Public Economics II: Public Expenditures
Lecture 2: Externalities

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Externalities: Definition

- An externality arises whenever the utility or production possibilities of an agent depends **directly** on the actions of another agent.
- Directly means the effect is not transmitted through price mechanisms.
- Distinction between pecuniary vs non-pecuniary externalities
  - Pecuniary: I buy an apple → price increase. But this is internalized by market prices and does not cause inefficiency.
  - Non-pecuniary: listening to loud music/pollution. These can enter directly into the utility/production functions of others.
- Only non-pecuniary externalities justify government intervention.

Model of Externalities

- Firms produce x cars at cost $c(x)$ of the numeraire good y
- Production generates x unites of pollution: $P(x) = x$
- Consumers have wealth Z and quasilinear utility: $u(x) + Z - dx$
  - d = marginal damage of pollution.
- Social Welfare: $SW(x) = u(x) + Z - c(x) - dx$
- Social optimum: $u'(x^*) = c'(x^*) + d$
  - Social marginal benefit (SMB) = social marginal cost (SMC)

Model of Externalities: Market Equilibrium

- Firms max profits:

$$\max\ px - c(x)$$

- Demand satisfies:

$$u'(x^D) = p$$

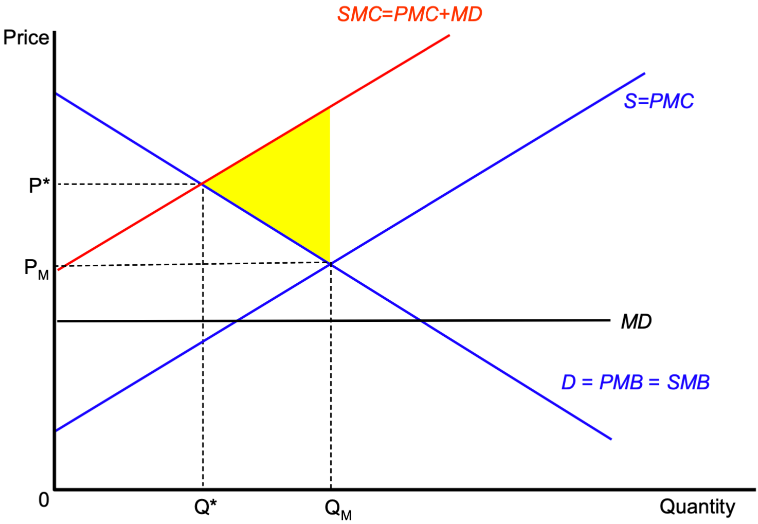
- Supply satisfies:

$$c'(x^S) = p$$

- In equilibrium *private* marginal benefit (PMB=PMC) equals *private* marginal cost (PMC < SMC):

$$u'(x^D) = c'(x^S)$$

- This is not Pareto efficient


SMC=PMC+MD
Price
S=PMC
P*
P
M
MD
D = PMB = SMB
0
Q*
Q
M
Quantity

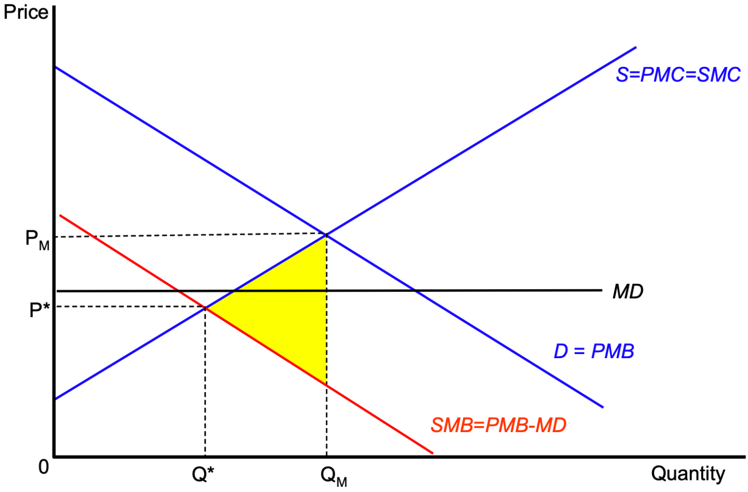
- Perturbation argument: social welfare can be increased by reducing production by Δx:

$$dSW(x) = u'(x)\Delta x - c'(x)\Delta x - d\Delta x$$

$$= -d\Delta x > 0 \quad \text{if} \quad \Delta x < 0$$

- First Welfare Theorem fails.

- There is an analogous result for consumption externalities.


Price
S=PMC=SMC
P_M
MD
P*
D = PMB
SMB=PMB-MD
0
Q*
Q_M
Quantity

Remedies for Externalities

1. Coasian bargaining
2. Pigouvian corrective taxation
3. Regulation
4. Cap-and-Trade

Coasian Solution

Coase Theorem: If (1) markets are competitive (2) there is complete information and (3) no transaction costs, then if property rights are assigned then the efficient solution to externalities will result.

- Externalities emerge because property rights are not well defined.
- Suppose a firm pollutes a river and each unit of production causes damage d to a consumer who enjoys fishing in the river. If we assign property rights for the river to the consumer then the consumer has to agree to let the firm pollute the river.
- In a competitive market, consumer would charge d for every unit of output produced → firm's MC would become $c'(x) + d$ resulting in the first best outcome.
- Symmetric solution when the firm owns the river.
- The assignment of property rights affects the distribution of surplus but not efficiency.

