The Green Paradox
A Hotelling *Cul de Sac*

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Carbon Tax

- CO_2 emissions → climate change
- More or less proportional to fossil fuel use
- *Marginal damages* increase through time
- Conventional policy proposal:

  increasing, Pigovian tax per unit

The Hotelling Paradox

- Hotelling's rule: to maximize NPV, produce s.t. marginal net benefit rises at the interest rate
- Rising tax → revise: ↑ present, ↓ later
- Paths of *p* and *q* "tilted"
- Paradox: tax *increases* current emissions
- High, decreasing tax?

Stock Effect

- The paradox holds for a Hotelling model in which marginal cost increases as a function of the depletion of reserves: Hans-Werner Sinn
- Considered to be general

Hotelling Equilibrium

- Sectorial: pools reserves; with some exceptions decisions made for the aggregate
- Paths (q(t),p(t)) simultaneously determined

Shortcomings

1. no sunk capital (exploration & development)
2. no constraint to “tilting” output
3. reserves aggregated in decisions

Simple Change

Industrial rather than Consumptive

1. Reserves distinct; decisions by separate firms
2. Discrete, sunk investments → $q(0)$
3. *Natural decline* $q(t) = K \exp(-\alpha(K)t)$
4. "Tilt", $-\alpha(K)$, given by geology & investment

Away from Hotelling

- Incentives apply to and decisions are made at individual reserves

a. Tax affects incentives, decisions
b. Partial equilibrium: given path *p(t)*
c. Simplified, simulated
d. Capital *K* invested at start; unit price *P*

Present Values

- Expressions simplified: enhanced recovery
- $q(0) \propto K$
- $V(K, T, \{\tau\}) = -E - PK$

$$+ \sum \{p_t q_t - [a q_t + bK] - \tau_t q_t\} e^{-rt}$$

- Of carbon damages from emissions
- $D(K, T, \{\tau\}) = \sum d_t \, q_t e^{-r_d t}$, $r_d \neq r$?
- Of taxes
- $G(K, T, \{\tau\}) = \sum \tau_t q_t e^{-rt}$

Conditions

- Variable profits (in braces) ≥ 0
- NPV to firm ≥ 0 (total sunk cost *E* + *PK* must be recovered from discounted net revenues)
- *Shadow* value of capacity *v(t)* > 0 on an interval (produce up to geological constraint):

$$P = \sum_{t=1}^{T} v(t)e^{-rt}$$

Variable & Fixed

- Variable (as tax varies):

  initial extraction $q(0) = K$, investment; productive life of reserve T;

  ultimate recovery, $\int q(t)\, dt$

- Fixed:

  properties of initial reserve

Valid Comparisons?

- A lot of changes. What else must be held fixed to provide equal tax "effort"?

1. Share of rents $G(K,T,\{\tau\})/V(K,T,\{\tau\})$?
2. Total rents over positive paths of τ_t?
3. Government's take: $G(K,T,\{\tau\}) = \alpha V(K,T,\{0\})$?

The Choice

- We choose no. 3, NPV of tax (50% of social value gross of damages before tax)
- Equal effort literally true of only one reserve for a given path of the tax
- A good choice? There *is* no good choice:

  this is a problem with Hotelling model pinpointed by partial eqm. model

Predicted Effects of Royalty

- Reduction in exploration
- Decrease in investment and initial production
- Delay of investment in enhanced recovery
- Decreasing royalty has lower investment than increasing (as predicted)
- Ultimate recovery increased for decreasing royalty and decreased for increasing royalty (“sort of” predicted)
- Life of reserve longer for decreasing royalty
- Rent to firm tends to be lower for decreasing royalty

Partial Weakness

- Decisions at reserve level: *partial* equilibrium
- Sectorial Equilibrium? Price?
- IAMs need many strong assumptions
- Simpler: let price obey paradox's predictions, proceed as before
- Valid?

Partial-Sectorial Model

- Guesses about price path
- Benchmark: 1.5% increase in price with no tax
- tax ↑ at 3% → 2% ↑ in *p*
- tax ↓ at 3% → 1% ↑ in *p*
- Results broadly similar
- Company prefers rising royalty

Unexpected

- *Strong* green paradox if tax → ↑ $D(K,T,\{\tau\})$
- Yes, if decreasing tax and social $r_d = 0.014$ (Stern) while private $r = 0.08$:
- Why? Increase in ultimate production, almost negligible discounting
- Should we discount at different rates?

CBA

- Many taxes fail a *cost-benefit* test

  DWL of tax (resource) more than offsets gain from reducing CO2 damages (environmental)

  – *taxes that pass: **increasing,** with low discounting of damages*

Paradox Unrealized?

- Tax does not affect current production; does affect investments, new & enhanced
- Suppose minimal effect on *r* in g.e.
- Exploration decreases at each prospect
- Each new reserve has smaller investment
- Must be a large and continuing backward “tilt” of sinking cost at marginal exploration and development projects now facing a lower price
- Timing?

Efficient Policy

- Paradox meaningless when consider technology
- Likely the increasing tax is superior: Pigovian, minimizes DWL
- Source of recent decrease in price:

  high price → change in technology → entry