

Development and the Environment
Public policy issues

Development and the environment

Three main problems to be explained:

Over-production of a polluting activity → Excess pollution due to local and global negative externalities.

Under-provision of an environmental service due to missing markets to internalize positive externalities.

Over-extraction from a renewable natural resource and **under-provision** in maintenance of the resource, both leading to destruction.

The **basic concepts** of environmental economics to explain these outcomes are (1) market failures due to externalities, (2) incomplete property rights and difficulties to sustain collective action for managing common property resources, (3) public goods, (4) high private discount rates, (5) sustainability considerations, (6) differential relative valuation of income and environmental amenities between poor and rich countries, and (7) missing markets for environmental services.

The environment as a development issue: Poor people are often the most affected by resource depletion and environmental degradation, while rarely being major contributors, except at the local level in highly populated fragile and economically lagging regions.

Table 1: Major environmental issues and concerns

Environmental Issue	Why we should be concerned			
	Disruptions to the global food balance	Disruptions to food balances at regional and country levels	Global and regional environmental externalities	Local problems that impact on significant numbers of poor people
Water scarcities	Water scarcities in major food producing regions may affect aggregate world food supplies and prices	Water scarcities in major producing regions may disrupt country or regional food supplies	Reduced flow of fresh water in rivers affects aquatic life and coastal areas	Exhaustion of local groundwater and aquifers
Global climate change	May adversely affect world food supplies and prices	May adversely affect regional and country food supplies	May trigger massive loss in biodiversity and flooding of coastal areas	May adversely affects livelihoods for large numbers of poor people
Over-intensification of crop and livestock systems	Disruption to world trade in livestock products. Risk of triggering major animal and even human disease pandemic	Disrupt regional consumption and production of livestock products. Risk of major crop disease outbreak that affects regional production and food supplies	Pollution of major waterways with far reaching impacts into coastal areas. Loss of biodiversity, including agricultural biodiversity. Risk of human disease epidemic	Local water pollution from nitrates, pesticides and animal effluent. Pesticide poisoning through application. Degradation of irrigated land through salinization and water logging
Deforestation due to extension of farming		Flooding of lowlands and silting of dams and irrigation infrastructure reduces river basin and country food production	Carbon emissions contribute to global climate change. Flooding of lowlands and silting of dams affects urban areas and nonfarm economy (e.g. reduced electricity generation). Loss of valued biodiversity and ecological systems	Loss of forest products and services to local people
Soil degradation in backward regions (e.g. much of Africa)		Reduce food production at regional levels.	Degradation of upper watersheds of important river basins, loss of biodiversity, local climate change	Unsustainable production systems that cannot keep up with local food and livelihood needs.

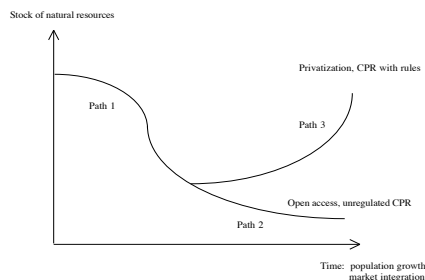
(from Peter Hazell)

I. Negative and positive externalities

See separate handout below

II. Incomplete property rights: open access resources and common property resources

- Examples of consequences of open access: overfishing, deforestation, exhaustion of underground aquifers, overgrazing and desertification, soil erosion in watersheds and siltage of reservoirs.
- This may occur when ownership of these resource is not defined (open access resource) and people consider the harvesting cost but not the cost imposed on others due to depletion when making their harvesting choices. They are over-extracting relative to the social optimum. There is market failure as private parties fail to consider the impact of their activities on others. This is the “tragedy of the commons”.
- Overuse can also occur under common property resource (CPR) if the community that owns the resource fails to cooperate in managing the resource. Each member then extracts without taking into account the cost that he imposes on others through depletion, leading to overuse. Hence, there is over-extraction from the resource
- Population pressure (Ester Boserup), market integration, and economic development with open access resources (Path 1) lead to depletion of the stock of natural resources, but also to increased demand for environmental protection. This may lead to changes in property rights (privatization) and to CPR with cooperation (Path 3), or it can fail (Path 2).



III. Public Goods

3.1. The problem of public goods

Another case of market failure. Public goods have two characteristics:

- i) **Nonrivalry in consumption:** Consumption by one does not preclude consumption by others.
- ii) **Nonexcludability in use:** There is no barrier to use. Access to the good cannot be restricted.

Example of public good: Air quality, knowledge, infrastructure.

Individual suppliers could not charge for use. There is market failure in provision of public goods. No one likes paying for the public good above his/her marginal benefits and all would like to be "free riders." There is under-provision of public goods by the market.

3.2. The delivery of public goods

Public good cannot be optimally provided by market forces. Who delivers public goods?

1. **Government** uses tax revenues to deliver public goods. Examples: Research, defense, parks, environmental protection, roads and infrastructure.
2. **Other providers** of public goods: The church, the rich (they sponsor events and donate to foundations and schools), foundations.
3. Public goods can also be provided by "**collective action**": Volunteer collaboration of citizens to finance and support projects with benefits they share.
 - Collective actions result in institutions such as:
 - (1) Water user associations. They share the cost of conveyance canals and pumps.
 - (2) Village associations: delivery of local public goods (club goods).

