Bycatch-Saving Technological Change

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Three Purposes

- 1. Demonstrate a way of thinking about bycatch-saving technical change
  - increased selectivity
- 2. Maximum economic yield (MEY) with technical change that increases catchability of target species and reduces bycatch
- Will sketch out a basic model, skip most steps, then show MEY under various conditions
- 3. What incentivizes research & development for bycatch-saving technical change?

Bycatch-Saving Technical Change is Largely Endogenous

- Endogenous technical change
  - Source of technology & research and development (R&D) within fishery sector
  - Hence R&D responds to incentives
  - Incentives created by direct regulation, incentive-based regulation, technology policy
  - Bycatch species typically endogenous
- Exogenous technical change
  - Source of technology and R&D from outside of fishery sector
  - Both exogenous and endogenous, but IT exogenous

Notation…(1)

- Y(t): Target species catch
- B(t): Bycatch species catch
- S(t): Target species stock (biomass)
- Z(t): Bycatch species stock (biomass, currently excluded from model)
- $A_Y(t)$: State of technology for production of target species (part of catchability coefficient q)
- $A_B(t)$: State of technology for production of bycatch species (part of catchability coefficient q)
- E(t): Effort
- F(S(t)): Target species surplus production growth function

Notation…(2)

- $p > 0$ = constant per unit price at which harvest of the target species can be sold
- $c \geq 0$ = constant per unit cost of effort
- $v \geq 0$ = constant cost per unit of bycatch
  - If no bycatch penalties (costs), then v = 0

Some Fundamental Equations

- (1) Target species catch equation

$$Y(t)=h[S(t), AY(t), E(t)] = A_Y(t)E(t)S(t)$$

- (2) Bycatch species catch equation

$$B(t)=b[A_B(t),E(t))] = A_B(t)E(t)$$

- Work in progress to add Z(t)
  - (optimal control problem becomes very complex)
- (3) Stock dynamics equation
- $S''(t)=F(S(t)-Y(t))$
- '' denotes time derivative

Relative Bycatch

- Relative bycatch B(t)/Y(t) can be reduced by technical change that:
- (1) reduces bycatch, i.e. $A''_B(t) < 0$
- (2) increases target catch, i.e. $A''_Y(t) > 0$

$$\frac{B(t)}{Y(t)} = \frac{A_B(t)}{A_Y(t)\,S(t)}$$

Research & Development (R&D)

- R = Relative amount of R&D for target species,
  where $0 \leq R \leq 1$
- 1 – R = relative amount of R&D for bycatch species
- Technology stocks evolve over time as:

$$A''_Y(t) = \eta_Y \, R(t) \, A_Y(t)$$

$$A''_B(t) = \eta_B \, \mathbf{[1-R(t)]} \, A_B(t)$$

where η_Y (η_B) represents probability that allocation of research effort to increasing target species productivity (reducing bycatch) will successfully increase $A_Y(t)$ [$A_B(t)$] by one unit.

Discounted Present Value of Profits

$$\int_0^{\infty} \underbrace{[pY(t) - c(t)E(t) - vB(t)]}_{\text{Profit}} e^{-\delta t} dt, \qquad (7)$$

where δ denotes the instantaneous discount rate.

Sole Owner (Society) Optimization Problem

- Choose E(t) and R(t) to maximize profits subject to growth of resource stock and other constraints

Hamiltonian for Optimal Control Problem

$$H = \underbrace{[pY - cE - vB]e^{-\delta t}} + \underbrace{\gamma[F(S) - Y] + \theta_T[\eta_T RA_T] + \theta_B[-\eta_T RA_B]},$$

Profit

Constraints

where γ, θ_T, and θ_B are Lagrange multipliers or shadow values from the constraints

Solution Yields Three Cases for R (Relative R&D)

$$R = \begin{cases} 1 & if \quad \theta_T \eta_T A_T > -\theta_B \eta_B A_B \\ 0 & if \quad \theta_T \eta_T A_T < -\theta_B \eta_B A_B \\ ? & if \quad \theta_T \eta_T A_T = -\theta_B \eta_B A_B \end{cases}.$$

- For each of these three cases consider:
- (1) MEY stock
- (2) Fundamental equation of renewable resource economics
  - Solution to maximizing Hamiltonian
  - Gives optimal E(t), Y(t), B(t), S(t), Z(t)
- (3) Figure in terms of target species

R(t) ≡ 1: All R&D for Target Species & Bycatch Technology Constant…(1)

$$F'(S) + \frac{[F(S)+\eta_T S]}{S[pSA_T(t)-(c+vA_B^0)]} + \frac{[c+vA_B^0]}{S[pSA_T(t)-(c+vA_B^0)]} = \delta,$$

