Lecture 5

Environmental policy with pre-existing distortions

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Roadmap

So far we have looked at single sector economies with:

- Pollution distortions
- Competitive markets
- Market power distortions

Now we will learn about multi-sector economies

How does environmental policy spillover into these other sectors?

How does environmental policy interact with revenue-raising taxes (e.g. income taxes)?

Environmental policy with leisure

First we extend the model so that labor supply is **elastic**

- Households have a choice of either working or leisure time

To focus on the key intuition we assume: [1]

- There is a representative (single) firm
- There is a representative household

This allows us to treat individual and aggregate behavior the same

1: The underlying critical assumption is that utility and profit functions take what's called a Gorman form.

Environmental policy with leisure

Define the following:

- X is consumption of the polluting good
- Z is consumption of the *numeraire* good (i.e. the relative good)
- N is the hours of leisure time
- E is aggregate emissions

Utility is then:

$$U(X, Z, N, E) = U(X, N) + Z - D(E)$$

where $U_{XX}, U_{NN} < 0$ and $U_{XX}U_{NN} - U_{NX}^2 > 0$ and the person is endowed with some amount of time T to allocate between work and leisure

Environmental policy with leisure

Wages earned by the household are w, and we assume demand for labor is perfectly elastic

i.e. demand is horizontal at w

Household income is then: $w \cdot (T - N)$

We can now write the households utility maximization problem as:

$$\max_{X,N,Z} U(X, Z, N, E) = U(X, N) + Z - D(E)$$

$$\text{subject to:} \quad w \cdot (T - N) = Z + pX$$

Substitute the budget constraint in for Z to get an unconstrained problem

Environmental policy with leisure

We can substitute the budget constraint in for Z to get an unconstrained problem:

$$\max_{X,N} U(X, Z, N, E) = U(X, N) + w \cdot (T - N) - pX - D(E)$$

with FOCs:

$$U_X = p \qquad U_N = w$$

which implicitly define the demand function for consumption $X(p, w)$ and the demand function for leisure $N(p, w)$

Environmental policy with leisure

How do choices of X, N respond to a change in price p?

Differentiate both FOCs with respect to p:

$$U_{XX}\frac{\partial X}{\partial p} + U_{XN}\frac{\partial N}{\partial p} = 1 \qquad U_{NN}\frac{\partial N}{\partial p} + U_{XN}\frac{\partial X}{\partial p} = 0$$

We have two equations and two unknowns so we can solve to get:

$$\frac{\partial N}{\partial p} = \frac{-U_{XN}}{U_{XX}U_{NN} - U_{XN}^2} \qquad \frac{\partial X}{\partial p} = \frac{U_{NN}}{U_{XX}U_{NN} - U_{XN}^2}$$

Environmental policy with leisure

$$\frac{\partial N}{\partial p} = \frac{-U_{XN}}{U_{XX}U_{NN} - U_{XN}^2} \qquad \frac{\partial X}{\partial p} = \frac{U_{NN}}{U_{XX}U_{NN} - U_{XN}^2}$$

$\frac{\partial X}{\partial p}$ is negative since U is concave $(U_{NN} < 0, U_{XX}U_{NN} - U_{XN}^2 > 0)$

The sign of $\frac{\partial N}{\partial p}$ equals the sign on $-U_{XN}$

If X and N are substitutes, $-U_{XN} > 0$, and leisure increases in the price of the consumption good

If they are complements, $-U_{XN} < 0$, and leisure decreases in the price of the consumption good

Environmental policy with leisure

If N is going on a picnic and X is hot dogs: X and N are complements

If the price of hot dogs goes up 1000% then you will go on fewer picnics

If N is going on a picnic and X is video games: X and N are substitutes

If the price of video games go up 1000% then you will go on more picnics

Environmental policy with leisure

The firm side of the economy will be the same as before: it produces X and emits E and for simplicity we will focus on the specific case:

$$\Pi = pX - C(X) \text{ where } E = \delta X$$

We will also assume:

- $\delta = 1$ so we can use E and X interchangeably
- $C'(X) > 0, C''(X) \geq 0$
- The polluting industry's demand for labor is small relative to the entire economy, i.e. wages are effectively fixed for the household

Environmental policy with leisure

Now lets solve for the social optimum:

$$\max_{X} W = \underbrace{U(X,N) + w\cdot(T-N) - pX - D(X)}_{\text{Consumer Utility}} + \underbrace{pX - C(X)}_{\text{Firm profit}}$$

To focus on interactions with non-regulated industries, we assume the regulator cannot determine the allocation of leisure and labor

The consumer chooses N according to the FOC $U_N(X^*, N) = w$ and then Z given the budget constraint $Z = w(T-N) - pX^*$

One way you can think about this is as if the regulator imposes a quantity standard X^* and then a market price p^* arises which affects leisure demand

Environmental policy with leisure

The FOC for the optimum is:

$$U_X - D'(X) - C'(X) + [U_N - w]\frac{\partial N}{\partial X} = 0$$

where the last term captures the households **indirect** leisure response to the regulator's policy choice

Given household utility maximization $U_N - w = 0$ and the condition is then:

$$U_X - C'(X) = D'(X)$$

Marginal abatement cost $(U_X - C'(X))$ equals marginal damage $(D'(X))$!

Environmental policy with labor market distortions

Elastic labor supply/leisure doesn't change the efficiency condition

Now suppose the government needs to raise revenue with a labor income tax m in order to finance government services

It needs to finance a budget of size G

The consumer's utility maximization problem is:

$$\max_{X,Z,N} U = u(X,N) + Z - D(E)$$
$$\text{subject to } (1-m)w(T-N) = Z + pX$$

Where the budget is scaled down by $(1-m)$ reflecting the income tax

Environmental policy with labor market distortions

The FOCs are:

$$u_X = p \qquad u_N = (1-m)w$$

The labor tax causes an inefficiency in the labor market: the marginal value of leisure (u_N) is no longer equal to the marginal value of labor (w)