However, collective action is not easy:

- Establishment of organizations for collective action is a political challenge due to free riding (prisoner's dilemma).
- Organizations that control public resources (e.g., waterways) may be managed to serve the interest of subgroups (problem of capture).
- Successful collective action requires:
 - Positive expected individual **benefits** from cooperating.
 - Ability to **monitor** the behavior of others.
 - Ability to **enforce** rules (punish those who do not respect the rules).
 - Time to **learn** to cooperate (tit-for-tat) and derive future benefits from cooperation (Folk theorem).

Example: provision of maintenance services under devolution of management of forest resources and irrigation systems to ejido communities in Mexico.

IV. Discount rate: private vs. social

General discounting formula: present value of a future value F_t obtained t years from now:

$$PV(F_t) = \frac{F_t}{(1+i)^t}, \text{ where } i \text{ is the discount rate.}$$

Examples of present value of \$100 of future income:

Discount rate: i (%)	Year 0	Year 1	Year 2	Year 5	Year 10	Year 30	Present value of stream of 100 over 30 years
0 (environmentalist)	100	100	100	100	100	100	3,000
2 (social)	100	98	96	91	82	55	2,240
10 (private)	100	91	83	62	39	6	941
25 (speculative)	100	80	64	33	11	0.1=10¢	400

If the private discount rate (set by the financial market as the interest rate) is higher than the social discount rate, this leads to **under-valuation** of the future and to **accelerated depletion** relative to the social optimum.

V. Sustainability

5.1. Renewable and non-renewable resources

A key issue is depletion of natural resources (NR).

- NR can be classified as **renewable** (fish, forest) or **nonrenewable** (minerals, oil).
- Renewable resources can be sustained if use does not permanently exceed the natural growth rate of the resource.

For many fisheries, wildlife, or forests, excessive extraction leads to reduction of stock and in some cases to extinction: use is not sustainable.

5.2. How to define sustainability?

Sustainability is aimed at stabilizing resource stocks at a socially desirable level. The Bruntland Commission defines sustainability in the use of a resource as allowing a level of welfare for the next generation that is not inferior to the welfare of this generation as a consequence of the level of use this generation makes of the resource.

There is market failure in securing sustainability since the next generation is not here to bid for conservation of the resource. Hence, sustainability has to be a goal of this generation.

Problem: How is welfare defined? What is being sustained?

Sustainability of fish extraction: constant yield (no technological change, no substitutions). Figure 1.

Sustainability of yield: can deplete soil, but use technological change to sustain yields on declining soil quality. Figure 2.

Sustainability of income: can deplete the resource but tax part of the benefits to invest in other sources of income (US: cut the trees, and invest in industry = activity substitution) (Figure 3).

5.3. Other problems to achieve sustainability:

Irreversibility: Situations where future effort cannot correct for current or past damage. Ecosystems have thresholds of irreversibility that limit the possibility of restoration.

Uncertainty: Lack of knowledge about the performance of economic and ecological system. Uncertainty requires (1) learning and (2) caution in action (precautionary principle).

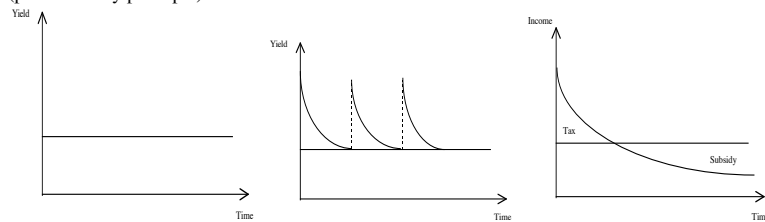


Figure 1

Figure 2

Figure 3

VI. Economic development and environmental protection

- Poor countries value additional income more than pollution abatement; rich countries may value pollution abatement more than additional income. For this reason, environmental regulation may not exist or may not be enforced in poor countries.
- Developing countries with medium levels of income per capita (say, above \$2,000/year) have severe pollution problems such as air pollution, water pollution (e.g., China).
- Protection against overuse of natural resources occurs mostly in richer countries with GNP/capita of, say, above \$5,000/year. Rich countries will develop policies to protect resources that provide environmental services and to internalize externalities.
- There may exist a **Kuznets environmental curve** between emissions and GDPpc (e.g., SO₂ (acid rain), hydro-fluorocarbons (ozone), but not CO₂). If it does not exist, rising per capita incomes will not solve the environmental problem alone.



VII. Missing markets for environmental services

See separate handout below

VIII. Conclusions

Environmental problems are created by **market failures**.

7.1. If **negative externality** (pollution), there is **over-production** relative to the social optimum.

If there is **positive externality** (R&D, education), there is **under-provision** relative to the social optimum.

7.2. If there are **incomplete property rights** (open access, CPR without cooperation), there is over-extraction from the resource leading to exhaustion.

7.3. If the good is a **public good**, there is **under-provision** by the market and by the community if it does not cooperate (free-riding, Prisoner's Dilemma).

