Mathematical Bioeconomics and the Evolution of Fisheries Economics Revisited

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Introduction

- Twenty-one years ago, I participated in a conference to honour Colin on his 60th birthday – I gave a paper reviewing Colin's contributions to fisheries economics, with the title:
    - *Mathematical Bioeconomics* and the Evolution of Modern Fisheries Economics
- Today, I am revisiting this paper and will ask if my earlier conclusions have held up, and, if so, will then ask what has happened over the intervening two decades

The Major Contributions

- In that earlier conference, I said that Colin's major contributions were twofold, and closely interlinked:
  - A. firmly establishing fisheries economics within the framework of the economist's theories of capital and investment
    - dynamic vs. static economics models of the fishey
  - B. constructing a bridge between fisheries economics and marine biology

Colin's Predecessors

- No one suggests that Colin was first to recognize significance of capital theory and biology to fisheries economics
  - recognized decades earlier – e.g. Anthony Scott, H. Scott Gordon, even some marine biologists recognized of capital theory for fisheries management – Pacific halibut, 1937
- Nonetheless, up until 1970s, capital theory and biology pushed well into the background in fisheries economics

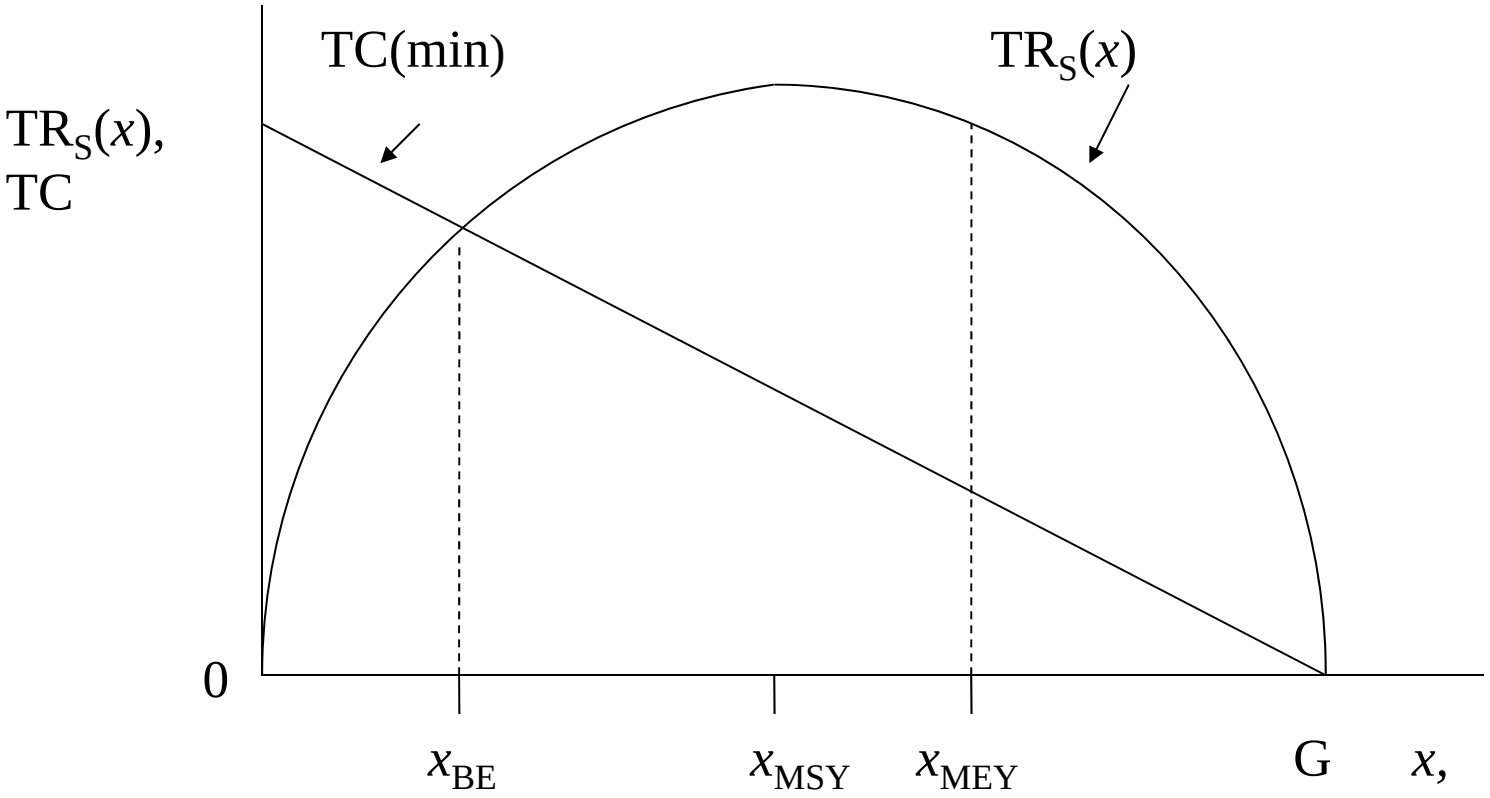
The Last Two Decades

- What has happened over the past two decades?
  - basically, the fisheries economics that Colin did so much to develop has come into its own
  - will argue that many key fisheries management issues can be addressed in economics terms, only with the aid of dynamic analysis ,e.g. rebuilding of fishery resources overexploited in the past -theory of investment of critical importance.

The State of the Art in Mid-1970s

- When Colin appeared on the scene 40 years ago, fisheries economics was dominated by the static economic model of H. Scott Gordon, which rested upon the biological model of M.B. Schaefer – Gordon-Schaefer model
  - continues to have a strong influence today
- Gordon primarily concerned with the consequence of the fishery resource being “common pool” –absence of any property rights, private or public – consider the following, where x denotes the biomasss.

The Gordon-Schaefer Model



TC = The cost of harvesting the sustainable yield, or harvest (F(x))
$TR_S(x)$ = pF(x) – Total sustainable revenue; Sustainable Resource Rent = **$TR_S(x)$ - TC**

Gordon's Conclusions

- Gordon concludes that:

- If the fishery were in fact managed optimally, from society's point of view, resource would be stabilized at x_{MEY}, where sustainable resource rent is maximized – Maximum Economic Yield
  - $x_{MEY} > x_{MSY}$