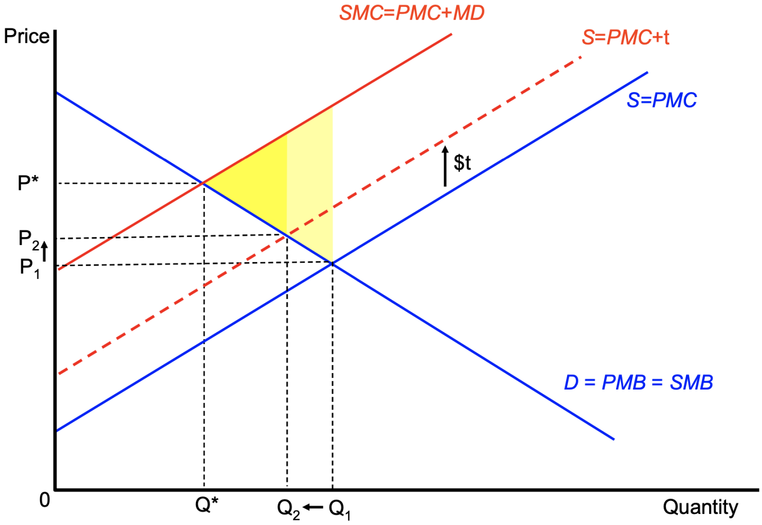
Coasian Solution: Limitations

1. Transaction/bargaining costs likely exist.
   - Many people are affected by pollution e.g. water pollution or air pollution.
   - Coasian solution would require millions of agents to coordinate and bargain → huge transaction costs.
   - To reduce these costs need an association to represent agents in bargaining → government?
2. Information problems
   - Often hard to identify the precise source of damage: industry has incentive to underreport.
   - Atmospheric pollution is very diffuse: hard to measure marginal damages and know who is damaged, agents have incentive to report damages even if none.

Corrective (Pigouvian) Tax

- Impose a tax on production equal to marginal damage (at the social optimum).
- In our simple model the optimal tax is $\tau = d$:
  - Firms profits become: $px - c(x) - dx$ and their optimality condition is $c'(x) + d = p$
  - Efficiency is restored.
- General principle: set tax equal to **marginal damage** which is the wedge between SMC and PMC.

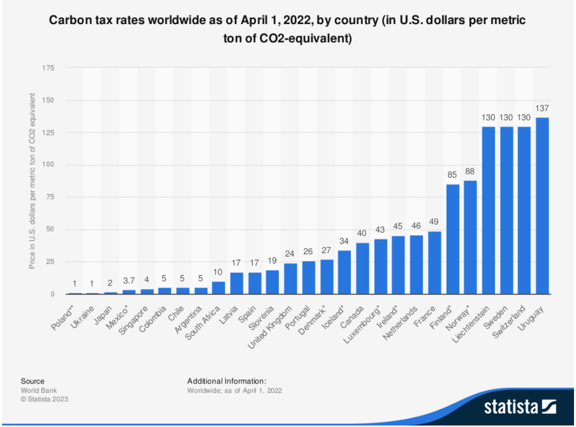
Corrective Tax



Practical problems with corrective tax

- To set optimal tax need to know the MD function: difficult when it is not constant (which it probably isn't).

- What is the optimal Carbon tax?



Regulation

- Quantity-based restriction: reduce pollution or output to a fixed level or face legal sanctions
- In simple model: properly set quantity regulation and corrective taxes produce the same outcome.
- Disadvantages of Quantity Regulation:
  - Allocative inefficiency: if heterogeneity in cost of reducing pollution the wrong firms will be reducing pollution (those with high costs)
  - Dynamic inefficiency: no incentive to innovate on the margin.

Cap and Trade

- Cap total emissions and then provide firms with permits that allow emissions.
- Firms then can trade these permits to pollute.
- Hybrid of regulation and Coasian solution: it creates a market for pollution.
- In equilibrium: firms with the highest MC of pollution reduction will buy the most permits.
  $\longrightarrow$ allocative efficiency is restored.
- Firms are bearing the marginal cost of pollution like under a corrective tax.
  $\longrightarrow$ dynamic efficiency is restored.

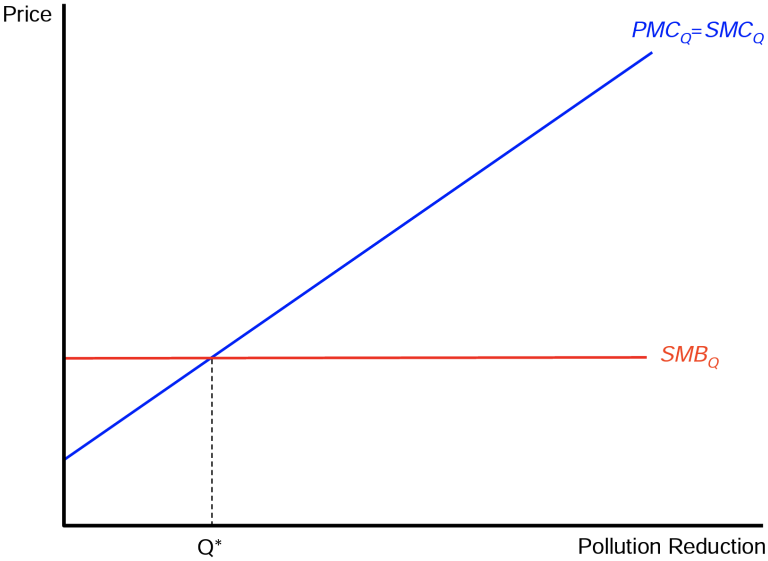
Weitzman (1974): Prices vs. Quantities

- Price mechanism (tax) and quantity mechanism (permits) are identical in simple model, which should be used?
- This assumes we have full knowledge of the MB and MC curves.
- Weitzman (1974): With uncertainty about the true MC and MB, P and Q methods may no longer be equivalent.
- Which is more optimal will depend on the shape (steepness) of these curves.

Weitzman (1974): Prices vs. Quantities

- Easier to illustrate using the market for pollution reduction.
- Let $B(Q)$ be the social benefit of pollution reduction
- Let $C(Q)$ be the social cost.
- In the simple model above:
  - $MB = B'(Q) = d$
  - $MC = C'(Q) = u'(x) - c'(x)$ loss in (private) surplus from producing less of good x.
  - More generally MC should be thought of as the cost of reducing pollution through the cheapest means.

