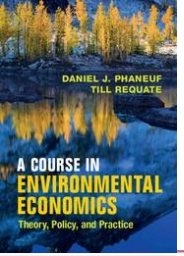


Environmental Economics

Lecture 6

(based on Chapter 7 in textbook)

Environmental Policy with Pre-existing Distortions



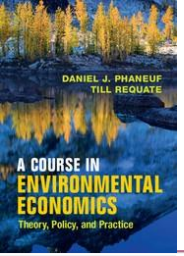
Intro

- We consider now how environmental policy might spill over into other markets.

- Government revenue is often raised via **labor taxes**, thereby encouraging the overconsumption of leisure, causing potentially substantial welfare loss.

1. **Emission taxes** can be used to fix the **pollution externality**.
2. Since **revenue** is also **raised** in the process, a **tax swap** is possible.

- Our objective to examine how **interactions with pre-existing distortions** might cause us to alter the performance ranking of policy instruments.

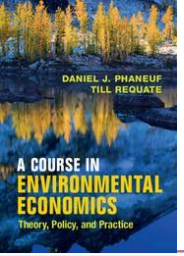


7.1 Extending the Model

- Consumer utility depends on:
  - Consumption of polluting good.
  - Damages suffered from emissions.
  - Leisure time.

- One representative consumer and one representative firm.
- Treat individual and aggregate outcomes as the same.

- $U(X, Z, N, E) = u(X, N) + Z - D(E)$.
- X: consumption of the polluting good.
- N: denotes the hours of leisure time.
- E: aggregate emissions.
- $D(E)$: damage function.



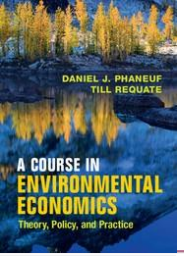
7.1 Extending the Model

- We assume $u(X, N)$ is **strictly concave**
- $u_{xx} < 0$
- $u_{NN} < 0$
- $u_{XX} \times u_{NN} - (u_{XN})^2 > 0$
- We make no restrictions on the cross effect $u_{xN} = u_{Nx}$.

- Person is endowed with time T.
- Wages are earned to purchase X and Z.

- Demand for labor is **perfectly elastic** economy wide.

- Disposable income of household: $w(T - N)$.



7.1 Extending the Model

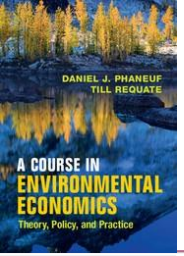
- **Consumer's problem** when there is **no distortion** in the labor market:

$$\max_{X,N} U = u(X,N) + Z - D(E) \qquad s.t. \qquad w(T-N) = Z + pX \tag{7.1}$$
$$= u(X,N) + w(T-N) - pX - D(E).$$

- F.O.C.: $u_x(X,N) = p$ and $u_N(X,N) = w$

- To obtain a comparative static relationship between N and p we differentiate the two F.O.C.s with respect to p:

$$u_{XX}(X,N)\frac{\partial X}{\partial p} + u_{XN}(X,N)\frac{\partial N}{\partial p} = 1 \tag{7.2}$$
$$u_{NN}(X,N)\frac{\partial N}{\partial p} + u_{NX}(X,N)\frac{\partial X}{\partial p} = 0$$

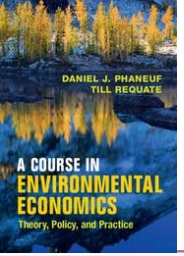


7.1 Extending the Model

- Solving this equation system linear in $\frac{\partial X}{\partial p}$ and $\frac{\partial N}{\partial p}$ gives us the comparative statics expressions:

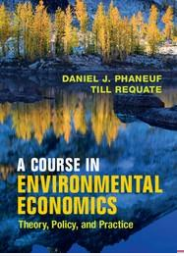
$$\frac{\partial N}{\partial p} = \frac{-u_{XN}}{(u_{XX}u_{NN} - u_{XN}^2)} \begin{matrix} < \\ = \\ > \end{matrix} 0 \qquad (7.3)$$

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



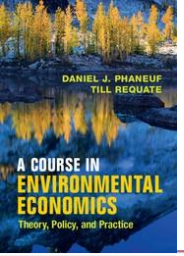
7.1 Extending the Model

- Denominator is for both expressions positive by the concavity of the utility function.
- $\frac{\partial X}{\partial p}$ is negative by the properties of the utility function.
- Sign of the numerator for $\frac{\partial N}{\partial p}$ depends on the complement or substitute relationship between X and N, and so is indeterminate in general.
- If leisure and the dirty good are substitutes, the demand for leisure increases when the price of the dirty good goes up.

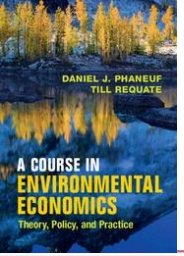


7.1 Extending the Model

- Firm's problem is unchanged from previous chapters.
- *Case 2*: $E = \delta X$ and $\delta = 1$.
- We assume the representative price-taking firm produces X and discharges emissions E.
- Firm´s problem is to maximize profits: $\prod = pX - C(X)$.
- Cost function $C(X)$ in general has the properties:
- $C'(X) > 0$
- $C''(X) \geq 0$
- Absent any regulation of emissions, the firm produces at the point where price equals marginal cost.



Optimum with No Labor Market Distortion



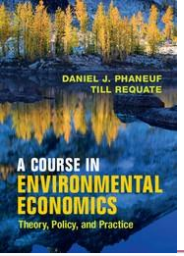
7.1.1 Optimum with No Labor Market Distortion

- The regulator´s problem is to choose the level of X and therefore emissions $E = X$ to maximize the economic surplus from the dirty good.

$$\begin{aligned}\max_x W &= u(X,N) + Z - D(X) + pX - C(X) \\ &= u(X,N) + \underbrace{w(T-N) - pX}_{Z} - D(X) + pX - C(X) \\ &= u(X,N) + w(T-N) - D(X) - C(X)\end{aligned} \tag{7.4}$$

- Budget constraint of the consumer: $Z = w(T - N) - pX$.

- F.O.C.: $u_N(X^*, N) = w$



7.1.1 Optimum with No Labor Market Distortion

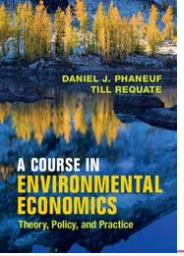
- Differentiate W with respect to X:

$$u_X(X,N) - D'(X) - C'(X) + \left[u_N(X,N) - w\right]\frac{\partial N}{\partial X} = 0 \qquad (7.5)$$

- Since the consumer´s optimal choice of N results in $u_N - w = 0$, the condition reduces to:

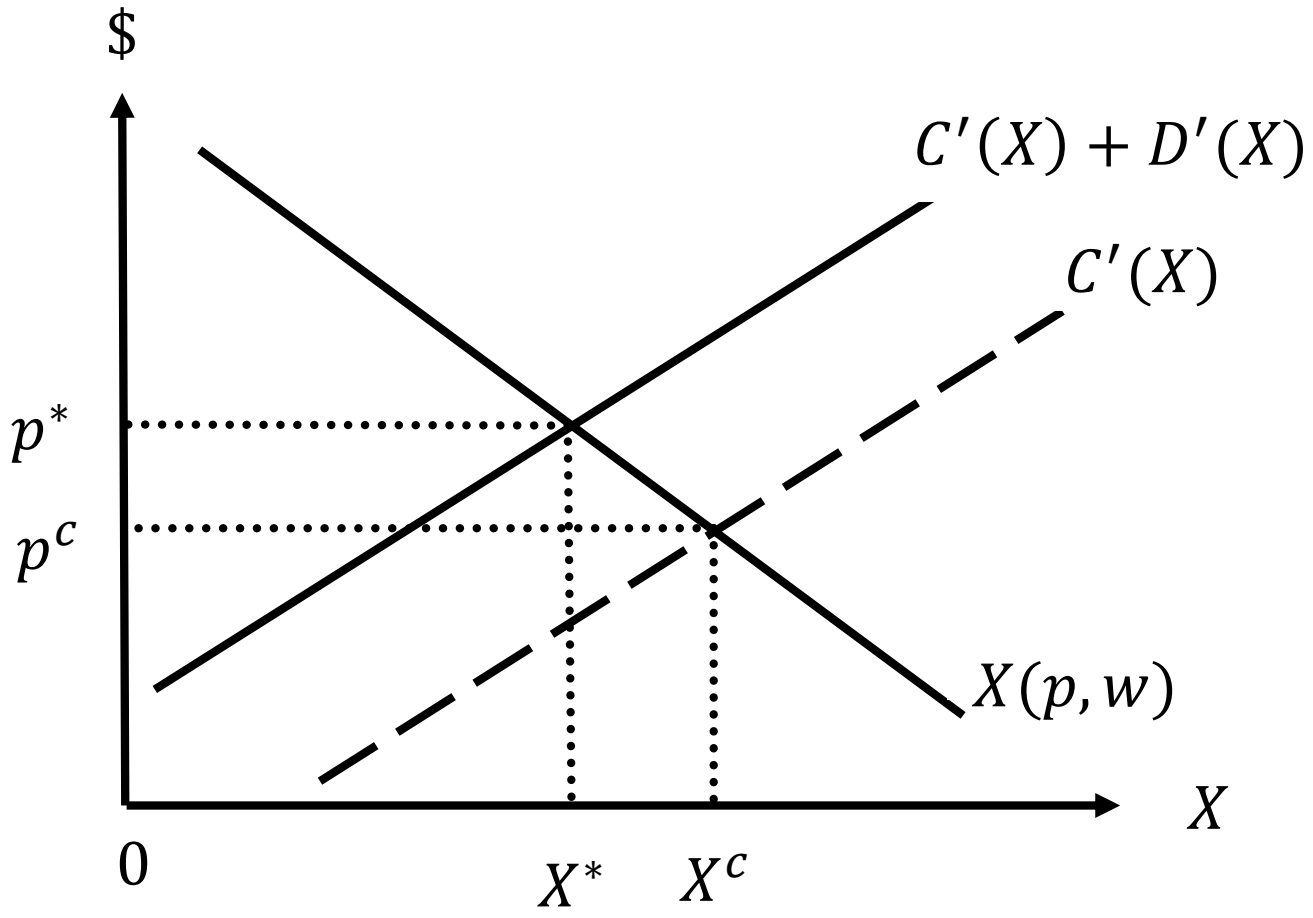
$$u_x(X,N) - C'(X) = D'(X) \qquad (7.6)$$

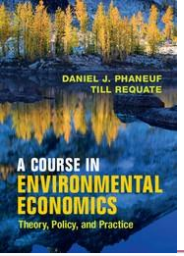
- Marginal cost equals marginal damage.