- If the fishery is "common pool" in nature, and fishing industry competitive, fishery will expand to point where sustainable resource rent is completely dissipated – Bionomic Equilibrium, $x = x_{BE}$
  - note the resource consequences: $x_{BE} < x_{MEY}$

Hesitant First Steps Towards a Dynamic Economic Model of the Fishery

- Scott Gordon, in the mid-50s agreed that static models of the fishery are inadequate – dynamic capital theoretic model required.
- First attempt came in the early ’60s – study by J. Crutchfield and A. Zellner – republished in 2003 (C-Z, hereafter)
  - did very innovative empirical work, which continues to be recognized, but had, as well, the first ever dynamic economic model of the fishery – dynamic version of Gordon-Schaefer model.

C-Z Model

- The C-Z dynamic economic model correct, but conclusions “questionable”.
- Model of a private single owner of the resource.
  - equation for optimal x, x*, not amenable to economic intuition
  - assume that $x_{BE} < x_{MSY}$, and let private owner’s discount rate be δ

  – maintained that $x^* = x_{MEY,}$ only if $\delta = 0$. If $\delta > 0$, then $x^* < x_{MEY}$, BUT :

$$\lim_{\delta \to \infty} x^* = x_{MSY}$$

C-Z Model Implications

- If, the dynamic models of the fishery tell us that x* could NEVER be below $x_{MSY,}$ then what on earth is the point of enduring the pain of these dynamic economic models and their incomprehensible equations.
  - difference between x* and x_{MEY} will be trifling
  - static economic models of the fishery not perfect, but **"good enough"!**
    - if $x(0) = x_{BE}$, there is the awkward problem of moving from that level to x*, but not to worry.

The Clark Challenge

- In the early ’70s Colin started writing articles claiming to show that the private fishery resource owner’s x* could easily be below x_{MSY}
  - to drive his point home, in ’73 wrote two articles demonstrating that, under right circumstances, private owner could drive the resource to **extinction!**
    - caused a sensation

- If Colin was right, then difference between dynamic and static models of critical importance
  - Economics profession regarded Colin’s extinction result as “interesting”, but of theoretical interest only- the static model continued on, seemingly unscathed

The 1975 “Simplified Approach”

- In ’75, Colin co-authored an article that put forth economically comprehensible fishery resource investment decision rules – the Fundamental Equation of Renewable Resource Exploitation.
  - consider the following from the linear, autonomous version of the dynamic economic fishery model

$$F'(x^*) - \frac{c'(x^*)F(x^*)}{p - c(x^*)} = \delta$$

$$p - c(x^*) = \left[\frac{d}{dx^*} \left\{ (p - c(x^*))F(x^*) \right\} \right] \frac{1}{\delta}$$

The Fundamental Equation

- Consider the second version of the FE.
  - can be shown that, given the linearity assumptions and the underlying Schaefer model, the C-Z key equation drops out of this second version.

