Incentive-based Subsidy and Tax for Efficient Generation Investment

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Introduction

System operator: Social welfare maximiser

$$\max_{\text{Price}}(\text{Consumer surplus} + \text{Producer surplus} + \text{Merchandising surplus} - \text{Externalities}).$$

Producer i: Profit maximiser

$$\max_{\text{Output}} \text{Producer surplus}_i(\text{Price}, \text{Output}_i).$$

- Small number of producers - market power
- No consideration for externalities such as pollution

There is a mismatch in desired outcomes. Regulation can address this[1].

[1] Loeb, M. & Magat W. A., 1979. "A Decentralized Method for Utility Regulation," J Law and Econ.

Outline

- Organisation
- Producers, consumers and merchant
- Need for regulation and problems with price caps
- Proposed regulatory scheme
- Conclusion - Properties of the scheme

Organisation

- Regulatory phases (denoted by τ) - investment
- Spot market - production and consumption
- Producers - Generators, Oligopoly (denoted by i)
  - Investment in generation capacity in regulatory phases
  - Generation in the spot market
- Consumers - Loads, Continuum
  - Consumption in the spot market
- Merchant - Transmission System Operator, Monopoly
  - Investment in transmission capacity in regulatory phases
  - Follows generator's investment decision
  - Transmission capacity connects buses (denoted by j)

Producers - Investment and Pollution

- Investment in generation capacity made during τ, $k_{ij} \geq 0$
- Generation capacity at τ, $\sum_{\tau' \leq \tau} k_{ij}$
- Production in spot market limited by capacity investment in regulatory phases - dependence on production can be transferred to capacity

- Pollution attributed to generation[2]
- Pollution depends upon choice of technology
- Pollution abatement, e_{ij}
- Pollution production, $x_{ij} := x_{ij}(k_{ij}, e_{ij})$ - non-decreasing in k_{ij}, non-increasing in e_{ij}
- Externality associated with pollution, $E_{ij} := E_{ij}(x_{ij})$

[2]Kim, J. C. & Chang, K. B., 1993. "An optimal tax/subsidy for output and pollution control under asymmetric information in oligopoly markets," J Regul Econ.

Producers - Cost and Revenue

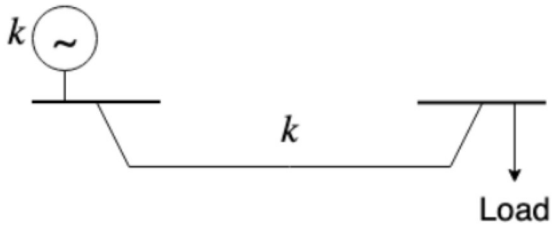
- Cost of generation, $C_{ij} := C_{ij}\left(\sum_{} k_{ij}; \sum_{} e_{ij}\right)$
- Total cost of generation, $\sum_{} C_{ij}$ - non-decreasing
- Cost of investment, $C^{G}_{ij} := C^{G}_{ij}(k_{ij}; e_{ij})$ - increasing
- Total cost, $\sum_{} C_{ij} + C^{G}_{ij}$ - convex

- Revenue, $R^{G}_{ij} := R^{G}_{ij}\left(\sum_{} k_{ij}\right)$
- Total revenue, $\sum_{} R^{G}_{ij}$ - non-decreasing

Consumers & Merchant

- Utility, $U_{\square} := U_{\square}\left(\sum_{\square} k_{\square}^{0} | \forall i^{0}\right)$ - non-decreasing and concave

- Cost of investment in transmission capacity, $C^{\mathrm{T}}_{\square} := C^{\mathrm{T}}_{\square}\left(\sum_{\square} k_{\square}^{0} | \forall i^{0}\right)$ - non-decreasing
- Total cost, $\sum_{\square} C^{\mathrm{T}}_{\square}$ - convex



System operator:

