Carbon Abatement as a Strategic Variable: Implication for Energy Suppliers in a Carbon Constrained Environment

Dr Jo Voola

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CONTEXT OF THE STUDY

- André, F. J., & Arguedas, C. (2018). Technology Adoption in Emission Trading Programs with Market Power. *The Energy Journal*, *39*(01).
- Creti, A., & Sanin, M.-E. (2016). *Does environmental regulation create merger incentives?* (No. 16–07; Documents de Recherche). Centre d'Études des Politiques Économiques (EPEE), Université d'Evry Val d'Essonne.

Converse Argument: Rivalry for market share, and interdependence between firms promotes strategic behavior and brings about endogenous industry structures –such as dominant and fringe players and mergers. In our analysis, the potential to gain market power brings about investment in abatement technologies and market structure is endogenously determined.

ENVIRONMENTAL REGULATIONS

- Unregulated Environment is defined:
- $C_A = C_{Output} = C_{mc}$
- Regulated Environment
- $C_A^R = C_{output} + C_E = C_{mc}^R$
- $C_{A,mc}^R > C_{A,mc}$

ENVIRONMENTAL REGULATIONS

- Tightness or Looseness of Environmental Regulations
- Weighting of the Cost of Externality relative to Output Cost Component:
- $C_E = \propto C_O$ and hence $\propto = \frac{C_E}{C_O}$
- A tighter/looser environmental policy is represented by higher/lower value of α.

Green Technology

- Two Technology – OT – say Coal Powered Stations
- New Technology – NT – say technologies and processes that as reduce externalities – example- processes and combinations such as [Gas+ Hydrogen + Solar+ Wind+ Tidal Powered] Stations.
- Two parameters of NT: Cost of Using NT – R and effectiveness of the NT measured as *f* where *f* has a value of $0<f<1$.
- And when used, $fC<C$
- C corresponds to $C_A^R = C_{output} + C_E = C_{mc}^R$
- $C_A^{R,NT} < C_A^{R,OT}$

MONOPOLY

- Decision Making for Firm in Monopoly
- $\pi(q) = pq - c(q)$
- In a regulated environment where c_{mc}=$c_{output} + c_e$, the monopolist will employ effort R up to the point where,
- $\pi(q) = pq - c(q - R)$
- Such that $\frac{dc}{dR}$<0
- R is the amount of effort used in reducing its costs.

MONOPOLY

- The monopolist will invest in cost reduction until the marginal benefits of cost reduction equal the marginal cost. Motivated by high powered incentives to reduce costs due to residual claim.
- $-\frac{dc(q,^{\pi}R^{\pi})}{dR}=1$
- Investment until they reap all the benefits of cost reduction and internalise all benefits from cost reduction
- Strategy is NOT a consideration in a Monopoly where are no interdependencies.

DUOPOLY

- Two identical firms X and Y which share a market.
- Constant cost specification with constant returns to scale.
- P= $a - bQ = a - b(q_X + q_Y) = a - bq_X$-$bq_Y$
- $C(q_i) = cq_i$
- $a - 2bq_X$-bq_Y=c
- $q_X = \frac{1}{2}[s - q_Y]; q_Y = \frac{1}{2}[s - q_X]$
- S measure of market size.
- S=$\left[\frac{a-c}{b}\right]$

COURNOT EQUILIBRIUM

- Cournot non-cooperative equilibrium output pair for the firms is
  - $q_X = q_Y = \frac{S}{3}$
  - $q_X = q_Y = \frac{(a - c_X)}{3b} = \frac{(a - C_Y)}{3b}$ and $C_X = C_Y$
  - $P = c + \frac{1}{b}$ bS

DUOPOLY WITH COST DIFFERENTIAL

- C(q_i) = $c_i q_i$ where $i = X, Y$
- If C_X<C_Y $and\ if\ C_Y < C_X$
- $S_X = {}^{(a-c_X)}/_{b}$ $S_Y = {}^{(a-c_Y)}/_{b}$ such S_X>S_Y since C_X <C_Y
- In equilibrium lower cost firm enjoys greater sales and greater share.
- Lerner Index of Market Power $\frac{P-c_i}{P}$; $i = X, Y$