7.1.1 Optimum with No Labor Market Distortion

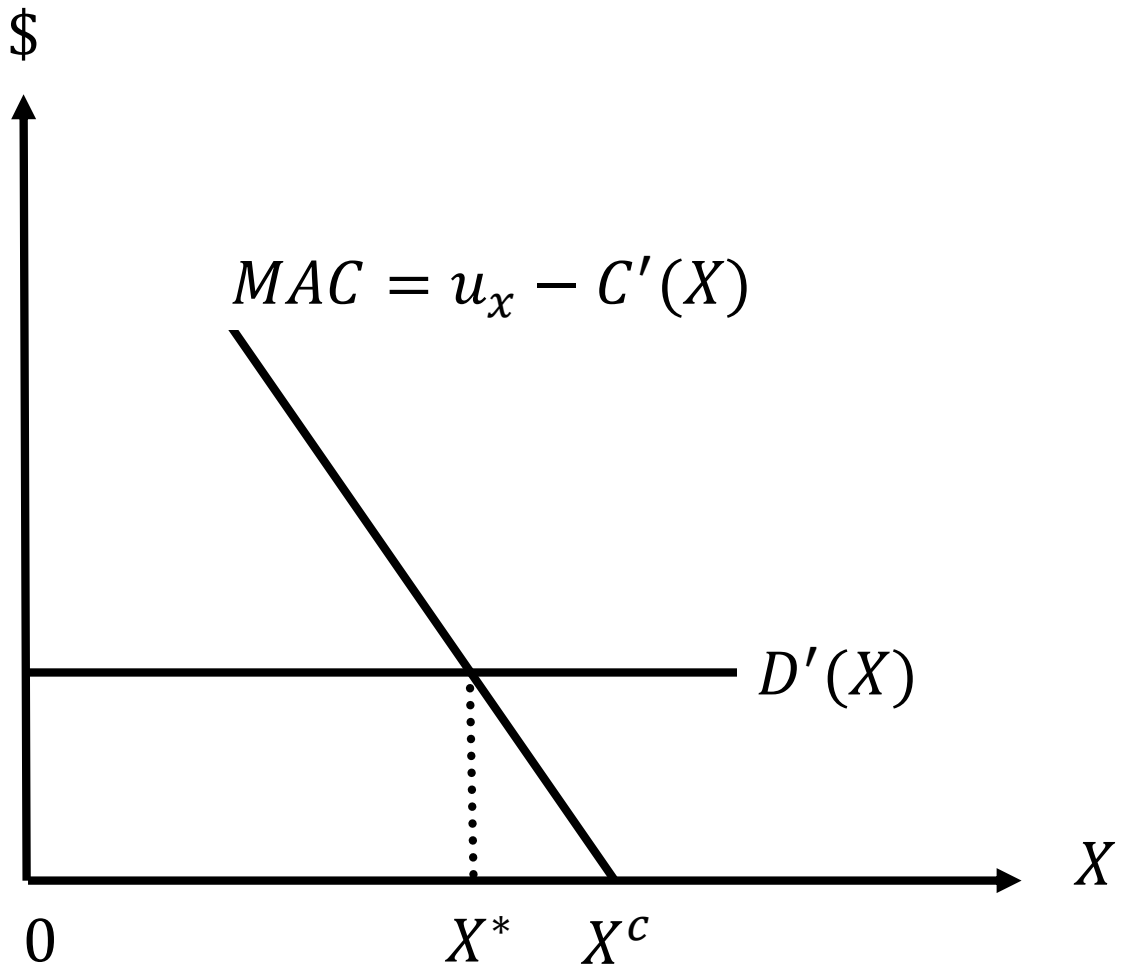
Figure 7.1 Panel A: Interaction between environmental policy and labor/ leisure

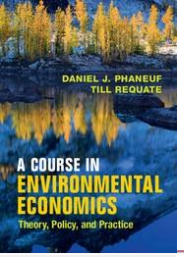




7.1.1 Optimum with No Labor Market Distortion

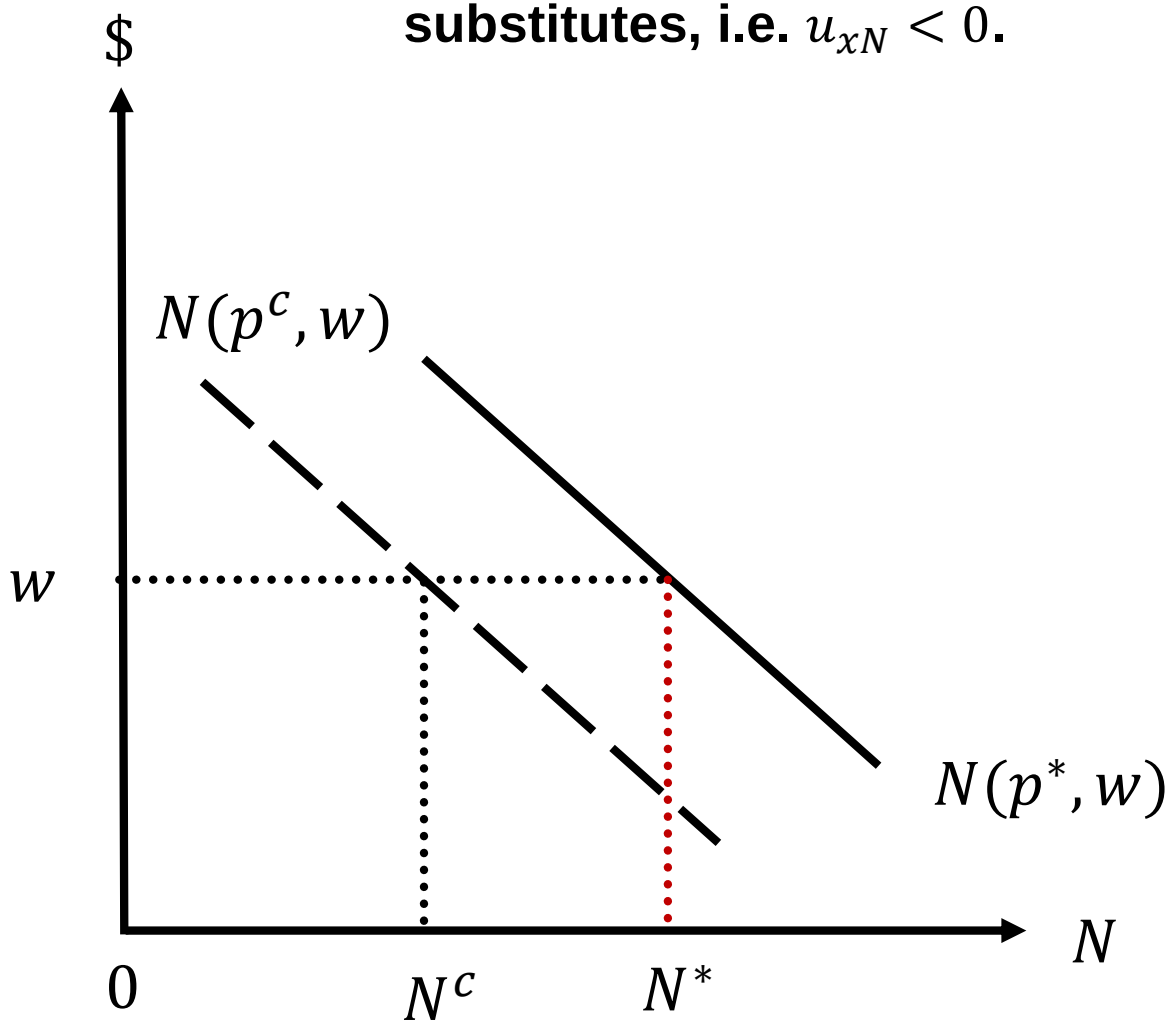
Figure 7.1 Panel B: Interaction between environmental policy and labor/ leisure

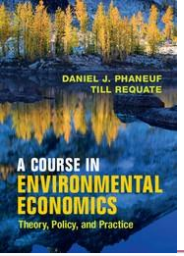




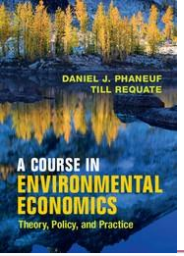
7.1.1 Optimum with No Labor Market Distortion

Figure 7.1 Panel C: Interaction between environmental policy and labor/ leisure, case of substitutes, i.e. $u_{xN} < 0$.





