Stochasticity and Overcapacity in the Pure Open Access Fishery

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Research Questions

In the pure open access fishery:

1. When capital is perfectly non-malleable, can stochastic recruitment cause overcapacity;

2. If so, what relationship exists between stochastic recruitment and overcapacity; and

3. What is this relationship when the capital stock is quasi malleable (i.e. depreciates)?

Outline

1. Motivation
2. The Model
3. Results
    1. Surplus production
    2. The stochastic fishery with perfectly non-malleable capital
    3. Stochasticity and overcapacity
    4. The stochastic fishery with quasi-malleable capital
    5. Simulation of mean capital utilisation ratio
    6. Stochasticity and overcapacity when capital is quasi-malleable
4. Conclusion

Motivation

- Overcapacity is a major issue in open access fisheries (see Munro, 2010; Grèboval and Munro, 1999).
- In the pure open access fishery, where there is no manager, the causes of overcapacity are not clear (see Munro, 2010).
- In a process termed “Ludwig’s ratchet,” episodes of favourable recruitment in such a fishery have been linked to the accumulation of fishing capacity (see Ludwig, Hilborn and Walters, 1993).
- This capacity could represent an excessive level when the environmental conditions return to normal.
- In this research we investigate the relationship between stochastic recruitment and overcapacity in the pure open access fishery.

Model Overview

- Our model is based on the Gordon-Schaefer model, where:
  1. Effort and capital are modelled separately.
  2. The capital stock is fixed in the short run and the capital utilisation adjusts instantaneously to the bionomic equilibrium or its maximum value of one.
  3. The adjustment of the capital stock occurs over a longer time period.
     - We model this using the Marshallian investment rule (see McKelvey, 1985).
  4. We introduce a stochastic multiplier on recruitment (Reed, 1979); and
  5. Examine two classes of capital (see Clark, Clarke and Munro, 1979):
     - perfectly non-malleable capital ($\gamma=0$, $I_t \geq 0$)
     - quasi-malleable capital ($\gamma>0$, $I_t \geq 0$).

Pure Open Access Bio-economic Model

- Harvest function: $h_t = qx_t E_t = qx_t \phi_t K_t, \quad 0 \le \phi_t \le 1$

- Growth function: $G(x_t) = z_t . r x_t \left(1 - \frac{x_t}{\overline{x}}\right), E[z_t] = 1,$

$$0 < z^{min} \le z_t \le z^{max}$$

- Sustainability constraint: $h_t = qx_t \phi_t K_t = G(x_t)$

Investment Rule

- Marshallian investment rule (McKelvey, 1985):

  "Fishers invest up until the point at which the average return to current capital $\bar{\mu}_t$ equals the cost of a fishing vessel c_I."

- For sustainable harvesting, in a myopic fishery:

$$\bar{\mu}_t = \frac{\overbrace{pq\bar{x}\phi_t.\left(1-\frac{qK_t}{z_t r}\phi_t\right)}^{\text{Average Total Revenue}} - \overbrace{c\phi_t - c_I\gamma}^{\text{Average Total Cost}}}{\delta} = AR_t - AC_t$$

Capital Dynamics

- Standard capital dynamics:

$$K_{t+1} = K_t - \gamma K_t + I_t$$

- Marshallian investment rule (see McKelvey, 1985):

$$I_t = \begin{cases} \gamma K_t - K_t + \dfrac{z_t . r}{pq^2 \bar{x}} . \left[\left(pq\bar{x} - c \right) - \left(\gamma + \delta \right) c_I \right] & \bar{\mu}_t > c_I \\ \gamma K_t & \bar{\mu}_t = c_I \\ 0 & \bar{\mu}_t < c_I \end{cases}$$