Normal Form Game

- 2 firm Duopoly X and Y,
- 2 Strategy , Strategy 1 =Use OT ; Strategy 2= Use NT;
- Strategy 2 involves cost R.
- Strategy 2 implies $c_X < c_Y$ and $c_Y < c_X$
- hence $S_X = \frac{(a-c_X)}{b} > \frac{(a-c_Y)}{b} = S_Y$

Normal Form Game

- Two Players and Two Strategies: 1=OT and 2=NT
- Payoff to each strategy represented in each cell.
- X_{11} Neither Firm X and Firm Y use NT
- X_{12} Firm X does NOT use NT while Firm Y uses NT
- X_{21} Firm X uses NT while Firm Y does not use NT
- X_{22} Both Firm X and Firm Y use NT
- Symmetry $Y_{11}, Y_{12}, Y_{21}, Y_{22}$
- Strategy 2 implies R as shown in red and blue arrows respectively diagram.
- fC<C when Strategy 2 is used.

	Y_1	Y_2
X_1	$(x_{11}\ \ y_{11})$	$(x_{12}\ \ y_{12}\text{-}R)$
X_2	$(x_{21}\text{-}R\ \ y_{21})$	$(x_{22}\text{-}R\ \ y_{22}\text{-}R)$

PAYOFF CALCULATIONS

- $X_{11} = \frac{(a - c^2)}{9b}$
- $X_{21} = \frac{(a - 2fc + 2)^2}{9b}$
- $X_{12} = \frac{(a - 2c + fc)^2}{9b}$
- $X_{22} = \frac{(a - fc)^2}{9b}$

$Y_{11} = \frac{(a - c^2)}{9b}$

$Y_{12} = \frac{(a - 2fc + 2)^2}{9b}$

$Y_{21} = \frac{(a - 2c + fc)^2}{9b}$

$Y_{22} = \frac{(a - fc)^2}{9b}$

MAGNITUDES OF PAYOFF (ORDER OF MAGNITUDE)

- When R=0 the magnitude of payoff ordering is as follows:
- $X_{21}>X_{22}>X_{11}>X_{12}$ and $Y_{21}>Y_{22}>Y_{11}>Y_{12}$
- Represented in the Normal Form Game

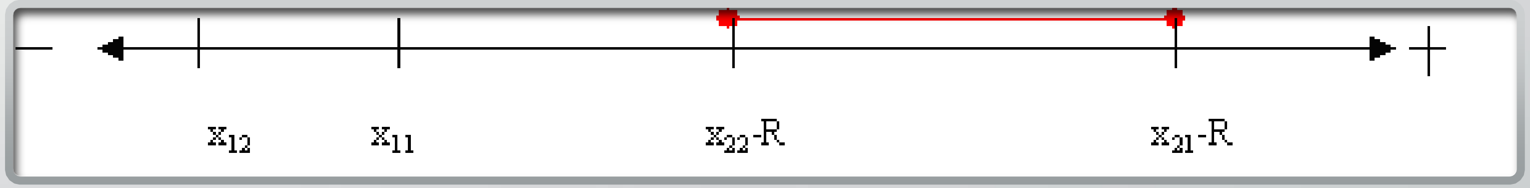
Payoff ordering when R=0

	Y_1	Y_2
X_1	$(x_{11}\ \ y_{11})$	$(x_{12}\ \ y_{12})$
X_2	$(x_{21}\ \ y_{21})$	$(x_{22}\ \ y_{22})$

