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Strategic relationships in resource markets II

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The bilateral resource monopoly

- The buyer side
  - Policies such as R&D programs, fuel taxes, or climate agreements imply coordinated action on the buyer side
  - Monopsony power follows
  - It is not natural to think that policies are designed before the market opens (as in DGS 1983)

- The seller side
  - Coordination of actions (cartel)
  - Incentive to distort policies to own advantage
  - “demand management” through supplies

The nature of the problem

"We've got almost 30 percent of the world's oil. For us, the objective is to assure that oil remains an economically competitive source of energy. Oil prices that are too high reduce demand growth for oil and encourage the development of alternative energy sources" (Adel al-Jubeir, foreign policy adviser of crown prince Abdullah of Saudi Arabia, Herald Tribune, Jan 24, 2007).

The nature of the problem

- Not an open bargaining situation
  - Explicit contracts are not conceivable in this context
  - Leadership on the seller side: DGS 1983, Gallini et al. 1983, Hoel 1983
  - Analysis of commitment: Lewis et al. 1986
  - MPE: Harris&Vickers 1995
  - Large literature on strategic Pigouvian taxation: reviewed in Liski&Tahvonen 2004

- These approaches may not capture what is material in the relationship
  - The idea of "demand management"
  - The purpose of this lecture is to capture this by building on Gerlagh&Liski 2011, JET

The problem

How much of the resource should be used before the transition towards the substitute is initiated?

- Symmetric information
  - Resource stock is public information
  - Will be relaxed
- Strategic interaction
  - One buyer, one seller
- Substitute
  - Backstop technology
  - adjustment delays
  - always available
  - Infrastructure interpretation

The problem

- Agent 1: Buyer (government)
  - Flow payoff u(q) from consumption q. dS/dt=-q
- Agent 2: Seller (monopoly)
  - Flow payoff π(q) from sales
- Connection between the two payoffs
  - $u(q)=\tilde{u}(q)-\tilde{u}'(q)q$ and $\pi(q)=\tilde{u}'(q)q$

- Strategies
  - $d_t=\{0,1\}$ for buyer
  - q_t for seller
- States
  - continuation: strategic interaction
  - interim: lasts k units of time
  - long-run: substitute surplus $\bar{u}$ (exogenous)

The problem

- No discounting. The payoffs determined as excursions above the long-run payoffs
- Seller's payoff: $$V(s_t) = \int_t^{T+k} \pi(q_\tau) d\tau$$
- Buyer's payoff: $$W(s_t) = \int_t^{T+k} [u(q_\tau) - \overline{u}] d\tau,$$
- Social surplus: $$\mathcal{W}(s_t) = V(s_t) + W(s_t) = \int_t^{T+k} [\widetilde{u}(q_\tau) - \overline{u}] d\tau$$

The first best

- Social surplus at T:

$$\mathcal{W}^I(s_T) = \int_T^{T+k} [\widetilde{u}(q_\tau) - \overline{u}] d\tau$$

- Optimal consumption solves:

$$\max_{\{q_\tau, T\}} \int_t^T [\widetilde{u}(q_\tau) - \overline{u}] d\tau + \mathcal{W}^I(s_T).$$

