Lecture 4: Environmental policies: instruments

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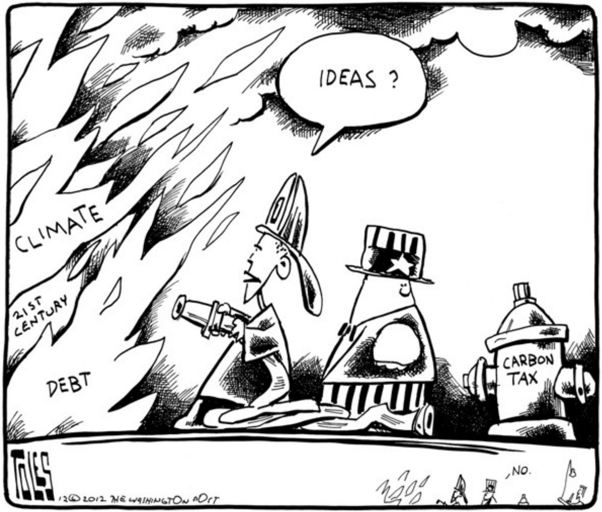
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Objective of the lecture

- Thinking about the design of environmental policies is arguably the main task of environmental economists.
- Once a given environmental target has been decided, the objective is to determine how to best achieve it.
- Since many instruments can potentially be used to attain the same target, **the choice over which specific policy to implement will depend on** their properties, in paricular in terms of **efficiency and equity**.

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$\rightarrow$ **The objective of this lecture** is to provide a framework and some general results that offer **some guidance about how to best chose among environmental instruments.**

Road map

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When instruments are not necessary – The Coasian approach

In some situations, the level of pollution can be reduced to an efficient target level in the absence of a control policy:

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- the idea is straightforward: externalities are cases of missing markets. If a dialogue is possible between the polluter and the polluted, a market may be created and the externality internalized;
- depending on who is the initial holder of the rights, the polluter may pay the polluted to accept a certain level of pollution, or the polluted may pay the polluter to agree to reduce it, to a level that is *efficient*;
- the initial allocation of rights to one or the other of these actors has in theory no implication on the efficiency of the resulting allocation;
- however, this initial allocation will obviously be critical from a redistributive point of view.

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→ The Coasian approach to externalities deviates from the Pigouvian "polluter-pays" approach: efficiency could as well be restored by polluted paying polluters to reduce their pollution. As long as transfers are possible, optimality can also be achieved.

The limits of the Coasian approach

The success of this approach is conditional on a number of assumptions: in practice for the majority of environmental problems it is inappropriate. It will fail to provide a socially desirable allocation when:

- there are significant transaction costs;
- the polluters or the polluted are too numerous and/or too difficult to identify for negotiation to be possible;
- appropriate transfers cannot be designed.

When instruments are necessary

We generally consider that there are two main types of approaches to environmental regulation:

- the regulatory "command-and-control" approach;
- the economic "market-based" approach.

→ While the first group of measures imposes the adoption of a certain behavior, the second group aims to induce this behaviour by providing the appropriate incentives.

On top of these two traditional approaches, one should also consider additional measures affecting individual behaviors (as with market based instruments) without providing traditional "market" incentives. These may form a third, very broad category of policy interventions.

Regulatory “command-and-control” instruments

The regulatory “command-and-control” approach to environmental regulation includes policies meant to reduce pollution through:

- rules imposed on production methods, e.g.:
  - vehicle consumption standards;
  - in Europe, only pesticides approved by the European Commission (after a scientific assessment by the European Food Safety Authority) can be used in agriculture.
- bans on certain products, e.g.:
  - on the use of chlorofluorocarbons following the Montreal Protocol;
  - on the use of leaded fuels (e.g. banned in 1996 in the US);
  - on constructions to protect some coastal areas.
- regulation of their use , e.g.:
  - banning polluting vehicles in certain city centers, or at certain times of the day/week;
  - reglementation on when and where certain pesticides can be used in agriculture.