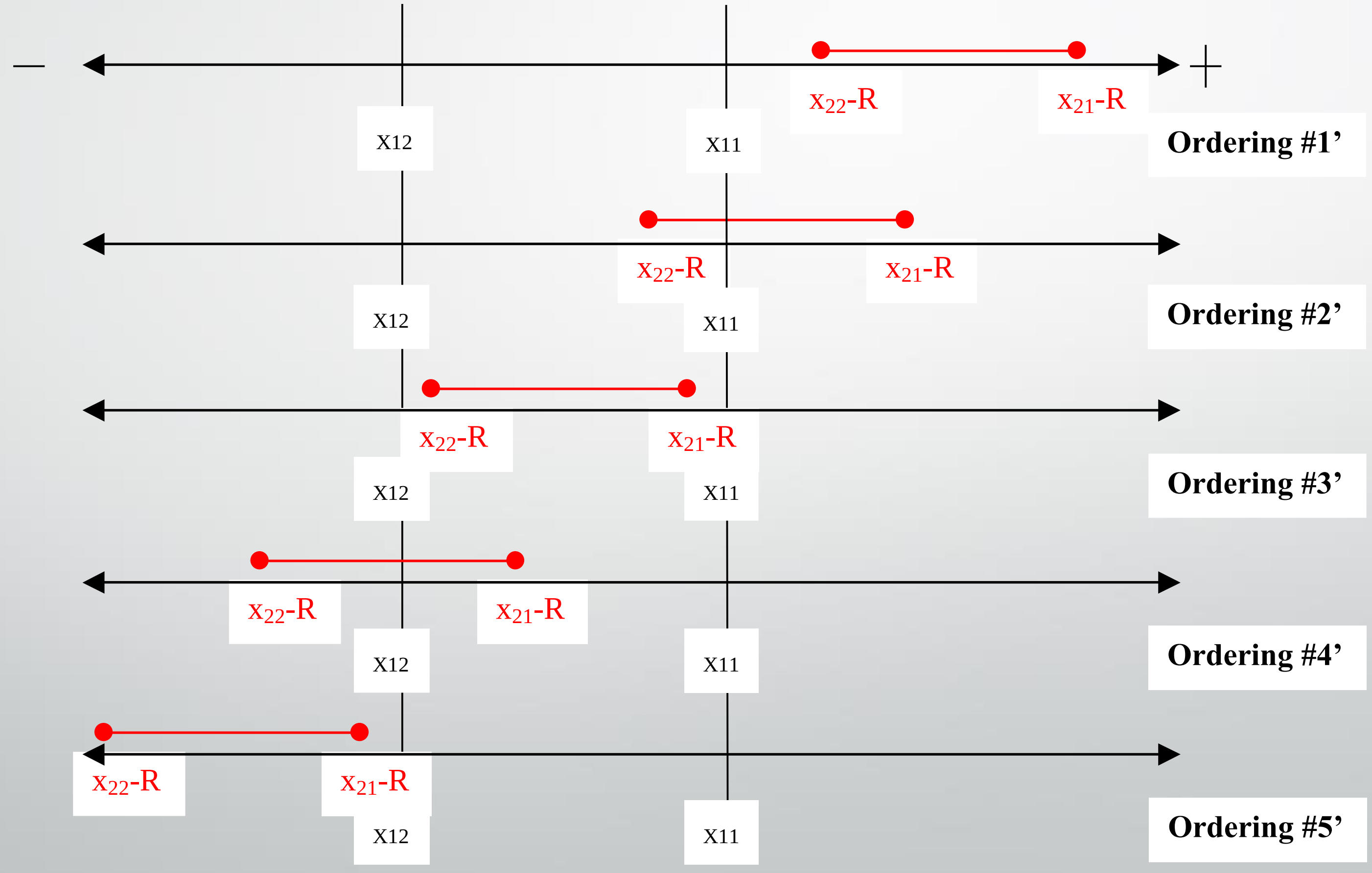
CRITICAL VALUES OF R

Values other than R=O causes a change in this order of payoffs.

The values of R when the payoff ordering changes is depicted in a diagram below:



CRITICAL VALUES OF R



MATRIX A
R = 0

Both firms use the technology, and both are better off .
Society is also better off as the good A is produced using NT.