Surplus Production

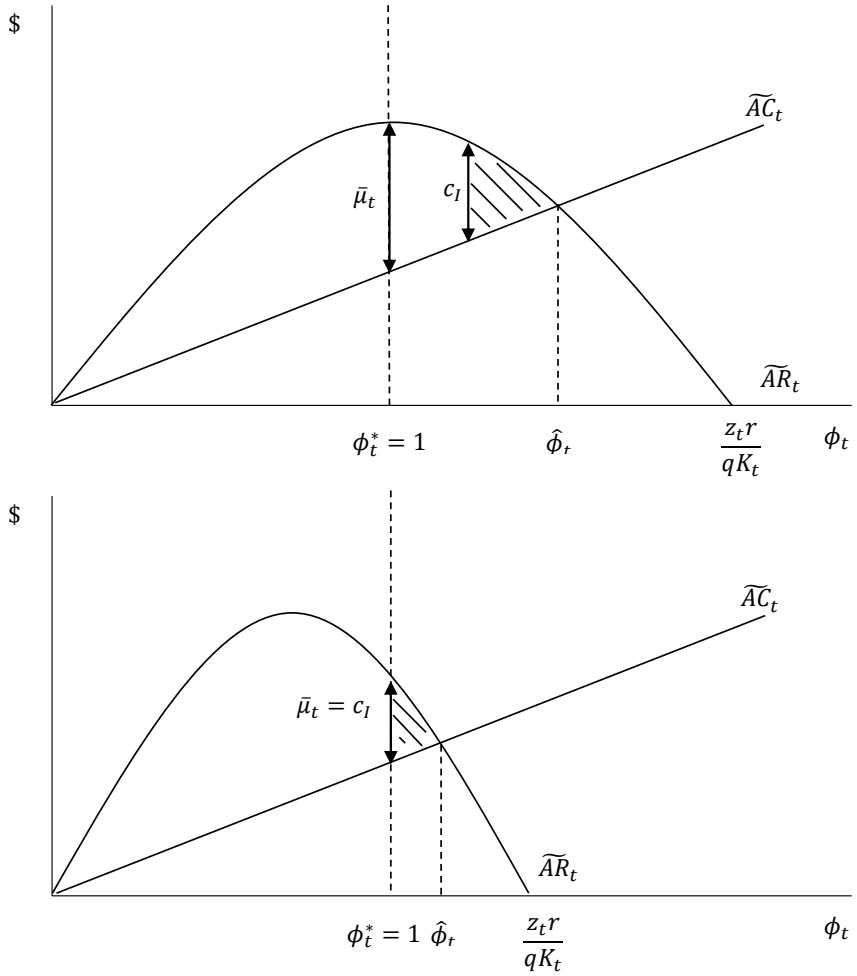

Figure 1: Surplus production model with perfectly non-malleable capital and a separate variable for fishing effort.

