Introduction to Payments for Environmental Services

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Roadmap

What are Payments for Environmental Services?

Payments for Environmental Services

- Payments for Environmental Services are **market-based** policy involving:
  1. buyer (program designer) willing to pay for an environmental outcome (**externality**)
  2. actors willing to achieve that outcome in exchange of the payment
- For example: **carbon offsets**
  1. buyer: a firm or an individual that wishes to reduce its carbon footprint
  2. seller: a project that performs actions to reduce CO_2 emissions
- often thought as a way to reduce climate impact **efficiently**

A Super Simple Example of PES

- Setting: one firm and $N = 100$ farmers
- Firm:
  - ⋆ produces goods at profit Π_F
  - ⋆ produces 100 tonnes of CO_2
  - ⋆ cost of decreasing emissions by one tonne is **large**: c_H
- Farmers:
  - ⋆ produce food with profit Π_A
  - ⋆ produce 1 ton of CO_2 each by residue burning
  - ⋆ cost of avoiding emission by one tonne is very **low**: c_L

Reducing Emissions Efficiently

Suppose we want to impose carbon **neutrality** on the firm. Compare

1. Without PES: the firm needs to reduce its own emissions
   - ⋆ needs to pay $100c_H$ directly
   - ⋆ might additionally default if $\Pi_F < 100c_H$
2. With PES: the firm can pay the farmers to reduce emissions
   - ⋆ compares paying $100c_H$ directly vs. paying c_L to 100 farmers
   - ⋆ since $c_H > c_L$ prefers paying the farmers
   - ⋆ farmers receive c_L and are now indifferent: don't burn

So PES achieves the **same** CO_2 target with a $100(c_H - c_L)$ **cost reduction!**

A Success Story: Deforestation in Uganda (Jayachandran et al. 2017)

- **Deforestation** is a major source of CO_2 emissions
- PES can help: pay landholders to keep forests standing (**preservation**).
- Setting of Jayachandran et al. (2017): Western Uganda
- Study a PES intervention
  - ⋆ Private forest owners (PFO) offered 70,000 UGX ha/year to preserve forest.
  - ⋆ Equivalent to about $28 in 2012 USD.
  - ⋆ Implemented from 2011 to 2013 with monitoring and payments at year end.
- RCT: 121 villages, randomly assigned **treatment** (60) and **control** (61).
- Track **tree cover** from high-resolution satellite imagery before and after.

Main Result: Deforestation Decrease

Tree cover **loss** was about halved in treated villages relative to control.

- Treatment villages lost 4.2% tree cover vs 9.1% in control.
- Results significant at the 5% level.
- No evidence of local **leakage/spillovers** (shifting of deforestation to nearby land).

Figure: Main result. Table 3 of Jayachandran et al. (2017)

	Village boundaries			PFO-level land circles		
	ΔTree cover (ha)	ΔTree cover (ha)	ΔLog of tree cover	ΔTree cover (ha)	ΔTree cover (ha)	ΔIHS of tree cover
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment group	5.549*	5.478**	0.0521**	0.245**	0.267**	0.0447*
	[2.888]	[2.652]	[0.021]	[0.110]	[0.106]	[0.023]
Control group	–13.371	–13.371	–0.095	–0.349	–0.349	–0.073
Control variables	No	Yes	Yes	No	Yes	Yes
Observations	121	121	121	995	995	995

Cost Benefit Analysis

- Value benefits using **social cost of carbon** (\$39 ton/CO_2 in 2012).
- Avoided tree-cover loss converted into **delayed** CO_2 emissions. Benefits depend:
  - ⋆ on post-program deforestation dynamics.
  - ⋆ on choice of discounting rate.
- Cost: about \$0.46 per ton of CO_2 delayed (payments + administration).

Figure: Main result. Table 5 of Jayachandran et al. (2017)

Scenario	Benefit per MT of CO_2 (\$)	Cost per MT of CO_2 (\$)	Benefit-cost ratio
1. Base case: Program effects undone over 4 years	1.11	0.46	2.4
2. Program effects undone immediately	0.37	0.46	0.8
3. Deforestation resumes at normal rate (permanent delay)	0.74	0.05	14.8
4. Base case except using effect size from PFO-level analysis	1.11	0.63	1.8

When Do PES Work?