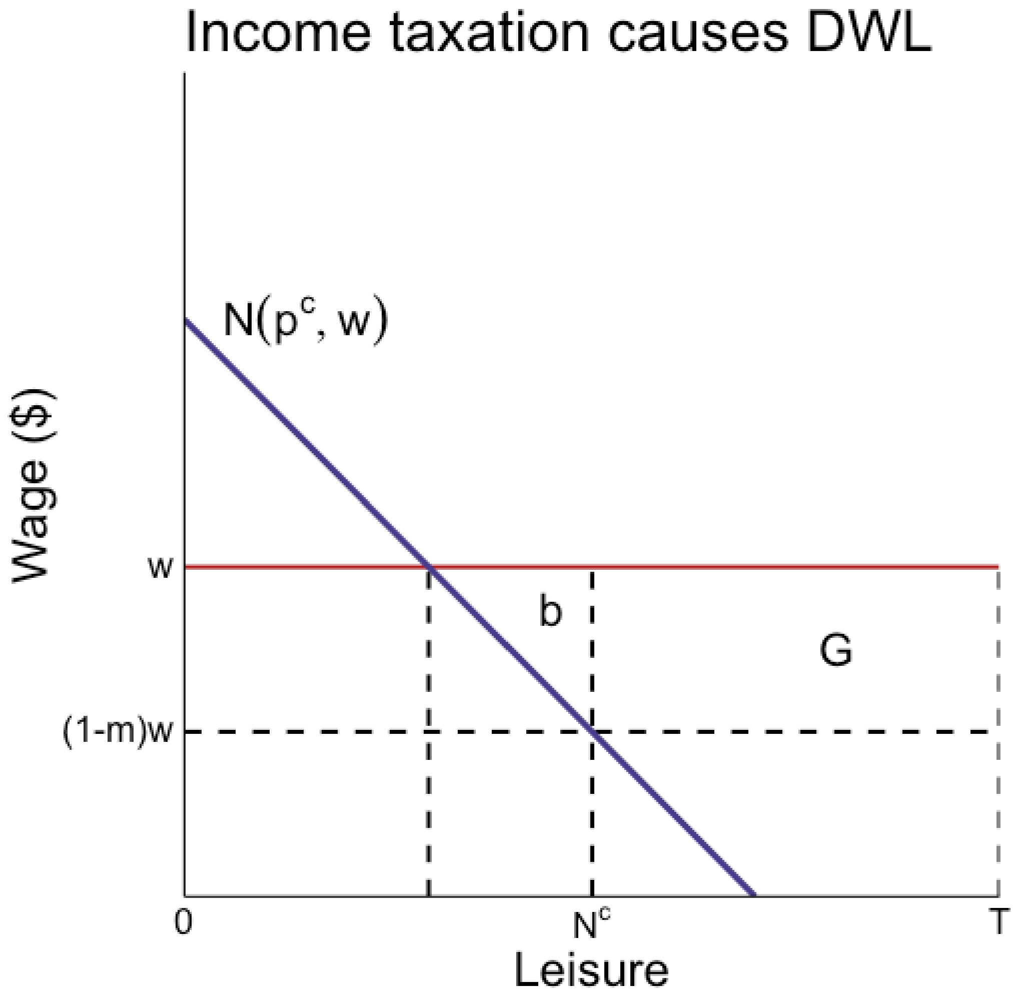
$u_N < w$ which means that the household overconsumes leisure

Another way to see this is to re-write the FOC as:

$$u_N + mw = w$$

The tax m makes the consumer act as if there is a subsidy mw on leisure

Environmental policy with labor market distortions



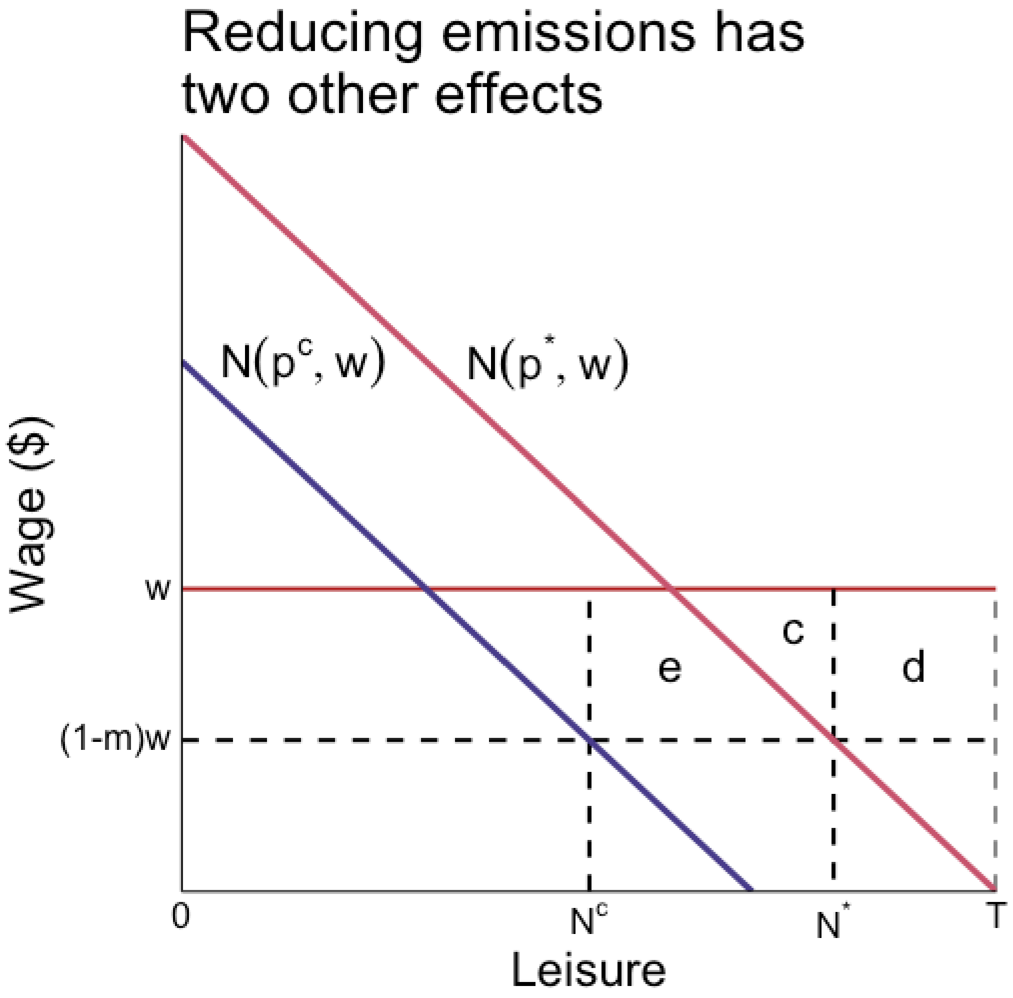
w is the perfectly elastic demand for labor

N^c is how much leisure the consumer chooses, since $(1-m)w < w$ this is too much and induces DWL equal to b