- What this second version makes obvious is the following:

$$\lim_{\delta \to \infty} x^* = x_{BE}!$$

Mathematical Bioeconomics

- *Mathematical Bioeconomics,*1976, elaborated upon, and greatly extended, the results of the ’75 article, e.g. multiple species fisheries
  - managing asset portfolios, rather than single resource assets

- Drove home the point that biological model foundation of the economic model of the fishery of vital importance - ***bioeconomics***
    - Munro’s dictum: if the underlying biological model is misspecified, the economic model of the fishery is, for policy purposes, worthless.

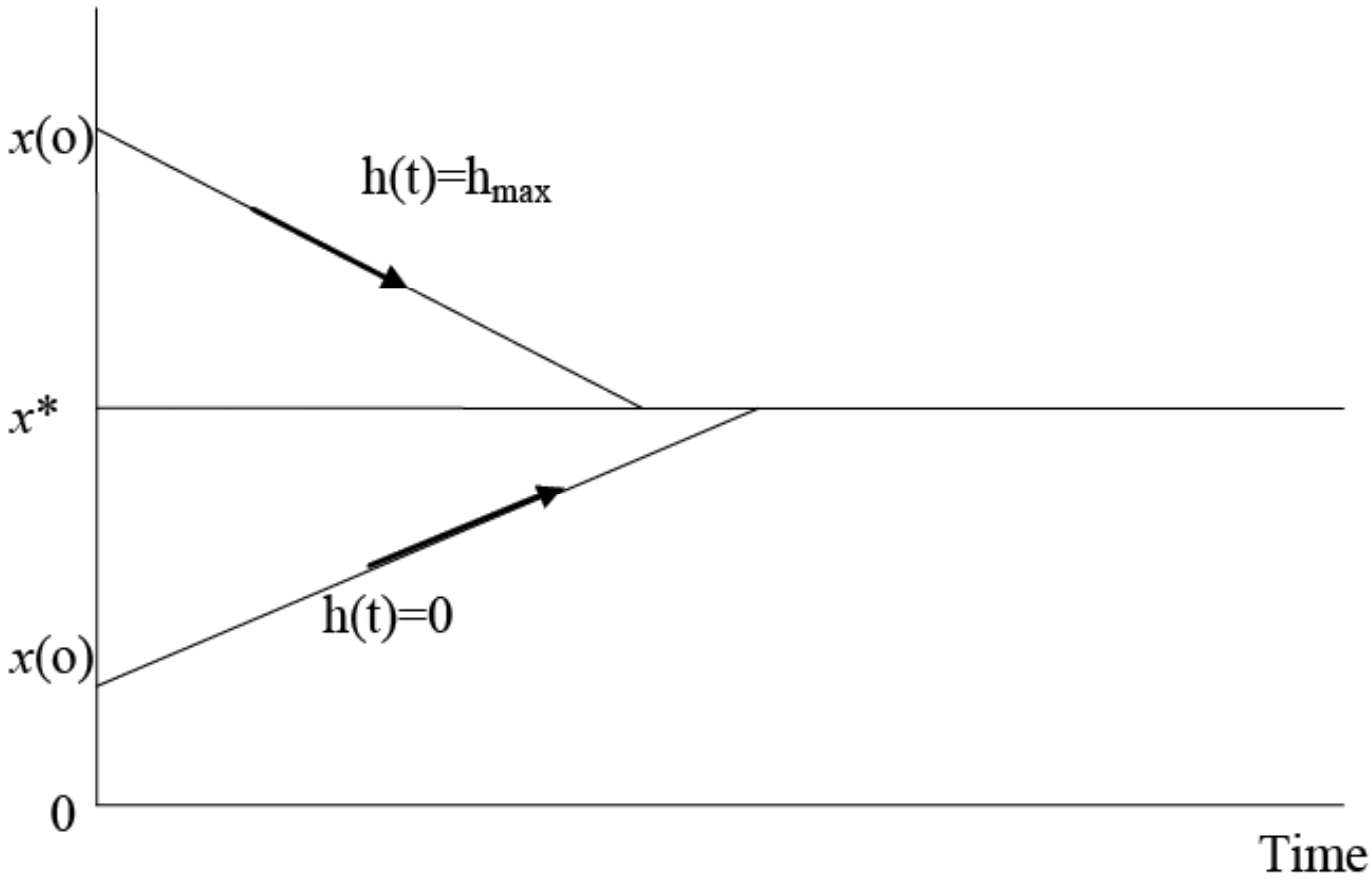
- The book quickly achieved the status of “classic”, and is now in its third edition