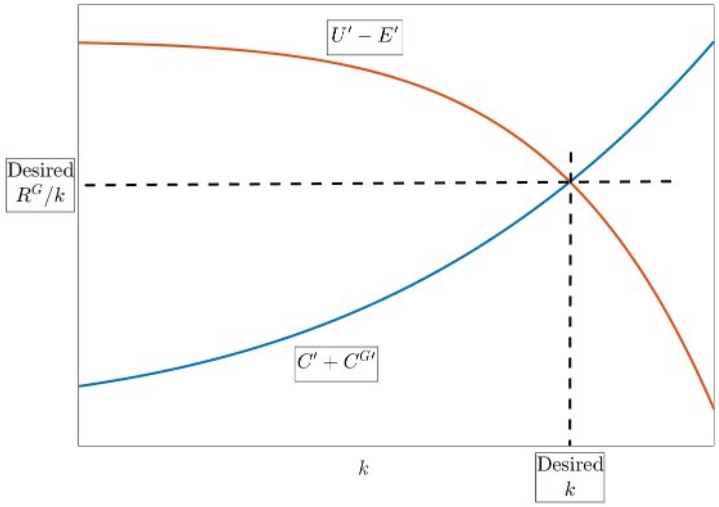
$$\max_{\quad} \sum \quad U - C - C^{G} - C^{T} - E \quad . \tag{1}$$

Generator i:

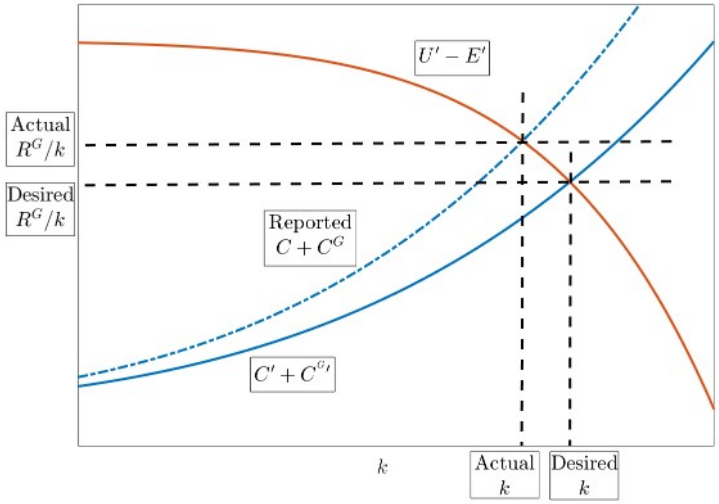
$$\max_{\quad} \sum \quad R^{G} - C - C^{G} \quad . \tag{2}$$

- Market power - generators suppress output to increase prices and hence, revenue
- No consideration for pollution

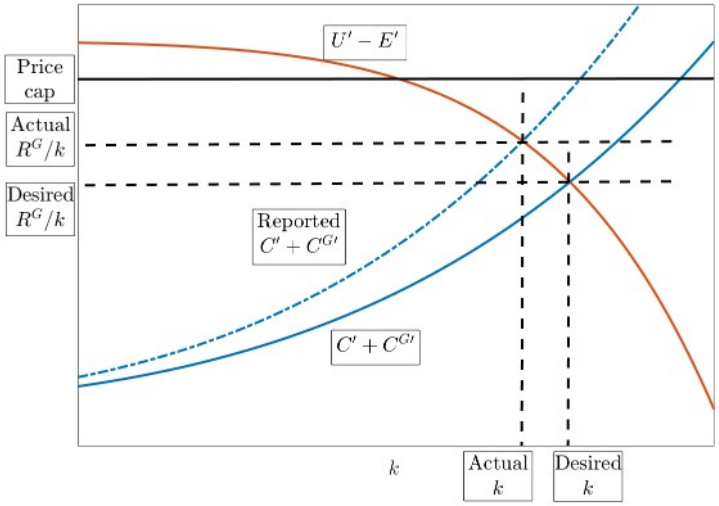
Social Welfare Optimisation - Illustration