This is called **excess burden**

The tax raises revenues equal to G: $mw \times (T - N^c)$

Environmental policy with labor market distortions



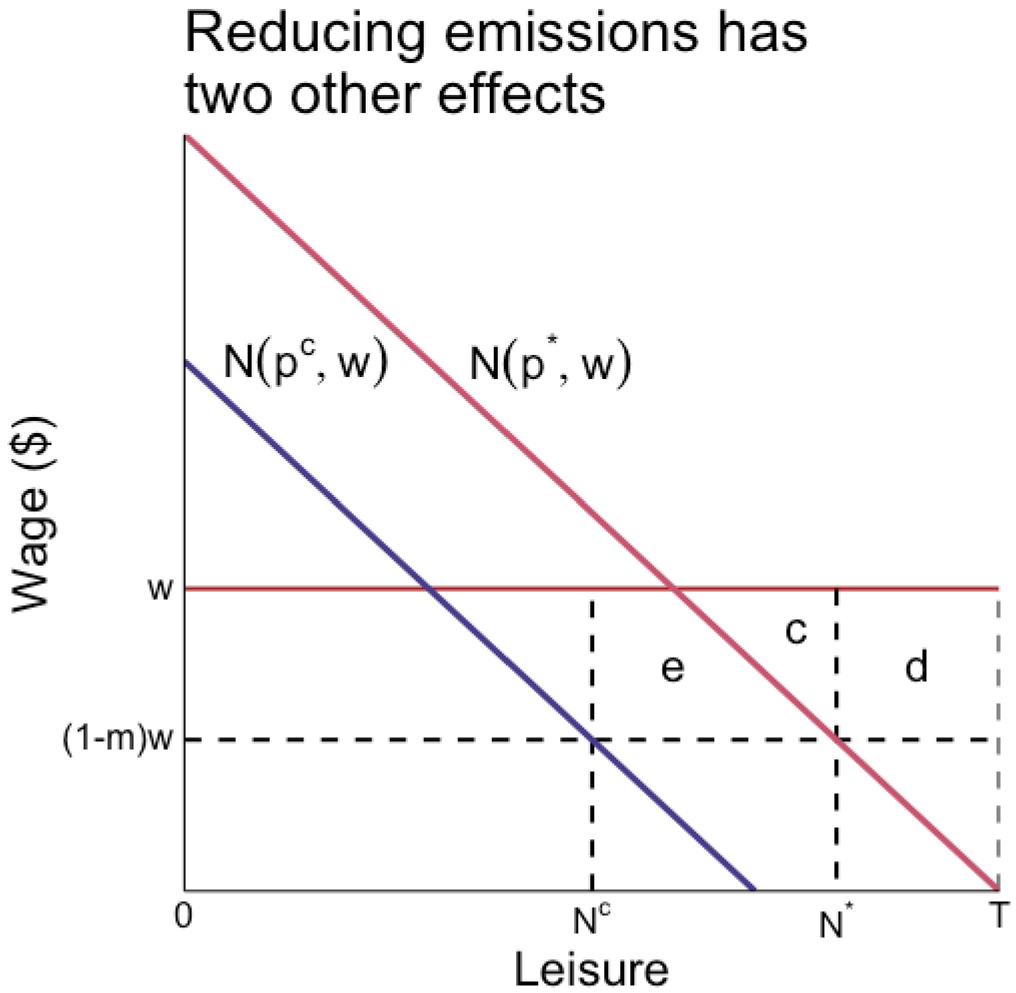
Suppose N and X are substitutes, and the regulator sets $X = X^*$ where $X^* \rightarrow MAC = MD$

This raises the price of X, shifts leisure demand to the **right**

New DWL is c, and government revenues are now only d

Change in DWL from $X^c \rightarrow X^*$ is indeterminant

Environmental policy with labor market distortions



Fixing the pollution externality had two effects:

1. Indeterminant effect on the distortion in the labor market
2. Reduced the amount of revenue the government raised through labor taxation

Second-best environmental policy

What does the optimal environmental policy look like if there's a pre-existing labor market distortion?

The government has a budget G it needs to finance using labor taxes or emission taxes

First let's consider the case where they can only raise revenue via a labor tax: this is non-revenue raising environmental policy

Second-best non-revenue raising environmental policy

If we cannot raise revenue with the environmental policy, the regulator chooses X (and E) and the marginal tax rate m to maximize the sum of profit and utility, subject to the budget constraint

The household consumes leisure according to the FOC:

$$U_N(\bar{X}, N) = (1 - m)w$$

given the regulator chose $X = \bar{X}$

The firm obtains profits:

$$\Pi = p\bar{X} - C(\bar{X})$$

Second-best non-revenue raising environmental policy

The marginal value of the dirty good comes from the consumers inverse demand:

$$P(\bar{X}) = u_X(\bar{X}, N)$$

which depends on N

First we need to learn how the endogenous variables N and p vary with $\bar{X}$

Let's do the comparative statics: differentiate the consumer's two FOCs with respect to $\bar{X}$

Second-best non-revenue raising environmental policy

$$u_{XX}\frac{\partial \bar{X}}{\partial \bar{X}} + u_{XN}\frac{\partial N}{\partial \bar{X}} = \frac{\partial p}{\partial \bar{X}} \tag{X FOC}$$

$$u_{NX}\frac{\partial \bar{X}}{\partial \bar{X}} + u_{NN}\frac{\partial N}{\partial \bar{X}} = 0 \tag{N FOC}$$

$\frac{\partial \bar{X}}{\partial \bar{X}} = 1$ so two equations, two unknowns; solving the system gives us:

$$\frac{\partial N}{\partial \bar{X}} = -\frac{u_{XN}}{u_{NN}}$$

$$\frac{\partial p}{\partial \bar{X}} = \frac{u_{XX}u_{NN} - u_{NN}^2}{u_{NN}} < 0$$

$\mathrm{sign}(\frac{\partial N}{\partial \bar{X}})$ depends on whether X and N are complements or substitutes

Second-best non-revenue raising environmental policy

Now that we know how the firm responds, return to the regulator's problem:

$$\max_{X,m} u(X,N) + Z - D(X) + pX - C(X) \quad \text{s.t.} \quad wm(T-N) = G$$

We still need to decide what the government does with its revenue

For convenience, we assume its returned to the consumer as a lump sum transfer so that:

$$Z = (1-m)w(T-N) - pX + G = (1-m)w(T-N) - pX + wm(T-N)$$
$$\Rightarrow Z = w(T-N) - pX$$

Income is unchanged for a given level of N under the tax and transfer

Second-best non-revenue raising environmental policy

The regulator's problem is then:

$$\max_{X,m} u(X,N) + \underbrace{w(T-N)}_{Z} - D(X) - C(X) + \lambda[wm(T-N) - G]$$

λ is called the **marginal welfare cost of public funds**

It measures the welfare cost of raising revenue by taxing labor

What's the FOC for m?