Economic "market-based" instruments

The economic "market-based" approach to environmental regulation includes instruments meant to provide economic incentives to reduce pollution, such as:

- taxes, e.g.:
  - a carbon tax.
- charges, e.g.:
  - for household waste collection.
- subsidies, e.g.:
  - environmental bonus on less polluting vehicles.
- tradable emission allowances, e.g.:
  - the EU Emissions Trading Scheme.
- economic property rights, e.g.:
  - concessions of natural resources.
- or a combinaition of these, e.g.:
  - deposit-refund systems that combine a tax (deposit) and a subsidy (refund), such as for bottles or batteries;
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→ Within these instruments, we typically distinguish two categories: price vs. quantity regulations. As long as the quantities are tradable, these two approaches are very similar (see later in the lecture).

Incentives without pollution pricing

In addition, there are many policies meant to address environmental issues that do not strictly fall within these two categories.

In particular, some policies attempt to change behaviors by changing incentives, although not directly pricing pollution. This is for example the case of:

- investments in public goods (e.g. building cycling paths).
- information provision policies (e.g. eco-labels);
- "nudge" types of policies (e.g. voting through your wastes);
- awareness campaigns (e.g. adds on biodiversity loss);
- etc.

Example: eco-labels

Example: voting through your wastes

Example: nudging for waste collection

Example: image to raise awareness

The relative merits of different instruments

To the extent that **more than one instrument can be used to meet a given environmental objective** (albeit with varying degrees of precision), the choice of instruments to be preferred **depends critically on all their other costs and benefits.**

The dual objective of decision-makers is therefore to determine:

- which instrument(s) can achieve an environmental objective at least cost (**efficiency objective**)...
- ...also considering how these costs are distributed among agents (**equity objective**).

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Cost-effectiveness and the market-based approach

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- by imposing a uniform price on the externality, equalization of the marginal costs of abatement across activities and actors;
- the emission reductions undertaken will be all those (and only those) requiring an effort lower than the price of the externality (Baumol & Oates, 1971);
- the environmental objective is attained at the lowest possible cost.

→ For this reason, these instruments are called **« cost-effective »**.

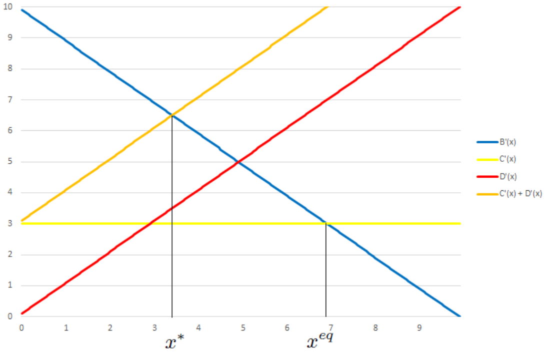
Cost-effectiveness and the "command-and-control" approach

For the same to be true of regulatory instruments, it is necessary to set specific standards for each polluter according to his or her abatement cost:

- when polluters are numerous and heterogeneous, and even more so when there are information asymmetries between polluters and the regulator regarding these costs, such a policy is not feasible;
- the costs of pollution abatement may thus be too high for those who have the greatest difficulty in changing their behavior and too low for others who could have reduced their pollution further.

$\rightarrow$ Since marginal abatement costs are not equalized, it is possible to achieve further reductions of aggregate pollution with an equivalent or lower level of aggregate effort.

Information costs – Back to our simple example



- Command-and-control: if the planner knows the private marginal costs (yellow curve), benefits (blue curve), and the SCP (red curve), then it can directly fix x^* as the maximum quantity of x that agent 1 is allowed to consume.
- Market-based: if the planner knows the SCP (red curve), it can make agent 1 pay the additional cost $D'(x)$ for consuming an additional unit of the polluting good. → Informationally much less demanding, especially with many heterogeneous polluters.

Market-based instruments and dynamic efficiency

From a **dynamic** point of view, the equalisation of marginal abatement costs also implies a better efficiency of market instruments, for example through innovation:

- command-and-control instruments impose a binary framework: a clean technology fixed by a standard is adopted or not;
- market instruments make (in our simple framework) any reduction in emissions profitable: thus, they provide incentives for the development of ever cleaner technologies.

$\rightarrow$ The intuition for dynamic efficiency is the same than for static efficiency: market-based instruments equalize marginal abatement costs across agents and across periods.