Market for Pollution Reduction



Optimal Policy with no Uncertainty

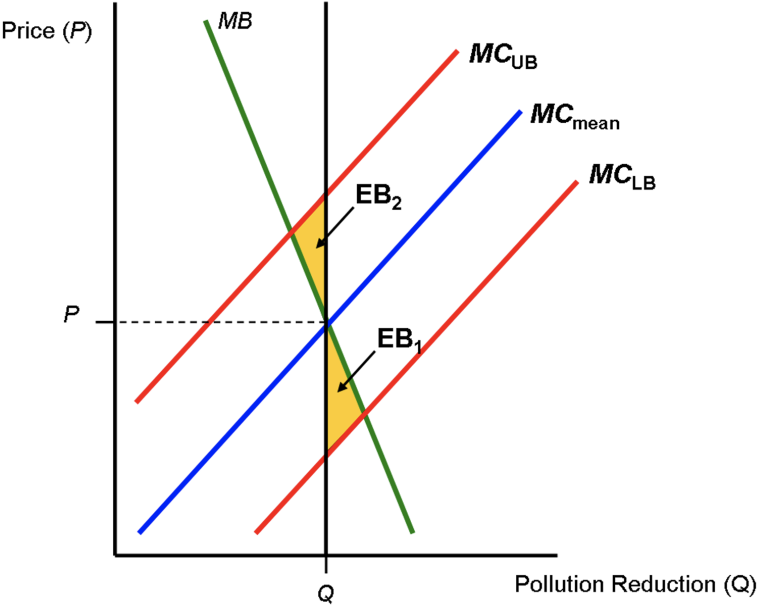
- Market equilibrium: $Q = 0$
- Social optimum: $B'(Q^*) = C'(Q^*)$
- Optimum can be achieved using either:
  - Quantity restriction: enforce emission reductions to Q^*
  - Price: set price for emissions of $p^* = C'(Q^*)$

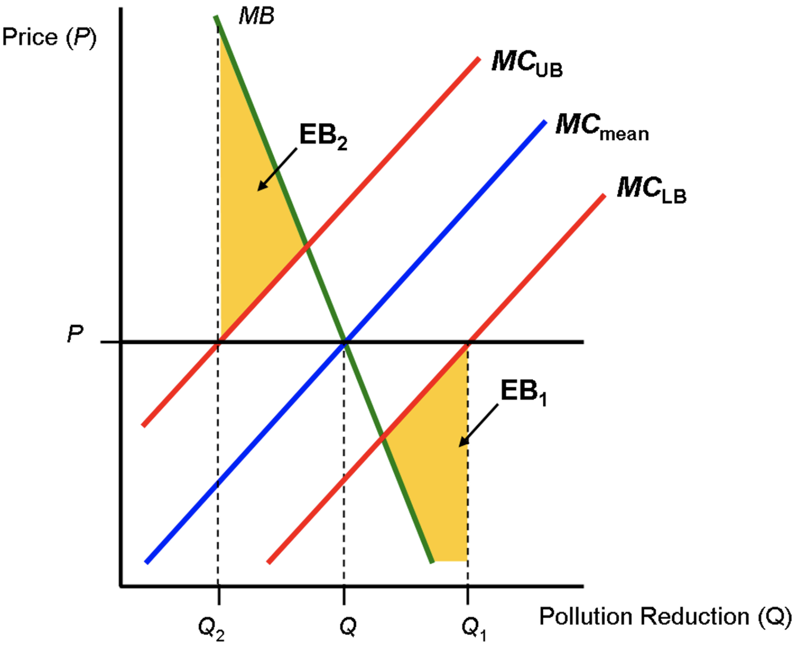
Optimal Policy with Uncertainty

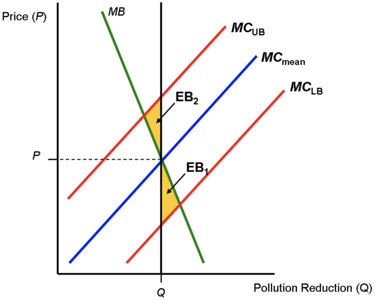
- Suppose there is uncertainty about the marginal costs of reducing pollution:
  - Cost is now $C(Q, \theta)$ where θ is unknown.
  - $C'(Q, \theta) \in [MC_{LB}, MC_{UB}]$, with mean MC_{mean}.
- Maximize **expected** social utility: $E_\theta[B(Q) - C(Q, \theta)]$
- F.O.C.: $B'(Q) = E_\theta[C(Q, \theta)]$, but:

$$E_\theta[B(Q^*) - C(Q^*, \theta)] \neq E_\theta[B(P(Q^*)) - C(P(Q^*), \theta)]$$

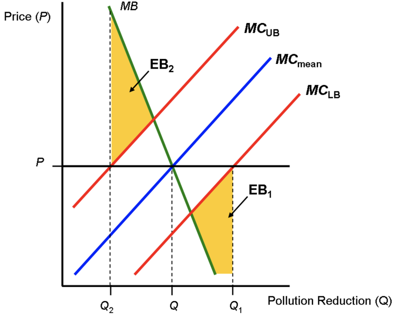
- Optimal choice depends on $\frac{B''(Q)}{C''(Q)}$.
- If MB curve is steep relative to the MC curve then quantity regulation is preferred.


Price (P)
MB
MC_UB
MC_mean
MC_LB
EB_2
P
EB_1
Q
Pollution Reduction (Q)

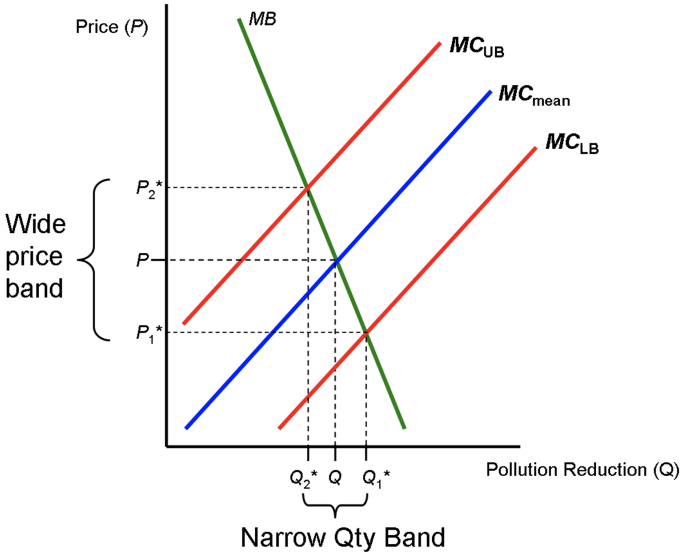

Price (P)
MB
MC_{UB}
MC_{mean}
MC_{LB}
EB_2
P
EB_1
Q_2
Q
Q_1
Pollution Reduction (Q)



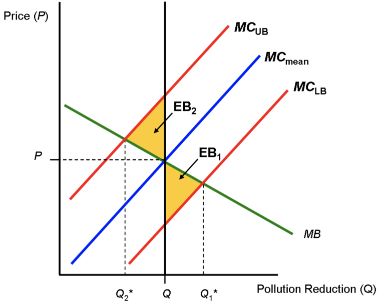
Price (P)
MB
MC_UB
MC_mean
MC_LB
EB_2
P
EB_1
Q
Pollution Reduction (Q)