Second-best non-revenue raising environmental policy

The FOC for m is:

$$(u_N - w)\frac{\partial N}{\partial m} + \lambda \left[w(T - N) - wm\frac{\partial N}{\partial m} \right] = 0$$

The household's optimal choice of N tells us that: $-mw = u_N - w$, we can substitute this in to get λ:

$$\lambda = \frac{wm\frac{\partial N}{\partial m}}{w(T-N) - wm\frac{\partial N}{\partial m}}$$

Whats the interpretation of the right hand side?

Second-best non-revenue raising environmental policy

$$\lambda = \frac{wm\frac{\partial N}{\partial m}}{w(T-N) - wm\frac{\partial N}{\partial m}}$$

The numerator is:

The welfare cost of changing m

Why?

Higher m increases leisure demand $\frac{\partial N}{\partial m}$

This times the **tax wedge** mw, the gap between w and actual wage after taxes, gives us the change in excess burden (i.e. the DWL d in the graph)

Second-best non-revenue raising environmental policy

$$\lambda = \frac{wm\frac{\partial N}{\partial m}}{w(T-N) - wm\frac{\partial N}{\partial m}}$$

The denominator is:

The change in tax revenue from higher m

First term is the increase in revenue on the inframarginal hours worked

Second term is the decrease in revenue from reduced hours worked

- Similar to $P(X) + P'(X)X$ for a monopolist

Second-best non-revenue raising environmental policy

$$\lambda = \frac{wm\frac{\partial N}{\partial m}}{w(T-N) - wm\frac{\partial N}{\partial m}}$$

Numerator and denominator combined give us:

The change in welfare from a change in m over the change in tax revenue from a change in m

This is the change in welfare from a change in tax revenue!

Second-best non-revenue raising environmental policy

Now consider the FOC for X:

$$u_X - D'(X) - C'(X) + [u_N - w - \lambda wm] \frac{\partial N}{\partial X} = 0$$

Recall that we know:

$$-wm = u_N - w \qquad \frac{\partial N}{\partial X} = \frac{\partial N}{\partial p} \frac{\partial p}{\partial X}$$

So that we can substitute in the consumer leisure response:

$$u_X - C'(X) + (1 + \lambda) \left[-\frac{\partial N}{\partial p} \frac{\partial p}{\partial X} \right] wm = D'(X)$$

Second-best non-revenue raising environmental policy

$$u_X - C'(X) + (1+\lambda)\left[-\frac{\partial N}{\partial p}\frac{\partial p}{\partial X}\right] wm = D'(X)$$

What are each of the terms:

$u_X - C'(X)$ is the marginal abatement cost

$D'(X)$ is marginal damage

$(1+\lambda)\left[-\frac{\partial N}{\partial p}\frac{\partial p}{\partial X}\right] wm$ is new

What's the interpretation?

Second-best non-revenue raising environmental policy

$(1+\lambda)\left[-\frac{\partial N}{\partial p}\frac{\partial p}{\partial X}\right] wm$ is called the **marginal interaction effect (MIE)**

It tells us how the optimal choice of X departs from X^* because of the labor market distortion

- Changing $\bar{X}$ changes the price p which changes the household's optimal choice of N

We need to account for this because the household's choice of leisure will respond to changes in X

Suppose N and X are substitutes, what does this mean?

Second-best non-revenue raising environmental policy

Substitutes means that $MIE > 0$

The marginal social cost of abatement $(MAC + MIE)$ has become **larger**

Intuition?

Its more socially costly to reduce X because the household increases N in response

This **exacerbates** the distortion caused by the income tax: the household was already undersupplying labor because of the income tax

Now the household undersupplies labor to an even greater extent

Second-best non-revenue raising environmental policy

Complements means that $MIE < 0$

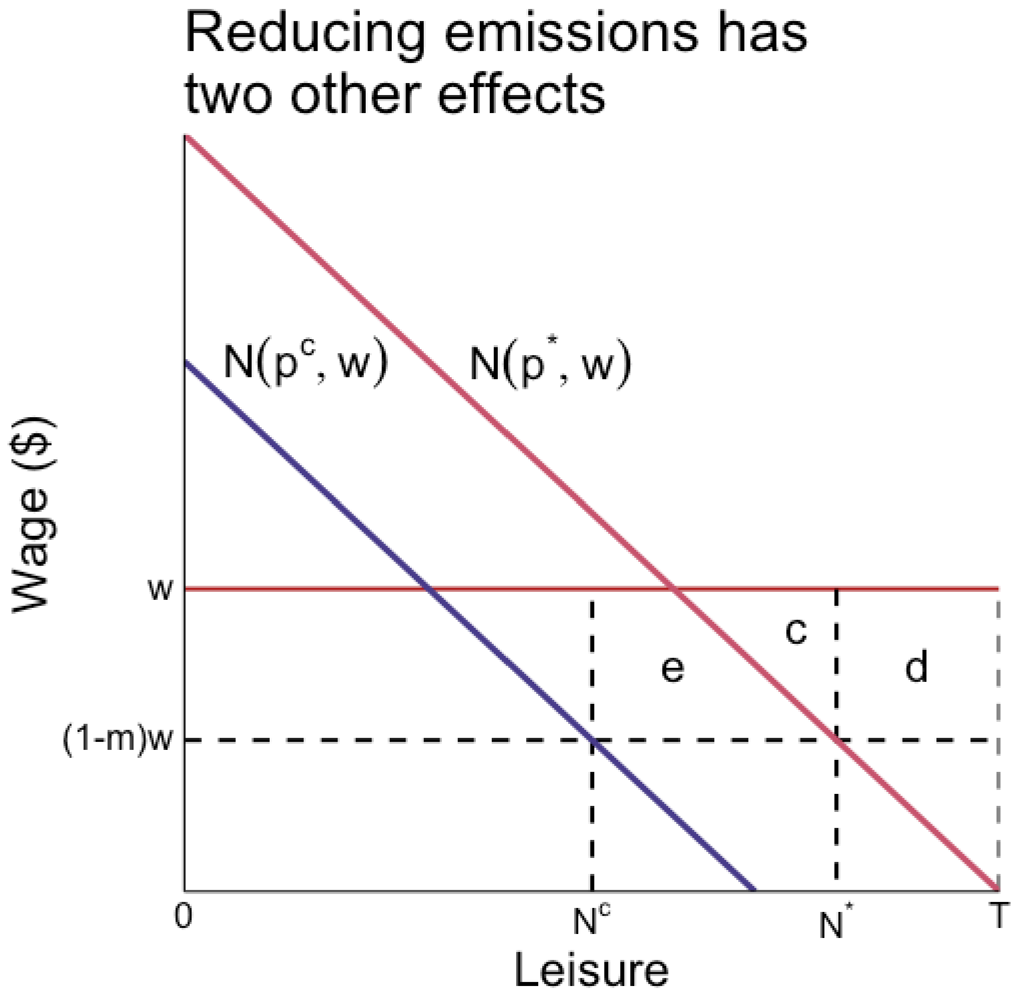
The marginal social cost of abatement $(MAC + MIE)$ has become **smaller**

Intuition?