Problems of PES

As many other types of policies, PES can suffer from multiple **issues**:

1. **moral hazard**: incentive to exert effort low once payment is received
2. **participation costs** can reduce take up (especially with delayed payment)
3. **leakage**: polluting activity is displaced nearby
4. **additionality**: take up more likely from those who would perform ES anyway

Solutions involving **monitoring** and **delayed** payment can help for 1 and 2.

Importance of Careful Design of PES: Jack et al. (2025)

- In North India, farmers often burn rice residue after harvest to clear fields quickly
- This creates a major air-pollution **externality** for downwind cities.
- Existing policy is not very efficient:
  - ⋆ Burning is officially banned, but enforcement is weak.
  - ⋆ Equipment subsidies do not fully cover the cost of alternatives.
  - ⋆ Farmers may face **liquidity constraints** and may distrust promised payments.
- Jack et al. (2025) run a RCT in 171 villages comparing:
  1. **Control:** no PES contract
  2. **Standard PES:** payment only after verification of no burning
  3. **Up-front PES:** split the payment in two:
     - part of payment made up front and unconditionally
     - remainder at the end after verification

Main Result: Burning Falls Only With Up-front PES

- Standard PES contract does *not* reduce burning relative to the control group.
- In contrast, **up-front PES**:
  - ⋆ increases contract compliance by about 10 percentage points
  - ⋆ reduces burning in satellite-based measures by about 7.7 to 11.5 percentage points.
- Two likely mechanisms: farmers under up-front PES are
  1. 7% more likely to say they **trusted** that the conditional payment would be made.
  2. 9.6% more likely to use alternatives to burning, such as balers (**liquidity**).
- But farmers do *not* report differences in whether cash shortages mattered.

Figure: Main result. Table 1 of Jack et al. (2025)

TABLE 1—CONTRACT COMPLIANCE, NOT BURNING, AND CRM USE

		Unburned		CRM techniques	
	Complied with contract (1)	Max. accuracy (2)	Balanced accuracy (3)	Baler (4)	Seeder (5)
Standard PES	0.085	0.020	0.008	−0.010	−0.020
	(0.015)	(0.030)	(0.042)	(0.037)	(0.023)
Up-front PES	0.183	0.077	0.115	0.096	0.013
	(0.020)	(0.032)	(0.042)	(0.039)	(0.026)
p-value: standard PES = up-front PES	0.000	0.071	0.008	0.014	0.157
Control mean	0.000	0.091	0.202	0.199	0.102
Standard PES mean	0.084	0.098	0.198	0.171	0.087
Up-front PES mean	0.185	0.161	0.313	0.295	0.112
Observations	1,668	1,664	1,664	1,387	1,387

The Issue of Additionality

In the Media: the Additionality Scandal

PES are in **turmoil** since studies revealed very low additionality

Figure: The Guardian article that initiated the turmoil.

News Opinion Sport Culture Lifestyle

The Guardian

Eur

World UK Climate crisis Ukraine Environment Science Global development Football Tech Business Obituaries

The age of extinction
Carbon offsetting

This article is more than 3 years old

Revealed: more than 90% of rainforest carbon offsets by biggest certifier are worthless, analysis shows

Investigation into Verra carbon standard finds most are 'phantom credits' and may worsen global heating

A Standard Model of Take-Up

Actors:

1. program designer: wants to set up a PES system
2. landowners: can adopt a practice that provides an ES, ex: not deforest

For landowner i:

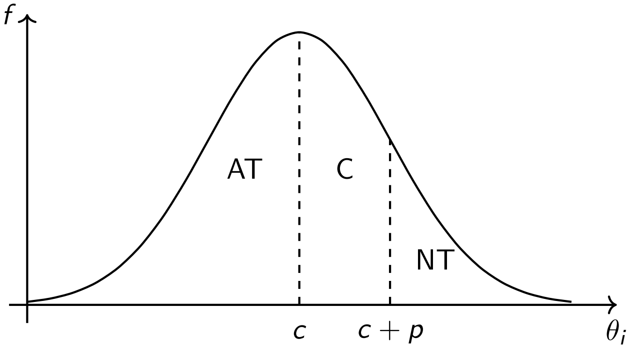
- **cost** of production (cost of deforestation) c
- heterogeneous **private benefit** of no action (deforestation) $\theta_i \sim F$

The program designer can choose a **payment** p for the ES (preservation)

The Landowner Choice

- For a given payment p, two options for a landowner who participates:
  - ⋆ If the landowner **deforests**, gets $\theta_i - c$
  - ⋆ If she **does not deforest**, gets p
- Therefore, **enroll** in the program if $\theta_i - c < p$.
- However, **absent** the program ($p = 0$) landowners don't deforest if $\theta_i - c < 0$.

