Green Paradox or Gray Normalcy?

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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:

  Pigovian tax per unit (a royalty), increasing

The *Hotelling* Paradox

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

Shortcomings of Hotelling Model

1. no sunk capital (exploration & development)
2. no constraint to “tilting” output (capacity)
3. all reserves aggregated
4. everything smooth

Reality

1. Reserves distinct, heterogeneous
2. Large, specific, sunk investments: choose $q(0)$
3. Natural decline $q(t) = q(0)\exp(-at)$

   Tilt, $-a$, given by geology

Model of Partial Equilibrium

- Incentives & decisions at individual reserves

a. Pigovian tax affects incentives, decisions
b. Partial equilibrium: given path *p(t)*
c. Simplified, simulated

Conditions

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

$$P = \int_0^T v(t)e^{-rt}\,dt$$

Valid Comparisons?

- Effects of a dynamic royalty (constant, increasing or decreasing)
- What held fixed to provide equal tax “effort”?

1. Share of rents?
2. Total rents over positive paths of tax?
3. Government’s take as a proportion of initial NPV?

The Choice (?)

- We choose no. 3, NPV of royalties (50% of social value gross of damages before royalty)
- Literally can be true for only one reserve for a given path of the royalty
- A good choice?

Effects of Any Royalty

- Reduction in exploration
- Decrease in investment and initial production
- Delay of investment in enhanced recovery

Decreasing vs. Increasing

- Decreasing royalty has lower investment than increasing (sort of predicted), greater ultimate recovery (not really predicted)
- Ultimate recovery increased for decreasing royalty and decreased for increasing royalty
- 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???
- IAMs need strong assumptions: Pindyck
- Simpler: let price obey paradox's predictions
- Valid?

“Partial-Sectorial” Model

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

Unexpected

- Strong green paradox: royalty ↑ NPV of damages
- Yes, if decreasing royalty and r_d = 0.014 (Stern) while r = 0.08: increase in ultimate production, slower but negligible discounting
- Should we discount at a different rate?

CBA

- Many royalties fail a cost-benefit test:

  DWL of royalty offsets gains from internalizing damages

- pass: increasing royalty with low discount of damages

Paradox Realized?

- Royalty does not affect current production; does affect investments in enhanced production
- 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 sunk cost at marginal exploration and development projects now facing a lower price
- Timing?