7.4. If the private **discount rate** is higher than the social discount rate, there is under-valuation of the future value of natural resources, and hence excessively rapid depletion of the resource by individuals.

7.5. If the social goal is **sustainability** (inter-generational equity), market forces will generally induce over-use relative to the sustainability objective as the next generation is not here to bid on the resource.

Solutions to these market failures require either **government interventions** (that can also fail) or the emergence of **new institutions** to make the market work (property rights) or to replace the market (contracts).

7.6. In **poor countries**, improving income may be more valued than improving environmental amenities. This explains why environmental regulation is weaker and less enforced in these countries.

EXTERNALITIES AND ENVIRONMENTAL POLICY

Introduction. Definition of externalities and market failures

- Markets fail if there is:
 - Imperfect information
 - Externalities (positive or negative)
 - Public goods
 - Increasing returns to scale (natural monopoly)
 - Non-competitive behavior.
- Welfare economics: with perfect markets, a competitive equilibrium is efficient (Pareto optimal). It maximizes the sum of producer and consumer surpluses. Under market failure, markets do not achieve an efficient allocation of resources. Interventions are needed, either by government (regulation) or through private deals (Coase Theorem).
- Production externality: the welfare of an individual is affected by the production decisions of others (e.g., air pollution from burning coal, groundwater pollution from using fertilizers, food contamination from use of pesticides, farm worker exposure to chemicals)
Consumption externality: the welfare of an individual is affected by the consumption decisions of others (e.g., noise pollution, choice of foods available in markets).
- With externalities, market prices do not reflect the true marginal cost or benefit of the goods and services traded in the market. Incentives are distorted. Markets fail.

I. Negative production externalities

Negative production externality: one individual's production decisions imposes costs on others not transmitted by the market. Figure 1.

- Social planner problem (social welfare maximization)

$$\text{Max}_q W(q) = B(q) - C(q) - E(q)$$

Where: $W(q)$ = social welfare function

$B(q)$ = total social benefit of q

$C(q)$ = total private cost of q

$E(q)$ = total external cost of q

$$\text{Solution: } MB - MPC - MEC = MB - MSC = 0$$

MB = marginal social benefit

MPC = marginal private cost

MEC = marginal externality cost

MSC = marginal social cost

Social optimum: q^* when $MB = MSC$

- Unregulated competition (private firm problem)

$$\text{Max}_q \pi(q) = B(q) - C(q)$$

Foc: $MB - MPC = 0$

Private optimum: q_c when $MB = MPC$

- Analysis: $q_c > q^*$ when $MEC > 0$. Hence, inefficient: excess production and excess pollution.

Need policy interventions to return the economy to the social optimum: $q_c = q^*$.

Different policy instruments have different efficiency and welfare implications.

Alternative policy instruments:

Tax on production, tax on consumption (polluter pays principle)

Output-reduction subsidy (if polluter has the right to pollute)

Quotas: Pollution standard, output standard

Tradable permits (e.g., Kyoto)
 Changes in organization: Unitization, cooperation
 Coase private negotiation

If positive environmental externality: need pay for the environmental service.

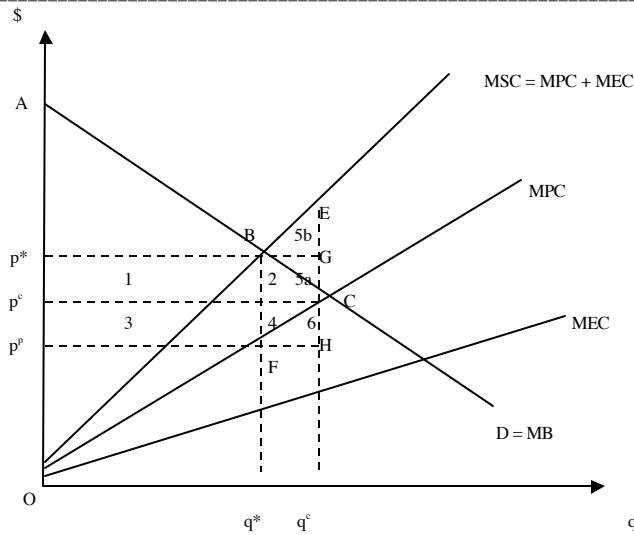


Figure 1. Production externality

MPC = marginal private cost
 MEC = marginal externality cost
 MSC = marginal social cost
 MB = marginal benefit = Demand

Social optimum at B where $MSB = MSC$

Social benefits = ABq^*O

Social cost = OBq^*

Social welfare = $ABO = \text{Producer surplus} + \text{Consumer surplus}$

Free market outcome at C

Social benefits = ACq^cO

Social costs = $OCq^c + OEC = OEq^c$

Social welfare = $ABO - BEC = \text{Producer surplus} + \text{Consumer surplus} - \text{Deadweight loss}$

Deadweight loss = BEC

Different targeting of the policy (which variable to regulate)

On outputs

On inputs

On externality (pollutant): most efficient if can be done.

• **Policy instrument 1: Externality tax or output tax rate**

Figure 1: Change solution from $C \rightarrow B$, producers at F; consumers at B.