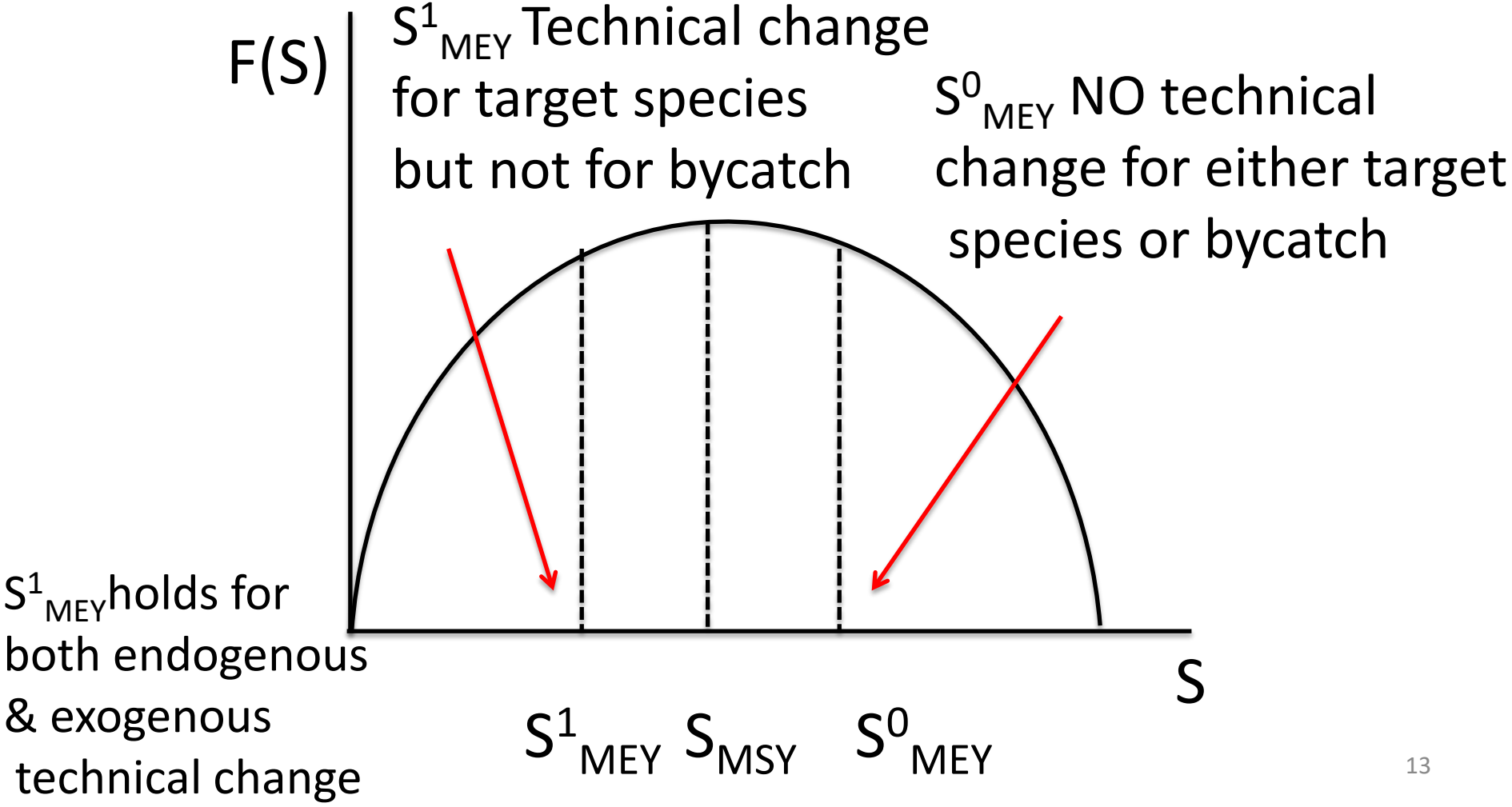
Marginal Productivity Target Resource Stock