A Labor Market Distortion



7.1.2 A Labor Market Distortion

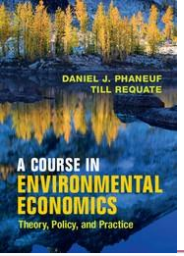
- Government needs to finance a fixed budget G.
- **Proportional tax on labor** income given by m.
- Household income given by $(1-m)w$.
- Consumer´s utility maximization problem:

$$\max_{X,Z,N} U = u(X,N) + Z - D(E) \qquad s.t. \qquad (1-m)w(T-N) = Z + px \qquad (7.7)$$

- F.O.C.s:

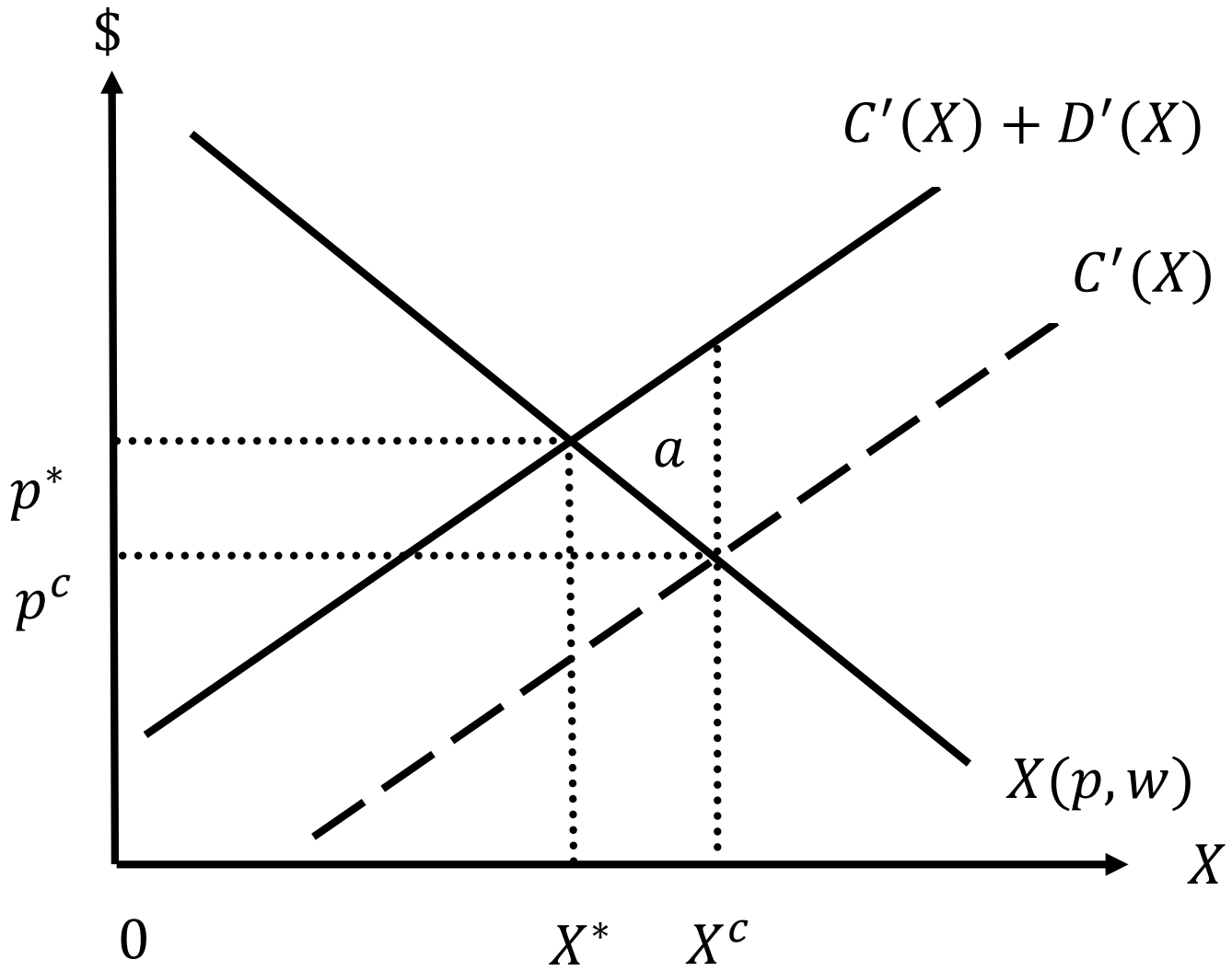
$$(i) \qquad u_X(X,N) = p \qquad (7.8)$$

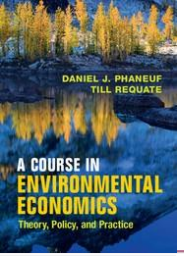
$$(ii) \qquad u_N(X,N) = (1-m)w$$



7.1.2 A Labor Market Distortion

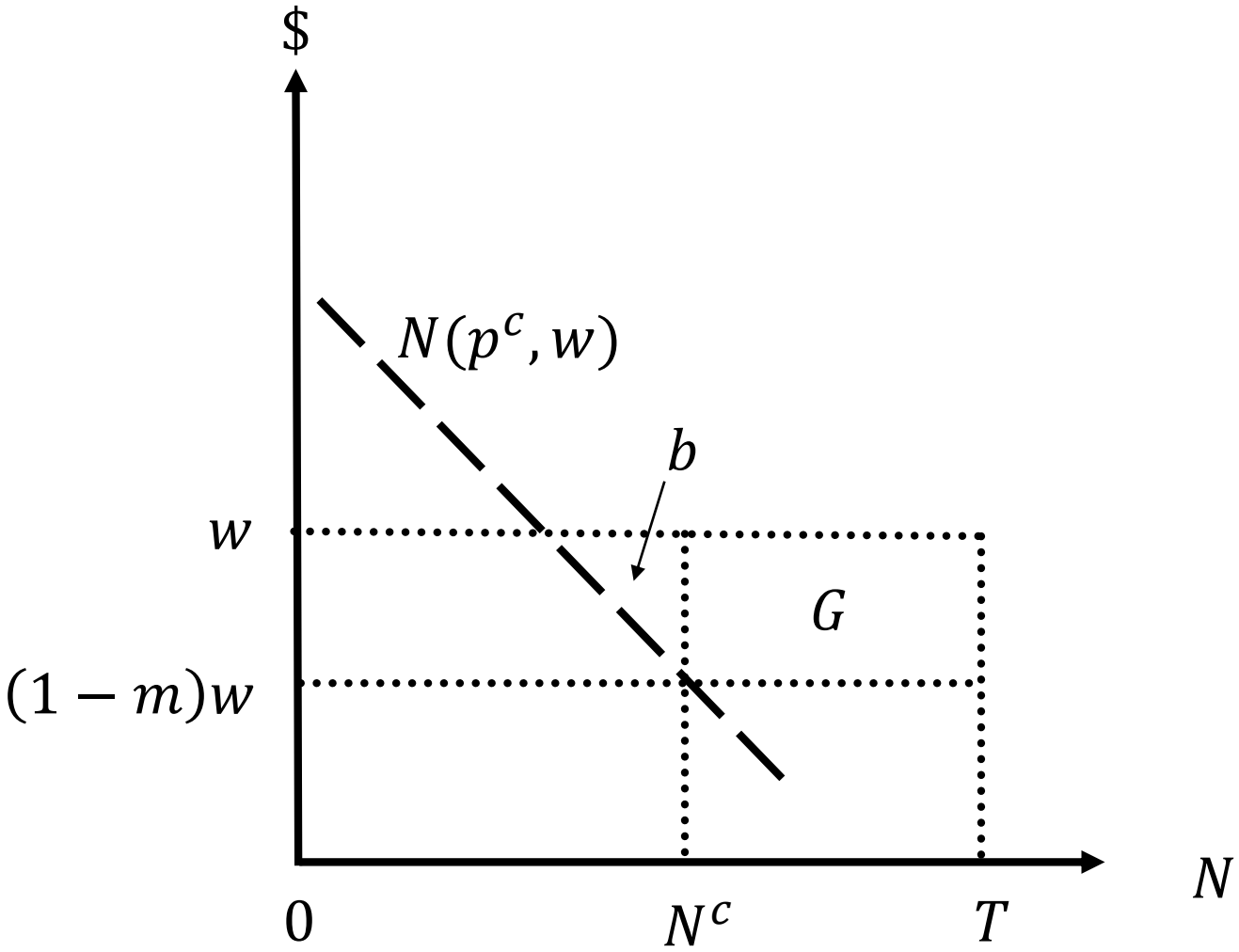
Figure 7.2 Panel A: Tax interaction and revenue effects

