

ECON-7102: Environmental Economics I

Class 9: Instrument Choice (iv)

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Today's agenda

1. Questions?
2. Housekeeping:
 - Abstract 2 due Sunday, 11:59 PM. Rapid-fire pitches Monday in class.
3. Today:
 - Environmental policy with “pre-existing distortions” (P&R Ch. 7)
 - West & Williams (2007)
4. For next class...

Environmental policy with “pre-existing distortions”

- Until now, we've only considered “partial equilibrium” results.
 - This means we've focused on the market for pollution abatement (or output markets) in isolation.
- Do our primary results so far (i.e., $MAC = MD$) hold in “general”?
- We will introduce labor–leisure tradeoffs and government revenue requirements into the model.

Environmental policy with “pre-existing distortions”

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 - This means we've focused on the market for pollution abatement (or output markets) in isolation.
- Do our primary results so far (i.e., $MAC = MD$) hold in “general”?
- We will introduce labor–leisure tradeoffs and government revenue requirements into the model.
- This framework is motivated by two questions:
 1. **How does environmental policy interact with imperfections in other markets?**
 2. **Is there potential for a “double dividend” (i.e., effective environmental policy that also reduces distortionary taxation)?**

Environmental policy with “pre-existing distortions”

Extending our model

- Same basic framework as before: one representative consumer and producer.
- Consumers split their time (T) between working and leisure (N).
 - Working provides wage w , so household income is $w(T - N)$. Demand for labor is perfectly elastic.
- Leisure provides utility: $U(X, Z, N, E) = u(X, N) + Z - D(E)$
 - *Leisure and the polluting good could be complements or substitutes.*
- Consumers maximize: $\max_{X, N} u(X, N) + Z - D(E)$ s.t. $w(T - N) = Z + pX$
 - $u_X = p \implies$ demand for polluting good: $X(p, w)$, with $\partial X / \partial p < 0$
 - $u_N = w \implies$ demand for leisure: $N(p, w)$, with $\partial N / \partial p \leq 0$
- Firms maximize profits as before. Assume $E = \delta X$ for simplicity.

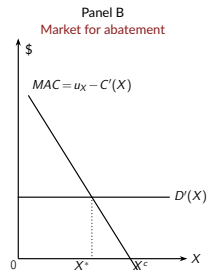
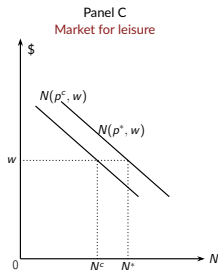
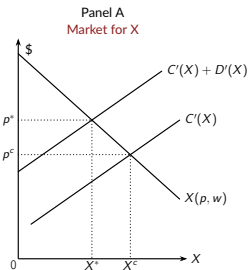
Environmental policy with “pre-existing distortions”

Regulator's optimum, without distortions

- Regulator chooses X (and, hence, E) but not leisure directly.
- Consumer will choose N^* such that $u_N = w$, so the labor market term drops out:

$$u_X(X, N) - C'(X) = D'(X) \\ \Rightarrow \text{MAC (incl. opp. costs) = MD.}$$

- Figure shows case where X and N are substitutes: *demand for leisure increases as price of X increases.*
- Environmental regulation moves the labor/leisure tradeoff, but optimality still holds because the marginal product of labor (w) equals the opportunity cost of leisure.



Environmental policy with “pre-existing distortions”

Introducing a labor market distortion

- “Labor market distortion” = a tax on income to raise governmental revenue.
- Labor is now taxed via proportional income tax (m) s.t. net income is: $(1 - m)w$

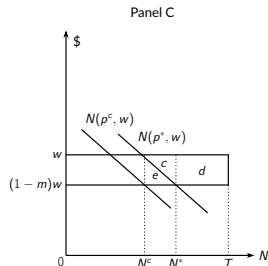
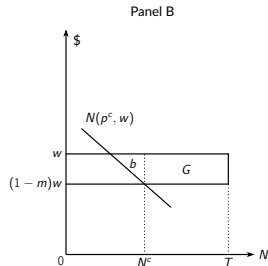
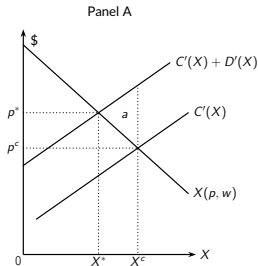
$$\max_{X, N} u(X, N) + Z - D(E) \text{ s.t. } (1 - m)w(T - N) = Z + pX$$

- FOCs:
 - $u_X = p$
 - $u_N = (1 - m)w$
 - Tax generates an inefficiency in labor market (effectively a subsidy to leisure)
 - Markets for both X and N are now distorted: too much X , too little labor.

