Environmental Policy under Imperfect Information: Incentives and Moral hazard

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Introduction

- Env.Policy Implementation can be achieved through different instruments (control agency).
- Any implementation system can be assessed according to a number of criteria:

1. Static Efficiency
2. Maintain a predetermined set of env. standards when changes in exogenous parameters take place
3. Provide incentives to the adoption of new clean technologies
4. Satisfaction of distributional or ethical notions
5. Informational requirements for the use of the implementation system
6. Cost of *monitoring* whether potential polluters comply with the given system and cost of *enforcing* the system in the presence of violators

Environmental Policy under Imperfect Information: Incentives and Moral hazard

- A situation implies Moral Hazard when:
  - Each discharger's net emissions or abatement efforts are not observable, while the outcome of all discharger's combined efforts is observed.

- Objective of the paper:
  - Design instruments (**CONTRACTS**) for achieving environmental targets when there is limited information with respect to individual net emissions or abatement efforts.

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- Terms of the contract:
  - The dischargers as a group are subsidized for abating pollutants
  - The amount of subsidy depends on: the deviations between the desired concentration levels and the measured levels at the receptor point.
  - The smaller the desviations the greater the subsidy to be distributed
  - When the desired standard is exceeded one or more dischargers are liable for a fine, while the rest receive subsidies
- Problems: Collective penalties might place financial strain on the whole group of firms.

A Dynamic Optimal Allocation Model

- Consider an economy with $i = 1, \ldots, n$ producers
- Producer i produces output using labor and capital (only one good)
- Output production generates pollution
- Good can be consumed or accumulated as capital in output production or pollution abatement processes

A Dynamic Optimal Allocation Model

- $Y_i(t)$ = total output by producer i at time t
- $\overline{c}(t)$ = per capita consumption at t
- $K_i^P(t), K_i^a(t)$ = total capital employed in output production and pollution abatement respectively
- $L_i^p(t), L_i^a(t)$ = total labor
- $L(t) = \sum_i (L_i^p(t) + L_i^a(t))$
- $I_i^P(t), I_i^a(t)$ = gross investment
- $P_i(t)$ = total pollution
- $A_i(t)$ = total pollution abated
- $E_i(t) = P_i(t) - A_i(t)$ = net emission of the pollutant
- $W(t)$ = ambient concentration of the pollutant
- $Q(t)$ = index of environmental quality at t
- $N(t)$ = population in the economy at t
- d = exponential depreciation rate of the capital stock
- γ = exponential natural pollution decay rate
- h = exponential rate of population growth

- Producers output:
  - $Y_i(t) = f_i[K_i^P(t), L_i^p(t)]\ \ \forall i$ (Concave twice differentiable and time invariant)
- Producer i's net capital formation is
  - $\dot{K}_i^P = I_i^P(t) - K_i^P(t),\ \ K_i^P(0) = K_i^{P0}\ \ \forall i$
  - $\dot{K}_i^a = I_i^a(t) - K_i^a(t),\ \ K_i^a(0) = K_i^{a0}\ \ \forall i$
- Lower bounds for gross investment undertaken by any producer
  - $0 \leq I_i^P(t) \leq \bar{I}_i^P\ \ \forall i$
  - $0 \leq I_i^a(t) \leq \bar{I}_i^a\ \ \forall i$

- Total output is located among consumption and gross investment
  - $\sum(Y_i(t) - I_i^P(t) - I_i^a(t)) - N(t)\overline{c}(t) \geq 0$
- Total labor force is a constant fraction of total population
  - $L(t) = \alpha N(t) = \alpha N(0)e^{ht}$
- Assuming Labor mobility among processes,
  - $\alpha N(t) - \sum_i (L_i^p(t) + L_i^a(t)) \geq 0$
- Producer i's output production generates pollution according to a strictly increasing convex and twice differentiable function,
  - $P_i(t) = P_i[Y_i(t)] \ \ \forall i$