Change in CS = $-1 - 2$

Change in PS = $-3 - 4 < 0$

Change in Government Budget = $+1 + 3 > 0$

Change in pollution = $+2 + 4 + 5$

Net social gain = 5

Externality tax t : optimum tax $t^* = p^* - p^p$

Tax eliminates the deadweight loss from externality.

Private firm problem: $\text{Max}_q \pi(q) = pq - C(q) - tq$

Solution: $p - MPC - t^* = 0$. Hence, optimum tax: $t^* = MEC(q^*) = \text{government revenue}$.

With a tax on externality (or on output if pollution is proportional to output), private optimum is at q^* .

• **Policy instrument 2: Output reduction subsidy (polluter owns the right to pollute)**

Figure 1: Change solution from $C \rightarrow B$, producers at F; consumers at B.

Change in CS = $-1 - 2$

Change in PS = $(-4 + 1) + (2 + 4 + 5a + 6) > 0$

Change in B = $-2 - 5a - 4 - 6 < 0$

Change in pollution = $+2 + 4 + 5$

Net social gain = 5.

Reduce pollution by paying subsidy $p^* - p^p$ for each unit of output not produced.

$\bar{q} = q^c$, current level of output.

s = subsidy per unit of output not produced.

Private firm problem: $\text{Max}_q \pi(q) = pq - C(q) + (\bar{q} - q)s$

Solution: $p - MPC - s = 0$. Hence, $s^* = p - MPC$.

Optimum subsidy: $s^* = t^* = MEC(q^*)$.

With subsidy, private optimum is at q^*

Government cost = $t^*(\bar{q} - q^*)$.

Analysis: costly on government. Highly attractive to firms: they gain rent 1 + subsidy (2 +5a +6).

Disequilibrium: cost of subsidy may increase in the long run if the subsidy attracts new firms into the industry.

- **Policy instrument 3: pollution standard or output standard** (command-and-control approach).
 q restricted to q^* .

1. Production quotas

Figure 1: Change solution from C \rightarrow B, producers at B; consumers at B.

Change in CS = -1 -2 < 0

Change in PS = -4 +1 > or < 0

Change in B = 0

Change in pollution = +2 +4 +5

Net social gain = 5 = BEC.

Producer surplus > Producer surplus under externality tax (as they capture the rent instead of government)

Consumer surplus = Consumer surplus under externality tax.

Analysis:

- Political economy of standards vs. taxes:

Producers prefer quotas over taxes: they gain 1 + 3

Government prefers externality tax over quota as does get tax revenues (that could be used to reduce distortive taxation elsewhere in the economy).

Consumers indifferent.

Pollution effects the same.

- Standards (regulation) vs. no regulation: Change in producer surplus can be positive or negative according to elasticity of demand.

2. Tradable quota

Producers bid for quota until all rent has been transferred to the quota owner.

Quota price = $p^* - p^p = t^*$

Producer surplus = Producer surplus under externality tax = OFp^p

Quota rent = Government budget under externality tax = p^*BFp^p captured by the legal owner of the quota.

3. Role of elasticity of demand

Inelastic demand: $q \sim q^*$: small inefficiency (-4 small, +1 large)

Elastic demand: $q \gg q^*$: large inefficiency (-4 large, +1 small)

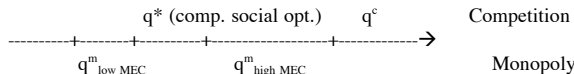
Inelastic demand and quota at q^* : firms get large rents and may gain from regulation since p increases as q declines (identical to monopoly rent). Producers of an inelastic good love to be regulated by output standards! ($1 \gg -4$)

4. Imperfect competition and externality policy

Monopoly: $q < q^*$

Externality: $q > q^*$

Net effect?



If low MEC: monopolist under-produces: needs subsidy

If high MEC: monopolist over-produces: need tax.

But monopoly is better than competitive firms as produces less of polluting product.

II. Polluter heterogeneity: transferable permits

Heterogeneous firms in ability to abate pollution.

Social planner needs determine: efficient level of pollution and efficient mix of pollution.

Use transferable permit system to allocate pollution abatement between firms in the most cost-effective fashion.

$i = 1, \dots, I$ firms (polluters)

X_i pollution generated by firm i

$B^i(X_i)$ monetary benefit of polluter i derived from pollution

$X = \sum_i X_i$ total pollution

$SC(X)$ social cost of pollution.

- Social planner problem: $Max_{X_i, X} L = \sum_i B^i(X_i) - SC(X) + \lambda \left(X - \sum_i X_i \right)$

λ = shadow price of pollution

Solution: $MB_i - \lambda = 0$, all i

$MSC + \lambda = 0$

Hence, $MB_i = MSC = \lambda$, all i

- Individual firm problem: $Max_{X_i} B^i(X_i)$. Solution: $MB_i = 0$.

Use a tax per unit of pollution: $t^* = MSC(X^*) = \lambda$,

or allow trading of pollution permits, with total pollution permits equal to optimal pollution level X^* .

Price of pollution permits at optimum = λ

Initial allocation of pollution permits = X^*/I if egalitarian

Permits traded at equilibrium price λ .