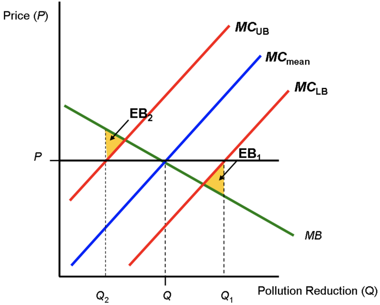


Price (P)
MB
MC_UB
MC_mean
MC_LB
EB_2
P
EB_1
Q_2
Q
Q_1
Pollution Reduction (Q)



Price (P)
MB
MC_{UB}
MC_{mean}
MC_{LB}
P_2*
P
P_1*
Wide price band
Q_2*
Q
Q_1*
Pollution Reduction (Q)
Narrow Qty Band


Price (P)
MC_UB
MC_mean
MC_LB
EB_2
EB_1
P
MB
Q_2*
Q
Q_1*
Pollution Reduction (Q)


Price (P)
MC_UB
MC_mean
MC_LB
EB_2
EB_1
P
MB
Q_2
Q
Q_1
Pollution Reduction (Q)

Optimal Policy with Uncertainty

- What happens if instead there is uncertainty about the marginal benefit of pollution reduction but costs are known?

- What happens if instead there is uncertainty about the marginal benefit of pollution reduction but costs are known?
- For a given p, the government knows the resulting Q given $p = C'(Q)$
- Price and quantity policies are again equivalent.
- Uncertainty matters only when it is about the cost/benefit schedule of the agent who chooses the level of pollution reduction.

Optimal Corrective Tax in General Equilibrium

- N homogeneous consumers have utility $U = u(C, D, l, G, E)$
- C, D = clean and dirty consumption goods.
- l = leisure, L = labour, $1 + L = 1$ with wage w
- G = public good produced by government with cost a
- $E = -ND$: environmental quality
- Assume $\{E, G\}$ is weekly separable from $\{C, D, l\}$ i.e. $\frac{\partial L}{\partial E} = 0$ etc.
- Assume Constant returns to scale production

Social Planner: First Best

Planner maximizes utility subject to resource constraint:

$$\max_{C,D,l,G} L = Nu(C, D, l, G, -ND) + \lambda[wN(1-l) - NC - ND - aG]$$

F.O.C.s:

$$0 = u_c - \lambda$$
$$0 = u_d - Nu_e - \lambda$$
$$0 = u_l - \lambda w$$
$$0 = Nu_G - \lambda a$$

- Implies: $\frac{u_D}{u_C} = 1 + \frac{Nu_E}{a} \rightarrow$ PMB = SMC
- $N\frac{u_G}{u_C}$ = a: Samuelson (1954) rule: $\sum_i MRS_i = MRT$

Market Economy: First Best

- Government sets taxes τ_D and τ_L and lump-sum transfer T
- C is the numeraire good with $(p_c = 1)$ and taxes $(\tau_c = 0)$
- Consumers face price $p_D = 1 + \tau_D$ and wage $\tilde{w} = (1 - \tau_l)w$
- Individual budget constraint: $C + p_D D = \tilde{w}L + T$

Households max utility s.t. BC ignoring the externality :

$$V(p_D, \tilde{w}, G, E) = \max_{C,D,l} u(C, D, L, G, E) + \lambda[\tilde{w}L + T - C - p_D D]$$

F.O.C.s:

$$u_C = \frac{u_D}{p_D} = \frac{u_l}{\tilde{w}} = \lambda$$

- Implies: $\frac{u_D}{u_C} = 1 + \tau_D$

Government maximizes indirect utility subject to balanced budget:

$$\max_{\tau_D,\tau_L,T,G} L = NV(P_D,\tilde{w},G,-ND) + \mu[\tau_D ND + \tau_L wNL - NT - aG]$$

FOCs:

$$\frac{\partial \mathcal{L}}{\partial \tau_d} = 0 = \underbrace{\overbrace{\frac{\partial V}{\partial p_D}}^{=-\lambda D(\text{envelope theorem})}}_{\text{private welfare loss}} - \underbrace{Nu_E\frac{\partial D}{\partial p_D}}_{\text{externality correction}} + \mu\left[\underbrace{D}_{\text{mechanical effect}} + \underbrace{\tau_D\frac{\partial D}{\partial p_D} + \tau_L w\frac{\partial L}{\partial p_D}}_{\text{behavioural responces}}\right]$$

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$$\frac{\partial \mathcal{L}}{\partial \tau_L} = 0 = \frac{\partial V}{\partial \tilde{w}} - Nu_E\frac{\partial D}{\partial \tilde{w}} + \mu\left[L + \tau_D\frac{\partial D}{\partial \tilde{w}} + \tau_L w\frac{\partial L}{\partial \tilde{w}}\right]$$

$$\frac{\partial \mathcal{L}}{\partial T} = 0 = \underbrace{\frac{\partial V}{\partial T}}_{=\lambda} - \mu \iff \lambda = \mu$$

$$\frac{\partial \mathcal{L}}{\partial G} = 0 = N\frac{\partial V}{\partial G} - \mu a \iff N\frac{\partial V}{\partial G} = \lambda a \qquad \text{(First best public good provision)}$$

Market Economy: First Best

FOCs, substituting $u_c = \lambda$, $\phi = N\frac{U_E}{U_C}$ and $\tilde{\phi} = \frac{\lambda}{\mu}\phi$

$$\frac{\partial \mathcal{L}}{\partial \tau_L} = 0 = D(\lambda - \mu) + \mu\left[(\tau_D - \tilde{\phi})\frac{\partial D}{\partial p_D} + \tau_L w\frac{\partial L}{\partial p_D}\right]$$

$$\frac{\partial \mathcal{L}}{\partial \tau_L} = 0 = L(\lambda - \mu) + \mu\left[(\tau_D - \tilde{\phi})\frac{\partial D}{\partial p_D} + \tau_L w\frac{\partial L}{\partial \tilde{w}}\right]$$

- Optimal taxes: $\tau_D^* = \tilde{\phi} = N\frac{u_E}{u_C}$ given $(\frac{\lambda}{\mu}{=}1)$ and $\tau_L^* = 0$
- HH's optimal choice: $\frac{u_D}{U_C} = 1 + N\frac{u_E}{u_C}$ (first best)
- Optimal tax = marginal damage (Pigou 1927)

Second Best with no lump-sum transfers

Government problem with no lump sum transfer T:

$$\max_{\tau_D, \tau_L, T, G} L = NV(P_D, \tilde{w}, G, -ND) + \mu[\tau_D ND + \tau_L wNL - aG]$$

- Same first order conditions, except no T means we don't have $\lambda = \mu$
- To get optimal taxes we have a system with two equations and two unknowns.