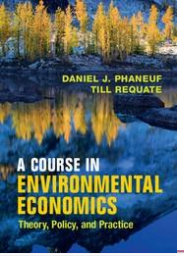




7.1.2 A Labor Market Distortion

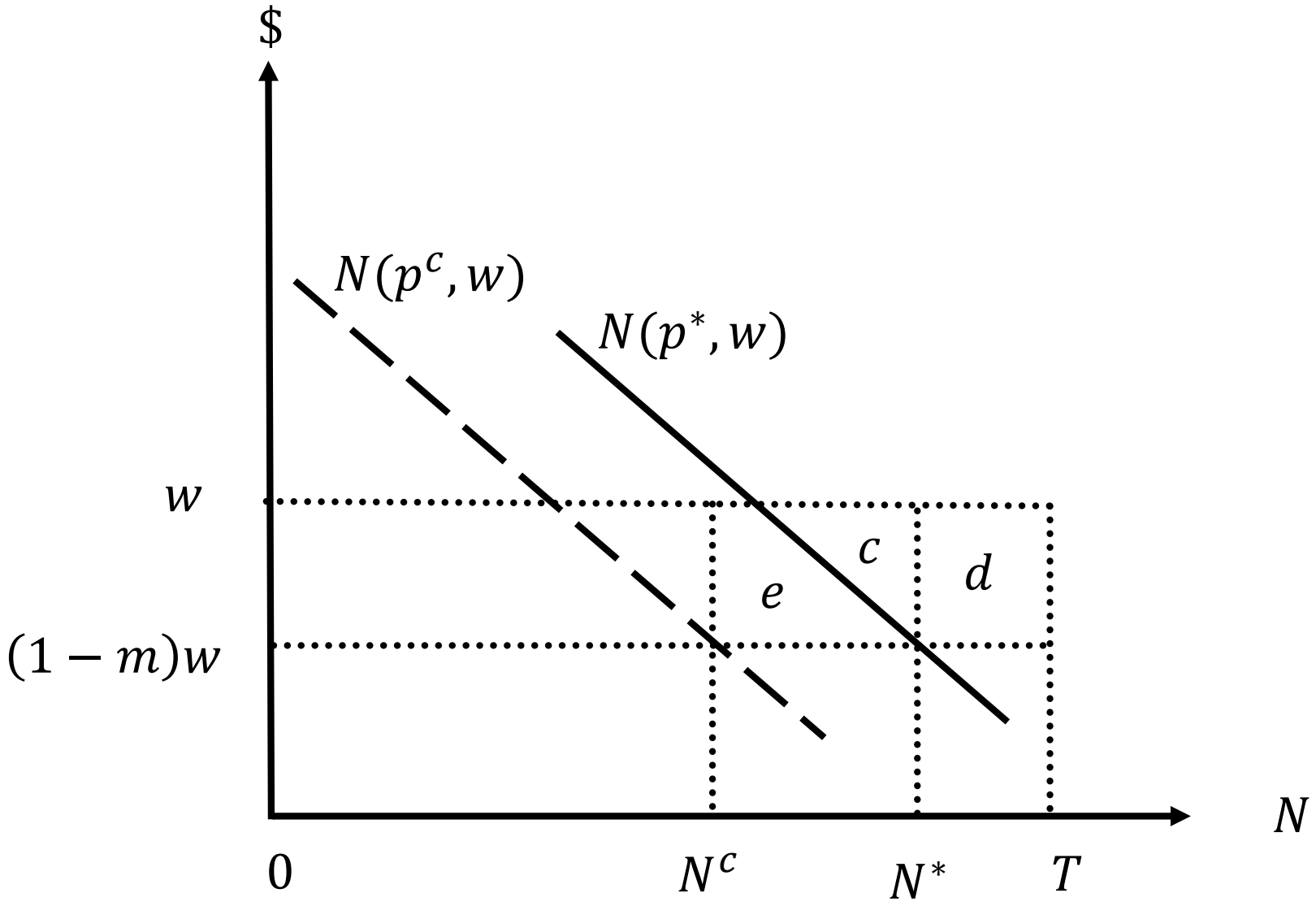
Figure 7.2 Panel B: Tax interaction and revenue effects

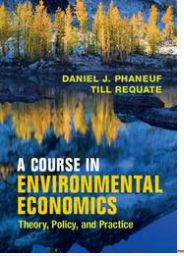




7.1.2 A Labor Market Distortion

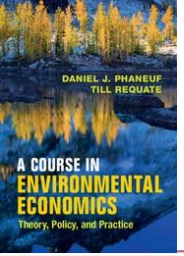
Figure 7.2 Panel C: Tax interaction and revenue effects



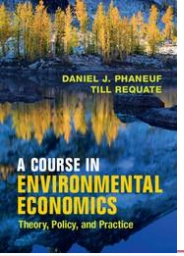


7.1.2 A Labor Market Distortion

- Panel A: “a“ = welfare loss through the externality.
- Panel B: “b“ = welfare loss though labor market distortion along the leisure demand curve.
- Panel C: “c“= welfare loss though labor market distortion by the shift of the leisure demand curve.
- Note that c>b or b<c (or b=c) are possible.
- Note also that goverment revenue shrinks : d<G.

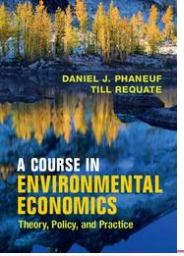


Second-Best Optimal Pollution Levels



7.2 Second-Best Optimal Pollution Levels

- Assume the government needs to finance a fixed budget of G and wants to control emissions.
- **First** we consider the case when **only labor taxation is available**.
- Emissions are controlled by a non-revenue raising standard in this case.
- **Subsequently**, we examine the more general case where the **government can tax emissions along with labor income** in order to raise revenue.

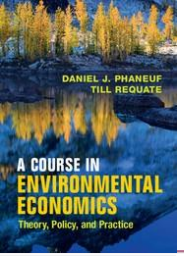


7.2.1 Non-revenue Raising Environmental Policy

- Representative firm sells the fixed quantity $\bar{X}$ at price p to earn profits: $\prod = p\bar{X} - C(\bar{X})$.
- Why $\bar{X}$ fixed? Because $E=\bar{X}$, and goverment wants to control $E=\bar{X}$.
- Consumer´s inverse demand function: $P(\bar{X}) = u_x(\bar{X}, N)$.
- Thus p and N are endogenous outcomes that are determined by the household´s response to the regulator´s choices for the dirty good.

$$u_X\left(\bar{X},N\right) = p$$

$$u_N\left(\bar{X},N\right) = \left(1-m\right)w \qquad (7.9)$$



7.2.1 Non-revenue Raising Environmental Policy

- For later reference we note that differentiating the conditions in (7.9) with respect to $\bar{X}$ leads to:

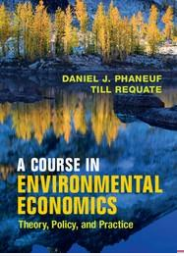
$$u_{XX}\left(\bar{X},N\right)+u_{XN}\left(\bar{X},N\right)\frac{\partial N}{\partial \bar{X}}=\frac{\partial p}{\partial \bar{X}} \tag{7.10}$$

$$u_{NX}\left(\bar{X},N\right)+u_{NN}\left(\bar{X},N\right)\frac{\partial N}{\partial \bar{X}}=0$$

- Which we can solve to obtain the comparative statics:

$$\frac{\partial N}{\partial \bar{X}}=-\frac{u_{XN}\left(\bar{X},N\right)}{u_{NN}\left(\bar{X},N\right)}\begin{matrix}\leq\\>\end{matrix}0 \tag{7.11}$$

$$\frac{\partial p}{\partial \bar{X}}=\frac{u_{XX}\left(\bar{X},N\right)u_{NN}\left(\bar{X},N\right)-\left[u_{XN}\left(\bar{X},N\right)\right]^{2}}{u_{NN}\left(\bar{X},N\right)}<0$$



7.2.1 Non-revenue Raising Environmental Policy

- Consumer's optimal response to the regulator´s choice of the polluting good:

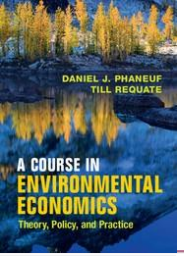
$$\frac{\partial N}{\partial \bar{X}} = \frac{\partial N}{\partial p}\frac{\partial p}{\partial \bar{X}} \tag{7.12}$$

- The regulator´s problem is to maximize the sum of utility and profit, subject to the government's revenue constraint:

$$\max_{X,m}\left\{u(X,N)+Z-D(X)+pX-C(X)\right\} \quad s.t. \quad wm(T-N)=G \tag{7.13}$$

- We assume that government revenues are returned back to costumers:

$$Z=(1-m)w(T-N)-pX+G \tag{7.14}$$



7.2.1 Non-revenue Raising Environmental Policy

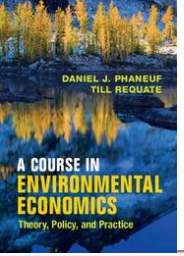
- Substituting out for Z using (7.14), we can reduce the regulator´s problem to

$$\max_{X,m} W = u(X,N) + w(T-N) - D(X) - C(X) + \lambda\left(wm(T-N) - G\right) \qquad (7.15)$$

- Where λ is the Lagrange multiplier
- Interpretation of λ: marginal welfare cost of public funds:

$$-\lambda = \frac{\partial W}{\partial G} \leq 0.$$

- λ measures the welfare consequences of each additional dollar of government revenue collected via taxing labor, where welfare falls when G increases due to the distortionary effect of the tax.



7.2.1 Non-revenue Raising Environmental Policy

- Consider the regulator's FOC for m:

$$\left(u_N(\bullet)-w\right)\frac{\partial N}{\partial m}+\lambda\left(w(T-N)-wm\frac{\partial N}{\partial m}\right)=0 \qquad (7.16)$$

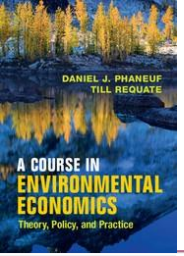
- From the consumer´s optimal choice of N we know that:

$$-mw = u_N(\cdot) - w$$

- We can derive an expression for λ as:

$$\lambda=\frac{w\frac{\partial N}{\partial m}m}{w(T-N)-w\frac{\partial N}{\partial m}m} \qquad (7.17)$$

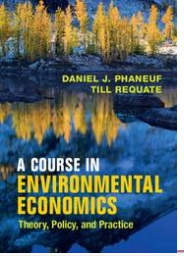
- This form of the first-order condition illustrates the interpretation of λ as the marginal welfare cost of public funds.