- Subject to the resource constraint, $ds_t/dt=-q_t$

The social first best

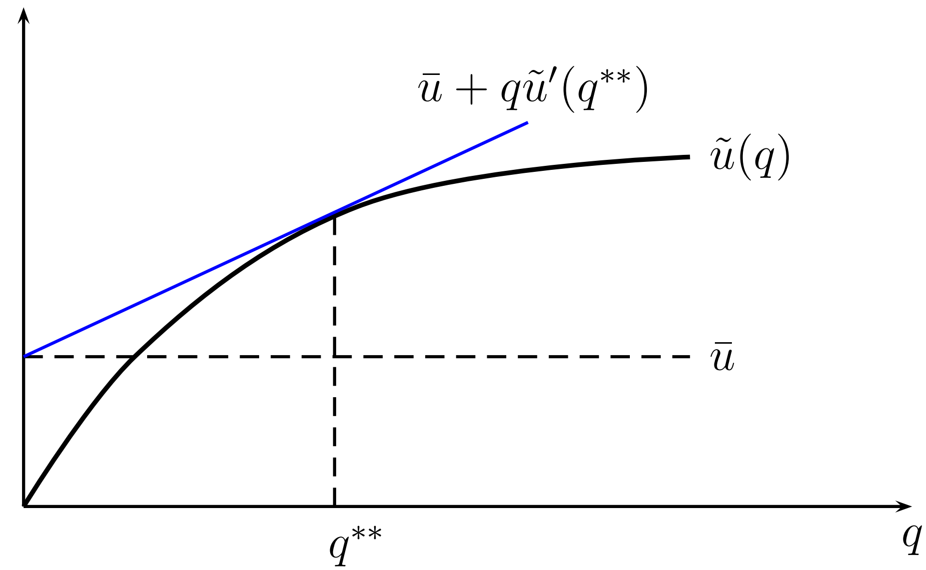


Figure 1: Determination of socially optimal supply

Buyer’s and seller’s preferred outcomes

- The seller’s first best: solve as above but replace utility with surplus flow u(q)
  - Buyer would like to consume faster, $q^*>q^{**}$
  - Reason: in the social optimum, the buyer receives only the long-run surplus $u(q^{**})=\bar{u}$ at all t.
- The seller’s first best: spread supplies as thinly as possible over time
- In the game that we analyze next, the outcome is in between these extremes

The game

- {1,…,N} discrete periods. Stopping period M≤N.
- Time is continuous but actions can be taken at time points $t_i=\varepsilon(i-1)$
- Timing each period t_i
  1. Seller offers q_t
  2. Buyer chooses $d_t=\{0,1\}$
  3. Market clears in state $d_t=0$ for the next ε units of time, or stopping payoffs realized
- Final outcome (h_M,M) $$h_M = (q_{t_1}, q_{t_2}, \ldots, q_{t_M}) \in \mathbb{R}_+^M$$
- Seller's strategy $$Q = \big(Q_1(\cdot), Q_2(\cdot), \ldots, Q_N(\cdot)\big)$$
- Buyer's strategy $$D = \big(D_1(\cdot), D_2(\cdot), \ldots, D_N(\cdot)\big)$$