We'll focus on the FOC for τ_D

$$\frac{\partial \mathcal{L}}{\partial \tau_D} = 0 = -\lambda D + \mu\left[D + (\tau_D - \tilde{\phi})\frac{\partial D}{\partial p_D} + \tau_L w \frac{\partial L}{\partial p_D}\right]$$

Use Slutsky eq. to write in terms of compensated demand:

- S_{XY}: elements of the Slutsky matrix $S_{DD} = \frac{\partial h_D}{\partial p_D}$, $S_{LD} = \frac{\partial h_L}{\partial p_D}$
- Slutsky equation: $\frac{\partial D}{\partial p_D} = S_{DD} - D\frac{\partial D}{\partial T}$

$$0 = D\left[\mu - \underbrace{\left(\lambda + (\tau_D - \tilde{\phi})\frac{\partial D}{\partial T} - \mu\tau_L w \frac{\partial L}{\partial T}\right)}_{:=\lambda'}\right] + \mu\left[S_{DD}(\tau_D - \tilde{\phi}) + w\tau_L S_{LD}\right]$$

- λ' = marginal social benefit of private income

First order conditions for taxes are:

$$[\tau_D] : 0 = D[\mu - \lambda'] + \mu[S_{DD}(\tau_D - \tilde{\phi}) + w\tau_L S_{LD}]$$
$$[\tau_L] : 0 = L[\mu - \lambda'] + \mu[S_{DL}(\tau_D - \tilde{\phi}) + w\tau_L S_{LL}]$$

These can be rearranged to give:

$$\frac{\tau_L}{1+\tau_L} = \frac{\epsilon_{LD} - \epsilon_{DD}}{-\epsilon_{DD}\epsilon_{LL} + \epsilon_{LD}\epsilon_{DL}} \times \frac{\mu - \lambda'}{\mu}$$

$$\frac{\tau_D}{1+\tau_D} = \frac{\epsilon_{DL} - \epsilon_{LL}}{\epsilon_{LD} - \epsilon_{DD}}\tau_L + \frac{\tilde{\phi}}{1+\tau_D}$$

- where $\epsilon_{XY} = S_{XY}\frac{p_Y}{X}$ = compensated elasticity of demand b/w X and Y.

Optimal Labour Tax

$$\frac{\tau_L}{1+\tau_L} = \overbrace{\underbrace{\frac{\epsilon_{LD} - \epsilon_{DD}}{-\epsilon_{DD}\epsilon_{LL} + \epsilon_{LD}\epsilon_{DL}}}_{>0 \text{ given Slutsky matrix is neg def}}}^{\text{diff. in comp. elasticities wrt } p_D,\ >0} \times \overbrace{\frac{\mu - \lambda'}{\mu}}^{\substack{\text{additional value of C for gov} \\ \text{compared to HHs}}}$$

Takeaways:

1) Tax L more if D is more elastic (standard Ramsey Tax result)
2) $\tilde{\phi}$ does not matter for labour tax
   - Externalities should be corrected only by taxing the externality-producing good.
   - Don't need to readjust income tax for every new externality.

Optimal Tax on Dirty Good

$$\frac{\tau_D}{1+\tau_D} = \underbrace{\frac{\epsilon_{DL} - \epsilon_{LL}}{\epsilon_{LD} - \epsilon_{DD}} \times \tau_L}_{\text{Ramsey (revenue raising) Term}} + \underbrace{\frac{\phi\frac{\lambda}{\mu}}{1+\tau_D}}_{\text{corrective term}}$$

Special Cases:

1) $\phi = 0$ (no externalities): standard Ramsey tax to raise revenue
   - Tax D more if L is more elastic or if it is more complementary to L.
2) $\epsilon_{DL} = \epsilon_{LL}$: revenue raising term = 0
   - $\tau_D^* = \phi\frac{\lambda}{\mu}$ Pigouvian tax adjusted by the MCPF
   - If numeraire consumption is more valuable for the government than for households (because must use distortionary taxation to raise public funds), then $\frac{\lambda}{\mu} < 1$ and $\tau_D^* < \phi$
   - Intuition: higher MCPF means that taxes are more distortionary, so we keep taxes lower.

3 $\epsilon_{DL} = \epsilon_{LL}$ and $\frac{\lambda}{\mu} = 1$ then $\tau_D^* = \phi$ (Pigouvian result).

Two approaches:

1. Indirect market-based methods
2. Contigent valuation

Contingent Valuation

- It is impossible to put a market value on some externalities.
- e.g. Protecting endangered species, or protecting a remote area with little human presence.
- A common method for putting a price on these things has been to directly ask people to put a value on these things in surveys.
- These "contingent valuation" surveys have two steps:
  1) Statement about a hypothetical scenario.
  2) Ask how much people would be willing to pay to avoid the scenario.
- e.g. How much would you be willing to pay to avoid the extinction of the whales? How much would you pay to avoid a large oil spill?

Contingent Valuation: Diamond and Hausman (1994)

Problems with this method:

1. There is no resource cost to respondents.
   - Warm glow: people feel good stating they are supporters of good causes $\rightarrow$ upwards biased estimates.
2. Lack of consistency in responses:
   - Framing effect: timing of questions matter. How much to save whales vs. how much to save seals depends on the order the questions are asked.
   - The amount to clean one lake = the amount to clean 5 lakes.

Diamond and Hausman: Experts are better positioned to make these assessments. Let them decide how to allocate budget for environmental protection. Size of overall budget can be be voted on by individuals.