→ So part of the effect would have been achieved anyway and is **not due** to PES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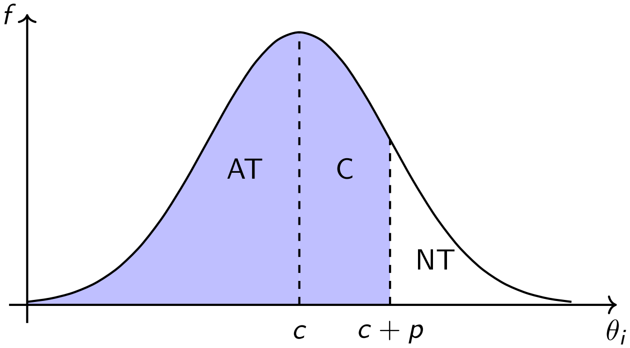
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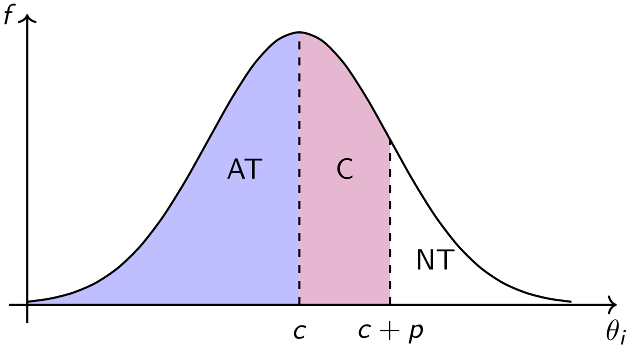
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PES Evaluation

Depending on their private benefit θ_i, landowners fall into three categories:

1. **Always Takers (AT)** if $\theta_i - c \leq 0$: non additional
2. **Compliers (C)** if $0 < \theta_i - c \leq p$: additional
3. **Never Takers (NT)** if $p < \theta_i - c$: out of program

Two questions to design and to evaluate PES:

- is benefit V per complier **enough** to justify paying compliers and always takers?
- how to answer if private benefit is **not observed?**

Designing Effective PES Systems: Theoretical Elements

Additionality and Asymmetric Information

- Additionality concerns **counterfactual** actions
- Counterfactual: what the landowner would have done absent the program
- When θ_i and c are observed, the counterfactual action can be perfectly predicted
- In this case, the program designer could **target** additional landowners
- Additionality would still be an issue only if the program designer cannot target:
  - ⋆ the program designer has to offer a unique p
  - ⋆ the program designer is bound to accept any program applicant
- It is however easier to think of additionality as **unobserved information**

An Asymmetric Information Framework

The most familiar framework to solve for the optimal p is **mechanism design**

1. The program designer does not observe θ_i but knows F and c
2. Program designer cares about maximizing **welfare**

$$W(p) = \underbrace{VF(c+p)}_{\text{ES benefit from C and AT}} + \underbrace{\int_{c+p}^{\infty} (\theta - c)\, dF(\theta)}_{\text{private gains from NT}} - \underbrace{\lambda p F(c+p)}_{\text{cost of funds}}. \qquad (1)$$

3. This is equivalent to maximizing $W(p) - W(0)$

First Order Conditions

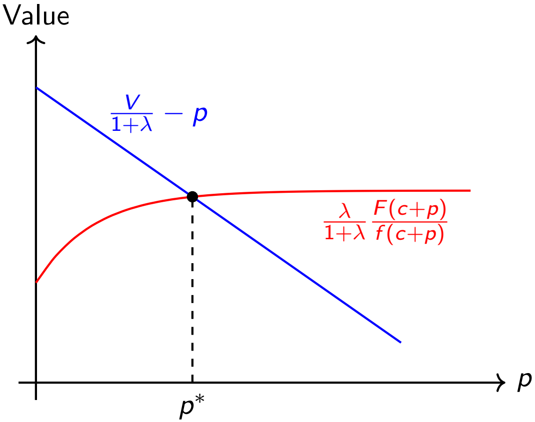
Deriving with respect to p leads to:

$$\frac{\partial W(p)}{\partial p} = Vf(c+p) - pf(c+p) - \lambda F(c+p) - \lambda pf(c+p) = 0. \tag{2}$$