Environmental policy with “pre-existing distortions”

Two distorted markets

- a is DWL from externality.
- b is excess burden of income tax.
- G is tax revenue.
- Panel C demonstrates difference between competitive vs. socially optimal leisure demand:
 - EB of tax shifts from b to c when regulator chooses X^*
 - Relative size of b or c is indeterminant
 - Tax revenue shrinks from G to d
- **Main point:** Env. policy can exacerbate distortions in other markets!



Second-best environmental policy

- **Basic idea:** taking “pre-existing distortion” as given, how should we set optimal environmental policies?
 1. Non-revenue raising policies (i.e., pollution standards).
 2. Policies that raise revenue, where what we do with the revenue matters.
- **General question:** *Can we use environmental policies to correct multiple market inefficiencies?*

Regulator sets $\bar{X}$, chooses m , and rebates revenue lump-sum:

$$\max_{X,m} W = \underbrace{u(X, N) + w(T - N) - D(X) - C(X)}_{\text{Sum of utility (less env. damages) and firm profit}} + \underbrace{\lambda[wm(T - N) - G]}_{\text{Government budget constraint with } -\lambda = \partial W / \partial G \leq 0 \text{ defined as the marginal welfare cost of public funds (MCPF). I.e., the welfare loss of each additional dollar of gov. revenue from taxing labor.}}$$

$$\lambda = \frac{\varepsilon_L m / (1-m)}{1 - \varepsilon_L m / (1-m)}, \text{ where } \varepsilon_L \text{ is the elasticity of labor supply} \implies \text{MCPF is small (large) when labor supply is inelastic (elastic).}$$

Second-best environmental policy

Non-revenue raising: choosing X

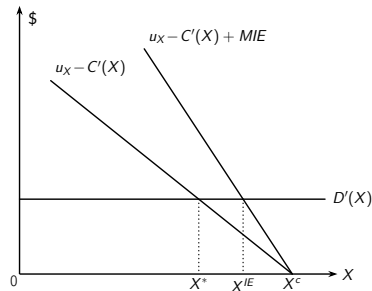
- Equilibrium condition for X :

$$\underbrace{u_X(X, C) - C'(X)}_{\text{Marginal abatement costs (MAC)}} + \underbrace{(1 + \lambda) \left[-\frac{\partial N}{\partial p} \frac{\partial p}{\partial X} \right] wm}_{\text{Marginal interaction effect (MIE)}} = \underbrace{D'(X)}_{\text{Marginal damages}}$$

Marginal interaction effect (MIE)

How the marginal social cost of reducing X changes with a tax-induced change in leisure.

- If X and N are substitutes ($\partial N / \partial p > 0$), then $MIE > 0$: MC of reducing X is larger with the distortion, so optimal pollution is *larger* than first-best.
- If X and N are complements ($\partial N / \partial p < 0$), then $MIE < 0$: MC of reducing X is smaller, so optimal pollution is *smaller* than first-best.



$\Rightarrow MAC \neq MD.$

Second-best environmental policy

Revenue raising policies

- Regulator sets emissions tax τ and chooses m to maximize welfare, where $G = wm(T - N) + \tau X$ and revenue is returned lump-sum.

$$\underbrace{u_x(X, N) - C'(X)}_{\text{Marginal abatement costs (MAC)}} + \underbrace{(1 + \lambda) \left[\frac{\partial N / \partial \tau}{\partial X / \partial \tau} \right] wm}_{\text{Marginal interaction effect (MIE)}} + \underbrace{\lambda \left[\tau + \frac{X}{\partial X / \partial \tau} \right]}_{\text{Marginal revenue effect (MRE)}} = \underbrace{D'(X)}_{\text{Marginal Damages}}$$

- Optimality is now given by: $MAC + MIE + MRE = MD$.

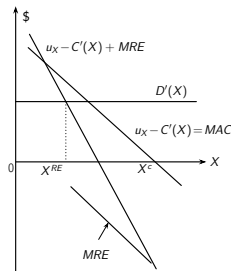
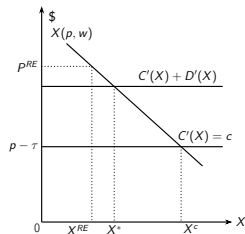
Second-best environmental policy

Marginal revenue effect

Marginal Revenue Effect

The marginal social cost of changes in X that arise from changes in revenue from a distorted market. That is, the cost of increased or decreased revenue from the distorted market needed to balance the budget.