Gains from trade: Firm with high MB_i buys permits

Firm with low MB_i sells permits

Need monitor that emission of each firm is $X_i \leq$ permit.

Benefits of pollution trading

- Efficient solution can be achieved:
By pollution tax: $t^* = \lambda$
or with quotas X_1^*, X_2^*, \dots if know the true social cost of pollution.
- If the objective is to reach the exogenous pollution level X^* , then best to use tradable permits since it does not require knowing the individual firm MB_i functions.

Problems associated with pollution permits markets

- Difficult to measure and monitor emissions of each firm.
- Many different pollutants: easier to regulate polluting activities than pollution. Hence, tax the level of activity instead of taxing pollution.
- If different local impacts of pollution: use several markets instead of one large markets? Induce optimal location of polluting firms across localities.
- Strategy: Set total pollution level X^*
Allocate pollution permits to firms X^*/I
Need not know MB_i
Firms equalize $MB_i = \lambda$ by trading permits
Need monitor that $X_i \leq$ permits held.

III. Property rights and the Coase theorem

Property rights = entitlements

Polluter may have ownership: e.g., upstream farmers own right to pollute (e.g., first come).

Polluted may have ownership: e.g., consumers of water may have right to clean water.

Coase theorem: if
Clear property rights
Full information
Low transactions costs

then, agents can bargain for a Pareto optimal allocation without government intervention, irrespective of who own property rights.

Parties agree on optimal transfer (bribe).

Parties need to be organized to engage in bargaining: need users association.

Hence, bargaining is more effective if small number of parties (low transactions costs in monitoring, negotiating, and enforcing). More effective if easily observed externalities.

Who captures the NSG is determined by who has the property rights.

Rights must be alienable (can be sold). Inalienable rights cannot be bargained.

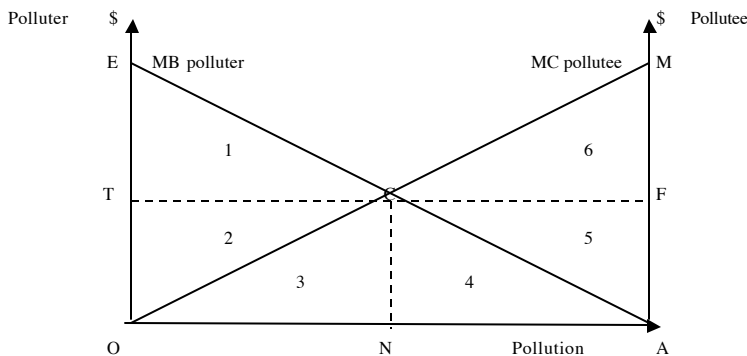


Figure 6. Coase theorem

Case 1: The polluter has the right to pollute

Initial outcome

Pollution occurs until MB of pollution for the polluter = 0 (OA)

Polluter welfare = OEA = 1+2+3+4

Pollutee welfare = - MOA = -3-4-5-6

Social welfare = OEC - MCA = (1+2) - (5+6)

Outcome after negotiation: pollutee pays the polluter \$F per unit of pollution reduction until $MC = MB$.

Pollution = ON

Polluter welfare = OECN + NCFA > OEA or $(1+2+3)+(4+5) > 1+2+3+4$, hence gains 5.

Pollutee welfare = -OCN - NCFA < - MOA or $-3-(4+5) > -3-4-5-6$, hence gains 6.

Net social gain = OEC = 1+2 > 0.

Case 2: The pollutee has the right to pollute

Initial outcome

Pollution = 0

Polluter welfare = 0

Pollutee welfare = 0

Social welfare = 0

Outcome after negotiation: polluter pays the pollutee \$T per unit of pollution emitted

Pollution = ON

Polluter welfare = ECT = OECN - OTCN > 0

Pollutee welfare = OTC = OTCN - OCN > 0

Social welfare = OEC

Importance of Coase theorem: if property rights over pollution are clearly assigned, if there is full information, and if transactions costs in negotiating are low,

IV. Conclusion: Components of externality policy

1. Pollution is not easily measured: How to regulate under imperfect information?

- Use proxies for pollution: input, output, technology used.

Example 1: tax input instead of pollution (tax on fertilizer as cannot measure the effect on water pollution (non-source pollution).)

Example 2: tax on the existence of an activity instead of pollution (annual business fee, building codes, equipment codes.)

- Subsidy to technology that helps decrease pollution (subsidy to the use of precision technology to reduce fertilizer use). Subsidy to adopters of technology to monitor pollution: adopters pay lower annual fee (reverse lemons (Akerlof): good polluters buy meters and drive away bad polluters).

2. Point vs. non-point pollution

- Point pollution: source easy to identify.
- Non-point pollution: source hard to identify (e.g., fertilizer or pesticide run-offs into water tables).

With non-point pollution:

- i) Regulate the cause of pollution: number of cows, location, waste disposal system.
- ii) Collective punishment: if pollution $> \bar{z}$, tax all potential polluters.
- iii) Induce collective action if polluters have local information: individuals monitor each others and impose social sanctions. Use local information and local social capital to regulate.

