Externalities

• Pareto Efficiency
• Market Failure: Competitive markets are not efficient
• Theoretical Solutions: Coase Theorem, Pigouvian taxes
• Policies: cap & trade, BC Carbon tax
Definition of Externality

• We will use the term externality to describe any cost or benefit generated by one agent in its production or consumption activities but affecting another agent in the economy.

• Well …..you may say that this is true for almost every action people take. But in the competitive market, I do not care if you buy milk or coffee. Your actions do not directly affect me if you consume ordinary goods (private goods).
Externalities--Introduction

• Externalities occur when some market transaction involves costs and/or benefits that accrue to people \textit{outside} the transaction
  – This means consumers and producers aren’t taking all of the relevant costs and benefits into account $\Rightarrow$ Social MB may not equal Social MC in equilibrium.
  – In such a case, equilibrium is inefficient
Types of Externalities

• We will distinguish between consumption and production externalities.
• Consumption externalities: An externality arising from consumption.
• Production externalities: An externality arising from production.
• These definitions are based on who is generating the externality, not who is affected by the externality.
On Which Side is Externality?

<table>
<thead>
<tr>
<th></th>
<th>Production</th>
<th>Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative</td>
<td>Pulp-mill pollution, acid rain</td>
<td>smoking; loud music</td>
</tr>
<tr>
<td>Positive</td>
<td>R&amp;D spillovers, agglomeration</td>
<td>Painting house; gardening</td>
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</tbody>
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Externalities--Introduction

• Some more examples:
  – Your asking a question in class may also help others to better understand the material
  – Chatting in library, during lectures
  – Beekeeping enhances pollination of neighboring crops
  – Bees might sting neighbors too!
Example of Production Externality

- Two inputs: Capital K, Labor L
- Two consumption goods: private good x and y.
- Production externality: production of good y creates pollution that harms consumer 1. That is, utility of consumer 1 is decreasing in the total amount of y, but increasing in the amount of y consumed.
- Person 1 and person 2 (consumers): strictly convex indifference curves with respect to the two goods consumed (decreasing MRS between goods).
- Producers: strictly convex isoquants (decreasing marginal rate of technical substitution between inputs). We also assume that production of the two goods does not exhibit increasing returns to scale.
Problems the economy must solve:

• How to allocate the existing stock of capital and labor efficiently between the production of good x and the production of good y.

• How to distribute these goods efficiently among the population once they are produced.
Production Efficiency

• An allocation of inputs (K and L) is production efficient if it is not possible to reallocate these inputs and produce more of at least one good in the economy without decreasing the amount of some other good that is produced.
Production Efficiency

\[
\max_{L_x, K_x, \lambda} f_x(L_x, K_x) + \lambda \left( f_y(L - L_x, K - K_x) - y \right)
\]

Interior solution:

\[
\frac{\partial f_x}{\partial L_x} - \lambda \frac{\partial f_y}{\partial L_y} = 0
\]

\[
\frac{\partial f_x}{\partial K_x} - \lambda \frac{\partial f_y}{\partial K_y} = 0
\]

\[
y = f_y(L - L_x, K - K_x)
\]

value function gives us all the product mixes on PPF: \( y(x) \).
Production Externality

• Recall that the production of good y causes damage to consumer 1.

• Hence the utility function of consumer 1 depends positively on the amounts of goods x and y consumed, but negatively on the total amount of good y produced.
Consumption Efficiency w/ Production Externality

• A distribution of goods is consumption efficient if it is not possible to reallocate these goods and make at least one person in the economy better off without making someone else worse off.

• Given a fixed amount of goods $x$ and $y$, and since the damage is done once good $y$ is produced, consumption efficiency requires that the marginal rate of substitution between goods $x$ and $y$ are the same for both consumers.
Product Mix Efficiency

- Which combination of goods will give us Pareto-efficiency?
- We can have efficiency in production and in consumption, and yet there is still room for a Pareto improvement, because we are producing too much of one good and not enough of the other.
- Product mix efficiency puts together both sides, consumers and producers.
Using PPF to solve for Pareto efficiency

\[
\max u_1(x_1, y_1, y) \\
\text{s.t. } u_2(x_2, y_2) = u_2 \\
\text{s.t. } x_1 + x_2 = x \\
\text{s.t. } y_1 + y_2 = y(x) \\
\max \left. u_1(x_1, y_1, y(x)) \right|_{x_1, y_1, x, \phi} + \phi(u_2(x - x_1, y(x) - y_1) - u_2)
\]

production externality affecting consumer 1
Pareto efficiency with production externality that harms consumer 1