Its less socially costly to reduce X because the household decreases N in response

This **alleviates** the distortion caused by the income tax: the household was undersupplying labor because of the income tax, but now reducing X increases labor supply, shrinking the labor market DWL

Second-best non-revenue raising environmental policy



$N^c \to N^*$ when $p^c \to p^*$ because of a change in X

This is $-\frac{\partial N}{\partial p}\frac{\partial p}{\partial X}$

This reduces tax revenue by $e + c$ which is just

$$(N^* - N^c)(w - (1-m)w)$$
$$= \underbrace{(N^* - N^c)}_{\approx -\frac{\partial N}{\partial p}\frac{\partial p}{\partial X}} mw$$

Second-best non-revenue raising environmental policy

The marginal welfare cost of recovering the lost tax revenue (in order to maintain gov't revenues G) by raising m is λ giving us a total welfare cost of:

$$\lambda(N^* - N^c)mw$$

But $(N^* - N^c)mw$ also happens to be the increase in excess burden: its a **direct welfare loss** in addition to the loss from having to increase m

So the total welfare loss is:

$$(1+\lambda)(N^* - N^c)mw$$

The discrete version of MIE!

Findings recap

If there's a government revenue constraint, and it can only be met with labor taxes then:

1. The marginal social cost of reducing X is higher if X and N are substitutes and lower if they are complements
2. The optimal level of pollution is larger if they are substitutes, lower if they are complements
3. The absolute value of the difference in first and second-best pollution levels is larger if:
    - Demand for X is more inelastic
    - Elasticity of substitution between N and X is greater

Second-best non-revenue raising environmental policy

We didn't actually show the last part yet

First define:

- ε_x as the own price elasticity $\frac{\partial X}{\partial p}\frac{p}{X}$
- η_{XN} as the elasticity of substitution between X and N: $\frac{\partial X}{\partial w}\frac{(1-m)w}{X}$

and take advantage of the **Slutsky symmetry condition** $\partial N/\partial p = \partial X/\partial w$

We can then use these to substitute into the MIE and get:

$$MIE = (1+\lambda)\left[-\frac{\eta_{XN}}{\varepsilon_X}\right]p\frac{m}{1-m}$$

Second-best non-revenue raising environmental policy

$$MIE = (1 + \lambda) \left[-\frac{\eta_{XN}}{\varepsilon_X} \right] p \frac{m}{1 - m}$$

MIE bigger if $|\eta_{XN}|$ is bigger (higher elasticity of substitution)

MIE bigger if $|\varepsilon_X|$ is smaller (more inelastic demand for X)

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Revenue raising environmental policy

Now suppose that the government raises revenues via emission taxation or auctioning permits

In our model the government has a revenue requirement:

$$G = wm(T - N) + \tau X$$

where τ is the revenue per unit of the dirty good

The regulator's problem is thus to select two tax rates: m and τ

For simplicity we still assume all tax revenues are returned lump sum to households

Revenue raising environmental policy

First derive household spending on the numeraire good:

$$Z = (1-m)w(T-N) - pX + G = w(T-N) - pX + \tau X$$

where the second equality comes from substituting out the govt's budget constraint: $G = wm(T-N) + \tau X$

The endogenous variables to be determined are: X, N and p, quantity of the dirty good, leisure, and the price of the dirty good

These are a function of the govt's choice of m and τ

Revenue raising environmental policy

The household FOCs are:

$$u_X = p \qquad u_N = (1-m)w$$

and the firm FOC is:

$$C'(X) = p - \tau$$

MU = MC of consumption and leisure

MR = MC of production

Next, as usual, differentiate the FOCs wrt τ

Revenue raising environmental policy

This gives us 3 equations and 3 unknown partial derivatives:

$$u_{XX}\frac{\partial X}{\partial \tau} + u_{XN}\frac{\partial N}{\partial \tau} = \frac{\partial p}{\partial \tau} \qquad \text{(Household X FOC)}$$

$$u_{XN}\frac{\partial X}{\partial \tau} + u_{NN}\frac{\partial N}{\partial \tau} = 0 \qquad \text{(N FOC)}$$

$$C''(X)\frac{\partial X}{\partial \tau} = \frac{\partial p}{\partial \tau} - 1 \qquad \text{(Firm X FOC)}$$

Substitute and solve...

Revenue raising environmental policy

Now solve for how the endogenous variables change in τ

$$\frac{\partial X}{\partial \tau} = \frac{u_{NN}}{H} < 0$$

$$\frac{\partial N}{\partial \tau} = \frac{-u_{XN}}{H} \lesseqgtr 0$$

$$\frac{\partial p}{\partial \tau} = \frac{u_{XX}u_{NN} - u_{XN}^2}{H} > 0$$

where $H = u_{XX}u_{NN} - u_{XN}^2 - C''(X)u_{NN} > 0$

Revenue raising environmental policy

Now that we know how the endogenous variables change we can solve for the regulator's optimal taxes

The regulator wants to maximize social welfare given the budget constraint:

$$\max_{m,\tau} \underbrace{U(X,N) + Z - D(X)}_{\text{household utility}} + \underbrace{pX - C(X) - \tau X}_{\text{firm profit}}$$

$$\text{subject to: } wm(T-N) + \tau X = G$$

Substitute in for Z from household spending:

$$Z = w(T-N) - pX + \tau X$$

And look at the τ FOC

Revenue raising environmental policy

$$\left[u_X - C'(X) - D'(X)\right] \frac{\partial X}{\partial \tau} + \left[\underbrace{u_N - w}_{-wm} - \lambda wm\right] \frac{\partial N}{\partial \tau} + \lambda \left[X + \tau \frac{\partial X}{\partial \tau}\right] = 0$$

Just follow the same steps as we did with the non-revenue raising case and divide by $\frac{\partial X}{\partial \tau}$ to get:

$$\underbrace{u_x - C'(X)}_{MAC} + \underbrace{(1+\lambda)wm \left[-\frac{\partial N}{\partial \tau} \bigg/ \frac{\partial X}{\partial \tau}\right]}_{MIE} + \underbrace{\lambda \left[\tau + X/\frac{\partial X}{\partial \tau}\right]}_{MRE} = D'(X)$$

Since the tax is per unit, we have that: $\frac{\partial N}{\partial \tau} / \frac{\partial X}{\partial \tau} = \frac{\partial N}{\partial p} / \frac{\partial X}{\partial p}$, MIE is similar in revenue and non-revenue raising contexts

Revenue raising environmental policy

What is this new term, MRE: $\lambda \left[\tau + X/\frac{\partial X}{\partial \tau}\right]$?