3. Regulation of pollution: tips for policy makers

- i) Use taxes (preferred by government): Tax on pollution or on pollution-generating inputs, outputs, activities or technologies.
- ii) Use subsidies (preferred by producers) for:
 - Production reduction
 - Abatement activities
 - The development of substitute technologies.
- iii) Use direct control policies (preferred by producers with inelastic demand): standards, quotas, technology standards, building codes: less efficient, but more output and employment.
- iv) Use trading in pollution rights (heterogeneous firms): transferable permits (preferred by those who receive large quotas). Allow firms to abate by a given total amount at lower cost.
 - v) Give clear definition of property rights to allow private deals (Coase theorem).
 - vi) Give support for R&D: new technologies to reduce, mitigate, and monitor pollution (win and win).
 - vii) Use education: make people feel concerned/guilty when they pollute (voluntary internalization of externalities)
 - viii) Use self-selection by consumers: exposure of polluters; labeling of green products. Works when consumers care and when they have alternative options.

ENVIRONMENTAL SERVICES

I. The problem defined

Origin of the problem. Market failures: missing markets for environment services (ES)

Consequences: private price < social value of the resource

Leads to: Under-investment in maintenance of the resource

Over-extraction from the resource and depletion

Solutions if the provider has property right over the resource (cannot expropriate)

Introduce a market for the service: PES

Introduce contracts for maintenance of the resource and provision of the service: PES

Regulate provision of the service (compulsion, expropriation of part of the owner's rights)

II. Types of environmental services

1. Ex-situ conservation of biodiversity (habitat for wild species, in-situ conservation of native species)
 - Intrinsic value: willingness to pay for preservation of the existence and option values of the resource.
 - Instrumental value: bio-prospecting, preservation of species
2. Carbon sequestration: forests (capture by growing trees, stocks in mature trees), soils (zero tillage), wetlands.
3. Protection of watersheds: reduce soil erosion, reduce siltage of reservoirs, increase water quality, increasing regularity of water flows and hence effective capacity of reservoirs.
4. Protection of landscapes, of open spaces

Remarks:

1. A same piece of land can deliver a multiplicity of services.
2. These services can be
 - Complementary: carbon capture and maintenance of biodiversity in forests
 - Competitive: trees reduce soil erosion but absorb water (e.g. eucalyptuses); increase the area in wetlands reduces native plants.
3. Services can be captured: Locally, Nationally, Globally
 - Who pays for the service depends on who captures it: local tax or market, national budget, international market or agreement.
4. Valuation of the services is difficult
 - Because there often are no markets: water, landscape, carbon capture, biodiversity
 - Because contingency valuation is difficult to do (biases due to framing).

Yet, to pay for environmental services, we need to:

Define the quantity: index of environmental services provided (what units., what weights)

Define the price to be paid per unit of the index

III. Examples of programs of PES

1. U.S. Conservation Reserve Program: 10-15 years contracts to retire farm land from production, 20 million hectares, pay the rental rate and 50% of the cost of the conservation project. Lands are ranked by the value of an Environmental Benefits Index. Partially introduced as a substitute to farm price support.
2. U.S. Wetland Reserve Program: permanent or 30 years conservation easements (payment = \$2,600/ha) and 75% of the restoration costs.
3. Private initiatives: Nature Conservancy, with a large menu of options
 - Purchase land for retirement at market price

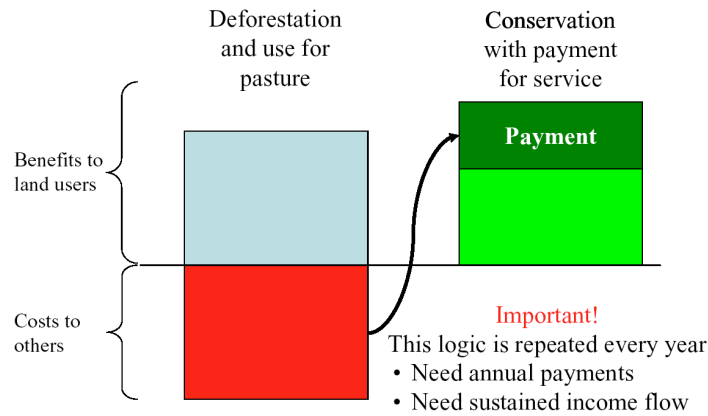
- Purchase conservation easements (development rights)
- Pay for management agreements (pay for service)
- Lease land for retirement

4. Costa Rica: Flat payments for 5 year management plans. Payment to forest owners based on national tax on gasoline. Prioritize choice of lands on the basis of the environmental service provided.