7.2.1 Non-revenue Raising Environmental Policy

- Demand for leisure: $N(X, (1-m)\cdot w)$.
- $L = T - N$ is labor supply.
- $-\partial N/\partial w = w(-\partial N/\partial w)$.
- Define the labor supply elasticity as:

$$\varepsilon_L = -\frac{\partial N}{\partial w}\frac{(1-m)w}{L} \qquad (7.18)$$



7.2.1 Non-revenue Raising Environmental Policy

- Substituting this into (7.17):

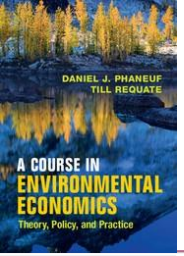
$$\lambda = \frac{\varepsilon_L m/(1-m)}{1-\varepsilon_L m/(1-m)} \tag{7.19}$$

- The regulator's F.O.C. for X is:

$$u_X(\bullet) - D'(X) - C'(X) + \left[\underbrace{u_N - w}_{-mw} - \lambda wm\right]\frac{\partial N}{\partial X} = 0 \tag{7.20}$$

- Through substituting and rearranging we obtain:

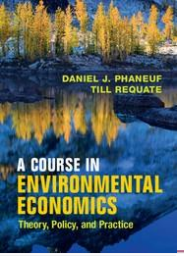
$$\underbrace{u_X(X,N) - C'(X)}_{MAC} + \underbrace{(1+\lambda)\left\{-\frac{\partial N}{\partial p}\bullet\frac{\partial p}{\partial X}\right\}wm}_{MIE} = D'(X) \tag{7.21}$$



7.2.1 Non-revenue Raising Environmental Policy

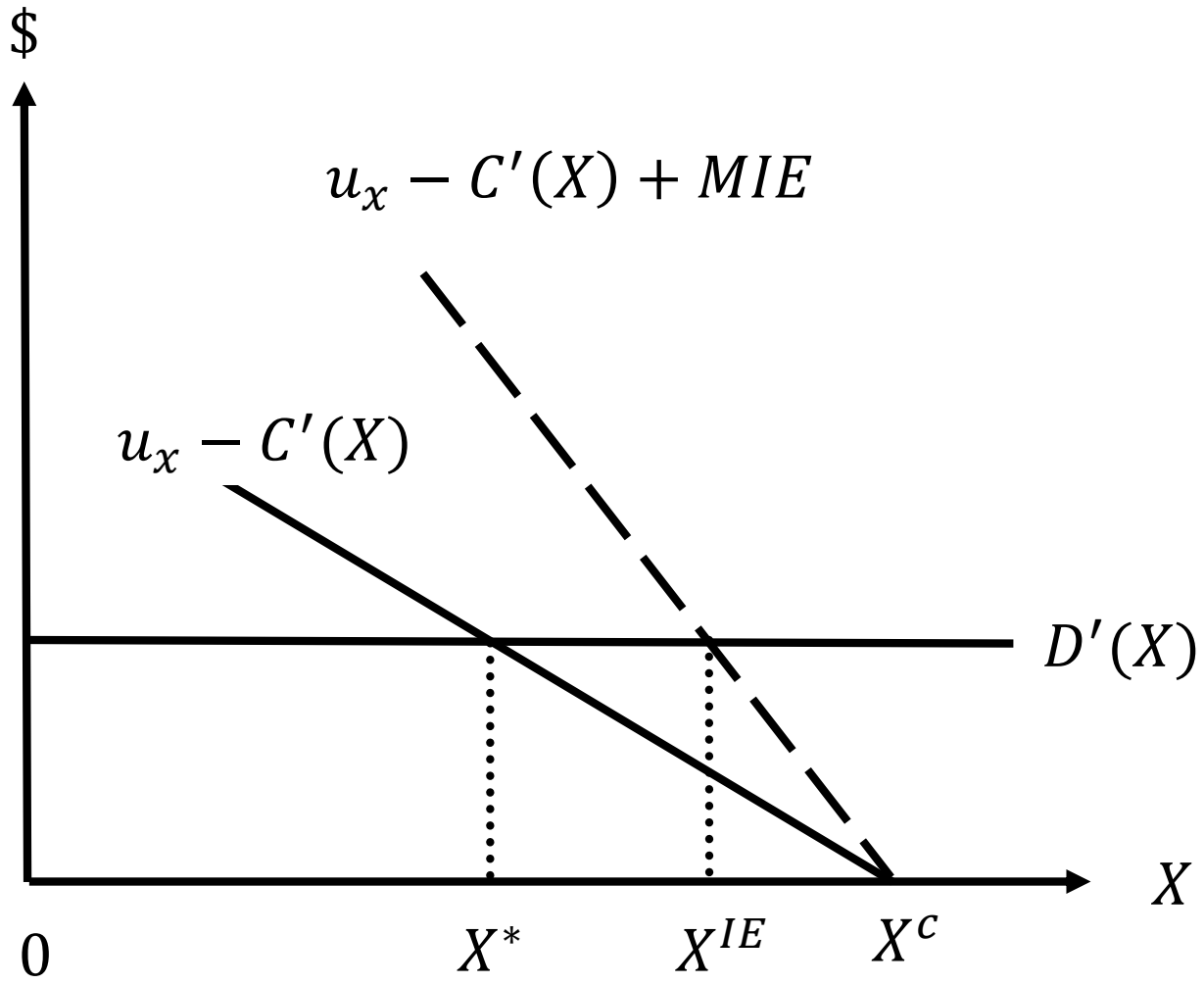
- Marginal interaction effect (MIE) arises because leisure demand responds to the policy-induced price change for X.
- We can express MIE more formally by noting that: $\frac{\partial p}{\partial X} = \frac{1}{(\partial X/\partial p)}$.
- Through substituting we gain:

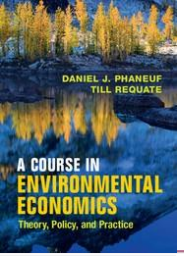
$$u_X(\bullet) - C'(X) + \underbrace{(1+\lambda)\left\{-\frac{\partial N(\bullet)}{\partial p} \Big/ \frac{\partial X(\bullet)}{\partial p}\right\} wm}_{MIE} = D'(X) \qquad (7.22)$$



7.2.1 Non-revenue Raising Environmental Policy

Figure 7.3 Optimal environmental policy with an interaction effect



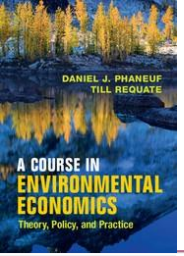


Proposition 7.1

Suppose there is a government revenue constraint, and that public funds can only be raised by taxing labor.
In this second best world, when the government needs to raise revenue via labor taxes, and cannot raise revenue via emission taxes, the optimal level of pollution is no longer characterized by the marginal abatement cost equals marginal damage condition. Instead, the interaction between the polluting good and the labor market causes social costs to diverge from the first best case, so that:

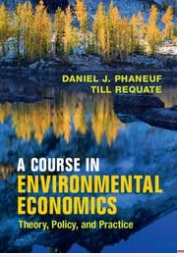
a) The marginal social cost of reducing X is higher than in the first- best case when X and N are substitutes, and lower when X and N are complements.

b) The optimal level of pollution is larger than in the first best case when X and N are substitutes, and smaller when X and N are complements.



Proposition 7.1

c) The absolute value of the difference between the first- and second-best pollution levels is larger when labor supply is more elastic, the demand for X is less price responsive, or the strength of the complement/substitute relationship between X and N is stronger.



7.2.1 Non-revenue Raising Environmental Policy

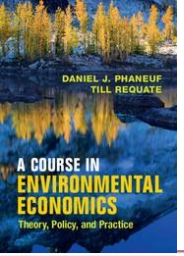
- Express MIE in form of elasticity to understand Prop 7.1(c):

$$MIE = (1+\lambda)\left(-\frac{\eta_{XN}}{\varepsilon_X}\right)p\frac{m}{(1-m)} \tag{7.23}$$

- Slutsky symmetry condition: $\dfrac{\partial N(\bullet)}{\partial p} = \dfrac{\partial X(\bullet)}{\partial w}$

$$\eta_{XN} = \frac{\partial X(\bullet)}{\partial w}\frac{(1-m)w}{X} \tag{7.24}$$

$$\varepsilon_X = \frac{\partial X(\bullet)}{\partial p}\frac{p}{X}$$



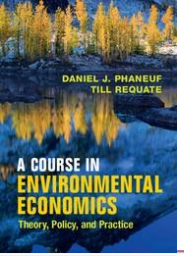
7.2.1 Non-revenue Raising Environmental Policy

- It is useful to reduce the expression for MIE:

$$\frac{m}{(1-m)} = \frac{\lambda}{(1+\lambda)\varepsilon_L} \tag{7.25}$$

- Substituting this expression into (7.23) provides a formula for MIE that depends directly on own, cross price, and labor supply elasticities:

$$MIE = \lambda\left(-\frac{\eta_{XN}}{\varepsilon_X}\right)\frac{p}{\varepsilon_L} \tag{7.26}$$



7.2.2 Revenue Raising Environmental Policy

- Revenue requirement can be met using two taxes:

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

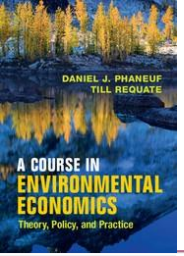
- Firms profit are given by: $\prod = pX - C(X) - \tau X$.