This allows to find an expression that implicitly defines the **optimal** p^*

$$p^* = \frac{1}{1+\lambda}\left(V - \lambda \frac{F(c+p^*)}{f(c+p^*)}\right) = 0. \tag{3}$$

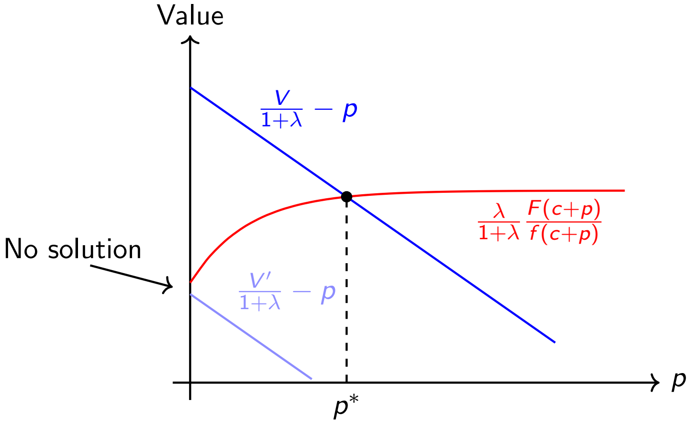
Graphical Solution



Equilibrium and Adverse Selection

- At the optimum $p^* < V$: price needs to be adjusted for the **presence of AT**
- The relevant term is the **inverse hazard rate** $\frac{F(c+p^*)}{f(c+p^*)}$
- Intuition: how many always takers per marginal complier?
- It is a measure of the importance of the **adverse selection** distortion
- In particular, if $\frac{F(c)}{f(c)} > \frac{V}{\lambda}$, no equilibrium p^*
- **Unraveling**: no payment such that the program is put in place

Equilibrium or Absence of Equilibrium?



Designing Effective PES Systems: Practical Solutions

What Can Be Observed?

- When θ_i is not observed, equilibria might fail to exist
- But in practice, **hard to observe** F and c as well
- Variables correlated with private benefits and costs might be available
- Program designer might also have **more instruments** than just p
- For example: **application costs**

The Importance of Application Costs: Jack and Jayachandran (2019)

Jack and Jayachandran (2019) argues that self-selection into PES depends not only on the **cost of conservation** a, but also on other **enrollment costs** t:

$$\text{Enroll if } p > a + t$$

(Link with previous model: opportunity cost $a = -c$ and no private benefit $\theta_i = 0$)

Administrative, informational, financial, or trust-related costs of enrollment affects:

- **how many** people enroll in the PES program
- **who** enrolls in the PES program

Importantly, if enrollment costs are **positively** correlated with conservation costs:

- those that have low application costs are less additional
- but they are also more likely to apply

$\rightarrow$ PES becomes less cost-effective

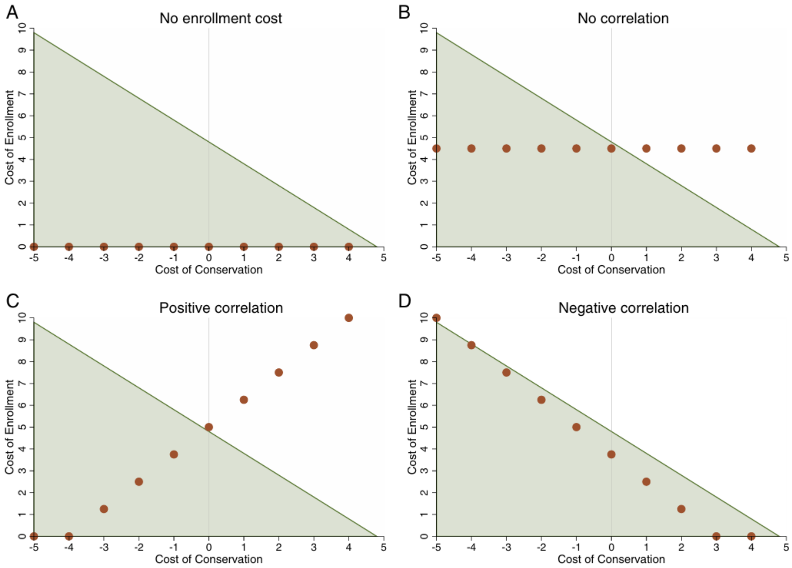


Figure: Illustration of the key mechanism in Jack and Jayachandran (2019).

