On optimal extraction under asymmetric information over reclamation costs

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Background and research questions

Background:
- Funds for reclamation are often insufficient
- Reclamation payment is the present reclamation cost
- Reclamation cost is private information
- Future reclamation cost is estimated by the firm

Research questions:
- How to design regulation including the contract between the regulator and the firm that gives the highest possible (expected) net benefits to the society?
- Properties of the regulation. In particular, how is pollution tax affected by firm’s private information?
Exhaustible resources and asymmetric information:

- Extraction cost is private information: Gaudet et al. (1995) and Osmundsen (1995)
- Initial resource stock is private information: Osmundsen (1998) and Martimort et al. (2018)

Reclamation:

- Yang and Davis (2018)
Extraction stage regulation: pollution tax $\Gamma$ and production horizon $T$; reclamation payment

Reclamation contract: reclamation effort $R$ and monetary transfer $M$
Reclamation contract

Regulator’s problem is to

$$\max_{\{R(\theta), M(\theta)\}} \int_{\theta}^{\bar{\theta}} (-D(n_T - R(\theta)) - C(R(\theta), \theta) - \lambda M(\theta)) f(\theta) \, d\theta$$

subject to the incentive compatibility constraint

$$-C(R(\theta), \theta) + M(\theta) \geq -C(R(\hat{\theta}), \theta) + M(\hat{\theta}) \quad (1)$$

for all $$(\theta, \hat{\theta}) \in \Theta^2$$, and the participation constraint

$$W(\Gamma, T) + [-C(R(\theta), \theta) + M(\theta)]e^{-rT} \geq 0 \quad \text{for all} \quad \theta \in \Theta \quad (2)$$
Optimal reclamation effort: illustration

Higher the firm’s cost type is, the smaller is the required reclamation effort.
The optimal transfer of the contract satisfies the following conditions:

\[ M'(\theta) < 0 \quad \text{and} \quad M(\theta) = C(R(\bar{\theta}), \bar{\theta}) - W(\Gamma, T)e^{rT}. \]

- High cost type receives a smaller transfer; low cost type receives the largest
- Net benefit of reclamation is negative and the total payoff zero for the highest cost type
- Total payoff is highest for the lowest cost type
Extraction stage: optimal regulation

Regulator’s optimization problem at the extraction stage is to

\[
\max_{\{q(t), T\}} \int_0^T \left( U(q(t)) - G(q(t), X(t)) - D(N(t)) \right) e^{-rt} \, dt + S(N(T), T)
\]

subject to

\[
\begin{align*}
\dot{X}(t) &= -q(t), \quad X(0) = x_0, \quad X(T) \geq 0, \quad (3) \\
\dot{N}(t) &= \alpha q(t) - h(N(t)), \quad N(0) = 0, \quad N(T) \geq 0, \quad (4) \\
q(t) &\geq 0. \quad (5)
\end{align*}
\]

Optimal shut-down date and the tax:

- Shut-down date: benefit of waiting with the shut-down equals the cost
- Pollution tax is the negative of the shadow value of the pollution stock (current value)
First-best vs. second-best pollution tax

The pollution tax under asymmetric information over reclamation costs can be higher or lower than the pollution tax under complete information.

Intuition: suppose low reclamation cost is the true type

- First-best: low cost firm can be allowed to pollute more. Low tax
- Second-best: true type is not known; decision is based on expected value. Higher tax should be used to protect against possibly high reclamation cost
Why not exclude some types?

The cut-off type:

- The type for which the society’s total present value of extraction payoff equals the present value of the reclamation contract
- If the cut-off type exists, then extraction is not allowed for higher cost types
Conclusion

Benefits of the optimal contract and regulation:

1. Saves public funds
2. Improves the state of environment
3. Too expensive sites are not permitted

Thank you!

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