Activity	Total payment per ha over 5 years	Annual disbursement (% of total)
Reforestation	\$480	50-20-25-10-5
Natural forest management	\$320	50-20-10-10-10
Forest regeneration	\$200	20x5
Forest protection	\$200	20x5

5. Many other countries have PES programs: Colombia (Cauca Valley), Ecuador, Mexico (watershed management)

IV. Logic of payment scheme



(Stefano Pagiola, World Bank, 2003)

V. Levels of payments: orders of magnitude

Environmental service	Annual value per hectare (US\$)
Carbon sequestration	\$30 (at \$5/ton) to \$240 (at \$40/ton)
Ecotourism	\$12 to 25
Hydroelectric power generation	\$10 to 20
Other hydrological benefits (drinking, irrigation)	\$7 to 17
Existence and option values	\$13 to 32
Bioprospecting	\$0.15 to \$1.00
Maximum combined service	\$72 to \$335 (average ~\$200/ha)

VI. How to obtain environmental services environmental services

- Negative externalities with property rights to the polluter
 - Need pay a subsidy to the polluter reduce pollution.
- Pay to conserve a service:
 - Buy the service, and impose penalty for failure to deliver.
 - Buy the land
- Pay to restore or develop a service
- Use direct control
 - Expropriation
 - Zoning: constraints on development
 - Require development permits.

VII. Targeting and policy design: the role of heterogeneity

A key issue in the design of an environmental service purchasing land is the determination of what to buy and how much to pay. Several considerations affect the "targeting" decisions.

There are differences in both environmental quality and cost of resources in different locations. For example, consider the case where we want to stop farming in a region so that native habitats can be restored. The lands may vary, both in terms of agricultural productivity and in the value of environmental products.

Suppose there are N landowners in a region and let $n = 1, \dots, N$ be an indicator of an owner. Assume constant environmental benefit (b) and agricultural profit (π) per acre of each unit, but benefits and profits vary across units. Let b_n be the environmental benefit per acre of unit n that has A_n acres. Let π_n be agricultural profit per acre of the unit n (this is the opportunity cost of the land in delivering environmental services = land rent in agriculture). Let units be ordered according to their π_n/b_n ratio, so that unit with $n = 1$ has the lowest cost of providing environmental benefits. π_n/b_n is the unit cost of environmental services provided by farm unit n . We can now construct the supply curve for benefits depicted in Figure 1.

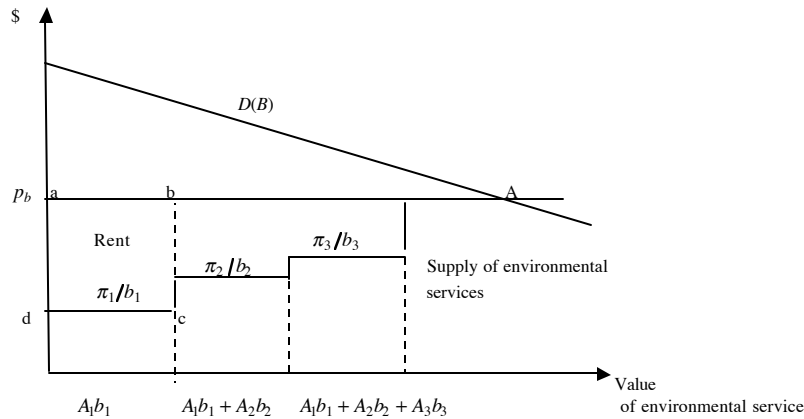


Figure 1. Payment for environmental service

Assume that society has a utility for environmental benefit $V(B)$. The marginal benefit curve $\frac{\partial V}{\partial B} = D(B)$ is the social demand for benefits. The social optimum occurs at A in Figure 1 where demand intersects supply. This will determine p_b , the social cost of environmental benefits.

Under the optimal solution, we will have a price p_b , so that all units with $p_b b_n > \pi_n$ will be contracted for conservation. All the units with $p_b b_n < \pi_n$ will continue in agricultural production, and there may be a marginal unit n^* that will be partially conserved.

The optimal policy can be carried out in three ways:

- (1) Competitive market solution: Offer farmers p_b for conservation. This solution is equivalent to the competitive market solution and units will accrue rent. In Figure 1, unit 1 will gain the rent abcd under this arrangement.
- (2) Discriminatory monopsonist: The regulator could behave as a discriminating monopsonist and offer farmer n an amount π_n per acre for his land that he wants to contract. In this case, the government (or the buying agency) captures all the surplus of the transaction.
- (3) Mixed approach: Offer a single price per region. In this case, there is price discrimination between regions, but not within.

When an agency has a limited budget and knows both b_n and π_n , it will maximize benefit by ranking lands according to their π_n/b_n ratio, paying these ongoing values, and capturing the entire surplus. Such an approach may anger farmers because prices per unit of benefits vary across farms and they do not capture rents from environmental amenities.

VIII. The Role of Correlation: benefit/cost targeting with no scale effect

Suppose b_n and π_n are correlated. A positive correlation means that high priced lands provide high environmental services (for example riparian lands that have high agricultural potential and high biodiversity). A negative correlation means that low priced land provide high environmental services (for example tropical forests that have high biodiversity but low agricultural potential). How should the conservation agency best allocate its budget in contracting for environmental services?

