

NATURAL RESOURCE ECONOMICS II
14.42 LECTURE PLAN 17: APRIL 26, 2011
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- PowerPoint Vignette: Are we running out of natural gas?
 - Point out the key roles of substitution (to coal, LNG) and of directed technical change (gas fracking).

PASTURE 1: EQUILIBRIUM IN NATURAL RESOURCE MARKETS

Setup:

Two periods.

Supply Side

Price taking firms

Supply has Hotelling costs. Firms are price takers (competitive supply)

$$\pi_t = \sum_t \delta^t [p_t - c_t] E_t + \lambda [Q_f - (\sum_t E_t)]$$

Maximize profits by taking derivative:

$$\delta^t [p_t - c_t] = \lambda$$

$$p_t = \lambda \delta^{-t} + c_t$$

“Hotelling Rule”

“Markup rises at the interest rate.”

Intuition: Storable good: I can store money or store the good between periods. I exploit in this period until indifferent between this period and next.

Same as constrained maximization of utility. Dorian’s point from last time: when maximizing utility, I get the same amount of utility from consuming odwalla bars vs. the numeraire good vs. an additional unit of “Resource” (wealth).

Total resource availability: $Q_T = FQ_f$

F=number of firms

Question: What’s the present value of the resource?

$$\sum_t \delta^t [p_t E_t - C(E_t)] = \lambda Q_f$$

(Brian pointed this out last time)

Question: This is an industry where firms are price takers, but they are making profits. How is this possible?

Answer: Not free entry – there is a finite amount of resources. Firms that own the resource earn a scarcity rent. If the resource is priced competitively, then we have zero profits.

We have characterized prices. What about equilibrium quantities?

Demand Side

Demand: $p_t = A_t - BE_t$

Can solve this out for extraction in equilibrium:

$$E_t = [A_t - c_t - \lambda \delta^{-t}] / B$$

Takeaway: extraction gradually falls, and eventually the resource is exhausted. This looks a lot like Hubbert's problem. Maybe we should be alarmed.

Equilibrium Quantities:

So, for two periods, we have a system of five equations (prices from supply side, demand E from demand function, and resource constraint) and five unknowns (p_s , E_s , and λ).

The period 0 demand equation gives:

$$E_0 = [A_0 - c_0 - \lambda] / B$$

From the period 1 pricing equation, we have:

$$\lambda = \delta [p_1 - c_1]$$

$$\lambda = \delta [A_1 - BE_1 - c_1]$$

Substitute in the constraint:

$$\lambda = \delta [A_1 - B(Q_T - E_0) - c_1]$$

Now sub this back into the period 0 demand equation:

$$E_0 = [A_0 - c_0 - \delta [A_1 - B(Q_T - E_0) - c_1]] / B$$

After some algebra:

$$E_0 = [A_0 - \delta A_1 - c_0 + \delta c_1 + \delta Q_T B] / [B(1 + \delta)]$$

Question: An equilibrium is a level of Q_f for all firms, plus a price. Is there one equilibrium?

Answer: No. There is one equilibrium set $\{E_0, E_1\}$, but it is indeterminate how much each firm produces in each period.

- Draw equilibrium on board. No discounting.

Question: We had a similar-looking graph last time. What are the differences?

- No discounting
- Slope comes not from increasing marginal costs but from decreasing demand.

PASTURE 2: COMPARATIVE STATICS

Now we can do comparative statics on the equilibrium.

Comparative static: Technological change

How to model?

Cost reductions.

What is your intuition? Naïve intuition: Cost reductions should reduce price, increase quantity

E_0 and E_1 : sum is fixed, so quantity can't increase

E_0 and E_1 : really depend on the relative cost reductions between the two periods: it still matters when it is more profitable to extract.

If E_0 and E_1 stay the same, then price remains the same, and consumers do not gain at all from cost reduction. Firms capture it all through increase in scarcity rents.

Comparative Static: Exploration.

Question: How to model this?

Answer: An increase in Q_f

This increases E in both periods and decreases price.

Comparative Static: Demand Decreases

e.g. from a recession, a drop in the last period A_1

Unanticipated vs. anticipated:

If unanticipated: Hotelling rule no longer holds ex-post.

If anticipated: Hotelling rule holds and E_0 is higher while E_1 is lower than without demand drop.

Question: What if A drops a lot? Do we have a lower bound on prices?

Answer: Yes, the cost. In that case, there is no scarcity rent.

Talk through this: the constraint doesn't bind, and this is just like a standard good (Odwalla bars) produced at a cost, without some limited factor of production.

Comparative Static: Discount Factor

What if the discount factor decreases (interest rate increases)?

Firms extract more now, less later.

If firms' discount rate different from social discount rate, we are off the optimum.

Social Optimum

Question: Is this the social optimum?

Answer: Yes. There are no market failures.

Dynamic efficiency. Maximize social surplus over periods.

Question: is it "fair" to consume more now? Yes! Intertemporal pareto efficiency.

This is not "sustainable," however: we are going to run out of the resource.

- PowerPoint vignette: Betting the Planet

PASTURE 3: FISHERIES – RENEWABLE RESOURCES

The Biological Model

- Fish population and growth figure

Question: Who can explain this figure?

Question: What is an equilibrium?