Marginal Stock Effect

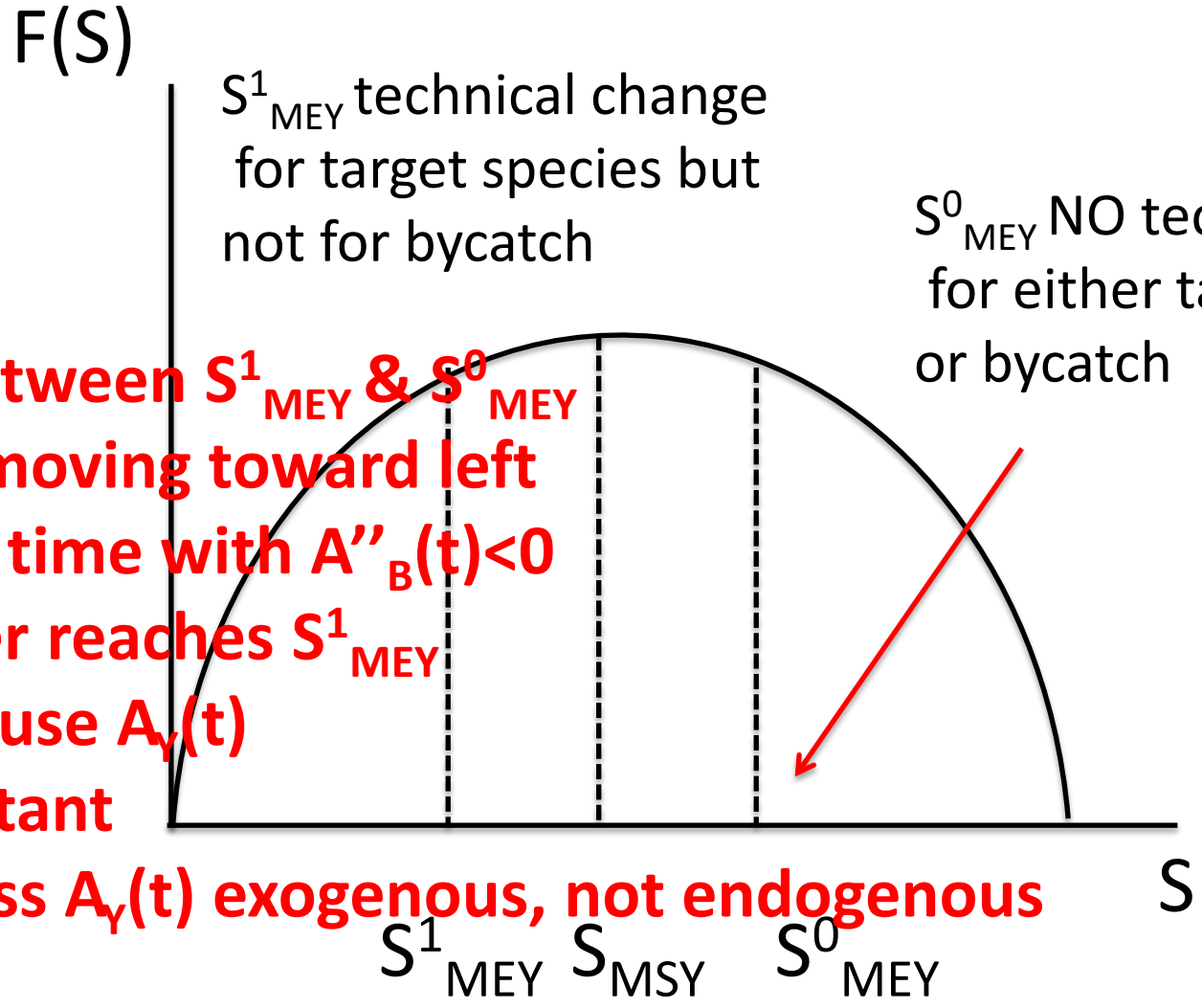
Marginal Technology Effect

Discount Rate

R(t) ≡ 1: All R&D for Target Species & Bycatch Technology Constant…(2)



R(t) ≡ 0: All R&D to Reduce Batch, Target Species Technology Constant



- **In between S^1_{MEY} & S^0_{MEY}**
- **But moving toward left over time with $A''_B(t)<0$**
- **Never reaches S^1_{MEY} because $A_Y(t)$ constant**
- **Unless $A_Y(t)$ exogenous, not endogenous**

Bottom Line…(1)

- Target species technical change lowers target MEY stock compared to no target species technical change
  - Endogenous and exogenous technical change
  - MEY stock < MSY stock, not MEY stock > MSY stock
- Accounting for bycatch species lowers target catch(because higher cost) & increases target species stock compared to without

Bottom Line…(2)

- Bycatch-saving technological change allows more target catch (because lower costs) & lower target MEY stock compared to without
- Accounting for bycatch and technical change for both target and bycatch species gives MEY stock lower than traditional MEY stock & can be lower than MSY stock

How to Incentivize Bycatch R&D?...(1)

- Price effect
  - Direct regulation and incentive-based regulation change relative prices and hence costs that incentivize R&D for bycatch reducing technical change
  - Innovate to lower now higher costs of target species production
- Market effect
  - Larger markets make profitable R&D for bycatch reducing technical change
  - Example: FAD bycatch research
  - Dolphin bycatch innovation

How to Incentivize Bycatch R&D?...(2)

- Direct regulation
  - Performance standards (quotas, limits)
  - Technology standards (required gear & operating requirements)
- Incentive-based policy instruments
  - Increase bycatch and target prices and costs so R&D to innovate and save costs
- Research on pollution, energy conservation, terrestrial conservation, climate, water shows both direct and incentive-based regulation can be important to induce technical change

How to Incentivize Bycatch R&D?...(3)

- Technology policy
  - Private R&D usually too low for social optimum because private sector does not enjoy all benefits of innovation
  - Public subsidizes R&D to achieve social optimum
  - In fisheries, often see public-private R&D
    - Circle hooks replace J hooks, eco-FADs, buoy gear for swordfish

Thanks!.....Questions?