The Stochastic Fishery with Perfectly Non-malleable Capital

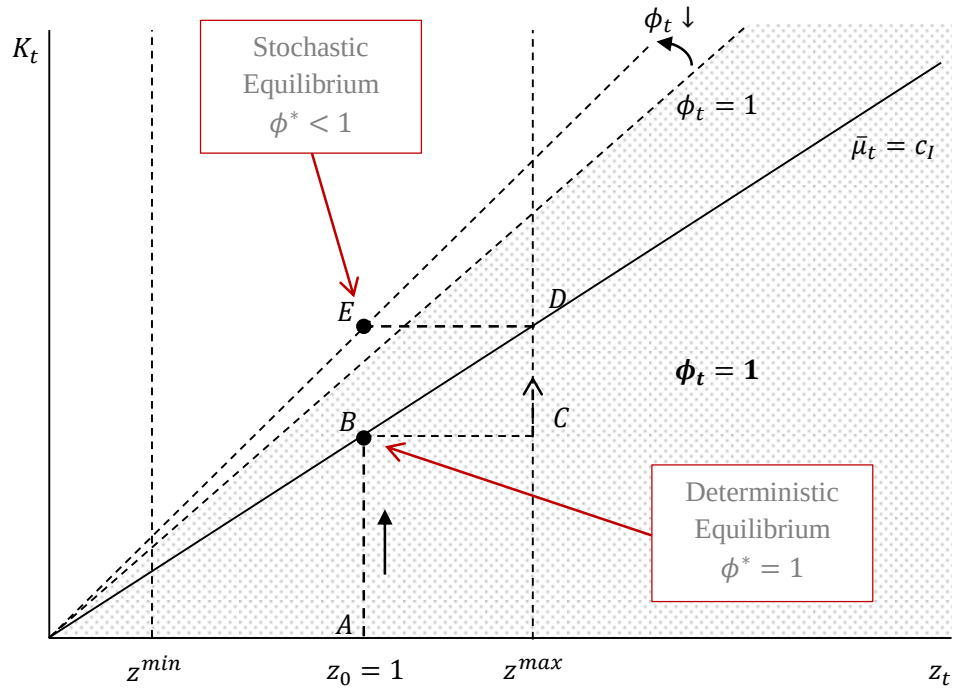

Figure 2: Phase portrait adjustment to a stochastic equilibrium.

Stochasticity and Overcapacity

- When the initial capital stock is low, environmental variation in the recruitment of the fishery can cause overcapacity.
- Positive fluctuations (i.e. $z_t > 1$) stimulate investment which causes overcapacity when recruitment returns to normal.
- These investments become more severe as the magnitude of the recruitment fluctuations increases, and thus the level of overcapacity also increases.
- Negative fluctuations ($0 < z_t < 1$) have no long run implications but cause a temporary dip in capital utilisation that is akin to *excess capacity*.
- When the initial capital stock is high, the fishery has overcapacity in the initial state.
  - This is somewhat like the orange roughy in Australia's South Eastern Trawl Fishery.

The Stochastic Fishery with Quasi-malleable Capital

Case: $\frac{2c_I\gamma}{pq\bar{x}-c}<1$

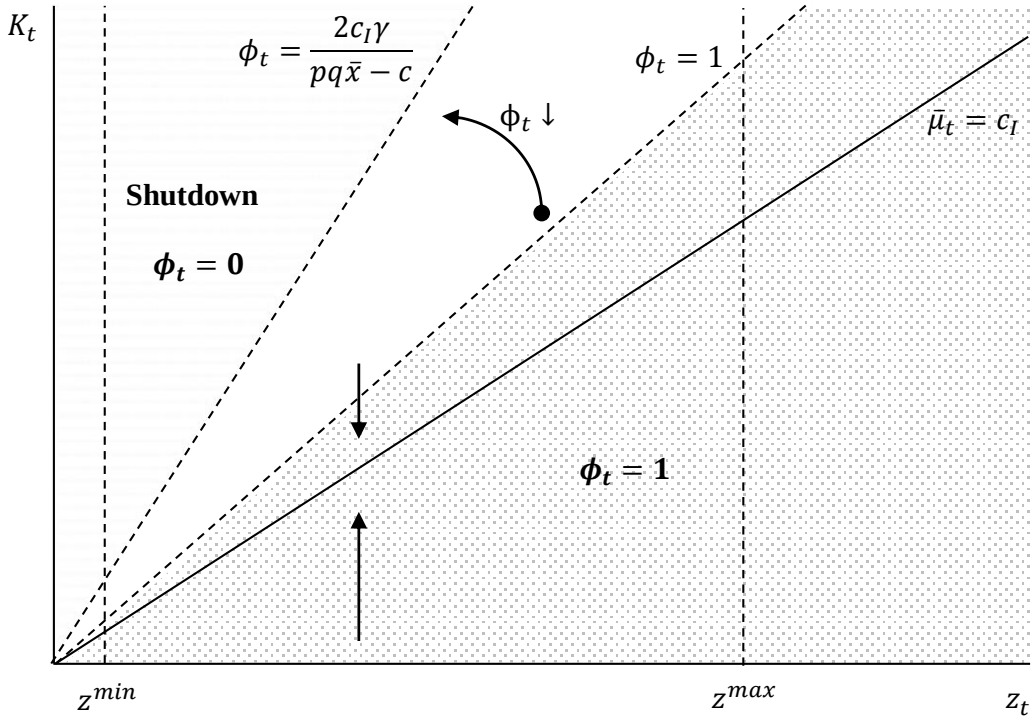

Figure 3: Phase portrait showing the stochastic equilibrium with a quasi non-malleable capital stock.