- Intuition: if we tax X more, we don't need as much revenue from labor taxes to satisfy gov. budget constraint.
- With constant MC and $p = c + \tau$: $MRE = \lambda \left(\frac{X}{\partial X / \partial p} + \tau \right) = \lambda \left(\frac{p}{\varepsilon_X} + \tau \right)$
 - ⇒ When emissions tax is small (relative to p) or demand for X is inelastic, the MRE will be negative.
- Figure assumes $MIE = 0$, so $MAC + MRE = MD$.
 - Bottom: Marginal social cost of reducing X is *smaller* when considering spillovers to labor market.
 - Implication: set τ higher than you would without distortions because you can earn more revenue per unit of X without large reduction in tax base.
- **Intuition:** Governments (should) want to raise revenue in the least distortionary way possible.



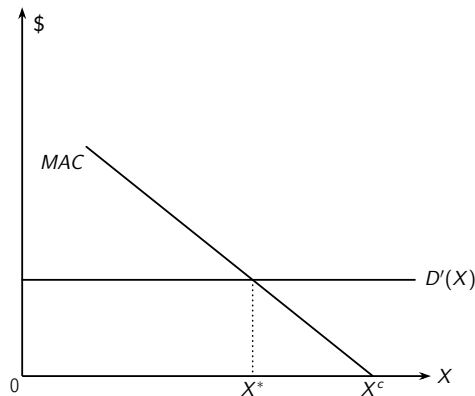
Double dividend

Double Dividend (two forms)

- (*Weaker form*): Welfare is greater when any revenues raised via environmental policy are used to reduce distortionary taxation rather than refunded in a lump sum fashion.
 - (*Stronger form*): Emissions fees should be set above partial equilibrium level, resulting in more pollution reduction and larger amounts of revenue.
-
- An aside: I was at a workshop in DC on environmental policy during the first Trump administration. In response to a question about carbon taxes, Kevin Hassett (then chair of Council of Economic Advisers in the Trump admin, now Director of National Economic Council) said something along the lines of:
 - ***“Even if you don’t believe in climate change, a revenue-neutral carbon tax that reduces distortionary capital tax rates is good economic policy.”***

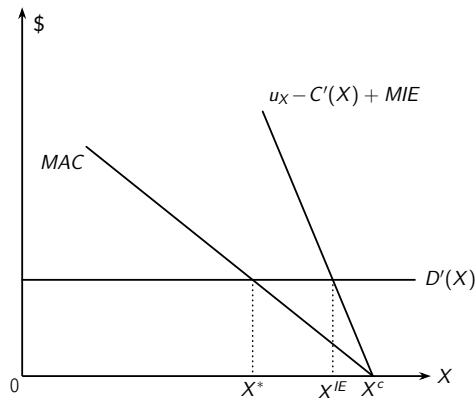
Double dividend

- Recall: $MD = MAC + MIE + MRE$
- (Prop. 7.3): **Strong form of DD** requires $MIE + MRE < 0$.
- **How likely is strong double-dividend?**
 - $MIE < 0$ requires X and N to be complements.
 - And/or MRE must offset a positive MIE .



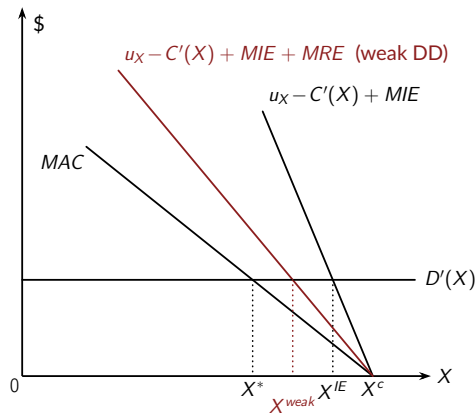
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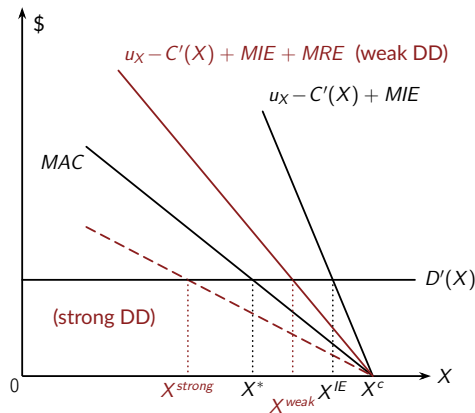
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- **How likely is strong double-dividend?**
 - $MIE < 0$ requires X and N to be complements.
 - And/or MRE must offset a positive MIE .
- This is an empirical question. One example: West & Williams (2007) find that gasoline and leisure are complements, so $MIE < 0$. They also find that $MRE < 0$, so strong double dividend is possible.