Answer: Places where $g=0$, i.e. the y-intercepts

Question: What are the equilibria if no fishing?

Answer: 0, S_{upper} , and S_{lower} .

Question: Which of these are stable?

Answer: 0 and S_{upper}

S_{lower} =minimum viable population

S_{upper} = natural equilibrium, carrying capacity

Question: What is the maximum sustainable yield?

Push question: What is a sustainable yield?

Answer: where exactly the potential growth amount is harvested.

So maximum sustainable yield is the max growth point.

Sustainable yield is s.t. Catch rate=Growth Rate

$g(S^)$ =maximum sustainable yield*

Mathematical model:

$$g=rS(1-S/k)$$

g =growth rate

r =replenishment parameter

k =Carrying capacity

S =amount of fish in fishery

Question: how would you model forests?

Question: What is MSY?

Answer: Maximum of the growth function.

$$Dg/dS = 0 \Rightarrow g_{MSY} = k/2.$$

Combined Biological and Economic Models

Setup:

- Considering only sustainable harvest levels
- Show that:
 - $MSY > \text{Efficient Yield}$

- Market Equilibrium harvest > Efficient harvest

Harvest function: Model harvest as a function of days.

$$h = qES$$

h = Harvest size

E = Days fishing

q = "Catchability coefficient"

S = Stock

- Fish catch per day ~ fish population.

Static Sustainability condition:

$$h = g$$

Find fishing hours at the maximum sustainable yield.

To do this, want E as a function of parameters.

Use the sustainability condition to get S and E in the same equation:

$$qES = rS(1 - S/k)$$

Then re-arrange terms to get S on LHS:

$$S = k(1 - qE/r)$$

Substitute in the harvest function $S = h/qE$:

$$h/qE = k(1 - qE/r)$$

$$h = qEk - kq^2E^2/r$$

Then take $dh/dE = 0$:

$$qk - 2q^2kE/r = 0$$

$$E_{msy} = r/2q$$

Now find the efficient yield:

Profit (net benefit) Function: Revenues - Costs

$$\pi = Ph - aE$$

a = Marginal cost of effort

- price is exogenous.
- Constant marginal cost

Substituting in the sustainability condition:

$$\pi = P(rs - rS^2/k) - aE$$

We still can't take the derivative because S is a function of E:

$S=h/qE$ from the harvest function

Optimum: Want the point that maximizes π , i.e. maximizes revenues – costs.

$$\pi = PqkE - Pkq^2E^2/r - aE$$

$$d\pi/dE = 0 = Pqk - 2Pkq^2E/r - a$$

$$MR = MC$$

Solve for efficient effort:

$$E^e = r/(2q) [1 - a/(Pqk)]$$

- Draw graph of this

Question: Is the MSY also the static sustainable efficient level?

Answer: No – only if MC of effort is zero. Otherwise, want to keep more fish in the sea so that it is easier to catch them.

Mathematically, you can see that $E^e > E_{msy}$

Comparative static: Question: what happens with Reduction in marginal costs.

Answer: This flattens the total cost line.

Increases efficient fishing days E^e and increases π .

Question: what happens with a positive discount rate?

Answer: We would fish more early until we reached a sustainable population that is at a lower level of population and profits than the static efficient

PASTURE 4: FISHERIES IN MARKET EQUILIBRIUM

A sole owner of the fishery will maximize profits.

If there is free entry, profits will drop to zero. Setting the above profit function to 0, we have:

$$\pi = PqkE - Pkq^2E^2/r - aE = 0$$

$$E = (Pqk - a) r / (Pq^2k)$$

$$E_{zp} = r/q [1 - a/(Pqk)]$$

This is twice the level of the revenue-maximizing effort: compare to above.

- Question: How to see this on the graph? Zero profits => Total Revenue = Total Cost.

Question: Is it right to *assume* the static sustainability condition?

- Discounting may not be zero
- There's no reason to assume that the optimum or the market equilibrium will give static sustainability.
- Could also do this as a maximization problem.

Question: Why is this not the efficient level?

Answer: Entrants are imposing an externality on existing fishermen and on future fishermen. Although if we wrote this down as a profit function, there is no contemporaneous externality in this model because marginal costs and prices are constant – there would in principle be infinite entry because the profit function is not concave.

Notice that there *is* a contemporaneous externality conditional on the sustainability condition.

The efficient solution might exhaust the fishery. The condition needed if the population growth rate is lower than the discount rate and the costs of extracting the last unit are sufficiently low.

PASTURE 5: POLICY CONSEQUENCES

So we are much more concerned about common property resources. What should we do?

- Monopoly ownership
 - If the monopolist has market power in the output (fish) market, this causes a distortion.
 - There might also be equity concerns.
- Taxes
 - These can generate the efficient outcome, but industry objects if revenue not recycled.
- ITQs
 - How to allocate?
 - Also some operational problems:
 - by-catch – what happens if you catch a restricted fish while you were trying to catch an unrestricted fish?
 - High-grading: catch the best fish, throw the bad ones back. But throwing back causes mortality, which hurts the fishery.
- Raising the cost of fishing: prohibiting use of newest nets, prohibit fishing near shore. But this is inefficient.
- Limitations on fishing seasons:
 - People buy larger boats

Questions I don't know the answer to: Why don't more fisheries consolidate? Why don't bargaining solutions arise more naturally?

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