Payoffs

- Buyer's payoff

$$W_i(h_i, Q, D) = \sum_{n=i}^{M} \varepsilon u(q_{t_n}) + W^I(s_{t_{M+1}})$$

$$W^I(s_{t_{M+1}}) = k(u(\frac{s_{t_{M+1}}}{k}) - \bar{u}).$$

- Seller's payoff

$$V_t(h_i, Q, D) = \sum_{n=i}^{M} \varepsilon \pi(q_{t_n}) + V^I(s_{t_{M+1}})$$

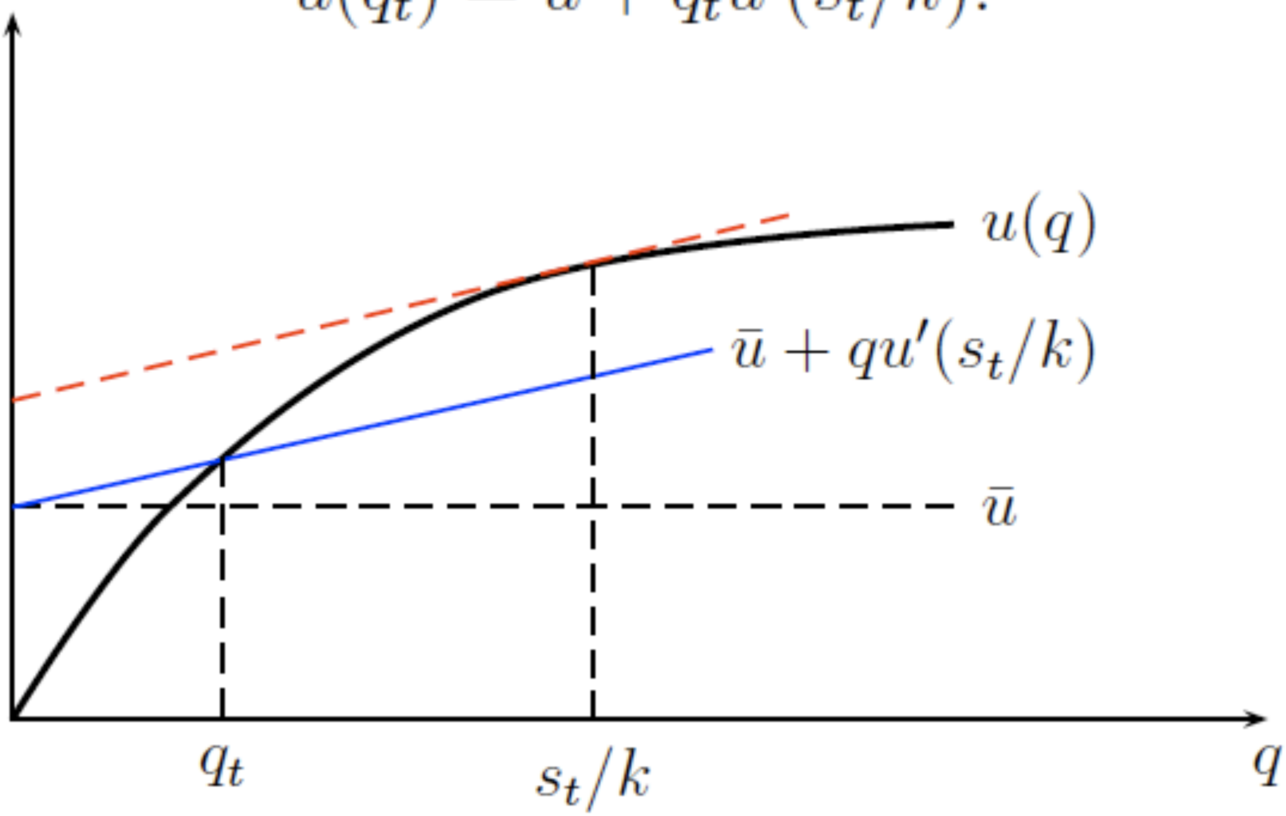
$$V^I(s_{t_{M+1}}) = k\pi(\frac{s_{t_{M+1}}}{k}).$$

Equilibrium

- Equilibrium strategy (Q*,D*) for any h_t
  - Q^* *maximizes* $V_i(h_i, Q, D^*)$
  - D^* *maximizes* $W_i(h_i, Q^*, D)$.
- Lemma: Unique SPE which is MPE (but nonstationary)
- Lemma: As N→∞, and ε→0, MPE converges
- Conclusion: there is a unique stationary continuous time MPE
- This MPE can be characterized by the buyer's indifference between continuation and stopping as follows:

Characterization

$$u(q_t) = \bar{u} + q_t u'(s_t/k).$$



Interpretation

- In equilibrium the buyer is indifferent between d=0 and d=1; otherwise the seller would leave too much surplus

- The buyer's value at t:

$$W(s_t) = \max_{d_t \in \{0,1\}} \left\{ \left[\varepsilon u\left(\eta(s_t)\right) - \varepsilon \bar{u} + W\left(s_t - \varepsilon \eta(s_t)\right) \right] (1 - d_t) + W^I(s_t) d_t \right\}$$

- Approximate for small ε:

$$W(s_t) = \max_{d_t \in \{0,1\}} \left\{ \left[\varepsilon u_t - \varepsilon \bar{u} - \varepsilon q_t W'(s_t) + W(s_t) \right] (1 - d) + W^I(s_t) d \right\}$$

- If d=0, then

$$u_t = \bar{u} + q_t W'(s_t)$$

- Which is the equilibrium condition stated as $W(s)=W^I(s)$

Implications

- Supplies increase over time
  - Buyer needs to be compensated to continue
  - Captures the idea of “bribing”
- Holds also under discounting, see next figure