Some semi-empirical evidence

From an empirical point of view, many studies point to the **lower effectiveness of command-and-control instruments** relative to market instruments when the latter operate under the ideal conditions of the stylized model described above.

Tietenberg (2006) lists 14 studies and shows that, for 12 of them, the use of **market instruments would lead to costs that are 40% to 95% (i.e. 20 times!) lower** than with command-and-control instruments.

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An important caveat: the underlying assumption that market-based instruments would operate in ideal conditions likely (although not necessarily) biases the results in their favor.

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Direct distributive effects

With respect to equity, no clear-cut result on how market-based mechanism compare with command-and-control policies:

- it largely depends on how the activity regulated is initially distributed in the population;
- it also depends on the heterogeneity of abatement cost functions (i.e. whether some agents may reduce their pollution with less efforts than others);
- it depends on the specific design of the policy;
- most of all, it depends on how society values the welfare gains and losses of different individuals.

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In the stylized model considered here, the distributive effects of instruments **do not matter as long as transfers are possible**: what matters is the maximization of aggregate surplus (through cost-effective policies), redistribution can occur in a separate stage to reach any desirable allocation. $\rightarrow$ **The lower the aggregate cost to reach the desired environmental target, the more resources left to redistribute to any agent**.

When such transfers are not possible, cost-effectiveness will no longer be the only objective (see later in the lecture).

Regressive vs. progressive policies

Although redistribution can occur in a separate stage, one still needs to understand the distributive properties of environmental instruments to design the redistribution. In particular, a critical consideration is whether the policy is progressive or regressive.

Generally speaking, **a progressive policy is one which favors individuals who were initially worse off relative to those who were initially better off**. A regressive policy is the opposite.

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To assess whether a given environmental policy is progressive/regressive, two elements need to be taken into account:

- the distribution of additional costs from the policy;
- the distribution of additional benefits from the policy.

Distributive effects from energy policies on households

Example: since energy consumption typically represents a higher share of poor households' budget (at least in developed economies), policies meant at reducing energy demand (such as energy taxes and carbon taxes) are often regressive (e.g. Poterba, 1991; Metcalf, 1999; Grainger & Kolstad, 2010).

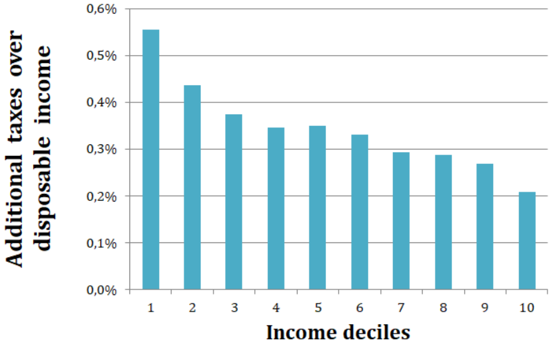

Figure: Average effort rate on the French energy policy reform 2016-2018 before revenue-recycling (from Douenne, 2020)

Distributive effects from energy policies on households

However, taxes or other environmental instruments being regressive does not mean a policy needs to be! → If transfers are possible between high and low income households, regressivity can be counteracted (e.g.West & Williams, 2004; Bento et al., 2009; Williams et al., 2015).

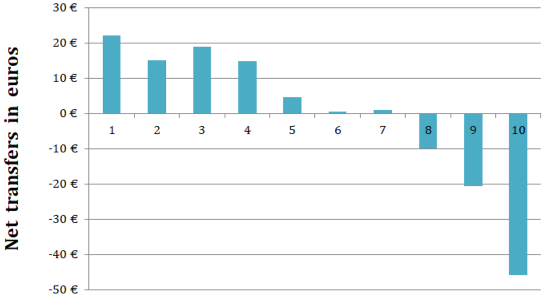

Figure: Net transfers from the French energy policy reform 2016-2018 after an hypothetical uniform revenue-recycling (from Douenne, 2020)

Heterogeneous benefits from environmental regulation

In addition to the new costs that arise from the policy, the ultimate distributive consequences also depend on the distribution of the policy's benefits:

- in general, richer households have a higher willingness to pay for the environment, and therefore experience greater benefits from a given environmental improvement;
- thus, poorer households will experience greater benefits only in situations where they were initially more exposed to the pollution mitigated by the policy;
- the heterogeneous exposure to pollution relates to the concept of "environmental justice", and the concept that poorer households are usually more exposed to pollution.