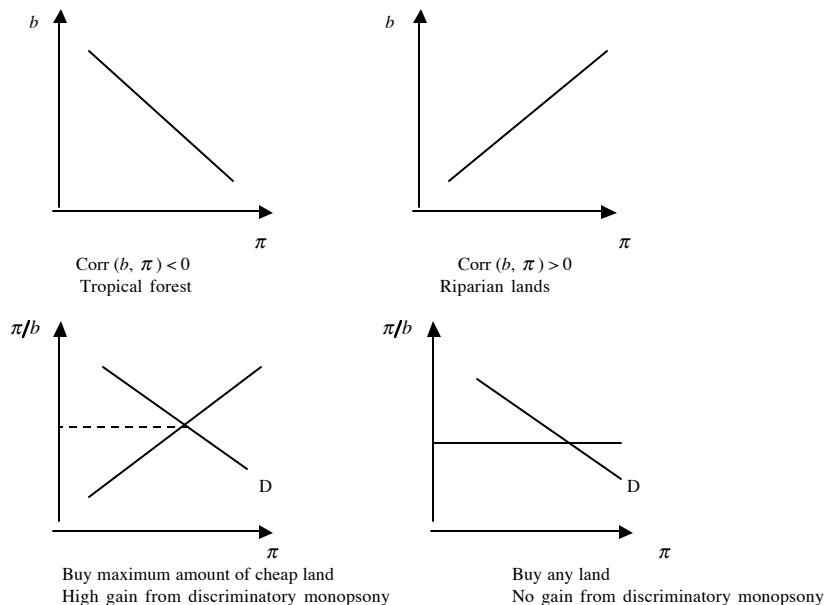


Figure 2

Outcomes between market and discriminatory monopsony solutions are substantial according to the correlation between land price and environmental value. Landowners will lose much more from the discriminatory solution when correlation is negative. If the correlation is negative and the purchasing fund is discriminatory, it will reach the optimal solution by targeting the cheapest land. In this case, the benefit maximizing solution also maximizes land purchased.

When there is positive correlation, the ratio π/b may not vary much across lands of different prices. In some cases it may be optimal to target the highest quality land (that will be the most expensive). In Figure 3, if the lands are $A_1A_2A_3A_4$ it is worth targeting the highest quality lands because they yield so much more environmental value. But if the relative difference in profits between high and low quality lands is much higher than difference in benefits, as in $B_1B_2B_3B_4$, the optimal solution is to target the lower quality land and buy more land with the given budget.

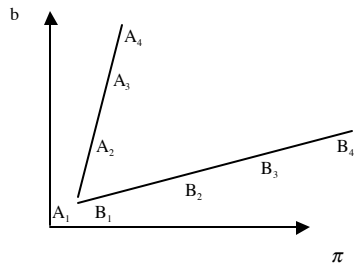


Figure 3

X. Market effects and slippage via prices

Thus far, we have assumed that the industry providing environmental services is small and that the program does not affect prices. But large land retirement programs may change agricultural supply and thus affect prices substantially. Assume that Y_n is the yield of the n^{th} firm. Its cost per hectare is C_n , and thus profit per hectare is $\pi_n = pY_n - C_n$. If, as a consequence of an land retirement fund, agricultural prices increase, profitability changes and that has to be taken into account in the design of the program.

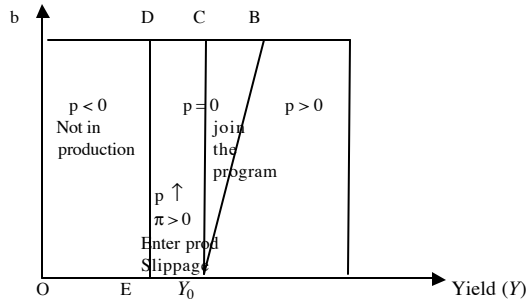


Figure 4

Suppose now that $C_n = C$. Figure 4 depicts a set of firms in the industry in the (b, Y) space. The initial price, before the purchasing fund is introduced is p_0 , and at a certain yield level \bar{Y}_0 , $p_0\bar{Y}_0 = C$. Before introduction of the purchasing fund, firms with $Y < \bar{Y}_0$ were not operating.

So, lands with Y smaller than \bar{Y}_0 were idle and provided free environmental services. Suppose now that a land retirement scheme is introduced and that only firms that were in operation before the program are allowed to join. Firms in the region \bar{Y}_0BC join the program, land is taken out of production, supply declines, agricultural prices increase, and agricultural profits rise. Firms in the region \bar{Y}_0CDE find it profitable to enter agriculture, and their activities reduce environmental services. This counter-productive effect is called “slippage”. The payment for environmental services caused agents that had “good” behavior to engage in counter-productive behavior. In some cases (Figure 4), the slippage effect may dominate the direct effect of a conservation program.

In situations like this one, the incentive has to be designed to counter possible slippage by paying firms in the area \bar{Y}_0CDE in Figure 3 not to modify this behavior. Another form of slippage occurs when farmers are following a socially desirable behavior before the conservation program is introduced because it is profitable for them to do so (i.e., leave land fallow), and then they realize that others are getting paid for the same activities. They may reverse their behavior in order to be entitled to receive payment in the future. For example, farmers that may have engaged in low tillage and realize that others that were practicing traditional tillage are now being paid a significant amount to switch to low tillage, may revert to traditional tillage (and thus, release greenhouse gases) to become entitled to the environmental services payments. Design of environmental services payments has to take such behavior into account and pay a good player so they will not revert to being a bad one.