

AAE / ECON / Forest 531 (Natural Resource Economics)

Practice Final Exam. *Suggested Solutions*

Please answer the following four questions, worth a total of 30 points. Questions 1 and 2 are worth 10 points each; questions 3 and 4 are worth 5 points each. Good luck.

1. **Mathematics / Derivation (10 points):** Consider how a competitive market will allocate a fixed non-renewable resource over time. Suppose demand for the resource is given by $p=25-(1/2)q$, where p is price and q is quantity. Further, suppose no marginal extraction costs, the discount rate is 5%, and the total resource stock is 7 units. Derive the market allocation of this resource (i.e. price and quantity in each time period) and show how the sustainability criterion of fairness across time periods could be satisfied with this allocation. State your assumptions.

The market allocation can be derived by appealing to Hotelling's Rule, where \$25 is the backstop price in time T – defined as the price that drives demand q to zero. Therefore,

$$p_{T-1} = 25/(1+.05) = \$23.8; \quad q_{T-1} = 50 - 2 * p_{T-1} = 2.4$$

$$p_{T-2} = 23.8/(1+.05) = \$22.7; \quad q_{T-2} = 50 - 2 * p_{T-2} = 4.6$$

So, the resource will be depleted in two periods with the above allocation. The consumer and producer surplus for this allocation is:

$$CS_{T-1} = (1/2)(\$25 - \$23.8)2.4 = \$1.44; \quad PS_{T-1} = \$23.8 * 2.4 = \$56.40$$

$$CS_{T-2} = (1/2)(\$25 - \$22.7)4.6 = \$5.29; \quad PS_{T-2} = \$22.7 * 4.6 = \$104.42$$

This allocation violates the sustainability criterion of fairness across time since the first period gets a total value of \$109.71 while the second period gets \$57.84, for a total 2-period present value of \$164.80. If the first period keeps \$82.40 and invests approximately \$27.31 of their surplus at 5% interest, the second period gets $\$57.84 + \$27.31(1.05) = \$86.52$ in surplus, thereby making the consumption pattern fair as the present value of \$86.52 in year 1 is \$82.40. The key assumption in the above analysis is that the second period generation views the investment as a substitute for the foregone resource consumption.

2. **Essay (10 points).** The general concept of open access has been used as an economic explanation for (a) the inefficiency of groundwater extraction, and (b) the historical collapse of the society on Easter Island. Carefully present the economic argument for the relevance of open access to these two resource management cases.

Open access refers to the situation where property rights to a resource are not well-defined – typically not exclusive – and thus the resource user extracts/harvests a resource until their one-period marginal net benefits of extraction/harvest are zero. Efficient resource management occurs when resource users solve a dynamic optimization problem where the solution is characterized by resource users equating their marginal net benefits of extraction/harvest to the marginal user cost. Scarcity of the resource is signaled by the marginal user cost, and so open access resource users lack the incentive to conserve.

Since landowners are generally free to drill and pump from underground aquifers below their land, property rights to groundwater are typically not well-defined and groundwater users generally ignore the marginal user costs of their actions. In this sense, groundwater users fail to account for the stock externality and pumping cost externalities imposed on future users by lowering the pool of groundwater too fast.

The argument for the relevance of open access to the collapse of Easter Island centers on the following three assumptions: i) the primary natural resource was a slow-growing palm tree, ii) population growth rates are positively related to the resource stock, and iii) property rights to the resource stock were not well-defined. In this sense, residents of Easter Island exploited the open access resource by harvesting too fast, thereby increasing population growth in the short run and driving the stock to an inefficiently low level which eventually lead to a population crash.

Short Answer Section (2-5 sentences; 5 points each)

3. Consider the extraction of a non-renewable resource by a competitive industry. Describe in general terms how the shadow price (i.e. marginal user cost) for this resource depends on (a) whether the demand curve for the resource is expected to be stable or shifting outward over time, and (b) the expected success of exploration for additional reserves. Explain.

The shadow price represents the value of a marginal increase in the stock, and so serves as an economic indicator of scarcity. With a non-renewable resource, the shadow price increases over time with constant demand, and increases at a faster rate with demand that shifts outward over time. Expectations of rising demand increase the value of using the resource in the future, and thus increase the shadow price. Expectations of additional future reserves generally reduce economic scarcity and can lower the shadow price.

4. Suppose the marginal net benefits of using a non-renewable resource stock are downward sloping – that is, the marginal net benefit of using the second unit is less than the marginal net benefit of the first unit at any point in time. Explain how the efficient time path of extracting the stock (i.e. increasing or decreasing over time) depends on the time path of the shadow price (i.e. marginal user cost) of the stock.

The efficient time path of extracting a non-renewable stock is characterized by the first order condition to a dynamic optimization problem that equates the marginal net benefits of using the stock to the marginal user cost. If the marginal user cost is higher in $t+1$ than in t , the downward sloping marginal net benefit curve implies that extraction in $t+1$ must be lower than in t . The opposite would be true if the marginal user cost were decreasing over time.