AAE / ECON / Forest 531 (Natural Resource Economics)

Midterm Exam. Thursday, October 23, 2008.

Suggested Solutions

Please answer the following five questions, worth a total of 30 points. Question 1 is worth 10 points; questions 2 through 5 are worth 5 points each. Good luck.

1. **Mathematics / Derivation (10 points)**: Consider the optimal steady-state management of a fishery where the net benefits derived from the fishery in time t are defined as $\pi_t = 8Y_t - Y_t^2$, and the resource has a natural rate of growth described by $F(X_t) = 2X_t - 0.5X_t^2$. Suppose the fishery is managed with an individual transferable quota (ITQ) system.
   a. Using the above information, are there conditions under which the bio-economic optimal stock size (X^*) will exceed the maximum sustained yield stock size (X^{MSY})? Explain.
   b. If the discount rate is δ=0.05, what will be the equilibrium quota price? Show your work.
   c. What effect will a higher discount rate have on the equilibrium quota price in an optimally managed fishery? Explain with intuition.

a. *Taking F'(X) and setting it equal to zero gives us X^{MSY}:*

$$F'(X) = 2 - X = 0$$

$$\Rightarrow X^{MSY} = 2$$

The fundamental equation of renewable resources is a necessary condition for X:*

$$F'(X) + \frac{\partial\pi/\partial X}{\partial\pi/\partial Y} = 2 - X + 0 = \delta$$

$$\Rightarrow X^* = 2 - \delta = 1.95$$

So, $X^* \leq X^{MSY}$ because the discount rate can never be negative. Intuitively, this occurs because fishery profits only depend on harvest and not the stock size.

b. *The equilibrium quota price equals the marginal net benefit of the last unit of harvest. The total harvest (total allowable catch) can be derived by recognizing that $Y^*=F(X^*)$ in steady state.*

$$Y^* = F(X^*) = 2(1.95) - 0.5(1.95^2) = 1.999$$

The marginal net benefit of the last unit of harvest – and hence, the equilibrium quota price – can be derived as:

$$\frac{\partial\pi}{\partial Y} = 8 - 2Y^* = 8 - 2(1.999) \approx 4 = P_{quota}$$

c. *A higher discount rate will require the fishery manager to increase the internal rate of return to the fishery, which can only be accomplished by reducing X^* since $F'(X^*)$ is decreasing in X. Since $X^*<X^{MSY}$ with a positive discount rate, a reduction in X^* will lower the total allowable catch (Y^*), which increases the marginal net benefit of the last unit of harvest, and <u>increases</u> the equilibrium quota price since the stock is more scarce.*

Short Answer Section (3-6 sentences; 5 points each)

2. The following statement is by the biologist E.O. Wilson:

   The worst thing that can happen… is not energy depletion, economic collapse, limited nuclear war, or conquest by a totalitarian government. As terrible as these catastrophes would be for us, they can be repaired within a few generations. The one process ongoing … that will take millions of years to correct is the loss of genetic and species diversity by the destruction of natural habitats. This is the folly our descendents are least likely to forgive.

   Briefly discuss the connection between Wilson's statement, option values, and the efficient conversion of natural habitats to developed uses.

   Wilson's point about the loss of genetic and species diversity is that the loss of natural habitats is irreversible. In addition, this is a case where the future human values of a diverse gene pool are uncertain. This combination of irreversibility and uncertainty are the basis for an option value. In this example, the option value arises because we may gain additional information about the benefits of a diverse gene pool if we delay irreversible habitat conversion. The implication for the efficient conversion of natural habitats to developed uses is that conversion should only proceed if the net value of conversion today exceeds the option value of preservation.

3. Consider the optimal management of a renewable resource over a *fixed* 20-year period. The net benefits of the resource in time t are described by $\pi(X_t, Y_t)$ and the natural growth of the resource is described by $F(X_t)$. Further, suppose the parameter λ_t represents the time-specific Lagrange multiplier for the relevant dynamic optimization problem. What is the effect of a high value of λ_{20} compared to a low value of λ_{20} on the remaining stock size in t=20 (X_{20})? Explain.

   The parameter λ_{20} represents the shadow price for a unit of the remaining stock. Higher values of λ_{20} imply a higher shadow price for the remaining stock than if λ_{20} was low. Therefore, all else equal, a higher value of λ_{20} implies a larger remaining stock size in t=20 since it is more valuable.

4. Suppose forest stands A, B, and C have identical growth functions of the form examined in class, and face the same timber price and replanting costs. The stands differ in that forest stand A will be harvested and the land abandoned, forest stand B will be harvested and replanted with trees intended for future harvest, and forest stand C will be harvested and turned into a housing development. In terms of efficiency, which stand – A, B, or C – should have the oldest harvest age? Which stand should have the youngest harvest age? Why?

The marginal benefit of waiting is identical across all stands since the growth function is identical and all stands receive the same timber price. Therefore, the stand with the lowest marginal cost of waiting will have the oldest harvest age, and the stand with the highest marginal cost of waiting will have the youngest harvest age. The marginal cost of waiting will be lowest for stand A, since it will be abandoned after harvest and land rent is not an opportunity cost of delay. Whether stand B or C has the youngest harvest age is ambiguous, and depends on i) the difference in the rental value of bare forest land compared to a housing development (high rental values increase the marginal cost of waiting), and ii) the magnitude of the replanting costs (which lowers the marginal cost of waiting for stand B).

5. Many fisheries are managed by regulated open access, where a total allowable catch (TAC) is set by a government agency, and the season is closed once the TAC has been reached. There is typically no restriction on the number of boats allowed to participate in the open season. Briefly discuss the major difference between regulated open access and bioeconomic management policies (e.g. individual transferable quotas, landings tax, etc.).

The premise behind regulated open access is to reduce effort, and the premise behind bio-economic policies is to introduce a shadow price of the stock to the fisher's harvesting decisions. Regulated open access suffers from multiple incentive problems that typically don't plague bio-economic policies. For example, closed season policies give an incentive for fishers to increase effort in open seasons and gives incentives for derbies. While regulated open access can be used to set a desirable stock size, the profitability of the fishery will not be maximized.