Measuring Externalities: Brookshire et al (1982)

- Infer willingness to pay for clean air using effect of pollution on property prices.
- Uses hedonic price regression to compare prices of property in polluted vs. non-polluted areas:

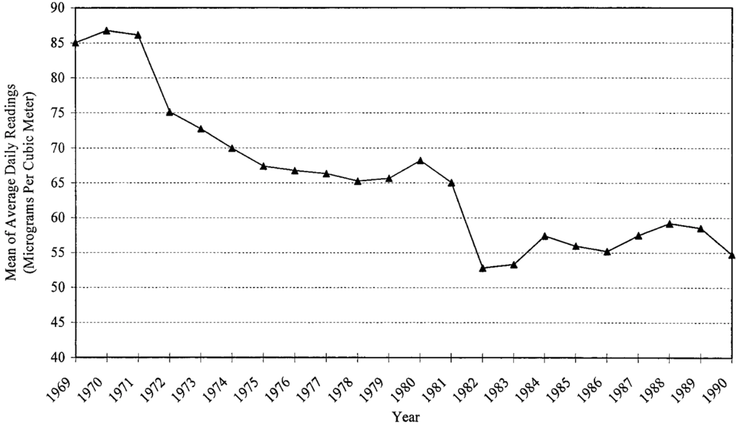
$$P_i = \alpha + \delta Pollution_i + X_i\beta + \epsilon_i$$

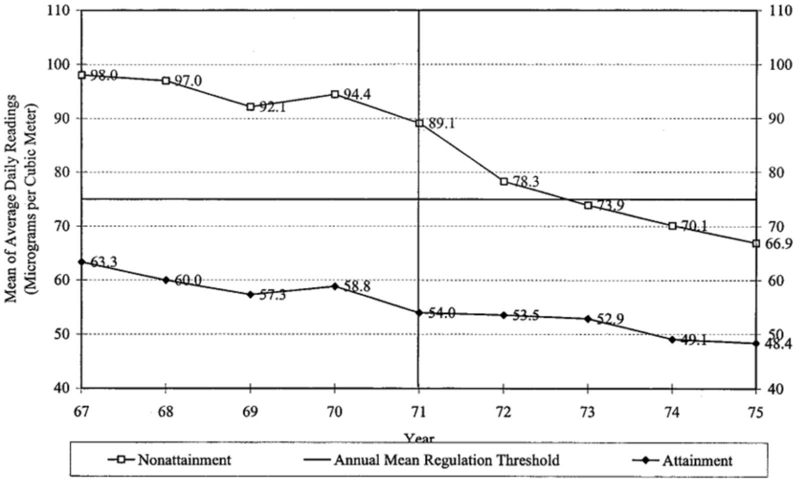
- Econometric issues:
  - Omitted variables
  - Self-selection bias. Those with low MWTP to avoid pollution may sort into high pollution areas.
    - δ would recover MWTP rather than societal average WTP.

Measuring Externalities: Chay and Greenstone (2005)

- Uses exogenous variation in Total Suspended Particulates (TSP; aka air pollution) to measure the impact of pollution reduction on housing prices.

- Clean Air Act 1970
  - Set air quality standards for 5 pollutants (TSPs included).
  - if a county had an annual mean concentration of TSPs $> 75\ \mu g/m^3$ they were assigned "Non-attainment Status".
  - States required to enforce regulation on non-attainment counties.


Mean of Average Daily Readings
(Micrograms Per Cubic Meter)
90
85
80
75
70
65
60
55
50
45
40
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
Year



Mean of Average Daily Readings (Micrograms per Cubic Meter)
110
100
90
80
70
60
50
40
98.0
97.0
92.1
94.4
89.1
78.3
73.9
70.1
66.9
63.3
60.0
57.3
58.8
54.0
53.5
52.9
49.1
48.4
67
68
69
70
71
72
73
74
75
Year
Nonattainment
Annual Mean Regulation Threshold
Attainment

Measuring Externalities: Chay and Greenstone (2005)

IV empirical strategy:

$$\Delta P_c = \Delta T_c \theta_{iv} + \Delta X_c \beta_p + \epsilon_c$$

$$\Delta T_c = Z_c \Pi_{TZ} + \Delta X_c \beta_T + u_c$$

Reduced form:

$$\Delta P_c = Z_c \Pi_{PZ} + \Delta X_c \beta_p + \epsilon_c$$

- where:
  - ΔP_c is the change in log housing prices between 1970 and 1980
  - ΔT_c is the change in average TSPs between 1970 and 1980
  - $Z_c = 1(T_c^{75} > 75\mu g/m^3)$
  - Given $Z_c \in \{0, 1\}$ we have $\theta_{iv} = \frac{\Pi_{PZ}}{\Pi_{TZ}}$ (Wald estimator).

Required Assumption: $E Z_c \epsilon_c = 0$ (exclusion restriction). Reasonable?

TABLE 3
CROSS-SECTIONAL AND FIRST-DIFFERENCE ESTIMATES OF THE EFFECT OF TSPS POLLUTION ON LOG HOUSING VALUES

	(1)	(2)	(3)	(4)
	A. 1970 Cross Section			
Mean TSPs (1/100)	.032	−.062	−.040	−.024
	(.038)	(.018)	(.017)	(.017)
R^2	.00	.79	.84	.85
Sample size	988	987	987	987
	B. 1980 Cross Section			
Mean TSPs (1/100)	.093	.096	.076	.027
	(.066)	(.031)	(.030)	(.028)
R^2	.00	.82	.89	.89
Sample size	988	984	984	984
	C. 1970–80 (First Differences)			
Mean TSPs (1/100)	.102	.024	.004	−.006
	(.032)	(.020)	(.016)	(.014)
R^2	.02	.55	.65	.73
Sample size	988	983	983	983
County Data Book covariates	no	yes	yes	yes
Flexible form of county covariates	no	no	yes	yes
Region fixed effects	no	no	no	yes

TABLE 4

ESTIMATES OF THE IMPACT OF MID-DECADE TSPs NONATTAINMENT ON 1970–80 CHANGES IN TSPs POLLUTION AND LOG HOUSING VALUES

	(1)	(2)	(3)	(4)
	A. Mean TSPs Changes			
TSPs nonattainment in 1975 or 1976	−9.96	−10.41	−9.57	−9.40
	(1.78)	(1.90)	(1.94)	(2.02)
F-statistic TSPs nonattainment*	31.3	29.9	24.4	21.5
	(1)	(1)	(1)	(1)
R^2	.04	.10	.19	.20
	B. Log Housing Changes			
TSPs nonattainment in 1975 or 1976	.036	.022	.026	.019
	(.012)	(.009)	(.008)	(.008)
F-statistic TSPs nonattainment*	8.5	6.2	9.3	6.4
	(1)	(1)	(1)	(1)
R^2	.01	.56	.66	.73
County Data Book covariates	no	yes	yes	yes
Flexible form of county covariates	no	no	yes	yes
Region fixed effects	no	no	no	yes
Sample size	988	983	983	983