- Pollution can be abated according to an abatement function independent of the ambient concentration of the pollutant
  - $A_i(t) = A_i[K_i^a(t), L_i^a(t)], \ \forall i$ (A_i has positive first derivatives, is concave and twice differentiable)
- Net emission at time t
  - $\sum_i E_i(t) = \sum_i \{P_i[Y_i(t)] - A_i[K_i^a(t), L_i^a(t)]\}$
- Ambient concentration of the pollutant at each t
  - $W(t) = W(0) + \int_0^t [\sum_i E_i(\tau) - \gamma W(\tau)] \, d\tau$
- The ambient concentration should never exceed some exogenously predetermined level
  - $\overline{W} - W(t) \geq 0$
- The economy's criterion function over a given time horizon,
  - $\int_0^t e^{-st} N(t) U[\overline{c}(t), Q(t)] dt$

- The current value Lagrangian for the problem is

$$\begin{aligned}
&\pounds\left(K^j, W, \bar{c}, I^j, L^j, p_i^j, \lambda, \mu, \nu, \kappa\right) \\
&\quad = N(t)U[\bar{c}(t), Q(t)] + \sum_i p_i^{\mathrm{p}}(t)[I_i^{\mathrm{p}}(t) - dK_i^{\mathrm{p}}(t)] \\
&\qquad + \sum_i p_i^{\mathrm{a}}(t)[I_i^{\mathrm{a}}(t) - dK_i^{\mathrm{a}}(t)] + \lambda(t)\left[\sum_i E_i(t) - \gamma W(t)\right] \\
&\qquad + \mu(t)\left[\sum_i (Y_i(t) - I_i^{\mathrm{p}}(t) - I_i^{\mathrm{a}}(t)) - N(t)\bar{c}(t)\right] \\
&\qquad + \nu(t)\left[lN(t) - \sum_i (L_i^{\mathrm{p}}(t) + L_i^{\mathrm{a}}(t))\right] + \kappa(t)(\widetilde{W} - W(t)) \\
&\qquad\qquad j = \mathrm{a}, \mathrm{p}, \quad (2.11)
\end{aligned}$$

- Optimal investment policy:
- If $P_i^j(t) = \mu(t)$, then $\widehat{I}_i^j(t) \in [0,\overline{I}_i^j] \;\; \forall i,j$
- If $P_i^j(t) > \mu(t)$, then $\widehat{I}_i^j(t) = \overline{I}_i^j \;\; \forall i,j$
- If $P_i^j(t) < \mu(t)$, then $\widehat{I}_i^j(t) = 0 \;\; \forall i,j$

- Society's valuation of optimal abatement is
  - $SB(t) = \lambda(t) \sum_i \widehat{A}_i(t)$
- Society's valuation of optimal net emissions is
- $SC(t) = \lambda(t) \sum_i \widehat{E}_i(t)$

- when individual monitoring is not possible, the agency observes only $W(t)$, which could be compared to the optimal path $\widehat{W}(t)$.Deviations cannot be attributed to a specific discharger.
- Solution: Efficient Contracts
- Efficient: It induces the dischargers to adopt optimal abatement policy in the absence of effective monitoring.
- Total subsidy:

$$\sum_i b_i(t) = SB(t) - TR = RSB$$

- The discharger's profit:

$$\Pi_i(b_i, A_i) = \Pi_i^0 + b_i - C_i(A_i)$$

- Condition for efficient contracts: A system of subsidies $\widehat{b}_i$, i=1,...,n is PO if there do not exist subsidies b_i^* and abatement levels A_i^* such that:
  - $\Pi_i(b_i^*, A_i^*) \geq \Pi_i(\widehat{b}_i, \widehat{A}_i) \;\; \forall i$
- Note that $A_i^* \in [0, \widehat{A}_i)$ denote the cheating abatement and $\widehat{A}_{-i} = (\widehat{A}_1, ..., \widehat{A}_{i-1}, \widehat{A}_{i+1}, ..., \widehat{A}_n)$the vector of optimal abatement levels of $-i$
- PO implies that

$$\Omega = \Pi_i(b_i^*, A_i^*, \widehat{A}_{-i}) - \Pi_i(\widehat{b}_i, \widehat{A}_i, \widehat{A}_{-i}) < 0 \quad \forall A_i^* \in [0, \widehat{A}_i)$$