Theory of Investment Questions

- Determining x* correctly (theory of capital question) important, but relatively minor contribution of dynamic model. Of much greater importance – theory of investment issues –appropriate rate of investment
  - ignored by static model, by definition
  - consider the optimal "approach path" from the 1975 linear, autonomous model:

$$h^*(t) = \begin{cases} h_{\max} \text{ if } x(t) > x^* \\ F(x^*) \text{ if } x(t) = x^* \\ 0 \text{ if } x(t) < x^* \end{cases}$$

The Linear Dynamic Economic Model of the Fishery and Optimal Approach Paths



Optimal “Approach Path” Implications

- The optimal “approach path” is in fact about the optimal *rate* of investment in the resource
  - it states that, if positive resource investment called for, invest at maximum rate – declare outright harvest moratorium to be maintained until x* achieved.
    - if this takes 20 years, or more, then so be it.

- Now a major policy issue: World Bank/FAO publication, *The Sunken Billions,* calls for a massive investment in world fishery resources; OECD project on The Economics of Rebuilding Fisheries

The Draconian Investment Rule

- The draconian resource investment rule, just set forth, seen by many fisheries economists as ***the optimal*** investment rule –harsh, but optimal.

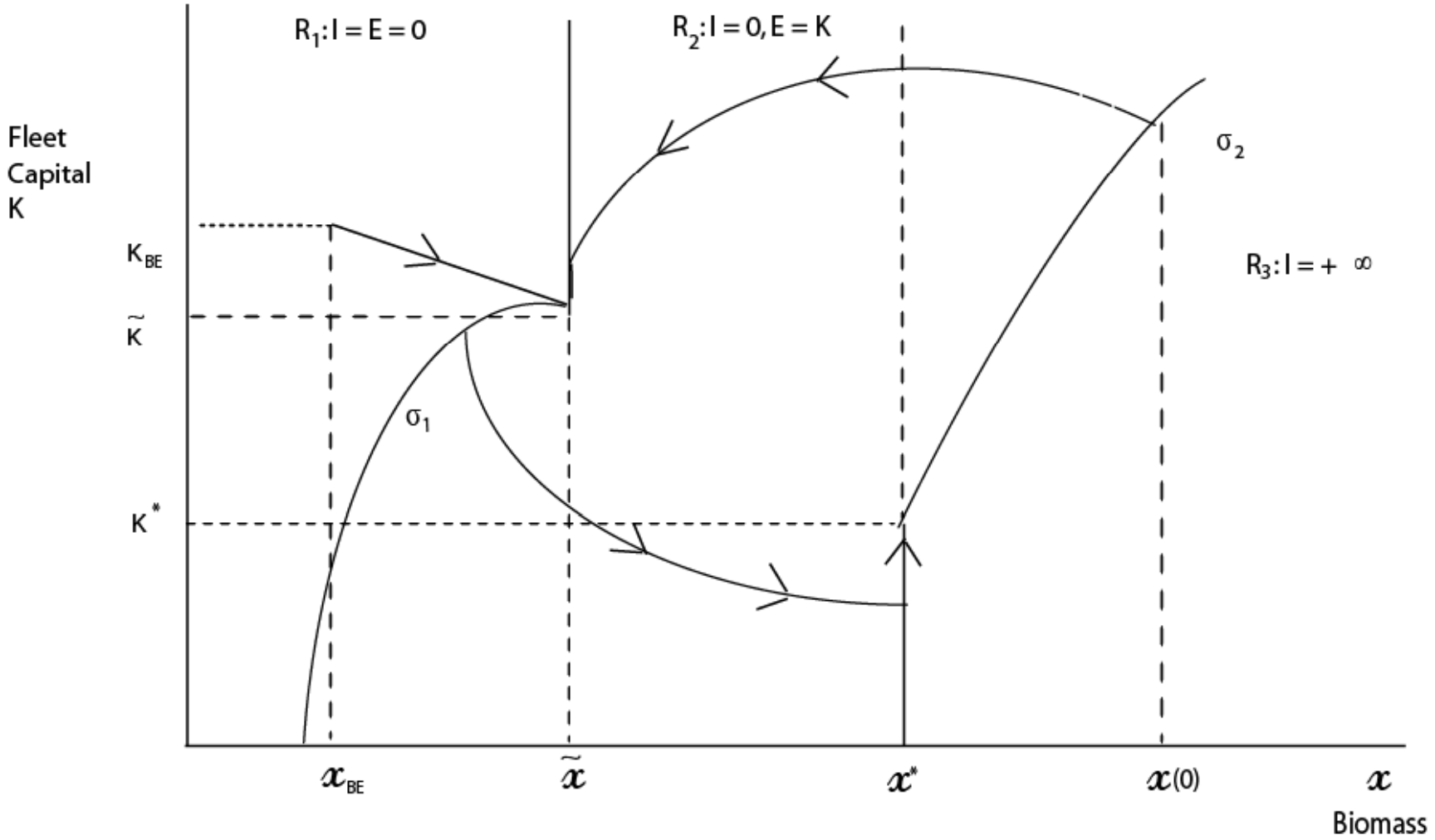
- Colin and associates forced to realize that the draconian investment rule is in fact optimal only under very special circumstances
  - rule of thumb: invest (disinvest) at maximum rate, *unless* there are penalties associated with rapid investment.