TABLE 5

INSTRUMENTAL VARIABLES ESTIMATES OF THE EFFECT OF 1970–80 CHANGES IN TSPs POLLUTION ON CHANGES IN LOG HOUSING VALUES

	(1)	(2)	(3)	(4)
	A. TSPs Nonattainment in 1975 or 1976			
Mean TSPs (1/100)	−.362	−.213	−.266	−.202
	(.152)	(.096)	(.104)	(.090)
Sample size	988	983	983	983
	B. TSPs Nonattainment in 1975			
Mean TSPs (1/100)	−.350	−.204	−.228	−.129
	(.150)	(.099)	(.102)	(.084)
Sample size	975	968	968	968
	C. TSPs Nonattainment in 1970, 1971, or 1972			
Mean TSPs (1/100)	.072	−.032	−.050	−.073
	(.058)	(.042)	(.041)	(.035)
Sample size	988	983	983	983
County Data Book covariates	no	yes	yes	yes
Flexible form of county covariates	no	no	yes	yes
Region fixed effects	no	no	no	yes

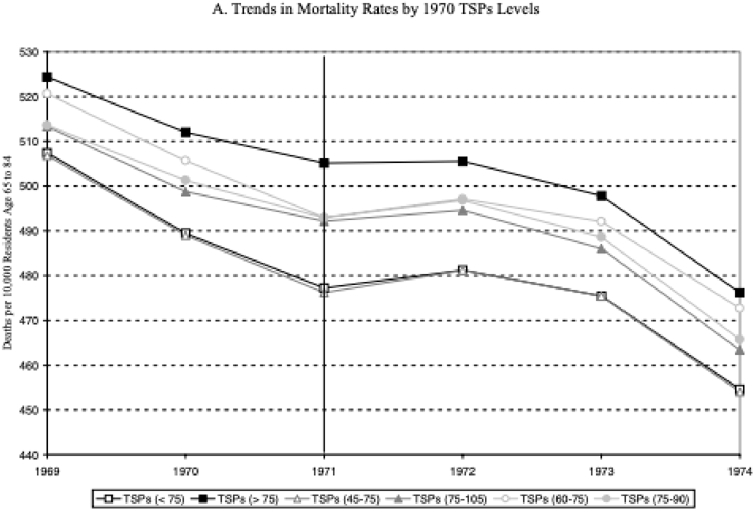
Measuring Externalities: Chay and Greenstone (2005)

- Results: 1% increase in pollution → 0.2-0.35% decline in house values.
- Suggests that the Clean Air Act increased housing values by $45 billion in non-attainment counties.
- Some concern about OVB remains as coefficients decline when more controls added.
- Does this empirical design deal with self-selection bias concerns?

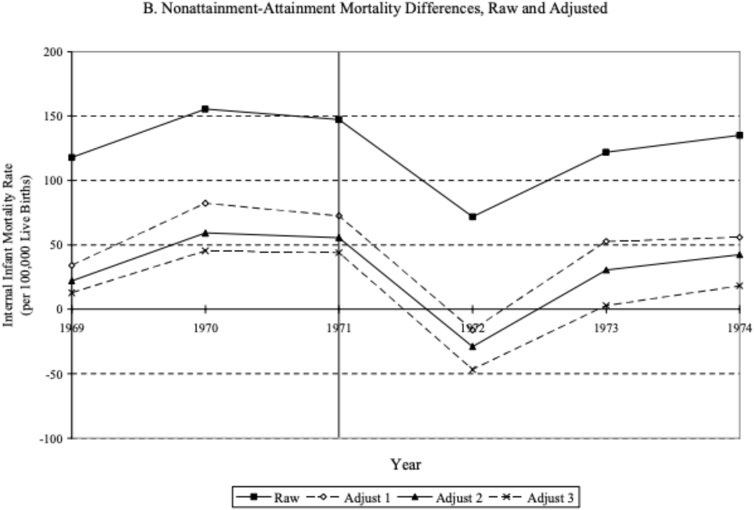
Question: What exactly is priced in here?

- Long-term health risks? Risk to health of children?

Measuring Externalities: Chay and Greenstone (2003)



Measuring Externalities: Chay and Greenstone (2004)



Measuring Externalities: Chay and Greenstone (2005)

- No statistically significant effect of CAA on short-term mortality adults in non-attainment counties.
  - Is prolonged exposure what is important for adults?

- One percent decline in TSPs 0.5 percent decline in infant mortality rate.
  - Question again: is this priced into the impact of home prices?

- Uses “toxic” plant openings and closings to estimate the causal effect of air pollution on housing prices and infant health outcomes.
- The show that these plants only impact air quality a relatively small distance from their location ($\approx$ 1 mile).
- Use a difference-in-differences design to compare those near to a plant opening/closing (within 1 mile) to those further away (1 to 2 miles).
- Argue that their research design holds changes in local amenities due to plant openings/closings (jobs) constant.

