ESM 242: Assignment #2
Due in class Wednesday April 29, 2009

1 Renewable Resources

1. Consider a renewable resource that is unexploited, and so the initial population is at carrying capacity. The resource is then opened up to harvesting, but no restrictions are placed on who can harvest, what technologies they use, or how much they harvest – it is an open access resource.

   (a) How would you calculate the present value of economic returns (i.e. economic rents) to this resource? Are they zero?

   (b) What conditions are required for this resource to be driven to extinction? How would you calculate how long it would take?

   (c) What conditions are required for this resource to be sustainably harvested?

   (d) How does environmental variability affect these conclusions?

2. Suppose a particular resource is governed by the following growth function:

$$X_{t+1} = X_t + rX_t(1 - X_t) - H_t \tag{1}$$

   where $r = 0.001$ is the intrinsic growth rate of the population, X_t is the resource stock and H_t is harvest in period t. **Note: Throughout this problem, X and H are both in units of 10^4 kilograms.**

   (a) Explain this equation in words.

   (b) Suppose $H_t = .01EX$. Explain this equation in words.

   (c) Profit is $\pi_t = pH_t - cE_t$ where $p = 200$ and $c = 1$. Fishermen enter when profit is positive and exit when profit is negative. The rate at which fishermen enter depends on the amount of profit that is being made: $E_{t+1} = E_t + \eta\pi_t$, where η is a "constant of proportionality". Assume $\eta = 0.3$. Simulate this system through time (for 75 year or so) with a starting stock of 1 and a starting effort of 1 ($X_0 = E_0 = 1$). Describe your results.

   (d) Suppose an oil spill instantaneously reduces the population to 10% of carrying capacity (i.e. to 0.1), and that effort is 1. What does this model predict will happen through time?

   (e) Why haven't we used an interest (or discount) rate in this problem?

3. Now we will play the role of a resource manager who accounts for the dynamic behavior of the resource stock in their management decisions.

   (a) Again, starting at $X_0 = E_0 = 1$, the manager wishes to maximize the net present value of profit to the industry over a 20 year time horizon (where the discount rate is 5%). The manager sets a landing tax of \$ τ per unit harvested. Note that this changes the industry profit to $\pi_t = (p - \tau)H_t - cE_t$, but the tax revenue is a direct transfer from industry to the government, so net profits to society are: $\pi_t = pH_t - cE_t$. What is the optimal tax, τ and corresponding effort in every period? How do these results compare to the open access results above?

(b) In addition to industry profit, the regulator recognizes an existence value of the resource stock. Suppose the existence value term is $EV(X_t) = \alpha \ln(1000X_t)$, where α is a positive constant. How does the inclusion of existence value into the objective function affect the optimal dynamics? (i.e. Optimize this system (by choosing τ) for different values of α) How do results depend on α?

2 Non-renewable Resources

1. In your own words, describe the Hotelling Rule for extraction of non-renewable resources. What is the "shadow value" of a natural resource?

2. You own a mine where the initial stock of the exhaustible resource is $R_0 = 1$. You obtain net benefits (either from using or selling the extracted resource) in period t of $\pi_t = \ln(1+q_t)$ where q_t is the amount you extract in period t. Your job is to determine the optimal extraction path over a fixed planning horizon.

   (a) If the discount rate (δ) is 5% and $T = 9$ (so you need to choose q_t for $t = 0, 1, 2, .., 9$), what is the optimal extraction path? (You may accomplish this by hand or with the help of a computer)

   (b) Demonstrate whether the computational result is consistent with Hotelling's rule.

   (c) What is the value of an incremental increase in initial reserves?

   (d) How would you expect the time series q_t to change with a change in δ and/or T? Draw a picture (by hand) that shows your prediction.

   (e) Using Excel, investigate how changes in δ and T change optimal extraction through time. Explain the results of your investigation.

3 Incorporating Uncertainty

In this question we explore the effects of uncertainty and variability on resource dynamics.

1. Refer to the open access problem above. Suppose both the price p and the intrinsic growth rate r vary through time. Based on historical data you believe $p \sim U[150, 250]$ and $r \sim U[.0005, .0015]$. Construct a Monte Carlo simulation model to simulate X and E over a 10 year period. Report and explain your results.

2. Refer to the optimal renewable resource harvest problem above. Suppose the regulator sets τ according to the policy you prescribed above. Conduct a Monte Carlo analysis to determine the effects of random p and r through time. Describe your results.

3. Under the above sources of randomness, how what would be the optimal choice of τ over a 20 year horizon?

4 Term Project

Describe the objective of your term research project for this class *in 3 sentences or fewer* .