- Time-to-build delay is the key
  - $k>0$ gives the buyer a share of the surplus
  - $k=0$ the seller takes all the surplus, and implements the first best
- The nature of the equilibrium opens up a role of asymmetric information
  - Small seller type can pretend to be large to postpone the demand change

Equilibrium (solid) and first-best (dotted) sales paths under discounting

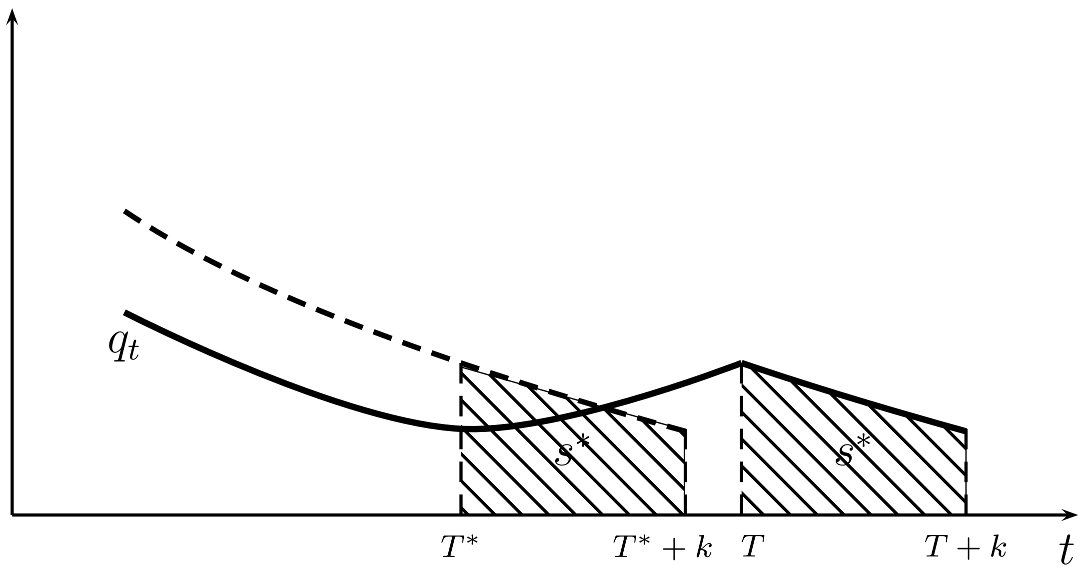


Fig. 3. Equilibrium supply path under discounting.

Incomplete information

When should a buyer of an exhaustible resource move to a substitute if only the seller knows the size of the resource?

- Asymmetric information
  - Seller is privately informed
- Strategic interaction
  - One buyer, one seller
  - Coasian dynamics, the seller's type not known
- Substitute
  - Backstop technology
  - adjustment delays
  - always available
  - infrastructure

Hidden information

- Hidden information about the seller's type
- Why important?
  - Early adoption of the substitute: some resource left over
  - Late adoption: scarcity during the build up of the substitute
- The problem for the buyer: only the seller knows
- Does the seller has a reason to hide?
  - Small seller may "over-report" its type to delay the buyer's decision
- Conceptual difficulty: dynamic signaling situation
  - Stationarity of beliefs assumed

Results

Increasing supplies followed by a supply shock an equilibrium phenomenon

- pooling of types: supply policy keeps the buyer indifferent between continuation and stopping without learning by consuming. Supplies increase over time (Gerlagh-Liski 2011,JET)
- Separation: small types run out of their stocks and find it individually rational trigger investment by a supply shock

Surplus sharing

- Buyer receives a share because of adjustment delay in moving the substitute (consumption smoothing motive, as in Kahn 1986, McAfee&Wiseman 2008); if the backstop is an instant option, no surplus to the buyer.