Second-best policy instruments

- **Emissions taxes:** Set tax: $\tau = D'(X) + MIE + MRE$ to achieve optimal output and emissions.
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- **Freely distributed permits:**
 - Same permit cap, but setting $X^{GE} < X^c$ causes prices to rise, demand for leisure will change, leading to MIE , but since no revenue is raised, cannot offset MIE . Therefore, cannot satisfy: $MD = MAC + MIE + MRE$.
 - Same logic holds for command and control.

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 - Same logic holds for command and control.
- **Subsidies:**
 - operate similar to taxes...
 - ...but, they require revenue to be raised *outside* of the market for X , leading to additional distortionary taxation in other markets.

Key takeaways

- Pre-existing distortions in other markets lead us to deviate from our $MD = MAC$ rule.
- Introducing labor/leisure tradeoffs allows for environmental policies to “spillover” into labor market (via interactions between leisure and the polluting good).
 - If X and N are substitutes, leads to more costly environmental policy than in PE
 - If X and N are complements, leads to less costly environmental policy than in PE
 - Can “easily” extend this line of thinking into other distorted markets (e.g., capital markets)
- New rule, when pre-existing distortions are present, is $MD = MAC + MIE + MRE$, which can lead to optimal X (and hence E) that are greater/less than partial eq'm.
- Prior to the adoption of IRA, environmental economists were pushing for a “carbon tax and dividend” approach to climate change.

ECONOMISTS' STATEMENT ON CARBON DIVIDENDS ORGANIZED BY THE CLIMATE LEADERSHIP COUNCIL

ORIGINAL CO-SIGNATORIES INCLUDE:

28 Nobel Laureate Economists

4 Former Chairs of the Federal Reserve

15 Former Chairs of the Council of Economic Advisers

ECONOMISTS' STATEMENT ON CARBON DIVIDENDS

Global climate change is a serious problem calling for immediate national action. Guided by sound economic principles, we are united in the following policy recommendations.

I. A carbon tax offers the most cost-effective lever to reduce carbon emissions at the scale and speed that is necessary. By correcting a well-known market failure, a carbon tax will send a powerful price signal that harnesses the invisible hand of the marketplace to steer economic actors towards a low-carbon future.

II. A carbon tax should increase every year until emissions reductions goals are met and be revenue neutral to avoid debates over the size of government. A consistently rising carbon price will encourage technological innovation and large-scale infrastructure development. It will also accelerate the diffusion of carbon-efficient goods and services.

III. A sufficiently robust and gradually rising carbon tax will replace the need for various carbon regulations that are less efficient. Substituting a price signal for cumbersome regulations will promote economic growth and provide the regulatory certainty companies need for long-term investment in clean-energy alternatives.

IV. To prevent carbon leakage and to protect U.S. competitiveness, a border carbon adjustment system should be established. This system would enhance the competitiveness of American firms that are more energy-efficient than their global competitors. It would also create an incentive for other nations to adopt similar carbon pricing.

V. To maximize the fairness and political viability of a rising carbon tax, all the revenue should be returned directly to U.S. citizens through equal lump-sum rebates. The majority of American families, including the most vulnerable, will benefit financially by receiving more in “carbon dividends” than they pay in increased energy prices.

<https://www.econstatement.org/>

- **Big question:** is there a potential “double dividend” from environmental taxes?
- **Narrower question:** what is the optimal gasoline tax when considering spillovers to distorted labor markets?
- **Even narrower:** by modeling the tradeoff between gasoline taxes and demand for leisure, can we empirically measure complementarity/substitutability in a way that allows us to calculate the optimal gas tax?
- Many studies in the “tax interaction” literature assume leisure and the polluting good are separable.
 - $\implies$ cross-price elasticity of dirty good and leisure do not factor into the optimal tax.
 - WW relax this assumption and estimate the cross-price elasticity.