- Household spending on the numeraire good is given by:

$$\begin{aligned} Z &= (1-m)w(T-N) - pX + G \\ &= w(T-N) - pX + \tau X \end{aligned} \qquad (7.27)$$

- Household and firm behavioral equations:

$$\begin{aligned} u_X(X,N) &= p \\ u_N(X,N) &= (1-m)w \\ C'(X) &= p - \tau \end{aligned} \qquad (7.28)$$



7.2.2 Revenue Raising Environmental Policy

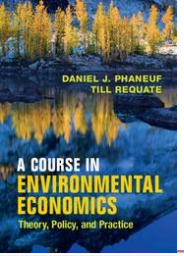
- Comparative Staitics:

- For later reference it is useful to differentiate the conditions (7.28) with respect to τ to obtain:

$$u_{XX}(X,N)\frac{\partial X}{\partial \tau}+u_{XN}(X,N)\frac{\partial N}{\partial \tau}=\frac{\partial p}{\partial \tau} \qquad (7.29)$$

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

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



7.2.2 Revenue Raising Environmental Policy

- Which we can solve to obtain the comparative statics:

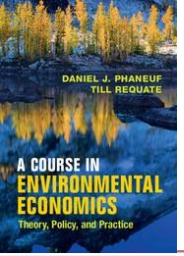
$$\frac{\partial X}{\partial \tau} = \frac{u_{NN}}{H} < 0$$

$$\frac{\partial N}{\partial \tau} = \frac{-u_{XN}}{H} \lessgtr 0 \qquad (7.30)$$

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

- Determinant of the Hessian matrix:

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



7.2.2 Revenue Raising Environmental Policy

- The regulator´s formal problem is to maximize the sum of utility and profits according to:

$$\max_{m,\tau}\{U(X,N)+Z-D(X)+pX-C(X)-\tau X\}$$

$$s.t. \qquad wm(T-N)+\tau X=G \qquad (7.31)$$

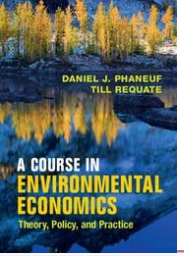
- We can simplify the regulator´s problems by substituting out for Z using (7.27)

$$Z=(1-m)w(T-N)-pX+G \qquad (7.27)$$
$$=w(T-N)-pX+\tau X$$

so that

$$\max_{m,\tau}\{U(X,N)+w(T-N)-D(X)-C(X)\}$$

$$s.t. \qquad wm(T-N)+\tau X=G \qquad (7.32)$$



7.2.2 Revenue Raising Environmental Policy

- Differentiating with respect to the emission tax rate τ:

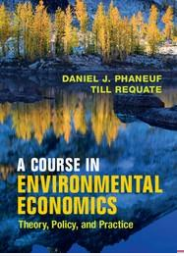
$$\left[u_X(\bullet)-C'(X)-D'(X)\right]\frac{\partial X}{\partial \tau}+\lambda\left[X+\tau\frac{\partial X}{\partial \tau}\right]+\left[\underbrace{u_N(\bullet)-w}_{-wm}-\lambda wm\right]\frac{\partial N}{\partial \tau}=0 \qquad (7.33)$$

- Dividing through $\partial X/\partial \tau$:

$$\underbrace{u_X(\bullet)-C'(X)}_{MAC}+\underbrace{(1+\lambda)wm\left[-\frac{\partial N}{\partial \tau}\Big/\frac{\partial X}{\partial \tau}\right]}_{MIE}+\underbrace{\lambda\left[\tau+X\Big/\frac{\partial X}{\partial \tau}\right]}_{MRE}=D'(X) \qquad (7.34)$$

- The interaction effects in the revenue and non-revenue raising contexts have a similar structure:

$$\frac{\partial N}{\partial \tau}\Big/\frac{\partial X}{\partial \tau}=\frac{\partial N}{\partial p}\Big/\frac{\partial X}{\partial p} \qquad (7.35)$$



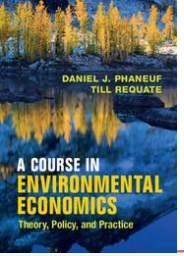
7.2.2 Revenue Raising Environmental Policy

- The total revenue collected from taxing X can increase or decrease with a change in the tax rate.

- *Marginal revenue effect:* change in the social cost of a unit of X.

$$MRE = \lambda\left(X \Big/ \frac{\partial X}{\partial p} + \tau \right) = \lambda\left(\frac{p}{\varepsilon_X} + \tau \right) \qquad (7.36)$$

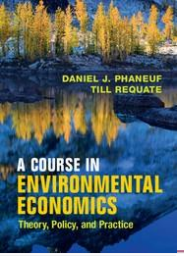
- MRE will be negative when the emission tax is relatively small to the price of the dirty good, and/ or when demand for the dirty good is inelastic.



7.2.2 Revenue Raising Environmental Policy

- To study the revenue effect in isolation from the interaction effect:
- Assumption: $\partial N(\cdot)/\partial p = 0$ so that $MIE = 0$.
- $C'(X) = c$.
- In this special case (7.34) reduces to:

$$\underbrace{u_X(\bullet) - C'(X)}_{MAC} + \underbrace{\lambda\left(\frac{p}{\varepsilon_X} + \tau\right)}_{MRE} = D'(X) \qquad (7.37)$$



7.2.2 Revenue Raising Environmental Policy

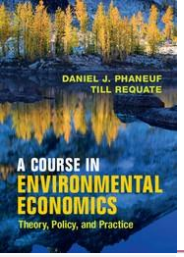
- Insight on the role of the revenue effect can be obtained by substituting $\tau = u_x - C'(X)$ from the consumer and producer problems in (7.28) into the expression

$$\underbrace{u_X(\bullet) - C'(X)}_{MAC} + \underbrace{\lambda\left(\frac{p}{\varepsilon_X} + \tau\right)}_{MRE} = D'(X), \qquad (7.37)$$

and solving for the optimal tax rate:

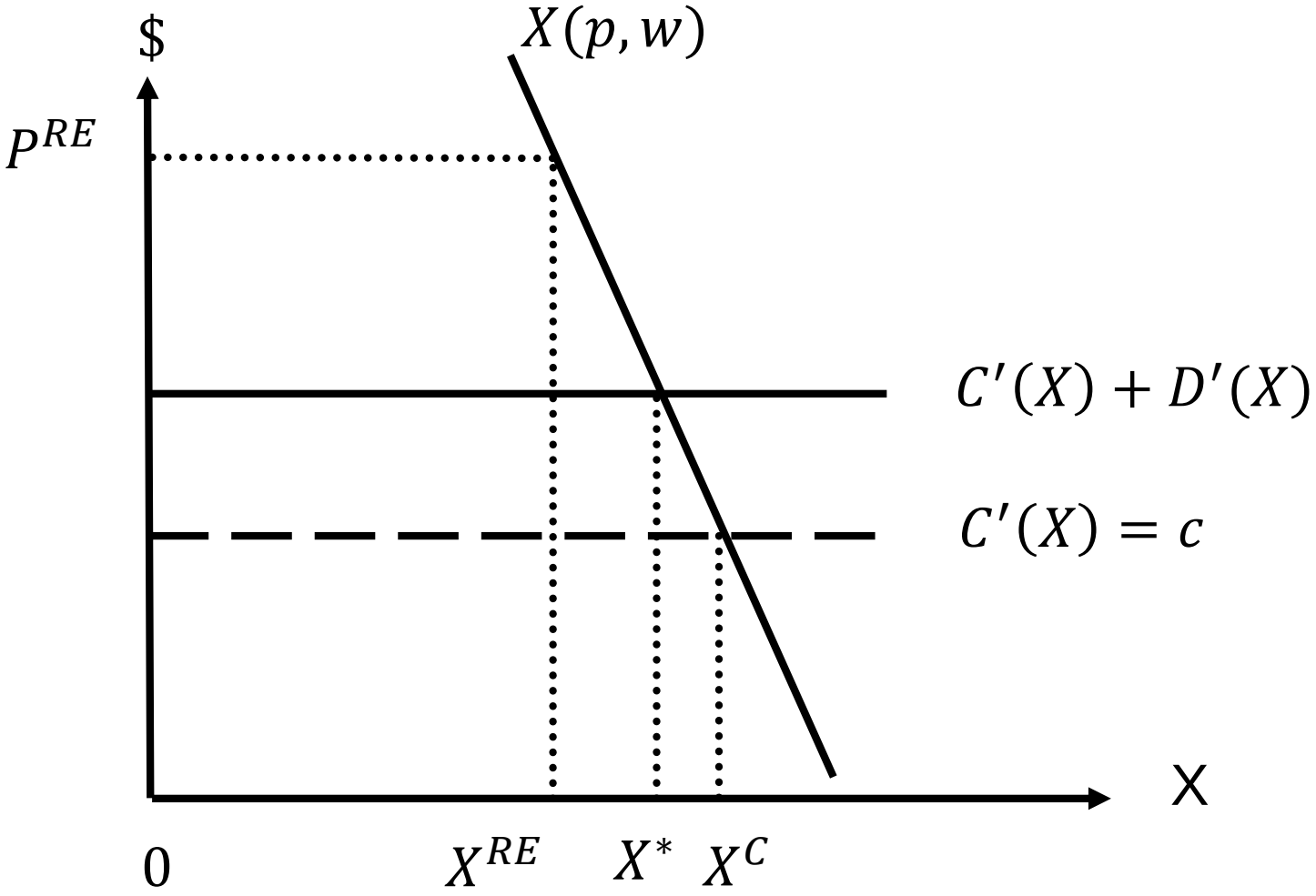
$$\tau^{RE} = \frac{D'(X)}{(1+\lambda)} - \frac{\lambda}{(1+\lambda)}\frac{p}{\varepsilon_X}. \qquad (7.38)$$

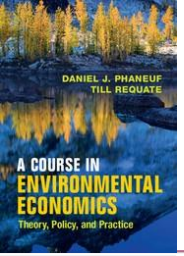
- τ^{RE} can be higher or lower than its partial equilibrium counterpart, depending on the size of the marginal cost of public funds and the elasticity of demand for the dirty good.