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Again, the distribution of benefits is ambiguous and is clearly context specific.

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Environmental policies in a second best world

So far we have considered a very simplified benchmark case of an economy whose only market failure was an environmental externality. This framework highlights the powerful mechanisms that flow from economic incentives.

However, these arguments are based on a number of assumptions that are in practice never fully satisfied.

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However, these arguments are based on a number of assumptions that are in practice never fully satisfied. $\rightarrow$ Recall from lecture 2: the Tinbergen principle states that we need as many independent instruments as market failures to restore efficiency, but in practice:

- the environmental externality is never the only market failure;
- there are far too many market failures to implement an equivalent number of instruments.

$\rightarrow$ In this situation, we have no reason to believe that implementing first-best policies (such as a tax equal to the social cost of pollution) will provide an efficient allocation. Other mechanisms come into play and may require some deviations from this benchmark.

Market-based mechanisms in a second best world

When other market failures come into play, the comparative advantages of market-based instruments need to be reconsidered.

For instance, while a carbon tax is theoretically the first-best measure to deal with the sources of climate change, in a second-best situation "a combination of policies is likely to be more dynamically efficient and attractive than a single policy" (Stern & Stiglitz, 2017).

To put it simply:

- other market failures may compromise the incentives of market-based mechanisms;
- the incentives from market based mechanisms may further affect other market failures.

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- the incentives from market based mechanisms may further affect other market failures.

Note: market-based solutions are obviously not the only ones being affected by other market failures. The efficiency of command-and-control policies may also greatly change.

Example of other market failures and their interactions

Imperfect information may lead to a misallocation of abatement efforts induced by a market-based instrument. Example:

- consider a tax on firms polluting emissions;
- in theory the tax will encourage producers to adopt the most efficient technology to reduce pollution and avoid a heavy tax burden;
- however, the diffusion of clean technologies may be slowed down by information frictions;
- in this case, regulatory instruments fixing standards on which technology to adopt can have the advantage of producing information on the best available technology.

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Public goods, if not addressed by proper policies, may reduce the efficiency of market-based (as well as command-and-control) instruments. Example:

- absent public transports or cycling paths financed by municipalities, abating pollution related to the use of private vehicles is much more costly.

Example of other market failures and their interactions

Imperfectly rational decision-makers may also prevent the efficient allocation of abatment efforts. Example:

- many consumers take time-inconsistent decisions and tend to purchase slightly cheaper but less energy-efficient goods that cost them more in the long run;
- since they heavily discount future costs, increasing the price of energy through a tax does not affect much their behavior;
- restricting their set of choices through standards (e.g. on light bulbs) or providing them information through labels (e.g. on energy efficiency of washing machines) may guide them towards better decisions.

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→ Climate change being a global problem, it is typically one that interacts with many other market failures. While a global carbon tax would certainly be a great step forward in fighting climate change, other instruments are also critical.

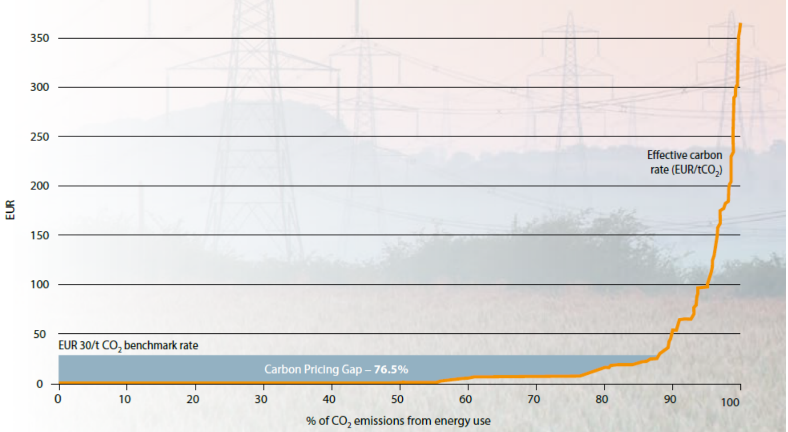
Multiple instruments to address multiple market failures: a caveat

