h \; C(p(h),h) \;\Rightarrow\; \underbrace{\left(p^{*}, \quad h^{*}\right)}_{\text{static optimal}}$$



$$C\left(p^*, \quad h^*\right) < C\left(p^{**}, \quad h^{**}\right) \text{if } r > 0; \quad C\left(p^*, \quad h^*\right) = C\left(p^{**}, \quad h^{**}\right) \text{if } r = 0$$

Linear Baseline

$$C(p,h)=\frac{1}{2}\left(\underbrace{gp^2}_{\text{damages}}+\underbrace{ch^2}_{\substack{\text{cost of}\\ \text{control}}}\right),\quad \frac{dp}{dt}=A(1-p)-h,\qquad p(0)=p_0,\quad h\geq 0.$$

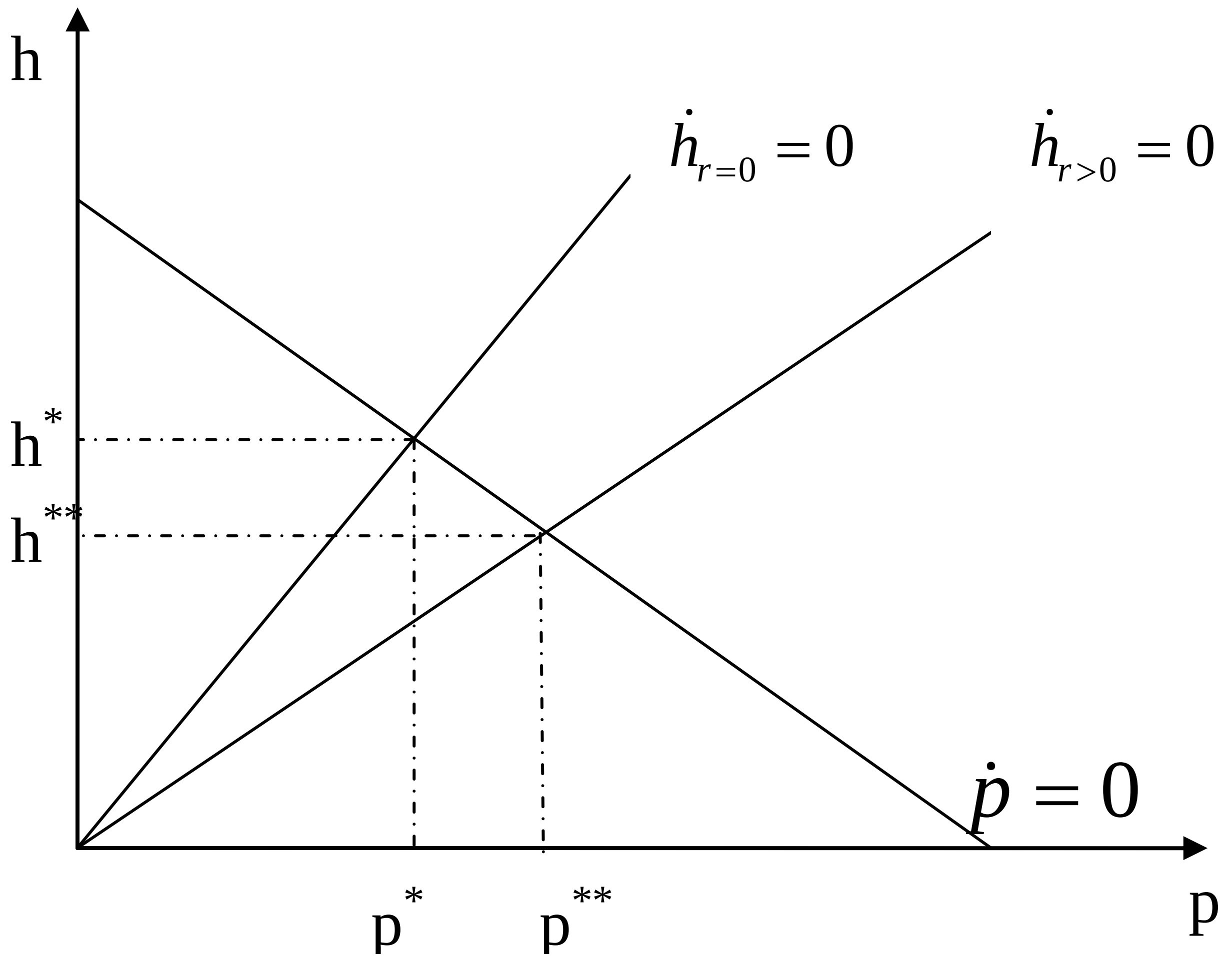
Dynamic Optimization

$$\rightarrow p^{**}=\frac{(A+r)A}{\left(\underbrace{\frac{g}{c}}_{-}+\left(\underbrace{A}_{+}+\underbrace{r}_{+}\right)A\right)},\qquad p(t)=p^{**}+\left(p_0-p^{**}\right)e^{-\lambda t}$$