- First Order Conditions are necessary and sufficient

\[
\frac{\partial u_1}{\partial x_1} - \phi \frac{\partial u_2}{\partial (x - x_1)} = 0
\]

\[
\frac{\partial u_1}{\partial y_1} - \phi \frac{\partial u_2}{\partial (y - y_1)} = 0
\]

\[
\frac{\partial u_1}{\partial y} \frac{\partial y}{\partial x} + \phi \left( \frac{\partial u_2}{\partial (x - x_1)} + \frac{\partial u_2}{\partial (y - y_1)} \frac{\partial y}{\partial x} \right) = 0
\]
Pareto Efficiency Conditions

• Combining equations from previous slide

$$\frac{\partial u_1}{\partial x_1} = \frac{\partial u_2}{\partial x_2}$$  
Consumption efficiency

$$\frac{\partial u_1}{\partial y_1} = \frac{\partial u_2}{\partial y_2}$$

Product mix efficiency

$$\frac{\partial u_1}{\partial y} + \frac{\partial y_1}{\partial u_1} = -\frac{\partial x}{\partial y}$$
Product Mix Efficiency

\[ \frac{\partial u_1}{\partial y} \frac{\partial u_1}{\partial x_1} + \frac{\partial u_1}{\partial y_1} \frac{\partial u_1}{\partial x_1} = -\frac{\partial x}{\partial y} \]

1’s MB of consuming y in terms of good x; also equal to 2’s MB

1’s MC of producing y in terms of good x

MC of producing y in terms of x
Taking account of negative externality

• The efficient product mix is determined not where MRS=MRT. The last unit of \( y \) consumed creates a benefit to society measured by the individual MRS of \( x \) for \( y \), but the marginal cost is composed of two components: MRT of \( x \) for \( y \) and the marginal external cost due to the harm an additional unit of \( y \) produced inflicts on consumer 1.
Determining efficient amount of good causing externality in Demand and Supply diagram

• If we assume quasi-linear preferences we can make the efficiency conditions visible in the Demand and Supply diagram.

• Recall we did this in the context of public goods already. Now use the same approach to discuss externality.
Q-linear prefs and production externality harming other production sector

• Let’s assume that both consumers have quasi-linear utility functions of the form

\[ u_i(x_i, y_i) = x_i + \gamma_i(y_i) \]

\[ \gamma_i' > 0, \gamma_i'' < 0. \]

• Consumers are not impacted by the production externality but sector x suffers from higher output levels of sector y.
Demand for good $y$

- Note that if we were to set-up the standard utility maximization problem for each consumer, we find

$$\gamma_1'(y_1) = \frac{p_y}{p_x}$$

$$\gamma_2'(y_2) = \frac{p_y}{p_x}$$
Horizontally adding demand

• Suppose $p_x = 1$. Then $p_y = \gamma_i'(y_i)$

• For a given $p_y$, total demand is equal to the sum of good $y$ demanded by each consumer at $p_y$.

➢ Adding individual demands for the private good horizontally gives us aggregate demand which we can interpret as our social marginal benefit curve.
Price of $y$/ Marginal Willingness to pay

\[ p_y = \gamma_1'(y_1) = \gamma_2'(y_2) \]

Social Marginal Benefit Curve

Demand 1

Demand 2

\[ y_1 + y_2 \]

Good $y$
Efficient provision of good that causes damage to other production sector

• We can draw the MRT in the above graph. It tells us the marginal cost of producing good $y$ to society in terms of the units of good $x$ society must sacrifice.

• Ignoring the damage production of good $y$ causes to the production of good $x$ would lead to a lower “MRT” than when this damage is taken into account.

• We look at production externalities harming another production sector again later.
Price of y/ Marginal Willingness to pay

Social Marginal Benefit Curve

Social Marginal Cost Curve

Marginal Cost Curve ignoring externality

Demand 1

Demand 2

Efficient y

Good y
Q-linear prefs and production externality harming consumer 1

• Again, let’s assume that both consumers have quasi-linear utility functions

• Consumer 1 is impacted by the production externality but consumer 2 is not.

\[ u_1(x_1, y_1) = x_1 + \gamma_1(y_1) - \delta(y) \]
\[ u_2(x_2, y_2) = x_2 + \gamma_2(y_2) \]
\[ \gamma_i' > 0, \gamma_i'' < 0, \delta' > 0. \]
Pareto efficiency with production externality that harms consumer 1

• From slide 16 using our specific functional forms, we find

\[ 1 - \phi = 0 \Rightarrow \phi = 1. \]

\[ \gamma_1'(y_1) = \gamma_2'(y - y_1) \]

\[ -\delta'(y) + \gamma_1'(y_1) = \frac{\partial x}{\partial y} \]
Demand for good $y$

- Note that if we were to set-up the standard utility maximization problem for each consumer, we find

$$\gamma_1'(y_1) = \frac{p_y}{p_x}$$

$$\gamma_2'(y_2) = \frac{p_y}{p_x}$$
Horizontally adding demand

- Suppose $p_x = 1$. Then $p_y = \gamma_i'(y_i)$
- For a given $p_y$, total demand is equal to the sum of good $y$ demanded at $p_y$.
  