Stochasticity and Overcapacity when Capital is Quasi-malleable

- As before, positive fluctuations in recruitment ($z_t > 1$) can stimulate investment that causes overcapacity.
- The level of overcapacity will now depend on the balance between the depreciation rate and the magnitude of recruitment fluctuations.
- Small negative fluctuations ($0 < z_t < 1$) lead to temporary excess capacity, as before.
- However sufficiently large negative fluctuations will now cause the fishery to shutdown.

Simulation of the Mean Capital Utilisation Ratio

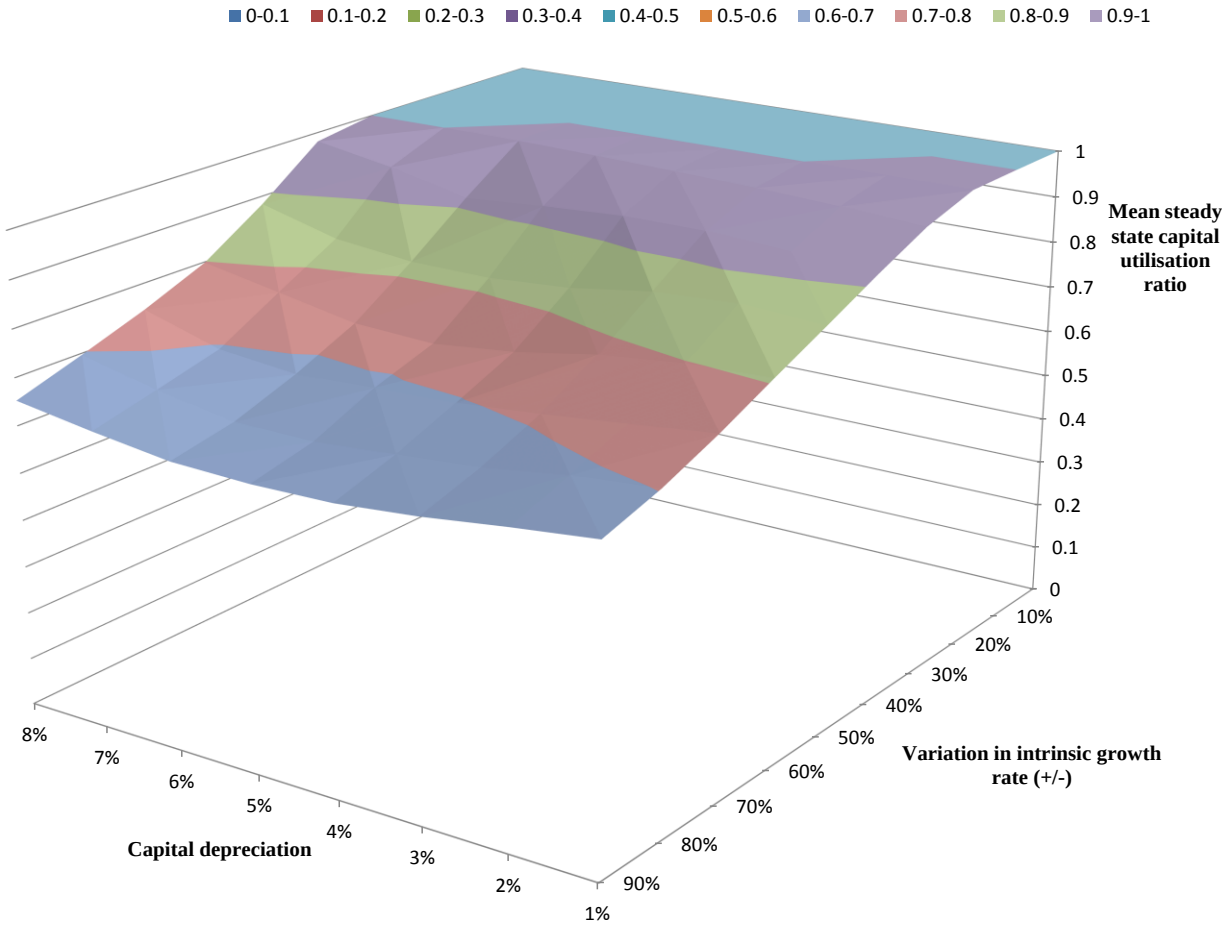

Figure 4: Surface plot of the mean steady state capital utilisation ratio for quasi malleable capital stock.