Incomplete information

- We proceed to continuous time directly

- Hidden information: s_0 random on $[s_L, s_H] = [\sigma_t - \theta_t, \sigma_t + \theta_t]$
- consumer surplus u(q) either strictly concave or convex
- Informed agent moves first: at each time t
    1. Seller offers q_t
    2. Buyer updates beliefs & chooses $d_t = \{0,1\}$
    3. Market clears in state $d_t = 0$ or stopping

- Equilibrium concept: sequential equilibrium in behavioral strategies

Stopping payoffs

- Buyer's belief: the remaining stock s_t is uniform on $[\sigma_t - \theta_t, \sigma_t + \theta_t]$
- If decision to adopt today, the buyer's payoff is

$$U^I(\sigma_t, \theta_t) \;=\; \mathbf{E}_{s_t} \int_0^k u(q_\tau^s) e^{-r\tau} d\tau + e^{-rk} \frac{\overline{u}}{r}.$$

- …and the seller's payoff

$$V^I(s_t) \;=\; \int_0^k \pi(q_\tau^s) e^{-r\tau} d\tau$$

- the game is over after investment

beliefs

- Beliefs: stationary
  - Belief of the seller type is a simple left-truncation of the prior
  - Not conditional on the history of past behavior
  - Posterior changes only for two reasons:
    - (i) $\sigma_t = d\sigma_t/dt$
    - (ii) supply q_t not rational for all seller types at (σ_t, θ_t).

beliefs

- Beliefs: stationary
  - acceptance function: $d_t = 0$ iff $q_t \geq \eta(\sigma_t, \theta_t)$
  - Buyer requires compensation for investment delay
  - Compensation determined by the stopping payoff
  - Truncation function: $q_t = \eta(\sigma_t, \theta_t)$ iff $s_t \geq \zeta(\sigma_t, \theta_t)$
  - Seller will only satisfy demand if such is profitable. It is not profitable if stock is too small

Two types of equilibria

- Small informational asymmetry
  - $\theta_0 \leq \theta^*$
  - pooling: updating only due to depletion (distribution shifts left)
  - Timing of adoption is public information

- large informational asymmetry
  - $\theta_0 > \theta^*$
  - separation: by seller's individual rationality some types would opt out (distribution becomes more precise)
  - Timing of adoption is private information

Buyer’s indifference: acceptance function

- Buyer’s value function under continuation

$$U^I(\sigma_t, \theta_t) = \varepsilon u(q_t) + e^{-r\varepsilon} U^I(\sigma_t - \varepsilon q_t, \theta_t)$$

- Continuous-time limit

$$u(q_t) = rU^I(\sigma_t, \theta_t) + q_t U^I_\sigma(\sigma_t, \theta_t)$$

- We want zero discounting, so we define an excursion payoff

$$W^I(\sigma_t, \theta_t) = U^I(\sigma_t, \theta_t) - \frac{\overline{u}}{r}$$

Buyer's indifference

- Which gives a Bellman equation for the excursion payoff

$$u(q_t) = \overline{u} + rW^I(\sigma_t, \theta_t) + q_t W^I_\sigma(\sigma_t, \theta_t)$$

- For which we can set r=0:

