The Green Paradox
A Hotelling *Cul de Sac*

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Carbon Tax

• $\text{CO}_2$ emissions $\rightarrow$ 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 $\rightarrow$ 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 $\rightarrow q(0)$
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
- $q(0) \propto K$
- $V(K, T, \{\tau\}) = -E - PK$
  
  $$+ \sum \{ p_t q_t - [a q_t + b K] - \tau_t q_t \} e^{-rt}$$

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

• 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 $\rightarrow$ change in technology $\rightarrow$ entry