West & Williams (2007)

Optimal tax on the dirty good

- Model setup is effectively the same as Ch. 7. Solve for the optimal gasoline tax τ_D^* :

The diagram illustrates the components of the optimal tax formula. It features four callout boxes pointing to parts of the equation:

- Marginal external cost of D** : Points to the first term $\frac{\theta}{\eta}$.
- Cross-price elasticity of leisure w.r.t. price of D** : Points to the term $\frac{\partial l^{hi}}{\partial p_D^h}$ inside the summation.
- Ratio of MCPF**: Points to the term $\frac{\eta-1}{\eta}$ inside the summation.
- Aggregate change in D w.r.t. change in τ_D** : Points to the denominator $\sum_h \frac{dD^h}{d\tau_D}$.

$$\tau_D^* = \frac{\theta}{\eta} + \sum_h \left[\sum_i \tau_L^{hi} \frac{\partial l^{hi}}{\partial p_D^h} - \frac{\eta-1}{\eta} D^h \right] / \sum_h \frac{dD^h}{d\tau_D}.$$

- Second term on RHS is > 0 if the dirty good is a stronger substitute for leisure than the average good, < 0 if it is a weaker-than-average substitute (or a complement).
- The second term is the optimal tax on the dirty good even if $\theta = 0$ (i.e., no externality at all).

West & Williams (2007)

Empirics

- Estimate an “Almost-ideal demand system” (AIDS): a flexible demand system requiring fewer functional-form assumptions, which delivers own- and cross-price elasticities for gasoline, leisure, and other goods.
- *Data*: Consumer Expenditure Survey, 1996–1998. Hours worked, gross pay, income, weekly gasoline expenditures.
 - *Leisure “expenditures”*: set $\bar{T} = 90$ hours/week (max hours worked in sample), leisure = $90 - \text{hours worked}$, priced at the net-of-tax wage.
 - Heckman correction to infer wages for non-workers.
- *Endogeneity*: instrument wages with occupation/state/gender means, real income with an alternative price index, gas prices with national average prices. Estimated by 3SLS.

Not important to understand all the details of this empirical model. AIDS models were common in older studies and do have attractive features, but are less commonly used these days.

West & Williams (2007)

Results

- Cross-price elasticity of labor w.r.t. gas prices is the number that matters.
- A positive elasticity increases the optimal gas tax, because higher gas prices discourage leisure.
- Does it make sense for gasoline and leisure to be complements?

"Compensated" elasticities = Hicksian demand.

"Uncompensated" = Marshallian. We'll circle

back to this for non-market valuation.

Table 5
Two-adult elasticities

	Gas price	Male wage	Female wage	Other good price
<i>Compensated price elasticities</i>				
Gasoline	-0.269 (-0.538 -0.011)	-0.123 (-0.269 0.003)	0.042 (-0.051 0.140)	0.354 (0.061 0.639)
Male labor	0.007 (0.000 0.015)	0.187 (0.105 0.272)	0.012 (-0.018 0.042)	-0.181 (-0.256 -0.096)
Female labor	-0.005 (-0.016 0.005)	0.028 (-0.030 0.087)	0.337 (0.252 0.427)	-0.321 (-0.415 -0.241)
Other good	0.012 (0.002 0.021)	0.102 (0.048 0.141)	0.095 (0.070 0.123)	-0.201 (-0.255 -0.134)
<i>Uncompensated price elasticities</i>				
Gasoline	-0.283 (-0.540 -0.021)	0.011 (-0.133 0.134)	0.110 (0.020 0.213)	0.178 (-0.285 0.646)
Male labor	0.013 (0.006 0.022)	0.062 (-0.019 0.152)	-0.049 (-0.080 -0.019)	-0.045 (-0.126 0.043)
Female labor	0.002 (-0.008 0.013)	-0.113 (-0.174 -0.055)	0.242 (0.158 0.329)	-0.165 (-0.252 -0.076)
Other good	-0.016 (-0.026 -0.007)	0.548 (0.314 0.588)	0.328 (0.295 0.362)	-1.090 (-1.154 -1.003)

Bias-corrected 95% confidence intervals are in parentheses, based on 1500 replications of a nonparametric clustered bootstrap.

West & Williams (2007)

Key takeaways, and discussion

- Gasoline demand and leisure demand seem unrelated, but WW show that the relationship between them moves the optimal gasoline tax a lot.
- Marginal external damages are \$0.77/gallon.
- Their preferred optimal tax is \$1.04/gallon.
 - Surprising result: even without externalities, we “*should*” tax gasoline at roughly \$0.33/gallon to reduce the distortion in the labor market.
 - This is evidence of the potential for a double dividend.
- Empirical analysis is critical for understanding how our “Ch. 7 theory” applies to policy.
- Thinking about future research: what aspects/assumptions of this paper might be improved upon?

For next class...

- **Mon Sep 28 — Class 10: Welfare analysis**
 - P&R Chapter 14
 - Willig, Robert D. (1976). “Consumer’s surplus without apology.” *American Economic Review*. [\[PDF\]](#)
- **Abstract 2** due Sun Sep 27, 11:59 PM ET. Rapid-fire pitches in class Monday.

caseyjwichman.com/econ7102/#week6