$$u(q_t) = \overline{u} + q_t \lambda(\sigma_t, \theta_t)$$

- Where $\lambda = W^I_\sigma$ is the expected shadow value of the resource

Stopping

- We can define

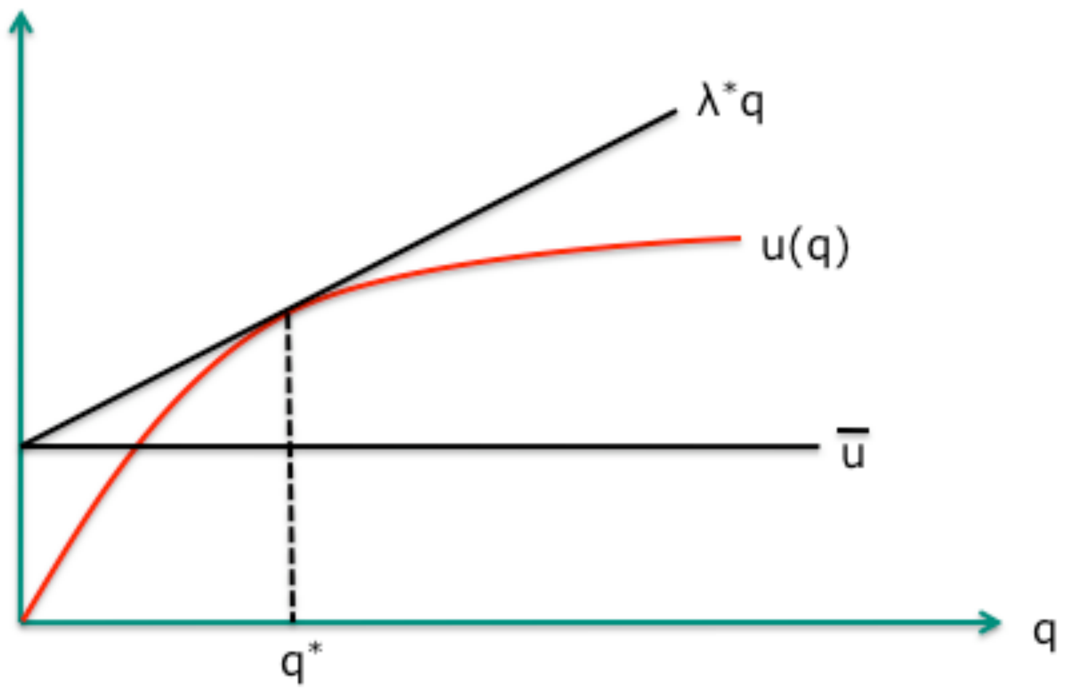
$$\lambda^* = \max\{\frac{\widehat{u}(q) - \overline{u}}{q}\}$$

- So that for all $\lambda \geq \lambda^*$ stopping must take place

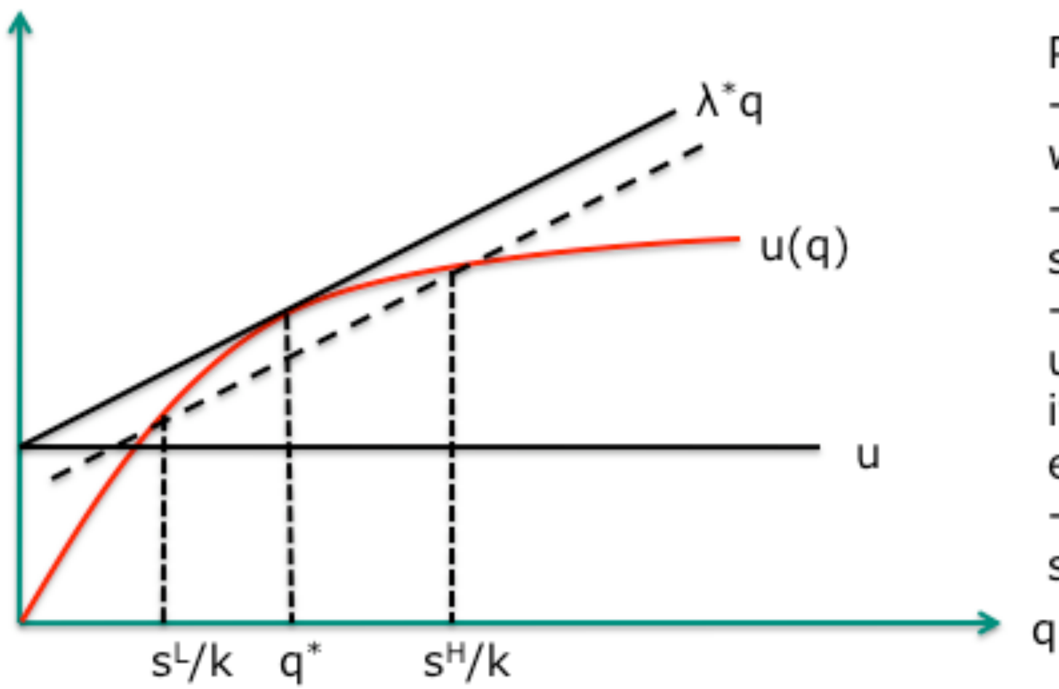
- For all $\lambda < \lambda^*$ it is possible to offer q such that the buyer does not invest