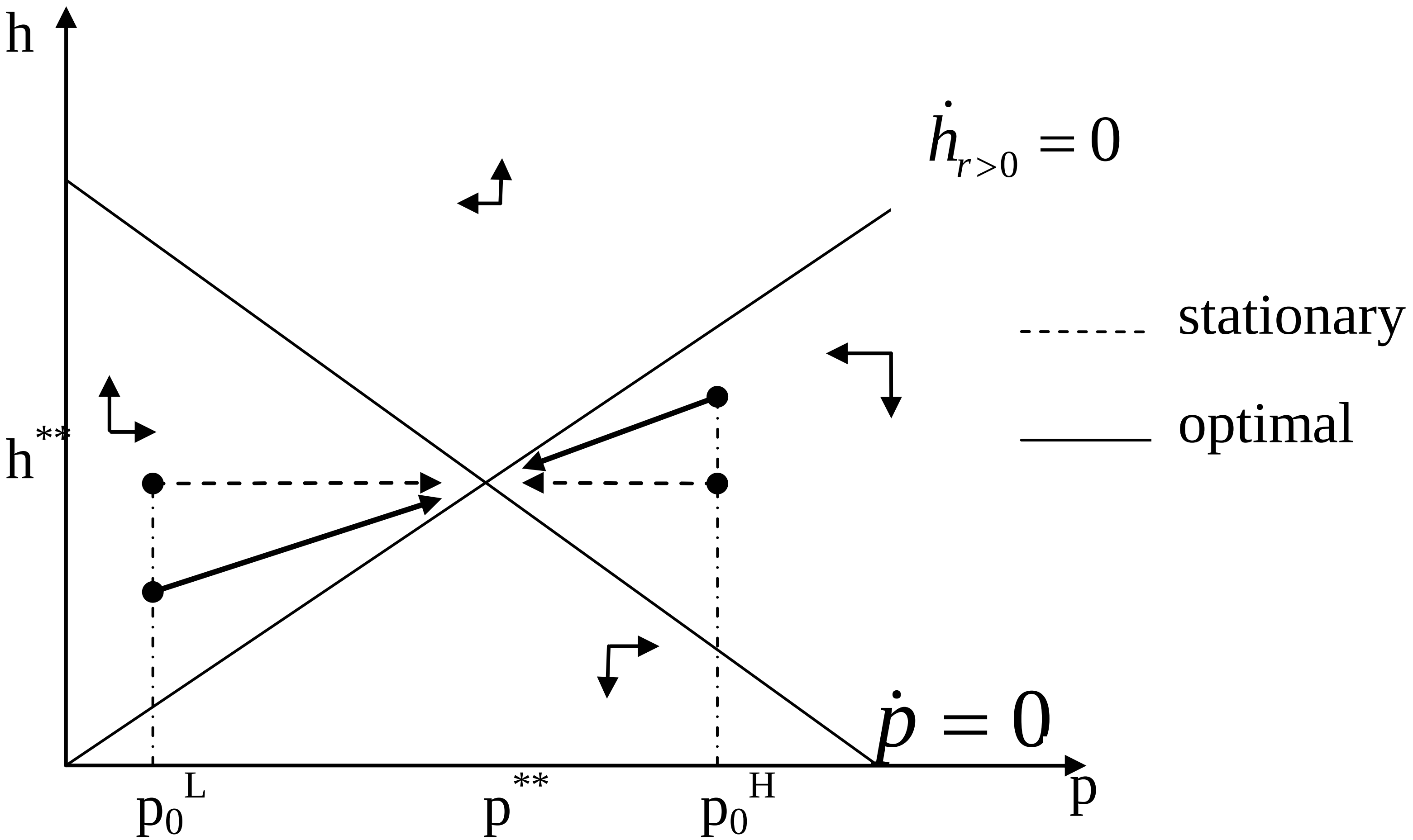
$$\rightarrow h^{**}=\frac{\frac{g}{c}A}{\left(\underbrace{\frac{g}{c}}_{+}+\left(\underbrace{A}_{?}+\underbrace{r}_{-}\right)A\right)},\qquad h(t)=h^{**}+(\lambda-A)\left(p_0-p^{**}\right)e^{-\lambda t}$$

$$\lambda=\sqrt{\left(\frac{r}{2}\right)^2+\left((A+r)A+\frac{g}{c}\right)}-\frac{r}{2}$$