It's the **marginal revenue effect**: the amount by which emission tax revenue changes when X changes, scaled by λ, the MC of public funds

MRE changes the marginal social cost of X because changes in τ affect how much revenue we need to raise with distorting labor taxation

Let's get some intuition at the corner case of $\tau = 0$

What's the sign of MRE?

Revenue raising environmental policy

$MRE(\tau = 0)$: $\quad \lambda \left[x / \frac{\partial X}{\partial \tau} \right]$

Here $MRE < 0$ because $\frac{\partial X}{\partial \tau} < 0$, what's the intuition?

$\rightarrow$ the additional revenue from an increase in τ lets us reduce labor taxes

$\rightarrow$ this reduces the distortionary tax in the labor market

$\rightarrow$ this reduces welfare losses in the labor market

$\rightarrow$ this reduction in welfare losses reduces the marginal social cost of reducing X, decreasing the optimal level of X

Revenue raising environmental policy

Is MRE always negative?

No

We can get some intuition by making a substitution:

$$MRE \equiv \lambda \left[\tau + X \Big/ \frac{\partial X}{\partial \tau}\right] = \lambda \left[\tau + X \Big/ \frac{\partial X}{\partial p}\right] = \lambda \left[\tau + p/\varepsilon_X\right] = \lambda\tau \left[1 + 1/\varepsilon_X^\tau\right]$$

where $\varepsilon_X < 0$ is the elasticity of demand for the dirty good and ε_X^τ is the elasticity with respect to the tax

Revenue raising environmental policy

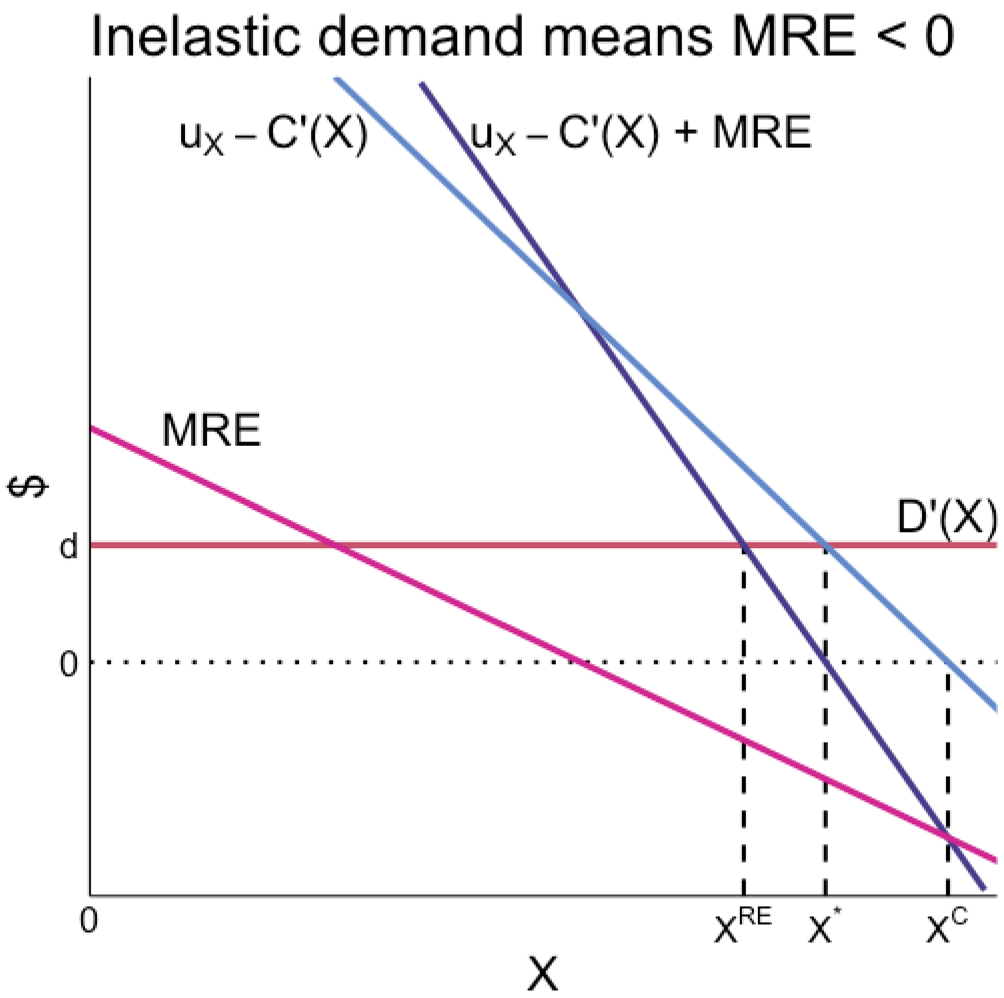
$$MRE \equiv \lambda \left[\tau + p/\varepsilon_X\right]$$

MRE is negative and increases total abatement if:

- demand for dirty good is sufficiently inelastic (ε_X small)
- the price of the dirty good is sufficiently larger than the emission tax

Why?