Stopping point

$$u(q_t) = \overline{u} + q_t \lambda(\sigma_t, \theta_t)$$



Pooling: moving support

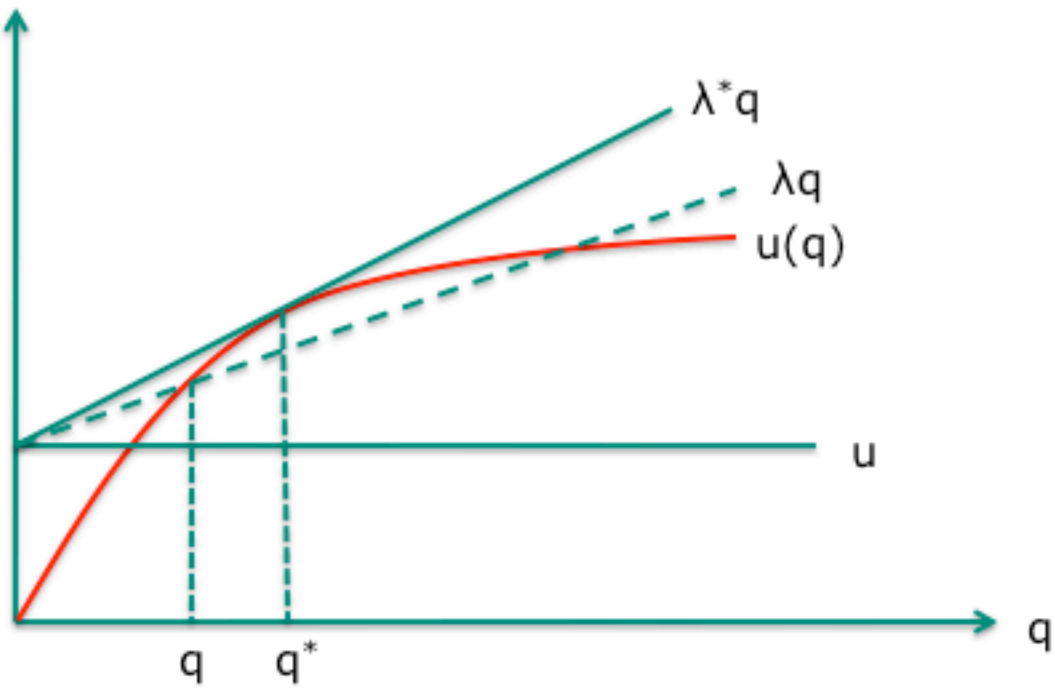


Pooling of types:
-buyer must invest without learning
-big seller cannot separate
-this point is ultimately reached if no separation earlier
-if $\theta_0 \leq \theta^*$, no separation at any t

Pooling: properties

- Supplies increase over time
- Investment date is common knowledge
- Symmetric equilibrium limit obtained when the informational asymmetry vanishes
  - The equilibrium already studied
- Adjustment delay in demand determines the surplus sharing
  - If $k \rightarrow 0$, the full resource surplus to the seller (first-best obtained). The informed agent takes the surplus: Coase conjecture

Separation



- Supplies must increase as the expected stock is depleted
- If the seller is small, it does not want to follow the path up to q*
- It will supply, q=s/k
- Buyers λ jumps up, and investment takes place
- This can happen if $\theta_0 > \theta^*$

Separation: properties

- Supplies increase over time but persistent probability of a supply shock
- Investment date is private information
- Adjustment delay in demand determines the surplus sharing

Some remarks: extensions

- Climate change I
  - no stock on the seller side but pollutant stock for the buyer
  - Time-to-build delays in adapting abatement technologies will shape the supply over time

- Climate change II
  - the timing of policies inducing innovations
  - Innovators have an incentive to wait that the value of the innovation increases with the pollution stock

”Application”: carbon taxation

- The bilateral monopoly model has been used to study the optimal externality taxation when the seller side is strategic

- This presentation builds on Liski-Tahvonen 2004; the literature is reviewed there

- The problem: what is the optimal tax when it has both Pigouvian and rent-extraction components?