		Y	
		OT	NT
X	OT	x_{11} ____ ____ y_{11} ____ ____ 1	x_{12} ____ y_{12} ____ ____ ____ ____ 4
	NT	x_{21} ____ ____ ____ ____ y_{21} ____ 2	x_{22} ____ ____ ____ y_{22} ____ ____ ____ 3

MATRIX B

$$R > [2a - fc - c] \times \frac{(c - fc)}{9b}$$

Dominant strategy is to use the abatement technology, although individual profits are higher when neither firm uses the technology. Equilibrium is in cell 3, although cell 1 depicts better individual outcomes. Both firms use the technology, and both are worse off, society gains.

		Y	
		OT (1)	NT (2)
X	OT	x_{11} y_{11} 1	x_{12} y_{12} 4
	NT	x_{21} y_{21} 2	x_{22} y_{22} 3

MATRIX C

$$R > 4(a-c) \times \frac{(c - fc)}{9b}$$

Equilibrium is either in cell 1 or cell 3.
This is where potential for strategic behavior takes place.
Cooperative equilibrium in cell 1 or non-cooperative aggressive behavior leads to cell 3.
Prisoner's Dilemma outcome. Both players are worse off using the abatement technology.
Scope of mergers occur.

		Y	
		OT	NT
X	OT	x_{11} y_{11} 1	x_{12} y_{12} 4
	NT	x_{21} y_{21} 2	x_{22} y_{22} 3

MATRIX D

$$R > \frac{4(a - fc)(c - fc)}{9b}$$

Dominant Strategy is in CELL 1 .Neither firm uses the technology

		Y			
		OT		NT	
X	OT	x_{11}	y_{11}	x_{12}	y_{12}
		1		4	
	NT	x_{21}	y_{21}	x_{22}	y_{22}
		2		3	

MATRIX E

$$R > \frac{3(2a - c - fc)(c - fc)}{9b}$$

Dominant Strategy is in CELL 1 .Neither firm uses the technology

		Y	
		OT	NT
X	OT	x_{11} y_{11} 1	x_{12} y_{12} 4
	NT	x_{21} y_{21} 2	x_{22} y_{22} 3

INTERPRETATION

- If the good A is produced in a duopoly, unlike in a monopoly, the abatement technology will be used as a strategic variable to gain market share.
- Uncertainty and the risk of loosing market share to rivals, causes investment into abatement technology, despite potential losses in margins from investment.
- Good A is likely to be produced using NT and changes in market structure occur at some cost of technology, even if investment makes the player worse off.

N-PLAYER OLIGOPOLY

- Examine the effect of cost-reducing technology on N-Player Symmetrical Oligopoly.
- 2 linear cost strategies, C_1(OT), C_2 (NT).
- $$C_1(q) = aq_i + b_i$$
- $a_2 < a_1$ - new technology has greater marginal efficiency and reduces externality
- $b_2 > b_1$ -but greater fixed costs.

N-PLAYER OLIGOPOLY

- 1.Smooth Demand Curve which is twice differentiable.
- 2. $D'(q) < 0$
- 3. $D''(q) \geq 0$
- 4. $\frac{d^2}{dq^2} qD(q) < 0$
- $q_i = argmax_{q_i} \pi_i\left(q_i; \{q_j : j \neq i\}\right)$