Revenue raising environmental policy

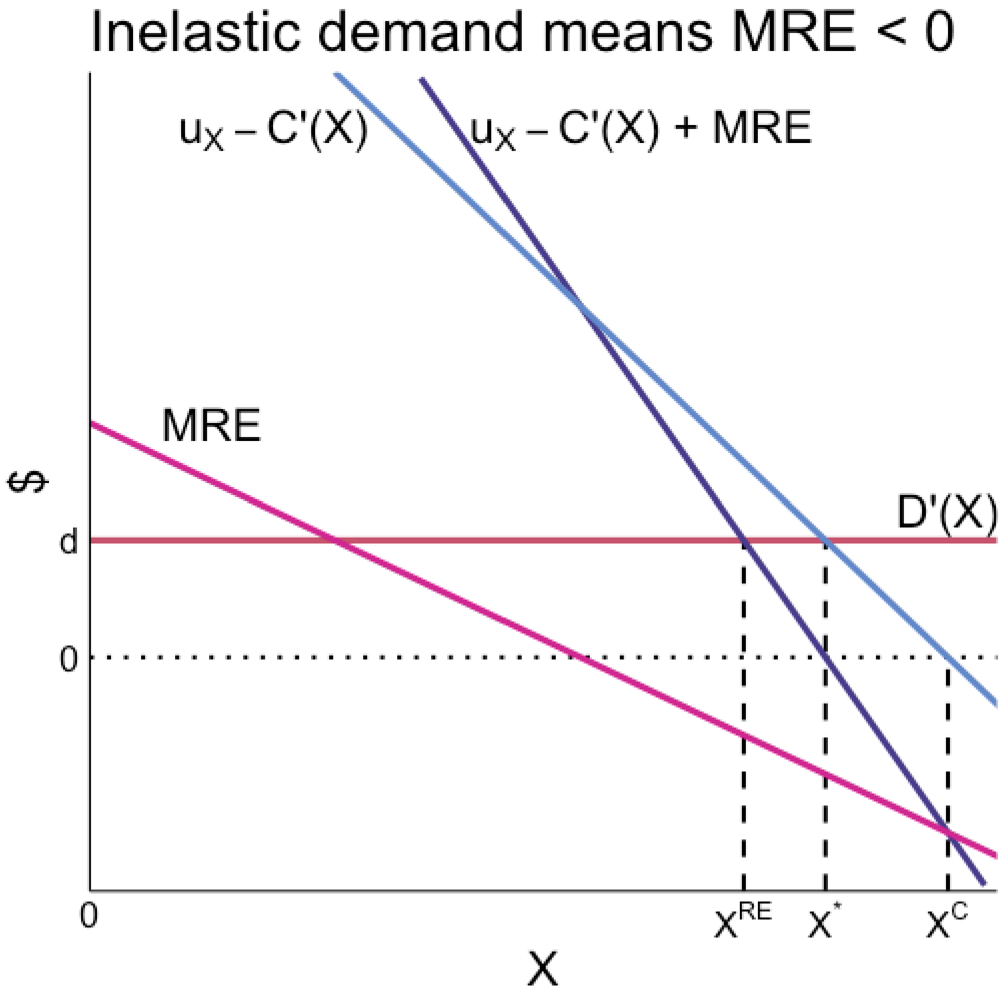


Demand for dirty good is sufficiently inelastic:

Suppose $\frac{\partial N}{\partial p} = 0$ so $MIE = 0$, $C'(X) = c, D'(X) = d$

Inelastic demand lets us raise more revenue from a small change in the tax

Revenue raising environmental policy

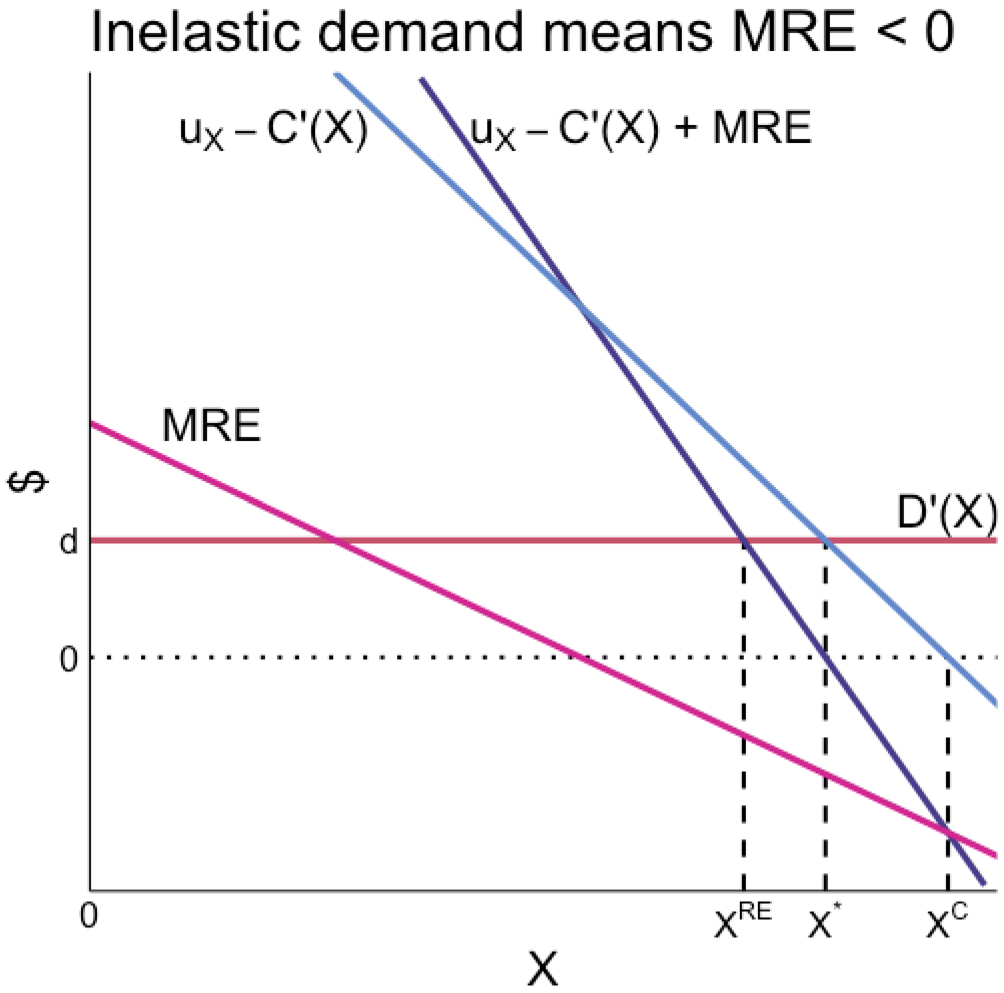


Inelastic demand lets us raise more revenue from a small change in the tax

This reduces the marginal social cost of reducing X

Optimal X with revenue-raising is lower than without: $X^{RE} < X^*$

Revenue raising environmental policy



We can also see that if $D'(X)$ was very large, making τ larger, we would be where $MRE > 0$

Double dividend

Is there a prospect for a **double dividend?**

There is a **weak double dividend** if welfare is always greater when revenue raised via environmental taxation is used to reduced distortionary taxation rather than refunded lump sum

- This is always true

There is a **strong double dividend** if the emission tax should always be set above the $MAC = MD$ level, resulting in greater pollution reductions and more revenue raised

- This may or may not be true

Double dividend

When is there a strong double dividend?