The setting

- The buyer's problem

$$V_{\mathrm{b}}(z;\Psi,p) = \operatorname*{Max}_{\Psi} \int_0^{\infty} \{u(q) - pq - d(z)\} e^{-\delta t}\, dt$$

$$\text{s.t.} \quad \dot{z} = q, \quad z(0) = 0, \quad q = q(p+\Psi),$$

- Consumer surplus u(q), producer price p, tax Ψ, damage d(z), CO2 stock z, demand q(p+Ψ)

- Consumer side chooses taxation Ψ simultaneously with the seller's price p

The setting

- The seller's problem

$$V_s(x; \Psi, p) = \underset{p}{\text{Max}} \int_0^{\infty} \{pq - qc(x)\} e^{-\delta t}\, dt$$

$$\text{s.t.} \quad \dot{x} = -q, \quad x(0) = x_0, \quad q = q(p + \Psi),$$

- Unit cost c(x) with c(0)>u'(0), stock in the ground x

- There is only one stock $z=x_0-x$

- Look for Markov strategies depending on x, p(x) and Ψ(x)

Benchmarks

•The pure Pigouvian tax for any supply thus pollution path:

$$\Psi(t) = \int_t^{\infty} d'(z(\tau))e^{-\delta(\tau-t)}\,d\tau$$

•The monopoly producer price in the absence of taxation:

$$p_c(t) = p_s(t) - \int_t^{\infty} q_c(\tau)c'(x_c(\tau))e^{-\delta(\tau-t)}\,d\tau$$

where p_s is the static monopoly price

Equilibrium prices

- Markov equilibrium tax can be expressed:

$$\Psi_{\mathrm{n}}(t) = \int_t^{\infty} \{d'(z_{\mathrm{n}}(\tau)) - q_{\mathrm{n}}(\tau)p'_{\mathrm{n}}(x_{\mathrm{n}}(\tau))\}e^{-\delta(\tau-t)}\, d\tau$$

- There is the Pigouvian and trade-policy component. If d=0, the second term seeks to delay consumption to depress prices

- Markov equilibrium producer price

$$p_{\mathrm{n}}(t) = p_{\mathrm{s}}(t) - \int_t^{\infty} \{c'(x_{\mathrm{n}}(\tau)) + \Psi'_{\mathrm{n}}(x_{\mathrm{n}}(\tau))\}q_{\mathrm{n}}(\tau)e^{-\delta(\tau-t)}\, d\tau,$$

- This can an also decrease over time.

Features

- For additional insights, the Markov Perfect Nash Equilibrium (MPNE) can be explicitly solved
- Assume $u(q)=aq-bq^2$, $d(z)=z^2$, $c(x)=c_1-c_2x$, where $c_1-c_2x_0>0$, $c_1>a$, $a-(c_1-c_2x_0)>0$. We can express the time paths as follows:

$$x_n(t) = (x_0 - x_e^\infty)e^{\alpha_n t} + x_e^\infty$$

$$q_n(t) = -\alpha_n(x_0 - x_e^\infty)e^{\alpha_n t}$$

$$\Psi_n(t) = V_b''(x)(x_0 - x_e^\infty)e^{\alpha_n t} + \Psi_e^\infty$$

$$p_n(t) = \tfrac{1}{2}(V_s''(x) - c_2 - V_b''(x))(x_0 - x_e^\infty)e^{\alpha_n t} + p_e^\infty$$

- where $\alpha_n<0$, and the long-run levels indicated by "∞"
- The long-run levels are efficient, so all distortions transitory