Although a mix of different policies is necessary to tackle major environmental problems, the multiplication of small sectoral measures may also be costly:

- the fragmentation of sectoral policies with numerous exemptions generates important differences in abatement costs between countries and between sectors, leaving room for significant opportunities to reduce emissions or their abatement costs;
- sectoral policies targeted towards a restricted set of actors are also more subject to lobbying pressure, creating a downward bias in the stringency of regulation;
- many of such policies are in fact very cost-ineffective (i.e. generate very large costs for small environmental benefits);
- many of such policies also reflect compromises between polluters and the regulator, and come on top of existing regulations, leading to a blur about the actual purposes and stringency of these mechanisms;
- to avoid "double taxation", the multiplication of these small measures may also delay the implementation of a more comprehensive policy covering a larger share of emissions.

Sectoral policies and heterogeneous carbon prices

Figure 2: **The carbon pricing gap**



Note: Estimate for 2018

Source: OECD (2018), *Effective Carbon Rates 2018*

→ Across all 42 OECD and G20 countries, enormous heterogeneity in the implicit carbon price between emission sources: 55% are not taxed at all, while a small share is subject to very high rates.

Economic impacts of environmental regulation

Where regulatory measures are significant, their effects on the economy are likely to lead to changes in the economic system.

For instance, by regulating the pollution of firms, environmental policies can force them to reduce their activity, thus:

- this may affect employment and wages;
- absent market failures (such as labor-market frictions), capital and workers move and the economy adapts;
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→ On this point, it is again difficult to conclude unequivocally about the relative merits of each instrument. Still, a substantial literature has highlighted the benefit of taxes and their potential "double dividend" effect.

Environmental taxes and the double dividend

To fund public goods or reduce inequalities, governments rely on distortionary taxes:

- taxing incomes may discourage labor supply and demand and increase unemployment;
- taxing capital may discourage investment;
- taxing commodities may discourage consumption;
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The double-dividend hypothesis states that not only environmental taxes improve the environment, but they may also generate positive impacts by substituting for other distortionary taxes in the economy (see Tullock, 1967; Terkla, 1984; Pearce, 1991).

Environmental taxes and the double dividend

The double-dividend (DD) hypothesis takes two forms. It is said:

- **strong** when the efficiency gains induced by reductions in old taxes exceed the efficiency losses induced by these new regulations $\rightarrow$ the environmental policy essentially becomes a free lunch;
- **weak** when there are efficiency gains induced but that do not compensate for the new distortions created $\rightarrow$ no free lunch, but still a comparative advantage of taxes relative to other non-revenue generating policies.

While the literature largely confirms the existence of a weak double-dividend, the evidence is more mixed as to its strong version (cf. Freire-González, 2018).

Some general principle with respect to efficiency in second best?

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Some general principle with respect to efficiency in second best?

Assessing the relative merits of different instruments in a second best setting (i.e. in the real world) is very challenging: it greatly depends on the environmental problem under consideration, and other issues that may interact with these measures. In general:

- market-based instruments can be considered necessary (although not sufficient) in the face of global problems with diffuse sources such as climate change, while regulatory instruments are all the more relevant when dealing with pollution whose sources are specific and well-known.
- the more ambitious the objective is (i.e. close to 100% abatement), the smaller the difference in effectiveness between the different approaches is likely to be (Goulder et al, 1999). Indeed, banning the use of a pollutant is equivalent to a tax high enough to ensure that no one produces and consumes it any more.
- in situations where differences in efficiency are small, other criteria are also likely to be decisive, such as the costs of implementing and managing the measure in question (e.g. the cost of monitoring compliance with standards, or of collecting taxes).

A last comment on the relative efficiency of different instruments

Traditionally, economists tend to favor market based mechanisms over command-and-control policies. Although they may sometimes underestimate how poorly certain markets work, this also reflects a belief that whether markets work well or not, their forces are very strong.