7.2.2 Revenue Raising Environmental Policy

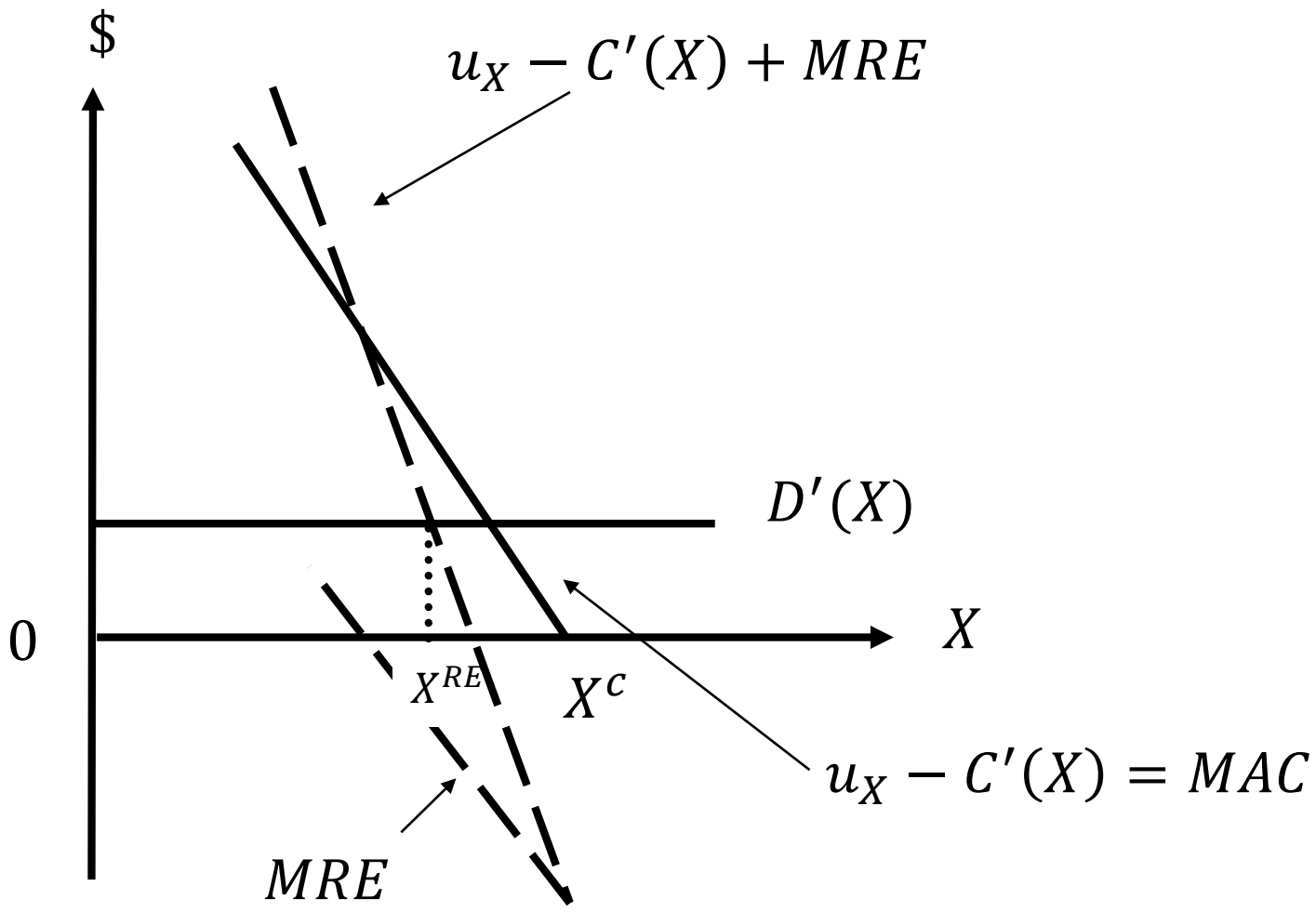
Figure 7.4 Optimal environmental policy with a revenue effect

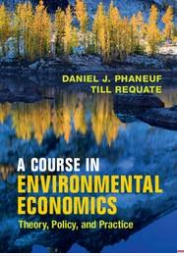




7.2.2 Revenue Raising Environmental Policy

Figure 7.4 Optimal environmental policy with a revenue effect

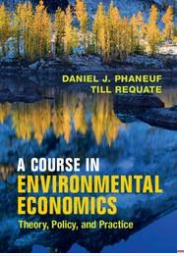




Proposition 7.2

Suppose there is a government revenue constraint, and that public funds can be raised by taxing labor and emissions. Suppose as well that there is no interaction effect. The optimal level of pollution in this case differs from the partial equilibrium case via a revenue effect labeled MRE, which measures the welfare effect of the increase or decrease in tax revenue that accompanies a change in the emission tax rate. The MRE:

a) *is smaller (less positive or more negative) when the demand for X is inelastic;*
b) *is smaller when the tax rate is small relative to the price of X;*
c) *lowers the social cost of abatement when MRE<0, implying the optimal quantity of the dirty good is smaller than the partial equilibrium optimum;*
d) *raises the social cost of abatement when MRE>0, implying the optimal quantity of the dirty good is larger than the partial equilibrium optimum.*



7.2.2 Revenue Raising Environmental Policy

- F.O.C. with respect to m for the regulator´s problem in (7.32):

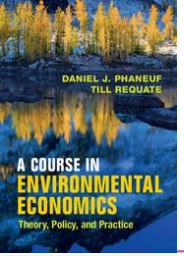
$$\left(u_N - w\right)\frac{\partial N}{\partial m} + \lambda\left(w\left(T - N\right) - wm\frac{\partial N}{\partial m}\right) + \left(u_X - D'\left(X\right) - C'\left(X\right) + \lambda\tau\right)\frac{\partial X}{\partial m} = 0 \qquad (7.39)$$

- Using again the consumer´s optimality condition $-mw = u_N - w$ we can rewrite the condition as

$$-wm\left(1+\lambda\right)\frac{dN}{dm} + \lambda w\left(T - N\right) + \left(u_X - D'\left(X\right) - C'\left(X\right) + \lambda\tau\right)\frac{\partial X}{\partial m} = 0 \qquad (7.40)$$

- And solve for λ as

$$\lambda = \frac{wm\frac{\partial N}{\partial m} - \left(u_x - D'\left(X\right) - C'\left(X\right)\right)\frac{\partial X}{\partial m}}{\left[w\left(T - N\right) - wm\frac{\partial N}{\partial m} + \tau\frac{\partial X}{\partial m}\right]}. \qquad (7.41)$$

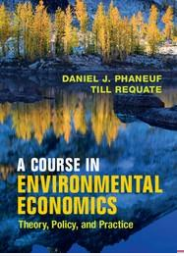


7.2.3 Prospects for a Double Dividend?

- Weak form of DD:
  Welfare is greater when any revenues raised via environmental policy are used to reduce distortionary taxation rather then refunded in a lump sum fashion.

- Strong form of DD:
  Emission fee should be set above its partial equilibrium level, thereby resulting in more pollution reduction and a larger amount of revenue raised vis-á-vis the partial equilibrium case.

$$\begin{aligned} MSC &= u_X(\bullet) - C'(X) + MIE + MRE \\ &= MAC + MIE + MRE \end{aligned} \qquad (7.42)$$



Proposition 7.3

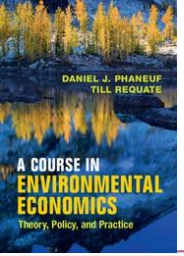
Within the context of the model examined thus far, a ***strong double dividend*** *is defined as an outcome in which the optimal level of the polluting good* X^{GE} *is smaller than its partial equilibrium counterpart* X^**, so that* $X^{GE}<X^*$.

This occurs when the net impact of the interaction and revenue effects serves to reduce the marginal social cost of reductions in X relative to the partial equilibrium case; i.e. MIE+MRE<0.

This can occur in one of two ways:

a) MIE<0 and MRE<0, or MIE<0 and |MIE|>MRE>0;

b) MIE>0 and MRE<0 where |MRE|>MIE.



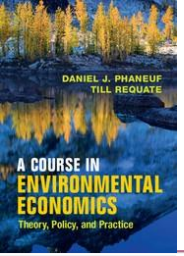
7.2.3 Prospects for a Double Dividend?

- We use again the case when $C'(X) = c$

$$MIE = \lambda\left(-\frac{\eta_{XN}}{\varepsilon_X}\right)\frac{p}{\varepsilon_L} \qquad (7.43)$$