Example of Application: Back to Jayachandran et al. (2017)

Remember the PES system of Jayachandran et al. (2017) in Uganda.

- Suppose enrollment is based only on low conservation costs
- Then enrollees should be those who would have conserved anyway (no additionality).

→ should find no effect

Jayachandran et al. (2017) does not find 100% compliance but still significant reduction in deforestation!

- Therefore selection into the program was not driven **only** by conservation cost.
- A likely reason is that familiarity with contracts affected take-up
- Indeed people with prior contract experience:
  - ⋆ were more likely to enroll
  - ⋆ have had **higher** counterfactual deforestation

Contract-related enrollment frictions may have **screened out** low-additionality landholders.

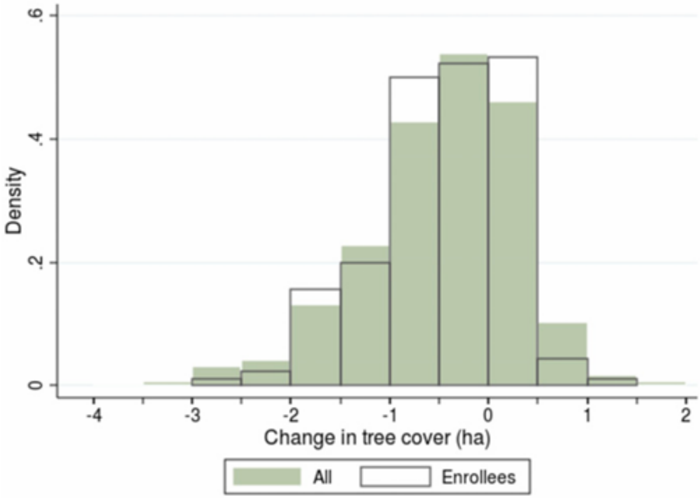


Figure: Counterfactual deforestation in the treatment group.

PES and Carbon Markets

The Potential of PES

If properly designed, PES have great potential

- PES as market-based instruments allow reductions at **lowest costs.**
- PES often regarded as necessary to reach **net zero** targets by 2050.
- PES reduce **inequality** by channeling finance from high to low-income countries.
- Proposal to link to regulatory carbon permits, such as EU ETS

PES vs. Tradable Permit Systems

PES are often associated with Emission Trading Systems (ETS)

- PES: pays actors for ES, typically project-level and **voluntary**.
- ETS: regulatory intervention, typically **binding**
  - ⋆ create **permits** under a binding cap
  - ⋆ covered emitters **must** hold permits to emit
  - ⋆ trade allowed at a market price

Different instruments, but many similarities. Both:

- put a **price** on carbon outcomes
- rely on incentives rather than pure command-and-control
- can channel finance toward **low-cost** abatement opportunities.
- require credible measurement, monitoring, and verification.

Pande et al. (2025): A Proposal to Unify PES and ETS

ETS are credible but narrow. PES systems are inclusive but often less credible.

Pande et al. (2025): best of both worlds?

Pillar 1: Unified Global Carbon Market

- Opt-in **global cap-and-trade** system
- Links jurisdictions and large firms
- Allocation reflects **differentiated** responsibilities

Pillar 2: MARVIN

- Measurement, Accounting, Risk Management, and Verification Institution
- Standardizes auditing and monitoring
- Prices risk for heterogeneous projects

Promise of a Unified Carbon Market

Promise: a global transparent carbon price, heterogeneous project contributions

Many reasons for optimism:

1. ETS are already spreading globally, so linkage increasingly **feasible**
2. Renewables are getting **cheaper**, but deployment constrained by financing costs.
3. Better **measurement** (remote sensing, AI, ex-post verification, risk pricing, ...)
4. **Market design** shows how institutions can align incentives.
5. EU ETS shows that free allocations can reconcile efficiency with **fairness**

Unification aims to combine **credibility, scale** and **equity**.

Conclusion

- PES are a nice example of environmental policy aimed at reducing **externalities**
- As any policy, requires careful planning and **design**
- Success requires theory, practice and knowledge of the context
- If appropriately managed, can help in achieving ambitious goals
- They are also an open and exciting field of **research**!

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