- and

$$\lambda(t)\frac{\partial W(\widehat{A}_i, \widehat{A}_{-i})}{\partial A_i} = \frac{\partial C(\widehat{A}_i)}{\partial A_i} \text{ where } W(\widehat{A}_i, \widehat{A}_{-i}) = \widehat{W}$$

- In the presence of deviations, a contract that does not involve fines but only subsidies is not efficient.
- **Contract A:** The discharger receives the full amount of subsidy if ambient concentration standards are met; if not, the subsidy is reduced according to the valuation of excess concentration of the pollutant.
  - if $W(t) = \widehat{W}(t)$, then $b_i = \widehat{b}_i(t) = \phi_i RSB(t)$ where $\phi_i = \frac{\widehat{A}_i}{\sum_i \widehat{A}_i}$
  - if $W(t) > \widehat{W}(t)$, then $b_i = b_i^*(t) = \phi_i [RSB(t) + \Gamma(t)]$ where $\Gamma(t) = \lambda(t)(W(t) - \widehat{W}(t))$
- Efficiency requires

$$[C(\widehat{A}_i) - C(A_i^*)] + \phi_i \Gamma(A_i^*, \widehat{A}_{-i}) < 0$$

- In words, the cost saving from cheating is lower than the subsidy losses
- However, if the opposite happens then the discharger will never follow the optimal policy

- **Contract B:** The discharger receives the full amount of subsidy if ambient concentration standards are met; if not, the subsidy is reduced according to the valuation of excess concentration of the pollutant.
  - if $\Gamma(t) = 0$, then $b_i = \widehat{b}_i(t) = \phi_i RSB(t)$ where $\phi_i = \frac{\widehat{A}_i}{\sum_i \widehat{A}_i}$
  - if $\Gamma(t) < 0$, then
  - $b_i = b_i^*(t) = \begin{cases} -F_i & \text{whit probability } \xi_i \in (0,1) \\ \widehat{b}_i + \phi_i'[\widehat{b}_m + F_m + \Gamma(t)] & \text{whit probability } 1 - \xi_i \end{cases}$ $\phi_i[RSB(t) + \Gamma(t)]$
- For $\Gamma(t) < 0, \sum_i b_i^*(t) = -F_m + \sum_i \widehat{b}_i + \sum_i \phi_i'[\widehat{b}_m + F_m + \Gamma(t)] = RSB + \Gamma(t), i \neq m$. The contract exhausts the available amount.

- Pareto Optimality requires

$$\Omega_i = \{-\xi_i F_i + (1-\xi_i)[\hat{b}_i + \phi_i'(\hat{b}_m + F_m + \Gamma(A^*, \hat{A}_{-i}))] - C_i(A_i^*)\} - [\hat{b}_i - C_i(\hat{A}_i)] < 0. \tag{3.5}$$

- Since Ω_i is strictly decreasing function of F_i, there should be a fine $\widehat{F}_i \in (0, +\infty)$ such that $\Omega_i(\widehat{F}_i) < 0$. Therefore Contract B is efficient.

- If the contract scheme is supplemented by sample monitoring of individual dischargers, then the fine could be lower.
- However, the efficiency of the contract does not depend on catching the violator
- As long as the fine are sufficient to make expected profits under cheating lower than under optimal abatement, the contract is PO
- Therefore, the efficiency depends upon making suboptimal abatements levels unprofitable.