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- what if a regulator fixes a standard greatly reducing the use of the dirty input in 80 of these sectors?
- whatever how market forces operate, pollution will decline in these sectors;
- but the price of the dirty input will go down since demand is reduced...
- ...and its use will go up in the 20 other sectors.

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→ Even though command-and-control measures intend to control the market, they do not prevent market forces to operate. This is not to say that these measures can never outperform those based on incentives, but that we should not be naive about their outcomes.

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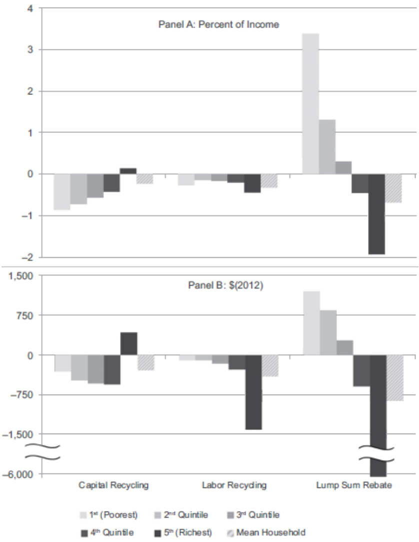
Distributive effects in second best: taxes vs. other instruments

In a second-best world, transfers being constrained, equity concerns become an important consideration for the design of environmental policies. Again, **no general result about which kind of instrument produces the best outcome**. Still, the following elements need to be considered:

- **where taxes are regressive** (e.g. when applied to energy consumption), **other forms of regulation are also likely to be**: a critical point is the initial distribution of the pollution between agents, which is the same whatever the instrument used (see for instance Jacobsen (2013), Davis and Knittel (2019) and Levinson (2019) on the regressivity of US fuel economy standards);
- **taxes generate a revenue**, which can be used to address distributive effects. For the same to be done with other policies, need to raise other (possibly distortionary) taxes or reduce other (potentially desirable) public expenditures;
- as seen above, a regressive (e.g. carbon) tax with a uniform lump-sum transfers may lead to a progressive policy;
- the tax revenue has competing potential uses: returning the revenue directly to taxpayers prevents a double-dividend that would minimize the aggregate costs of the environmental reform, but that would be non-neutral from a redistributive point of view (Williams et al., 2015): **equity-efficiency trade-off** (Goulder & Parry, 2008).

Figure 1
Welfare Change per Household by Quintile



Note: Welfare changes omit environmental benefits of the carbon tax.

Source: Williams et al, 2015

Multi-dimentional distributive effects

By implementing transfers between income groups, any regressive instrument can lead to a progressive reform. Still, the focus on distributive effects along the income dimension hides other important equity issues:

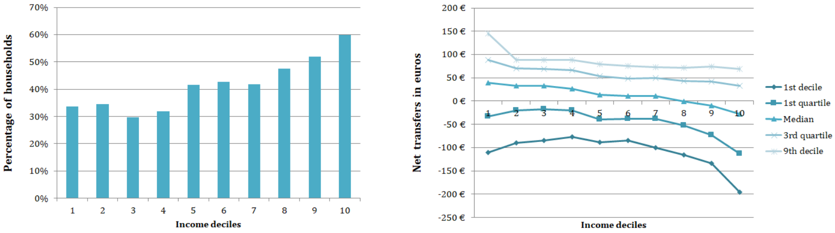


Figure: Share of households financially losing from the French energy policy reform 2016-2018 after an hypothetical uniform revenue-recycling (left), and distribution of net transfers per consumption unit (right) (from Douenne, 2020)

→ Even when a reform is progressive, there may be a lot of heterogeneity *within* income groups and a significant share of low-income households negatively impacted.

Multiple instruments for a multi-dimensional problem

The distributive effects of an environmental policy depend on its specific design as well as two pre-existing elements:

- the *ex ante* distribution of the regulated activity within the population;
- the distribution of abatment cost functions within the population.

Thus, there are essentially two approaches in dealing with distributive effects:

- redistributing resources to compensate those with an initially higher exposure to the policy (e.g. those consuming more energy);
- reducing abatment costs by providing better substitutes.

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- redistributing resources to compensate those with an initially higher exposure to the policy (e.g. those consuming more energy);
- reducing abatment costs by providing better substitutes.