Conclusions

1. When capital is perfectly non-malleable, positive fluctuations in recruitment can cause overcapacity (i.e. economic waste).

2. This overcapacity increases with the magnitude of the recruitment fluctuations.

3. When capital is quasi malleable, the level of overcapacity depends on both the depreciation rate and the magnitude of the environmental variation.
   - A simulation of our model suggests that overcapacity increases at a decreasing rate with the magnitude of environmental variation.

Thank you.

…Conclusions

- Also, if the capital stock is highly malleable, the capacity built up during the positive fluctuations could be dissipated to the surrounding fisheries, creating a further problem with capacity.
  - Such was the case for the Norwegian Spring Spawning Herring stock (see Greboval and Munro, 1999).

The Stochastic Fishery with Quasi-malleable Capital

Case II: $\frac{2c_I\gamma}{pq\bar{x}-c} \geq 1$

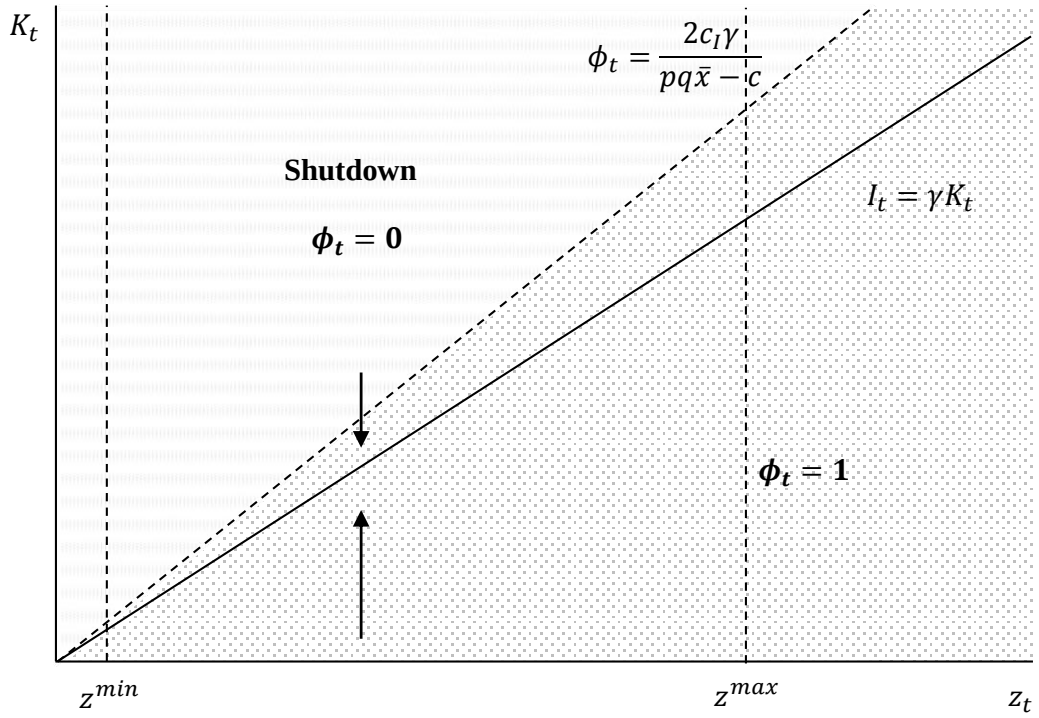

Figure 6: Phase portrait showing the stochastic equilibrium with a quasi non-malleable capital stock.