ECO6143 Natural-Resource Economics
Final Exam December 2007
University of Ottawa
Professor: Louis Hotte
Time allowed: 3 hours

1. (60 points) Private ownership, costly exclusion, and resource dynamics

We reconsider the poaching problem seen in class by introducing resource dynamics. Let us restate the situation:

Poaching can be viewed as a sequential *game between a resource owner and n poachers. In the first stage, the owner decides on the number of hours of labor he will hire ($L \geq 0$) to exploit the resource, say a fishery, and on the intensity with which he monitors poaching. As a result of this policing, each poacher expects to be caught with probability $\lambda \in (0,1)$. If the owner catches a poacher, he confiscates his catch but can exact no other penalty.*

We initially restrict attention to the second stage where the n poachers choose the number of hours of illegal activity simultaneously, after observing both L and λ. Assume that each poacher wishes to maximize his expected gain. Each poacher has T hours per day to work and can divide them between legal work and poaching. Legal work pays w per hour and the stolen catch sells for p per unit. If player i poaches for h_i hours, he earns in expectation:

$$\lambda w(T-h_i) + (1-\lambda)\left(w(T-h_i) + \frac{h_i}{h_i + h_{-i} + L} pF(h_i + h_{-i} + L)\right),$$

where $F(\cdot)$ is the total output function, $F'(\cdot) > 0$, $F''(\cdot) < 0$, and $h_{-i} = \sum_{j \neq i} h_j$.

1.a) (10) It was found that as $n \to \infty$, the equilibrium total hours of poaching is given by

$$p(1-\lambda)\frac{F(X^*)}{X^*} = w, \tag{1}$$

provided that $H^* > 0$, where $H^* = nh^*$ and $X^* = H^* + L$. Interpret briefly expression (1).

1.b) (15) Assume that the owner also pays a wage rate w to hired labor L. For fixed policing λ, show that the profit-maximizing owner will always choose L such that $H^* = 0$. With the help of a graph, compare this equilibrium with those of open access and efficiency. Discuss.

1.c) (15) Suppose now that the total output depends on the resource stock size $S(t)$ at instant t. (NB We are working in continuous time.) Let total output at t be given by $F(X(t), S(t)) \equiv S(t)L(t)^{\alpha}$, $\alpha \in (0,1)$. Average product of labor is now equal to $S(t)L(t)^{\alpha-1}$ and thus depends on the stock size, as would be expected for a natural resource. Given that there is a large number of poachers ($n \to \infty$), we assume that condition (1) still holds at any instant in a dynamic setting.

From now on, let $p = 1$ and $\alpha = 0.5$. Given λ and $S(t)$, compute the quantity of labor hired $L(\lambda, S(t))$ and the instantaneous profit $\pi(\lambda, S(t))$. (NB Expression (1) always holds with $H^* = 0$.) How do profits vary with respect to $S(t)$ and λ? (Assume $\lambda \in [0, 1/2]$.)

Interpret what happens to profits when $\lambda = 0$.

1.d) (10) Let the natural regeneration rate of the resource be given by the logistic function $G(S(t)) = S(t)(1 - S(t))$. With harvest, the resource stock dynamics are thus

$$\dot{S}(t) = S(t)(1 - S(t)) - S(t)\sqrt{L}. \tag{2}$$

Given λ, find the steady-state stock size S^{ss} for a profit maximizing owner. How does it compare with the steady-state stock size in open access?

1.e) (10) We now would like to endogenize the choice of policing λ in the above dynamic setting. Total policing costs are borne out by the owner and are denoted by $C(\lambda) = c\lambda$, where c denotes the marginal cost of increasing λ. Since expression (1) continues to hold, instantaneous profit levels (gross of policing costs) and hired labor are equal to the expressions found in **1.c)**. The present-value problem of the owner is thus

$$\max_{\lambda(t)} \int_0^{\infty} [\pi(\lambda(t), S(t)) - c\lambda(t)] e^{-rt} dt, \tag{3}$$

$$\text{s.t. } \dot{S}(t) = S(t)(1 - S(t)) - S(t)\sqrt{L(\lambda(t), S(t))} \tag{4}$$

where r is the discount rate. (NB You must substitute the expressions you found for $\pi(\lambda, S(t))$ and $L(\lambda, S(t))$ in **1.c)**)

i) Set-up the Hamiltonian for this problem and give the necessary conditions for a maximum. Interpret briefly.
ii) Characterize the steady-state stock size S^{ss} as a function of p, w, c and r. Through implicit differentiation, find how S^{ss} varies with the wage rate and discuss the difference with the classical case of a single owner with costless and perfect exclusion.

Answer one of the following two questions.

2. (40 points) Malthus revisited

Discuss the link between Malthusian growth and the current debate over sustainable development, population growth and natural resource depletion as seen by Brander (2007). Why is there so much emphasis on fertility rates and how can they be characterized by externalities?

3. (40 points) Rural privatization and transaction costs in general equilibrium

Explain, with the help of a graphic, how can rural privatization lead to a more conservative and (apparently) efficient use of a resource while decreasing GDP in the presence of transaction cost linked to privatization.