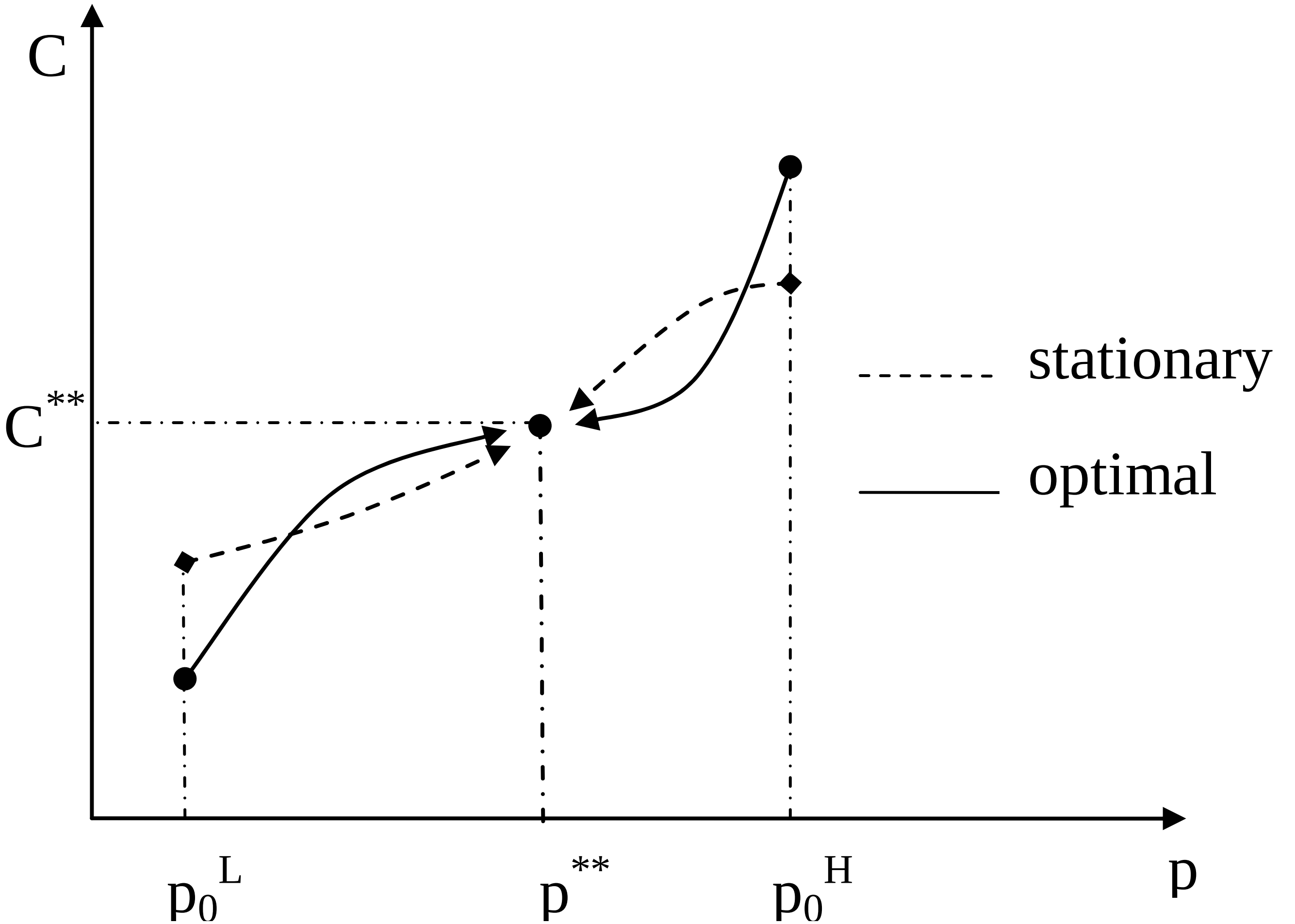
Baseline Steady States



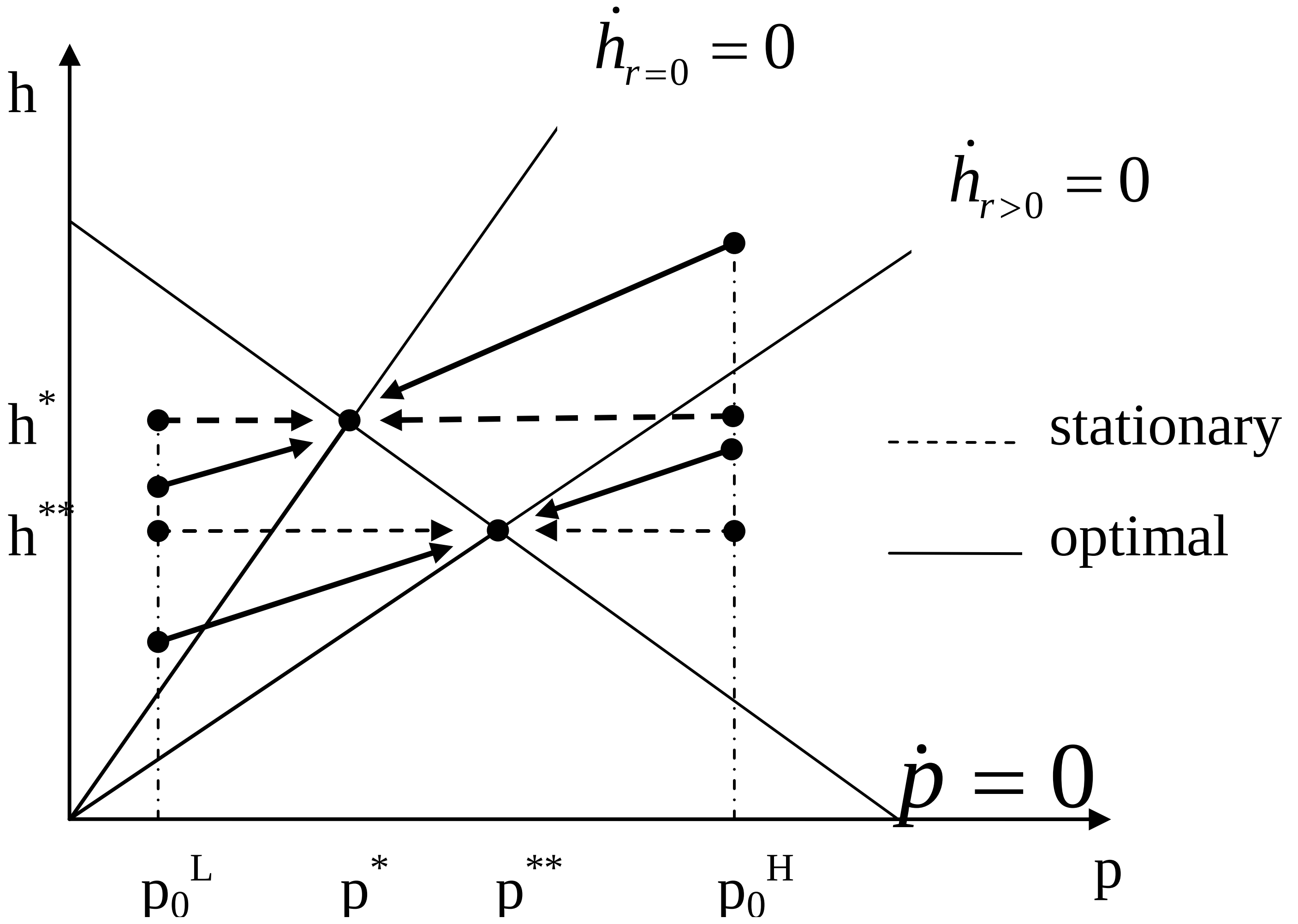
Transition Paths



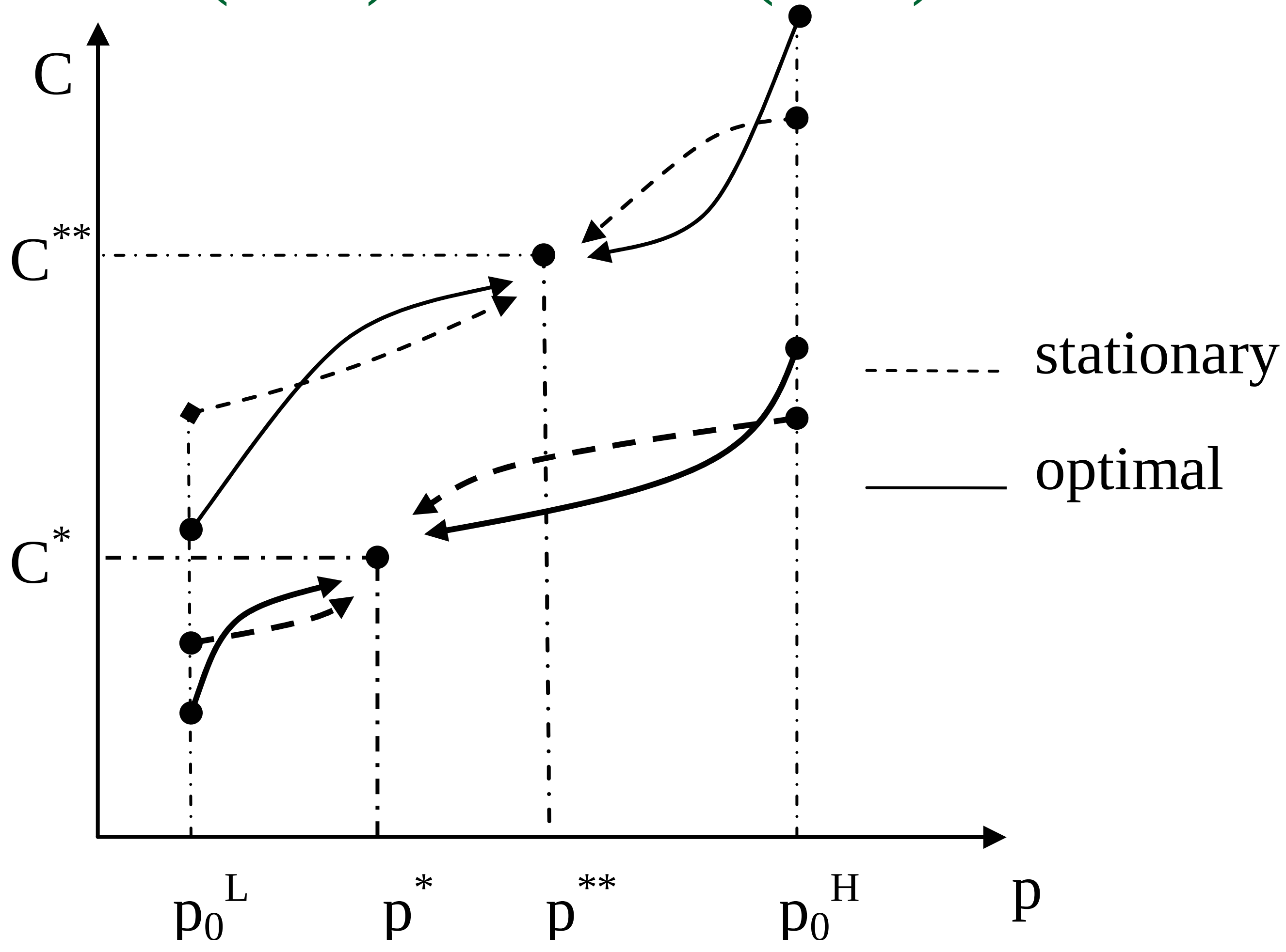
Transition Costs (Instantaneous)



Paths: Model A (r>0) versus B (r=0)



Costs (Instantaneous):
Model A (r>0) versus B (r=0)



Cumulative Costs

J_A v's J_B

- Depends on time of transition versus time at steady state

- If time of **transition** dominates – stationary costs will be relatively higher & stationary policies perform poorly

- If time at **steady state** dominates – stationary costs not much higher & stationary policies not bad

- Costs of (r=0) always lower than (r>0)

    - increased A leads to faster approach to (higher/worse) ss

    - increased (g/c) ratio leads to faster approach to (lower/better) ss

    - changes in r do not have a big effect on speed

Conclusions

Point: Stationary policies easy to derive and may not perform poorly in some situations

- With discounting – stationary policies can do well
- Static stationary policy a lot easier to determine than stationary policy from dynamic optimization, which in turn is easier to determine than the optimal path
- Allows a clear and concise view of the long-run equilibrium and the influence of critical parameters on this state, uncluttered by the complexity of a optimal characterization of the initial transients
- But: performance depends (even in the linear baseline) on A, (g/c) and r: if exploding (big A) or if (g/c) are high implement a stationary policy asap; else need more sophisticated policy (which you have time to develop)