Oligopoly and Strategy

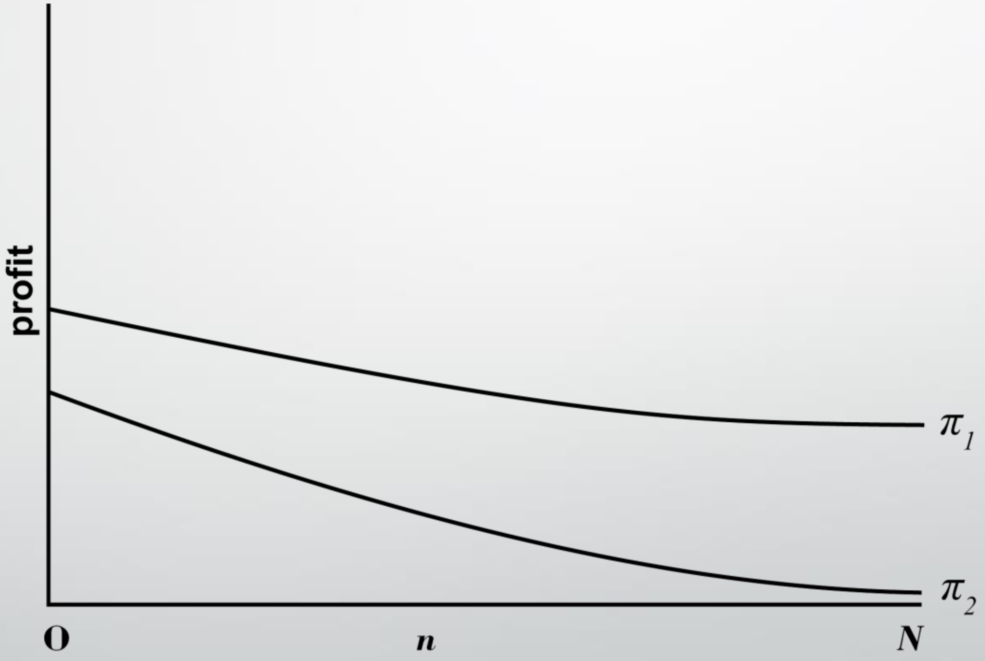
- Suppose n players in N player Oligopoly take the strategy of using the abatement technology with the parameters.
- $q_i(n) =$ qty. produced by players taking the strategy of using technology of using abatement technology.
- $\pi_i(n) = q_i(n)D\big(q(n)\big) - a_i q_i(n) - b_i$ =individual profit
- Provided $q_i(n) > 0$