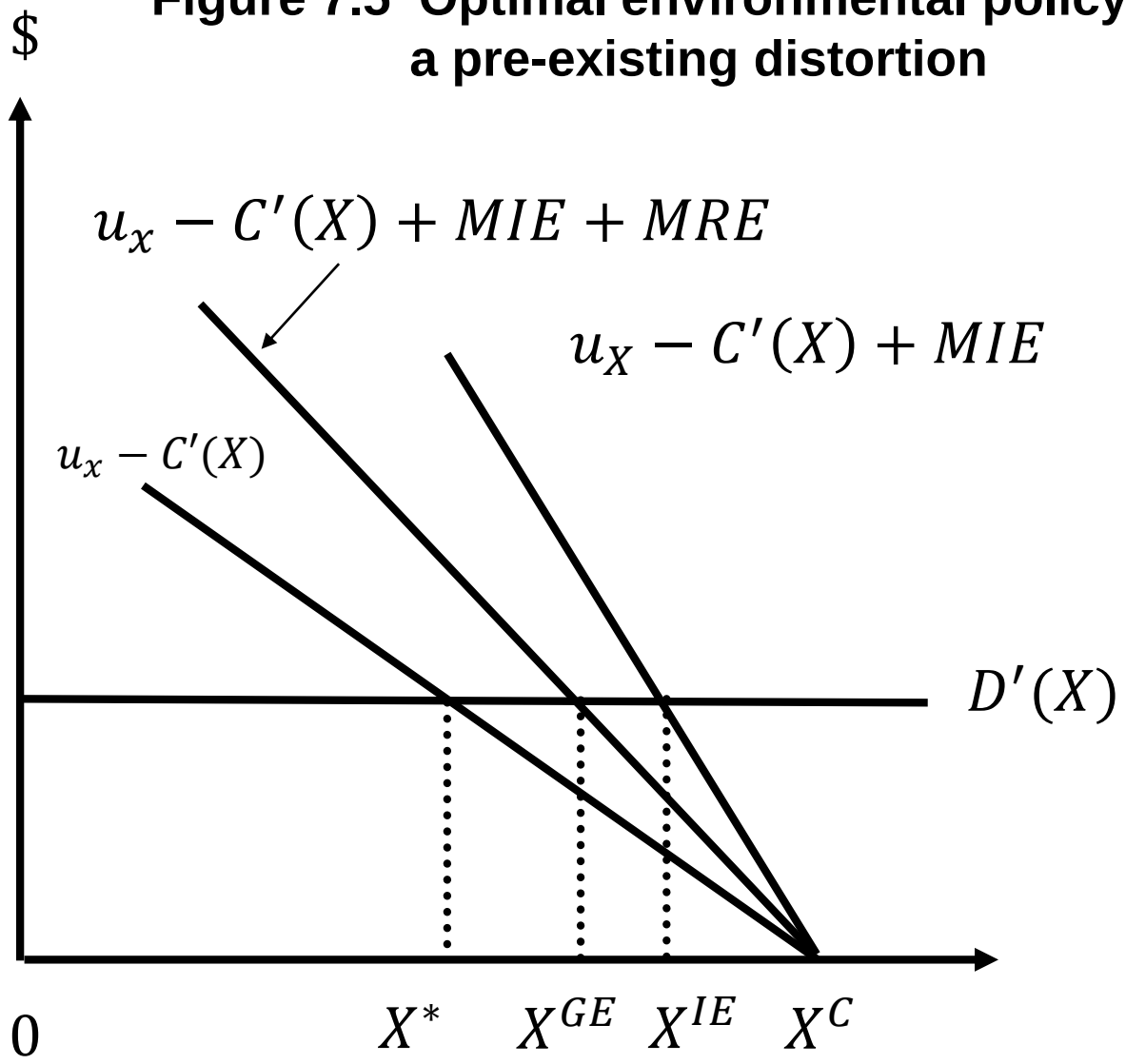
$$MRE = \lambda\left(\frac{p}{\varepsilon_X} + \tau\right)$$

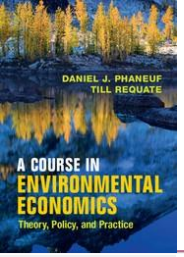
- In case $\eta_{XN} = \varepsilon_L$ (average substitutes):
- $MIE = -\lambda\frac{p}{\varepsilon_X} > 0$
- $|MRE| = \left|\underset{<0}{\lambda\frac{p}{\varepsilon_X}} + \underset{>0}{\lambda\tau}\right| \Rightarrow MIE > |MRE|$
- This suggests that on average we should not expect a strong form of double dividend.



7.2.4 Second-Best Optimal Pollution

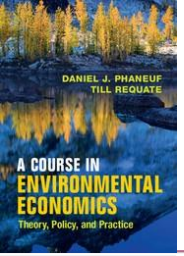
Figure 7.5 Optimal environmental policy with a pre-existing distortion



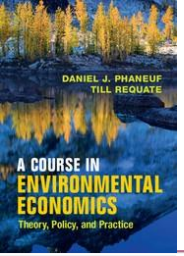


7.2.4 Second-Best Optimal Pollution

- Figure 7.5 shows the marginal damage, MAC,MIE and MRE curves jointly determine the optimal second-best pollution level.
- Figure drawn to reflect *MRE<0* and *MIE>0*, where the magnitude of the latter is dominant.
- Figure 7.5 represents current discussion in the literature, but is not completely general, in that a result in which $X^{IE} < X^{GE}$ is also possible.



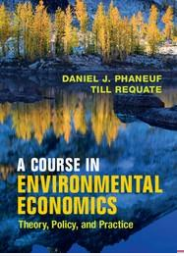
Policy Instruments



7.4 Policy Instruments

- Optimal pollution policy in a second best world must consider interactions with the existing tax system and government revenue needs.

- In what follows, we describe how each instrument's efficiency properties are altered when we move from the partial to general equilibrium context, when there are pre-existing distortions.



7.4.1 Taxes and Auctioned Permits

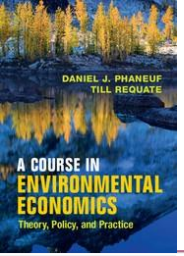
- $\prod = px - C(X) - \tau X$
- Firms maximizes profits by producing X: $p = C'(X) + \tau$
- Consumer maximizes utility: $u_X(\cdot) = p$
- Regulator sets the tax rate:

$$\tau = D'(X) + MIE + MRE \qquad (7.58)$$

- This assures an outcome which leads to X^{GE}

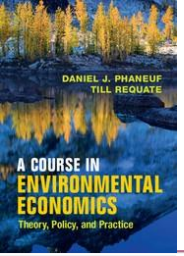
$$u_X(\bullet) = p = C'(X) + D'(X) + MIE + MRE \qquad (7.59)$$

- Story with auctioned permits nearly identical.



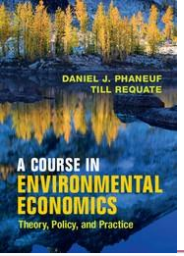
7.4.2 Freely Distributed Permits and Command and Control

- Regulator could also distribute X^{GE} emission permits for free.
- Labor tax revenue will be lost at X^{GE} relative to X^{C}, and not offset by a tax on emissions.
- Command and control even worse if firms are heterogenous.



7.4.3 Subsidies

- An abatement subsidy program is distinguished by its use of payments to polluting firms for their reduction in emissions.
- Functions like an emissions tax coupled with lump sum transfers to firms.
- Payment to firms implies the government´s budget must expand when a subsidy scheme is used, with no corresponding increase in revenue from policy.
- Additional distortionary taxation is needed to cover the increased government expenditure.



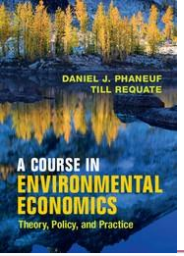
Example 7.4

- West and Williams (2007) estimate a household level demand system that includes equations for gasoline (the dirty good), leisure, and spending on all other goods.

- The main targets of estimation include the own price elasticities for gasoline and labor/leisure, along with the cross price elasticity for gasoline and leisure.

- The authors find small but negative cross price elasticities for leisure demand with respect to gas price, meaning that leisure consumption falls when the gas price increase – i.e. gas and leisure are found to be complements.

- These estimates imply that the optimal gas tax is approximately 35 percent greater than the marginal damage. In this specific context a double dividend is implied, since the higher tax on the dirty good induces an increase in labor supply.

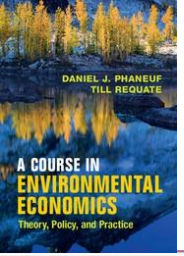


Example 7.4

- The second type of empirical work makes use of large-scale computable general equilibrium (CGE) models to predict optimal emission tax levels, which are based on richer and more realistic representation of the economy than is possible with an analytical model.

- The most enduring policy impact of the double dividend/tax interaction debate is arguably the recognition that revenue raising is a first order concern when evaluating the performance of different environmental policy instruments.

- Goulder and Parry (2008) calculate that a $20 per ton tax on carbon dioxide in the US would raise roughly $100 billion annually in the short term. They further suggest that the cost savings from the emission tax with efficient revenue recycling vis-à-vis a similar, non-revenue raising policy is on the order of $30 billion per year.



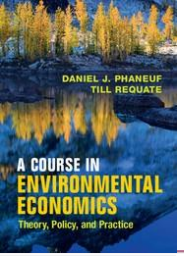
7.6 Summary

- In this chapter we have examined how thinking on environmental policy needs to be adjusted when we consider **interactions between** the **polluting** and **other sectors** of the economy.

- If the environmental policy causes an increase in the price of the polluting good, the **cross price relationship between leisure and the polluting good causes the demand for leisure to shift**.

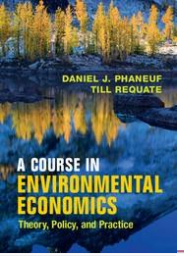
- Without distortions on the labor/leisure market, this spillover effect does not have efficiency ramifications.

- Our analysis demonstrated that things are otherwise when there is a pre-existing distortion in the labor market. **Too much of both the polluting good and leisure are consumed**.



7.6 Summary

- The optimal second best environmental policy depends on **two potential channels**.
- The first channel is the **marginal interaction effect (MIE)**, which arises when the demand for leisure shifts due to the change in the price of the polluting good.
- The second channel is the **marginal revenue effect (MRE)**, which arises when environmental policy allows for a **tax swap whereby labor tax revenue** is replaced by **revenue raised from taxing emissions**.



7.6 Summary

- We saw that a **strong double dividend** – i.e. a situation when it is optimal to set an environmental tax above marginal damage – **is unlikely in general**, since on average the marginal interaction effect is likely to increase cost at a magnitude larger than the marginal revenue effect lowers cost.

- Our results show that revenue recycling can be an important component to consider when evaluating the performance of different policy instruments:

- A **weak double dividend** always exists: This means: the revenues of an emission tax should always be used!