In practice, some policies may entail both approaches. For example, providing subsidies (either to all households or only those meeting certain conditions) for cleaner vehicles or to replace oil-fired boilers implies both a transfer to those initially more exposed who will receive the subsidy, and a way to facilitate the transition to less polluting consumption patterns.

When do we want to compensate for distributive effects?

Compensating for distributive effects entails costs, as scarce public resources have competing uses. For example, the revenue of a tax may be used to:

- compensate the losers from the policy;
- reduce pre-existing (distortionary) taxes;
- fund new public expenditures, such as green investments.

Thus, using the tax revenue for lump-sum transfers has an opportunity cost, and whether a given use of the revenue is better than others is essentially subjective.

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Thus, using the tax revenue for lump-sum transfers has an opportunity cost, and whether a given use of the revenue is better than others is essentially subjective. For example, one may want to redistribute resources like this:

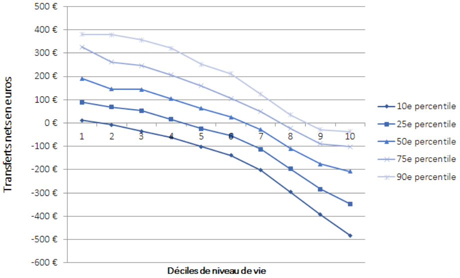

Figure: Distribution of net transfers per consumption unit from the French energy reform 2018-2022 after an hypothetical progressive revenue-recycling (from Bureau et al, 2019)

When do we want to compensate for distributive effects?

Some important considerations:

- society generally wants to avoid as much as possible regressive policies, because they take resoures away from those who have already less resources. If we assume that people have a decreasing marginal utility from consumption, a regressive redistribution will unambiguously negatively affect social welfare;
- such a mechanism is not as relevant when we consider redistribution between people with similar income levels (i.e. horizontal equity);
- if some people lose more than others because they pollute more, should we compensate them?
- whether someone gains or loses from environmental policies is often associated with past investments (e.g. house in the countryside). If we consider the policy as an unexpected change of the rules of the game, we do not necessarily want these people to be "punished".

$\rightarrow$ A related fundamental question is to what extent people are actually responsible for their own pollution. Here again, very subjective consideration and diverging views that can be difficult to reconcile (see next lecture).

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Efficiency equivalence in the first-best

In a first-best situation, all kind of market based instruments will be equally cost-effective: taxing the externality, subsidizing efforts to reduce it, or setting tradable quotas will be equally effective.

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Consider the example of a firm whose profits $\pi(e)$ are an increasing function of its pollution e, and whose production causes a social damage $D(e)$. Then:

- if the government sets a pollution tax, the firm will maximize $\pi(e) - \tau e$;
- if it sets a subsidy for pollution abatment relative to a benchmark $\bar{e}$, the firm will maximize $\pi(e) + s(\bar{e} - e)$;
- if it fixes tradable quotas $\bar{q}$, the firm will maximize $\pi(e) + p(e - \bar{q})$ where p is the equilibrium price of one unit of pollution permit.

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Then, if the policies are set such that $\tau^* = D'(e^*)$, $s^* = D'(e^*)$, and the total quantity of quotas allocated is such that the equilibrium price is $p^* = D'(e)$, then efficiency is restored in all three cases.

Distributive effects in the first-best

There is still a key difference between tax, subsidies and tradable permits in terms of how the burden of the policy is shared between the polluters and the polluted:

- a tax applies the polluter-pays principle, the burden is on the polluter;
- a subsidy leads to a transfer of wealth from the government (and therefore the tax payers, usually including both the polluters and polluted) to the polluter;
- tradable permits have similar distributive effects than a tax if they are auctionned, and similar to a subsidy when they are grandfathered.

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In the first best, these distributive consequences can be counteracted by lump-sum transfers to achieve any desired efficient allocation. In the second best, this is usually not possible and the direct distributive effects of the policy become critical.

In addition, absent such transfers these different mechanisms can lead to different levels of pollution since subsidies (or grandfathered permits) tend to maintain the most inefficient firms active.