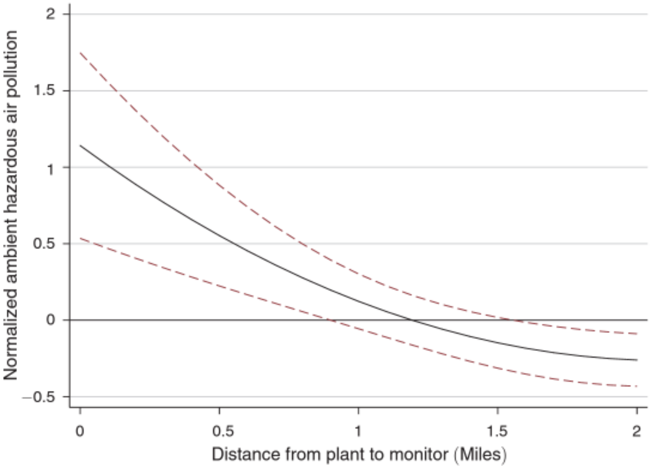


Figure 2. The Effect of Toxic Plants on Ambient Hazardous Air Pollution, All Pollutants

$$
\begin{aligned}
Y_{idt} = &\beta_0 + \beta_1 1[Plant\ Operating]_{it} + \beta_2 1[Near]_{it} \\
&+ \beta_3 (1[Plant\ Operating]_{it} \times 1[Near]_{it}) + \eta_{id} + \tau_t + \epsilon_{idt}
\end{aligned}
$$

- $d \in \{near, far\}$ location of HH (birth).
- Y_{idt} : average outcome (log house price or incidence of low birth weight) near plant j, within distance group d, in year t.
- τ_t time fixed effects, η_{id} plant distance fixed effects.
- $\beta_3 =$ DiD estimate:

$$
\begin{aligned}
\beta_3 = &\ (E[Y_{idt}|\text{near, operating}] - E[Y_{idt}|near, operating]) \\
- &\ (E[Y_{idt}|\text{far, operating}] - E[Y_{idt}|\text{far, not operating}])
\end{aligned}
$$

Required assumption: Parallel trends.

Measuring Externalities: Currie et. al. (2015)

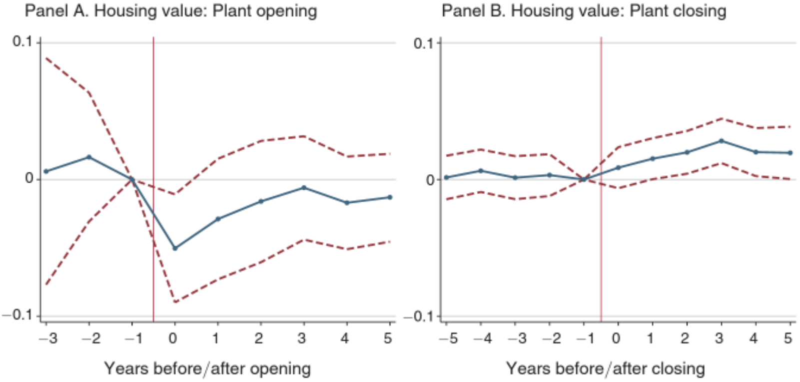


FIGURE 3. EVENT STUDY: THE EFFECT OF TOXIC PLANT OPENINGS AND CLOSINGS ON LOCAL HOUSING VALUES

Measuring Externalities: Currie et. al. (2015)

TABLE 2—THE EFFECT OF TOXIC PLANTS ON LOCAL HOUSING VALUES

	0–0.5 Miles		0.5–1 Miles		0–1 Miles		0–1 Miles (+/− 2 years)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. Estimated effect of plant operation								
1(Plant Operating) × Near	−0.030***	−0.022***	−0.010**	−0.012***	−0.015***	−0.014***	−0.009**	−0.010***
	(0.007)	(0.006)	(0.005)	(0.004)	(0.005)	(0.004)	(0.004)	(0.003)
Observations (plant-distance-year cells)	34,736	34,736	34,736	34,736	34,736	34,736	30,492	30,492
Plant × distance-bin FE	X	X	X	X	X	X	X	X
State × year FE	X		X		X		X	
Plant × year FE		X		X		X		X

Measuring Externalities: Currie et. al. (2015)

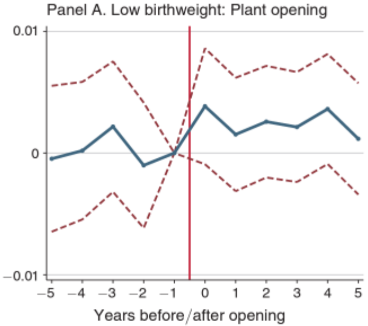


Figure 4. Event Study: The Effect of Toxic Plant Openings and Closings on the Incidence of Low Birthweight

TABLE 4—THE EFFECT OF TOXIC PLANTS ON LOW BIRTHWEIGHT

	0–0.5 Miles		0.5–1 Miles		0–1 Miles		0–1 Miles (+/− 2 years)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. Estimated effect of plant operation								
1(Plant Operating) × Near	0.0010	0.0012	0.0014**	0.0015**	0.0013**	0.0014**	0.0021**	0.0026***
	(0.0010)	(0.0012)	(0.0006)	(0.0006)	(0.0006)	(0.0007)	(0.0009)	(0.0009)
Observations	88,958	88,958	88,958	88,958	88,958	88,958	63,324	63,324
Plant count	3,438	3,438	3,438	3,438	3,438	3,438	3,438	3,438
Panel B. Estimated effect of plant openings and closings								
1(Plant Opened) × Near	0.0025	0.0022	0.0024***	0.0027***	0.0024**	0.0024***	0.0031*	0.0037**
	(0.0019)	(0.0018)	(0.0009)	(0.0010)	(0.0009)	(0.0008)	(0.0017)	(0.0017)
1(Plant Closed) × Near	−0.0002	−0.0007	−0.0009	−0.0009	−0.0007	−0.0009	−0.0016	−0.0021*
	(0.0016)	(0.0016)	(0.0009)	(0.0010)	(0.0009)	(0.0009)	(0.0012)	(0.0013)
H_0: Opening = −Closing (p-value)	0.44	0.56	0.32	0.28	0.22	0.24	0.51	0.48
Observations	88,958	88,958	88,958	88,958	88,958	88,958	63,324	63,324
Plant count	3,438	3,438	3,438	3,438	3,438	3,438	3,438	3,438
Plant × Distance-bin FE	X	X	X	X	X	X	X	X
State × Year FE	X		X		X		X	
Plant × Year FE		X		X		X		X

Measuring Externalities: Currie et. al. (2015)

- Opening a toxic plant reduces housing values by 11% within 0.5 miles ($4.25million per-plant).
- Housing prices stay depressed after plant closing → willingness to pay is not entirely comprised of health effects.
- Incidence of low birth weight decreases by 3.1% ≈ $5,600 decrease in lifetime earnings per plant per year.

Measuring Externalities: Currie et. al. (2015)

- This literature gives us some indirect evidence of externality costs of pollution.
- These likely don't capture everything. Long term impacts are hard to identify. Some pollutants released but not measured may have a more diffuse impact.
- Huge question: How do we price the impact of carbon emission on climate change?