- Essentially, $\pi'_i(n) < 0$, $\pi'_2(n) < \pi'_1(n)$.

OLIGOPOLY and STRATEGY

- In equilibrium, by symmetry, payoffs to each player should be approximately equal.
- Such that $\pi_1(n^*) \approx \pi_2(n^*)$
- The only way, that n^* will be far from n^*=0 or n^*=N
- n^*=N is unlikely since unilateral improvement is possible.
- n^*=0 is ruled out provided

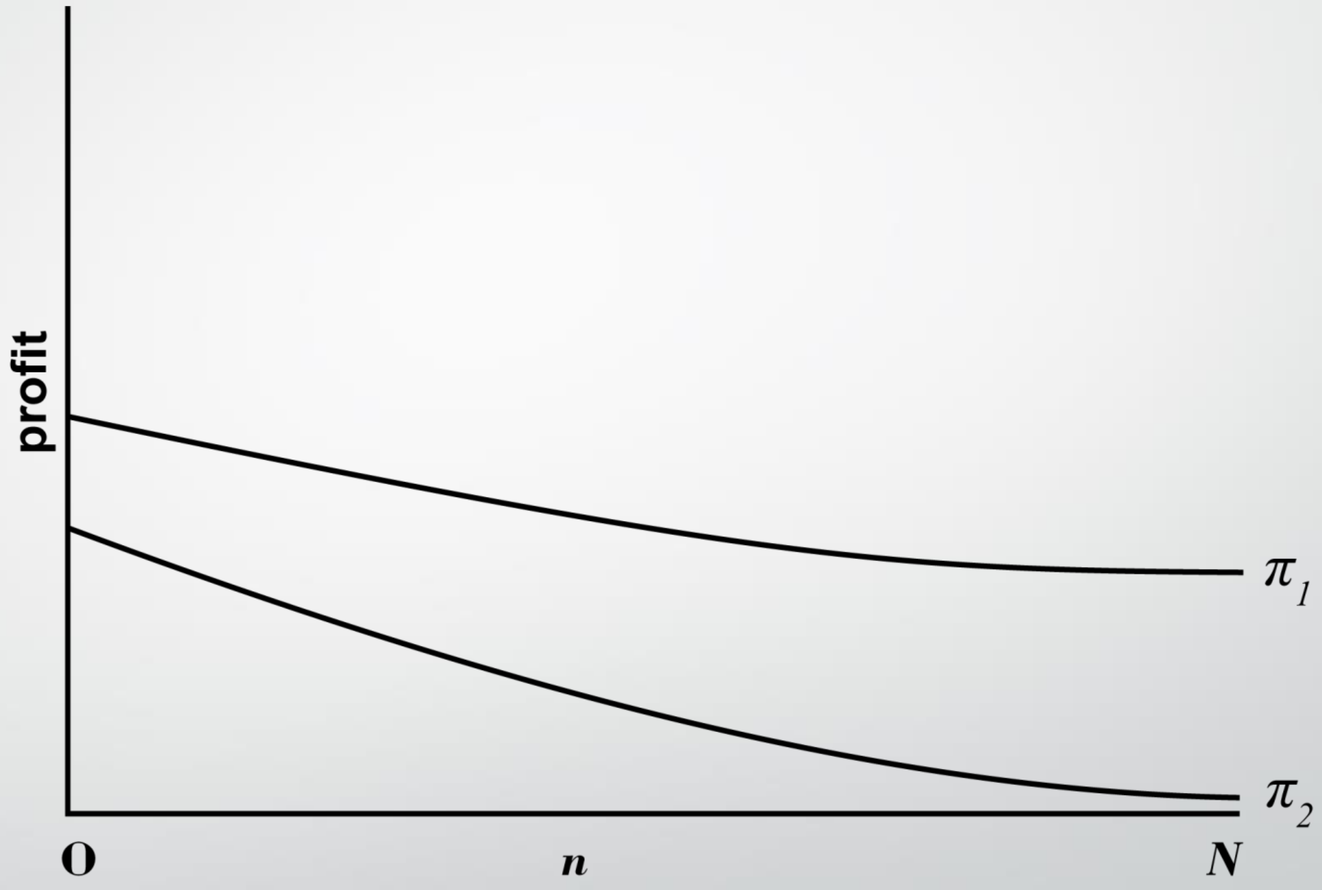
The General Picture – N player Oligopoly

