Rethinking the Commons Problem: The Knowledge Externality and Technological Change

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Organization

• 1. Introduction and Main Points
• 2. Golden Rule with and without Knowledge Externality
• 3. Empirical Case Study
• 4. Concluding Remarks
1. Introduction and Main Points
Technical Change and Knowledge Externality Exacerbate Commons Problem
Knowledge is Public Good with Positive Knowledge Externality...(1)

- Knowledge = new (and accumulated) technology.
  - Nonrivalrous input

- Now two externalities:
  - (1) common resource stock
  - (2) knowledge externality

- Knowledge introduced through investment in physical capital
  - Embodied technical change leading to learning by doing
Knowledge is Public Good with Positive Knowledge Externality...(2)

• Both externalities impact resource stock & economic optimum

• Endogenous growth limited by productivity of resource stock.
Nature of Technical Change

• Exogenous technical change reasonable assumption since most important source is information technology comes from sectors outside of fisheries.
• Knowledge externality makes technological change endogenous.
• Explicit investment in physical capital also makes technological change endogenous.
• Bioeconomic model with exogenous technical change and knowledge externality corresponds to 1986 Romer endogenous growth model
Linear Homogeneous Aggregator Functions & Effort Exponents

• Required for consistent aggregation and homothetic separability of rivalrous inputs
• Exponent = 1 for effort with rivalrous inputs
• Exponent < 1 for negative externality (congestion)
• Exponent > 1 for positive externality with nonrivalrous input (knowledge)
Types of Separability and Explicit Investment

• Consider only Leontief-Sono separability without explicit investment
  – Malleable physical capital

• Leontief separability with capital limiting factor and with explicit investment in physical capital gives similar results
  – Non-malleable physical capital
2. Golden Rule with and without Knowledge Externality
General Optimization Problem

The dynamic fishery model then looks like the following:

\[ PV(\pi) = \int_0^\infty \{ \pi [E_t, S_t] \} e^{-\delta t} dt = \int_0^\infty \{ ph(E_t, S_t, t) - cE_t \} e^{-\delta t} dt \]

Subject to

\[ \frac{dS_t}{dt} = F(S_t) - h(E_t, S_t, t). \]

Will implement with Logistic population growth
Golden Rule, Leontief-Sono Separability, No Explicit Investment, Knowledge Externality θ = 0

When θ = 0, the effort exponent is linear and the Golden Rule is written:

\[
F_s = \frac{cF(S_t)}{(p_q S_t e^{(\lambda+M_2 \psi) t - \mu(t,Z) - c})S_t} + \frac{c(\lambda+M_2 \psi - \partial \mu(t,Z)/\partial t)}{(p_q S_t e^{(\lambda+M_2 \psi) t - \mu(t,Z) - c})} = \delta.
\]

Own rate of interest
Marginal stock effect
Marginal technology effect

When θ = 0, the corresponding singular solution \( S_t^* \) is:

\[
S_t^* = \frac{K}{4} \left[ \frac{c}{P_q K e^{(\lambda+M_2 \psi) t - \mu(t,Z) + 1 - \delta/r}} \right] + \sqrt{\left[ \frac{c}{P_q K e^{(\lambda+M_2 \psi) t - \mu(t,Z) + 1 - \delta/r}} \right]^2 + \frac{8c(\delta+\lambda+M_2 \psi - \partial \mu(t,Z)/\partial t)}{P_q K e^{(\lambda+M_2 \psi) t - \mu(t,Z)}}}.
\]
Golden Rule, Leontief-Sono Separability, No Explicit Investment, Knowledge Externality $\theta > 0$

The production frontier is specified as (assuming $\beta_1 = \beta_2 = 1$):

$$Y_t = q k^\theta E_t^{\theta+1} S_t e^{(\lambda+M_2(\theta+1)\psi)t-\mu(t,Z)},$$

With $\theta > 0$, the model is non-linear in effort and non-autonomous,

$$\frac{\bar{Y}_E(Y_{EE}E+Y_{ES}S)}{PY_E-c} + F_S + \frac{cY_S}{PY_E-c} + \frac{\bar{r}_E}{PY_E-c} = \delta,$$

$$\frac{c^\theta}{E} \frac{E}{PY_E-c} + F_S + \frac{cF}{S(PY_E-c)} + \frac{c(\lambda+M_2(\theta+1)\psi t-\partial\mu(t,Z)/\partial t)}{PY_E-c} = \delta.$$
Limit Resource Stock

Own rate of interest = social discount rate

Fig. 1. Optimum Resource Stock under Alternative Technical Change Specifications.
3. Empirical Study
U.S.-Canadian Albacore Troll Fishery

• Annual data from US & Canada
  – LSDV/FE

• Biological parameters from international stock assessments

• Aggregate production function
Optimum Resource Stock with Different Knowledge Externality Values

- No knowledge externality $\theta = 0$, $\beta_1 = 1$
- Knowledge externality $\theta = 0.1$, $\beta_1 = 1.1$
- Knowledge externality $\theta = 0.2$, $\beta_1 = 1.2$

Note: Case I, homothetic Leontief-Sono aggregation of effort. KE = knowledge externality.
Open Access Resource Stock with and without Knowledge Externality over 100 Years

No bionomic equilibrium
Faster rate of decline with externality

No knowledge externality $\theta = 0$, $\beta_1 = 1$

Knowledge externality $\theta = 0.1$, $\beta_1 = 1.1$
5. Conclusions
Impacts of Technological Change

• BMELY < BMSY
Impacts of Knowledge Externality

• Exacerbates BMESY < BMSY
  – Get there faster

• Increases productivity of effort:
  – Dynamic increasing returns (creates endogenous growth)
  – Increases rate of embodied technical change
  – Increases effective stock of investment and knowledge-embodied physical capital
    • Fisher’s (1965) “better” capital is “more” capital

• Makes growth endogenous, limited only by productivity of resource stock
Thanks!......Questions?