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The case of perfect information

A standard problem in the literature about instrument choice is whether taxes or tradable quotas should be preferred:

- although both instruments have similar properties in the first-best, they may produce different outcomes in a second-best environment;
- in particular, they usually differ in situations of imperfect information;
- the seminal work of Weitzman (1974) identifies conditions under which imperfect information make one type of instrument preferable to the other.

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- the seminal work of Weitzman (1974) identifies conditions under which imperfect information make one type of instrument preferable to the other.

Let's consider a planner that wants to regulate the production of a polluting good. If we denote q the quantity of the good, the associated benefits are $B(q)$ and the associated costs $C(q)$.

In the first best, the planner is indifferent between setting the price p^* or the quantity q^* since both will equivalently lead to an efficient allocation:

$$p^* = B'(q^*) = C'(q^*)$$

The case of imperfect information

Weitzman then considers the case where there is uncertainty over costs and benefits. This uncertainty is captured by parameters θ and η so that the cost and benefit function are now $C(q, \theta)$ and $B(q, \eta)$. In this situation, the first-best price and quantity regulations are entire schedules such that:

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But in practice, such instruments are hardly feasible (high complexity, moral hazard problems in situations of asymmetric information, etc.). Thus, the second best problem of the planner is to find the best price or quantity to maximize the *expected* surplus. The government will either set:

- a quantity $\hat{q}$ such that:

$$E[B(\hat{q}, \eta) - C(\hat{q}, \theta] = \max_q E[B(q, \eta) - C(q, \theta]$$

- or a price $\tilde{p}$ such that, given the (uncertain) firm response $h(\tilde{p}, \theta)$, we will have:

$$E[B(h(\tilde{p}, \theta), \eta) - C(h(\tilde{p}, \theta), \theta] = \max_q E[B(h(p, \theta), \eta) - C(h(p, \theta), \theta]$$

Although neither $\tilde{p}$ nor $\hat{q}$ will lead to an *ex post* efficient allocation, one can still compare how these two instruments perform in expectation.

Relative merits under imperfect information

Weitzman defines the comparative advantage of prices over quantities as:

$$\Delta = \left(E[B(h(\tilde{p},\theta),\eta) - C(h(\tilde{p},\theta),\theta] \right) - \left(E[B(\hat{q},\eta) - C(\hat{q},\theta] \right)$$

Using a second order approximation, he shows that:

$$\Delta \approx \frac{\sigma^2(B'' + C'')}{2C''^2}$$

where σ^2 is the variance of θ, and B'' and C'' represent respectively the first derivative of the marginal benefit and cost functions, i.e. the slopes of the demand and supply functions.

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where σ^2 is the variance of θ, and B'' and C'' represent respectively the first derivative of the marginal benefit and cost functions, i.e. the slopes of the demand and supply functions. Thus, the sign of Δ simply depends on the sign of $B'' + C''$, with $B'' \leq 0$ and $C'' \geq 0$:

- when marginal costs are close to linear, C'' is close to zero and $\Delta < 0$ so quantities are preferred: setting the wrong price has very large consequences with constant marginal costs, leads to dramatic change in quantities. The same holds for B'' very large.
- conversly, when marginal costs are very steep, C'' is large and setting the wrong quantity will lead to large inefficiencies. The same holds for B'' close to zero. Prices are preferred when the curvature is lower for the benefit than for the cost function.

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Conclusions

When deciding on how to tackle a given environmental problem, policy-makers have the choice between policies forcing agents to adopt a certain behavior or policies inducing this behavior through market or non-market incentives.

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- In a more complex (and realistic) framework where there are more market failures than regulatory instruments:
  - the comparative advantage of market-based instruments must be reconsidered. Although they generally provide incentives to reduce pollution at a lower cost than other instruments, their interactions with other market failures may reduce their effectiveness or aggravate pre-existing distortions;
  - in such context, distributive effects are also a major concern since transfers cannot always be used;
  - although no instrument is always better than others, taxes are often appealing as they generate public funds that can be used to reduce other distortionary taxes or to compensate the losers.

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In this lecture we have considered a policymaker deciding on the best way to address environmental problems. In practice, policymakers take decisions under an additional constraint: public support. Next week we will see examples in which this additional constraint matters.