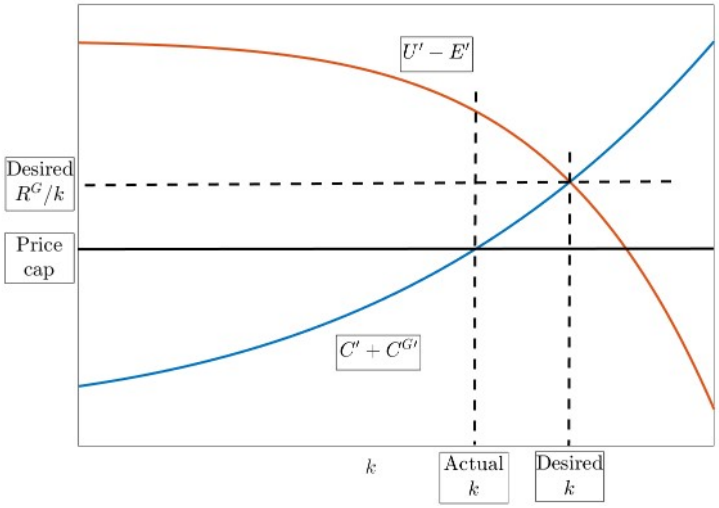
Market Power - Illustration



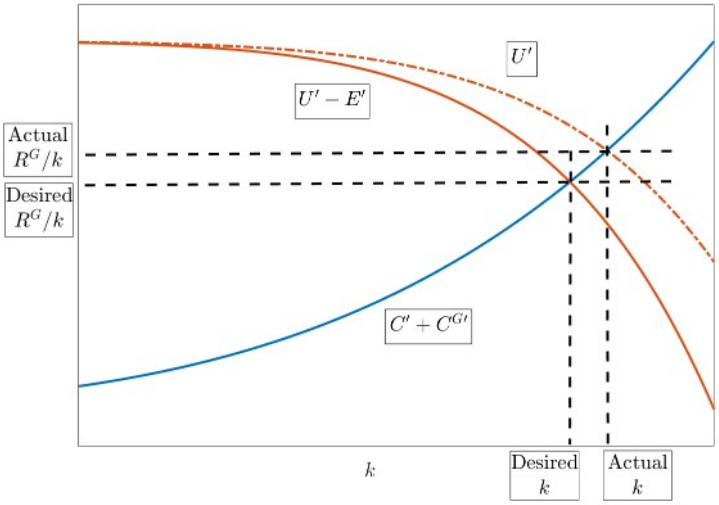
High Price Cap - Illustration



Low Price Cap - Illustration



Externality - Illustration



Proposed Regulatory Scheme

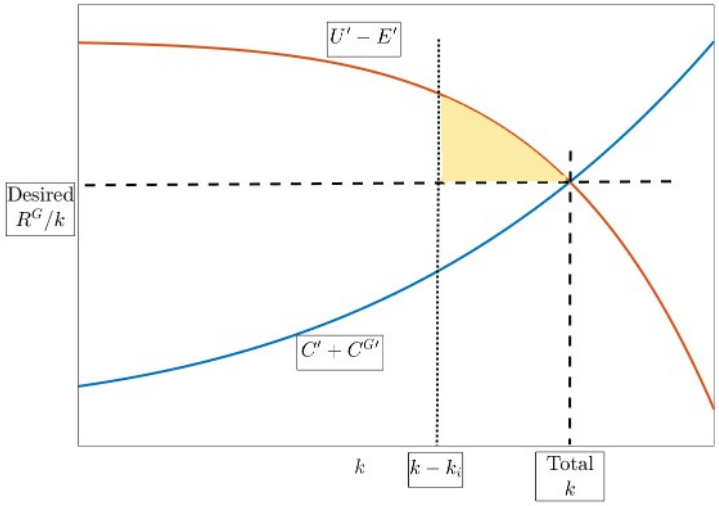
Regulator provides generators with

$$\phi_g = U_g \Big(\sum_{i'} k_{i'} - \sum_{i' \neq i} k_{i'} \Big) - C_g^{\mathsf{T}} \Big(\sum_{i'} k_{i'} + \sum_{i' \neq i} k_{i'} \Big) - E_g \Big(\sum_{i'} k_{i'} + \sum_{i' \neq i} k_{i'} \Big) - R_g^{\mathsf{G}} - F_g \quad (3)$$

where F_g is a fixed fee[3].

[3] Hesamzadeh, M.R. & Rosellón, J. & Gabriel, S.A. & Vogelsang, I., 2018. "A simple regulatory incentive mechanism applied to electricity transmission pricing and investment," Energy Econ, Elsevier.

Regulatory Scheme - Illustration



Properties of the Scheme

- The scheme is non-discriminatory.
- The regulator does not require information about the generators' cost functions.
- The subsidy of a generator decreases with increase in other generators' capacities.
- A Cournot equilibrium exists.
- The subsidy received is positive when there is a gain in social optimum, making participation voluntary.
- The regulator has to fund this scheme. However, the increase in consumer surplus and merchandising surplus due to the scheme is less than the subsidy.
- The subsidy encourages collusion.

- The scheme encourages generators to maximise social welfare.
- It is within the market framework.
- It incentivizes capacity investments.
- It eliminates market power.
- It encourages pollution abatement.
- Auxiliary schemes are required to solve the funding problem and address collusion.

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