Changes in the cost, b_2, of the new technology simply has the effect of translating π_2



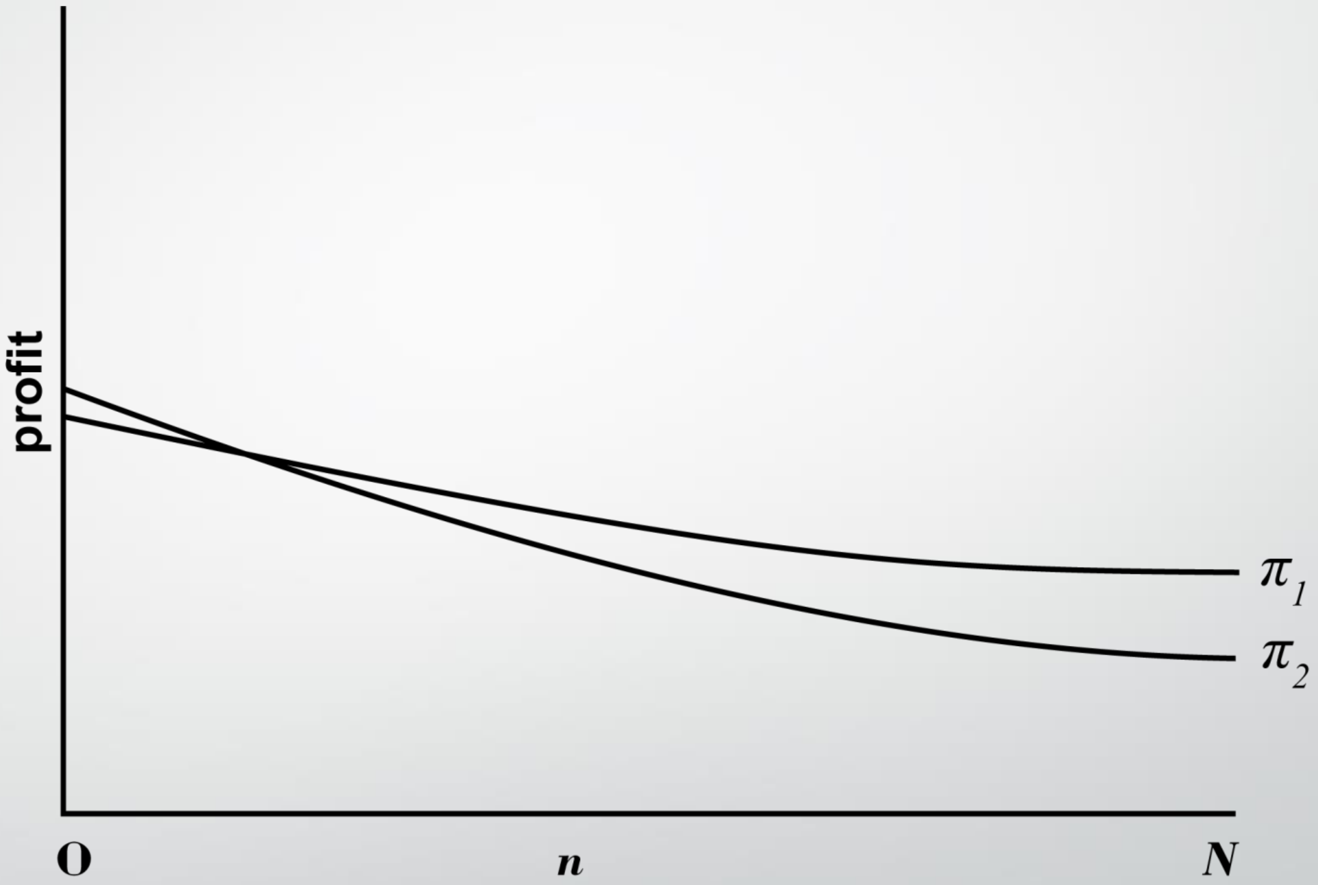
Results

High:
No-one benefits



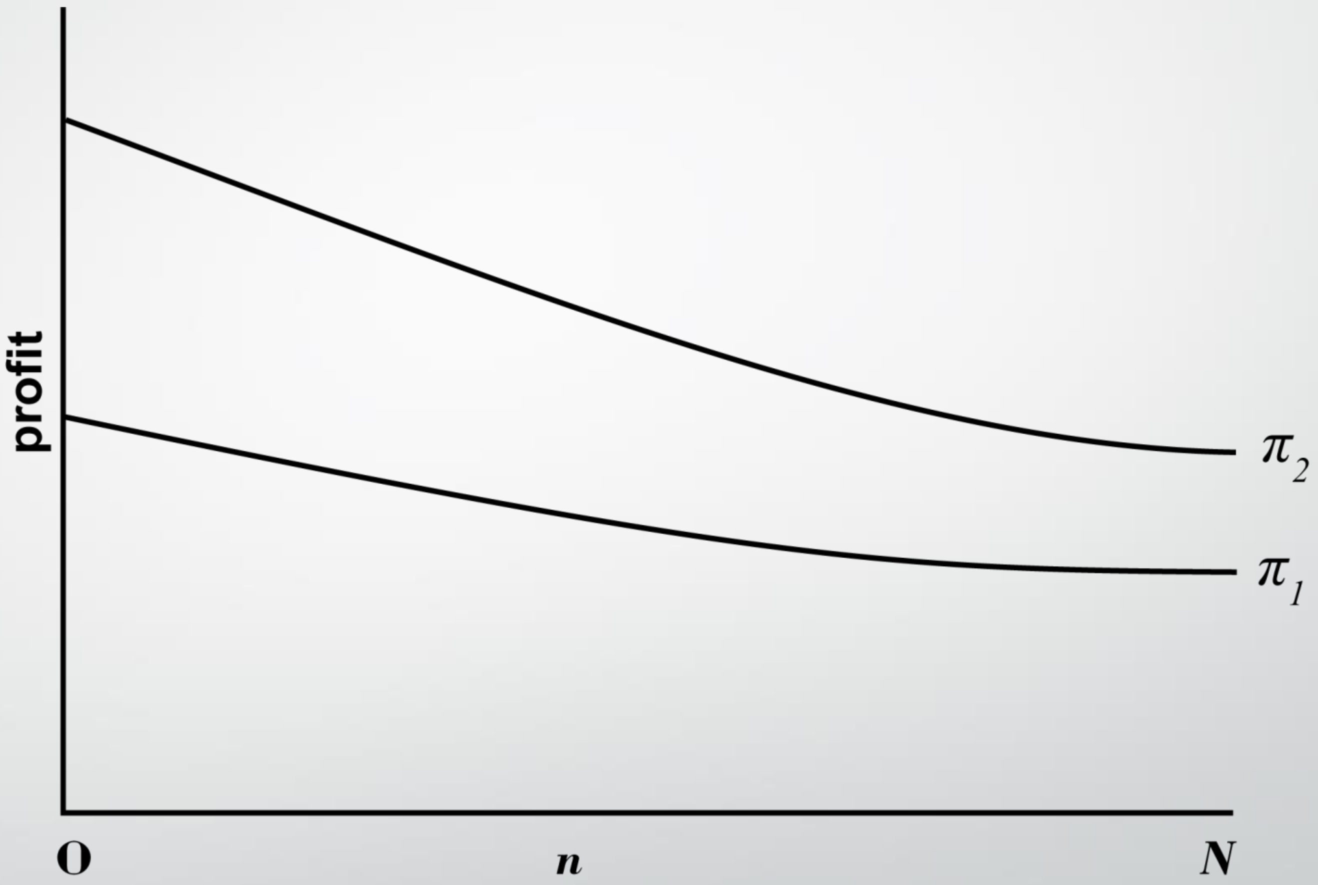
Results

Medium:
Environmentally beneficial outcomes. Consumers benefit



Results

Low:
Producers benefit



SUMMARY

- Modelled 2 player and *n* player industry;
- Competing for market share;
- Demonstrated interdependency in the use of abatement technology;
- Strategic behavior using abatement technologies;
- First Mover Advantages and Prisoner's dilemma can bring about changes in industry structure – the emergence of dominant and fringe players; or mergers.

KEY INSIGHTS AND POLICY IMPLICATIONS

- Environmental policies should be industry specific. Not a one size for all approach.
- Size and Numbers of suppliers in the market is a key consideration on deployment decisions.
    - In the analysis, the cost of investment was calculated with reference to demand and cost factors.

KEY INSISGHTS AND POLICY CONSIDERATION

- If abatement technologies are given away and the cost of deployment is effectively 0, suppliers uptake the technology readily and society benefits.
- When the cost of using the abatement technology to reduce externalities is 0, all firms use the technology. There is no uncertainty in the environment.
- Subsiding the use of the technology to this levels not a realistic option, and effectively means taxing elsewhere.
- An alternative is to make the technology so effective, that investment costs becomes negligible.

KEY INSIGHTS AND POLICY IMPLICATIONS

- When cost of technology is high, relative to demand and supply parameters, no firm takes up the technology and society is worse off.
- Environmental policies can be used to effectively reduce the cost of using the technologies, either through subsidies or encouraging innovation to reduce the cost of uptake.
- Alternatively, for these industries governments, may allow leniency and greater tolerance for these industries.

KEY INSIGHTS AND POLICY IMPLICATIONS

- Intermediate cost – the technology becomes potent as a strategic variable. At this cost, firms in the industry "take matters into their own hand"; become active participants in the deployment of abatement technology.
- The desire to gain market share and a competitive advantage over rivals becomes the incentive and driver for adoption of abatement technology.
- Firms in these industries may deploy technology to their own detriment – prisoner's dilemma follows.
- Policy makers can identify what the cost of the technology should be to bring this result.

KEY INSIGHTS AND POLICY IMPLICATIONS

- The extent to which firms in an industry invest for the purpose of reducing externalities in production activities,
  - is dependent upon the industry structure,
  - the behavior of their competitor.,
  - the tightness and looseness of the environmental policies.
  - effectiveness and cost of technology,
  - can bring about endogenous changes in industry structure due to rivalry and competition for market share.