To have a strong double dividend we need:
$MSC < MAC \Rightarrow MIE + MRE < 0$

This can happen via two pathways:

Pathway 1: $MIE, MRE < 0$ or, $MIE < 0$ and $|MIE| > MRE > 0$

In this pathway we have that leisure and the polluting good are **complements**

Price of X rises from τ, demand for leisure goes down, labor goes up

Double dividend

Is this likely to be true?

Not really: leisure and consumption are generally substitutes

Pathway 2: $MIE > 0 > MRE, |MRE| > MIE$

Here leisure and consumption are substitutes, but the revenue effect dominates the interaction effect

Let's look at this pathway in more detail

Double dividend

Again, assume $C'(X) = c$, this gives us that:

$$MIE = \lambda\left(-\frac{\eta_{XN}}{\varepsilon_X}\right)\frac{p}{\varepsilon_L} \qquad MRE = \lambda\left(\frac{p}{\varepsilon_X} + \tau\right)$$

where

$$\eta_{XN} = \overbrace{\frac{\partial X}{\partial w}\frac{(1-m)w}{X}}^{\text{cross-price elasticity}} \qquad \varepsilon_L = \overbrace{-\frac{\partial N}{\partial w}\frac{(1-m)w}{L}}^{\text{labor supply elasticity}} = \frac{\partial L}{\partial w}\frac{(1-m)w}{L}$$

Double dividend

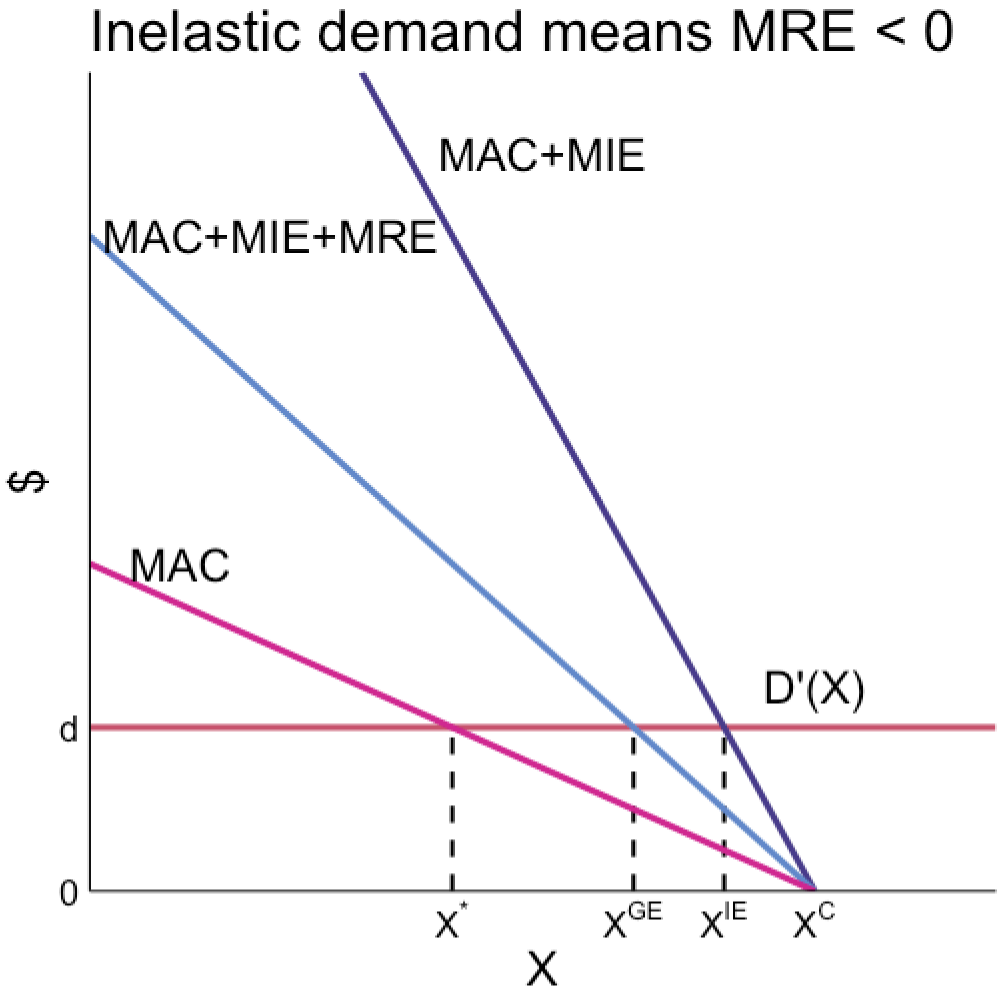
Suppose N and X are *average substitutes* which means the negative cross-price elasticity is equal to the the labor supply elasticity $\eta_{XN} = \varepsilon_L$

This is true if a 1% wage increase gives a $\eta_{XN}\% = \varepsilon_L\%$ spending increase

$$MIE = \lambda \left(-\frac{p}{\varepsilon_X} \right) < \lambda \left(\frac{p}{\varepsilon_X} + \tau \right) = MRE$$

$\Rightarrow$ we shouldn't expect a strong double dividend because MIE + MRE = $\lambda\tau > 0$

Revenue raising environmental policy



Even though there isn't a double dividend, MIE and MRE **still matter** for the optimal second-best pollution level

Optimal pollution X^{GE} is larger than first-best X^*, but less than the level without revenue recycling X^{IE}

Policy instruments with labor market distortions

How do environmental policy instruments work when we have the distortionary labor tax?

Taxes and auctioned permits are easy, just set the tax equal to:

$$\tau = D'(X) + MIE + MRE$$

or the number of permits equal to X^{GE} to obtain the optimal second-best outcome

The regulator obtains revenues $\tau X^{GE} = \sigma x^{GE}$ and recycles it to reduce labor taxation

What about freely allocated permits or command and control?

Policy instruments with labor market distortions

This would lead to the same *environmental* outcome, but not achieve the the welfare maximizing outcome

Why?

Free allocation and command and control do not generate revenues that let us reduce labor taxation

Setting $X^{GE} < X^c$ raises the price of X, increases leisure, and reduces revenues via the interaction effect

Without revenue from permits or taxes, the optimal pollution level is higher