Non-malleable Produced and Human Capital

- The biggest objection to the draconian resource investment rule is the havoc that it might create for fishing fleets and fishing communities
  - inability to transfer easily vessels, fishers out of the fishery – vessel and human capital non-malleable with respect to fishery
  - the 1975 model assumes implicitly that produced and human capital in fishery – perfectly malleable
  - led to the 1979 article with Frank Clarke on irreversible investment in vessel capital

Quasi-malleable Fleet Capital

- Most realistic case- can disinvest in fleet capital only through depreciation – fleet capital quasi-malleable
- If resource is to be re-built, harvest moratoria optimal only under extreme conditions, and then for limited time only – generally speaking, optimal rate of investment in resource below the maximum
  - mathematics difficult, but economic rationale straightforward- rapid resource investment carries penalties with it.



Optimal Fishery Resource Management with Quasi-malleable Fleet Capital
Source: Clark, Clarke and Munro, 1979.

An Unexplored Key Issue

- All of the analysis of non-malleable produced and human capital, and consequences arising therefrom, is in fact focused exclusively upon produced capital.
- Can draw some inferences about the consequences non-malleable human capital, but human capital is not produced capital.
- Rebuilding fishery resources- biggest problem is likely to be non-malleable human capital in fisheries, particularly in developing fishing states
  - need for research is urgent.

The Dynamic Economic Model & Other Areas of Fisheries Management

- Are there other areas of fisheries management for which the dynamic model is relevant? Answer: try to find areas for which that model is irrelevant.
- Two obvious and related examples:
  - uncertainty in fisheries management
  - time consistency of fisheries management policies, e.g. international fisheries

Is Anybody Listening in the Policy World?

- The ultimate question is whether any policy makers are taking the dynamic –capital theoretic- models seriously
  - these models used to be seen as far to complex to be of interest to policy makers
- The answer is that the concepts arising from the dynamic analysis are beginning to penetrate the policy world, although progress is still required.
- Best example comes from Australia, where the dynamic bioeconomic model is actually being applied – the pilot case – Northern Prawn fishery of the Gulf of Carpentaria

Source: http://en.wikipedia.org/wiki/File:Gulf_of_Carpentaria_map.png

Some Conclusions: Colin Clark – **The Revolutionary**

- In retrospect, I do not think that it is an exaggeration to refer to Colin's impact upon fisheries economics as the ***bioeconomic revolution***.

- The capital-theoretic economic model of the fishery, with its biological model foundation made explicit, is now firmly embedded in the literature, and is clearly influencing policy makers.

- I predict that, if we look forward to May 2112, it will be found that *Mathematical Bioeconomics* is still being studied with care by economists, biologists and policy makers.


Thank you for your attention