  ➢ Adding individual demands for the private good horizontally gives us the marginal benefit function ignoring externality
Price of \( y \) / Marginal Willingness to pay

\[ p_y = \gamma_1'(y_1) = \gamma_2'(y_2) \]

Marginal Benefit Curve w/o externality

Demand 1

Demand 2

\( y_2 \ y_1 \)

Good \( y \)
Marginal external cost function

• While the aggregate demand function measures the marginal benefit to society of good y in the absence of the externality, society must take the damage of $\delta'(y)$ into account when goods are to be produced efficiently. We can draw this function, the marginal external cost (MEC) function, in the same graph. For simplicity I’m assuming $\delta'(y) = \text{constant}$. 
Price of $y$/ Marginal Willingness to pay

Marginal Benefit Curve w/o externality

Demand 2

Demand 1

MEC

Good $y$
Social Marginal Benefit Curve

• What is the true social marginal benefit at any given $y$? It is given by the private benefit as measured by the MB curve minus MEC.
Price of y/ Marginal Willingness to pay

......Marginal Benefit Curve w/o externality
____Social Marginal Benefit Curve

Good y
Adding SMC curve

- We add the MRT to determine the optimal amount of good y in this economy.
Price of \( y \)/ Marginal Willingness to pay

Social Marginal Benefit Curve

Efficient \( y \)

Good \( y \)
Summary

• With quasi-linear preferences, we can find the efficient amount of the good causing an externality in the “demand and supply” diagram. If consumers are not affected by the externality, adding individual demands horizontally gives us the SMB curve. If consumers are affected, SMB differs from sum of individual demands; there is a flavor of the Samuelson condition because MEC needs to be vertically subtracted from aggregate demand to find SMB.

• Note that we could have found the same result by vertically adding MEC to SMC (see next slide)
Price of \( y \) / Marginal Willingness to pay

Marginal Benefit Curve w/o externality

MC w/o externality

Demand 1

Demand 2

Efficient \( y \)

Good \( y \)

SMC

MEC

Slide 38
Competitive Equilibrium

• Now that we understand Pareto efficiency in a general equilibrium model with production and a production externality, we want to find out if the competitive equilibrium in this model is Pareto efficient.

• First discuss what happens in the competitive equilibrium, then determine whether it’s Pareto efficient.

• Externalities are by definition not taken into account by the agents.
Production externality harming other firm

- Looking at an example of a local production externality
- Consider a world market for paper and bottled water.
- Two small firms are located next to each other, paper mill upstream, water treatment center downstream.
Paper and Water Economy

Paper Mill pollutes water

upstream

downstream

Water treatment center
Paper mill creates an externality

• While the waste does not impose a direct cost on the paper mill, it has an impact on the water treatment center.
• Hence the waste is external to the paper mill.
• We will assume that both the paper mill and the treatment center face a competitive market for their inputs and outputs. That is, only the WTC feels the impact of waste dumped into the river. Consumers purchasing from the world market are not impacted, nor are any other firms.
Assumptions cont’d

- The price of paper is given by $p$ and the price of 1 barrel of clean water is given by $w$.
- Let $c_p(x_p)$ and $c_w(x_w)$ be the strictly convex cost functions of the two firms in the absence of externalities.
- Further let $e(x_p)$ be the external cost imposed on the WTC by the paper mill.
Without externality

- Suppose first that there is no externality, i.e. $e(x_p) = 0$ for all output levels of the paper mill.
- Check that the solution is the same whether we maximize joint profits of the two firms or whether each firm is maximizing its own profit.
- Each firm is maximizing its own profit:

$$\max_{x_p} px_p - c_p(x_p)$$

$$\max_{x_w} wx_w - c_w(x_w)$$

FOCs

$$wrt x_p : p - c'_p(x_p) = 0$$

$$wrt x_w : w - c'_w(x_w) = 0$$
Without externality

- Maximizing joint profits of the two firms

\[
\max_{x_p, x_w} px_p + wx_w - c_p(x_p) - c_w(x_w)
\]

*FOCs*

\[
wrt x_p \colon p - c'_p(x_p) = 0
\]

\[
wrt x_w \colon w - c'_w(x_w) = 0
\]

- So we see, that in this case it doesn’t matter whether each firm maximizes its own profits or whether we maximize joint profits. That is, the market solution is also maximizing joint profits.
With externality: competitive equilibrium

- Now consider the same problem if the paper mill creates an externality for the water treatment center captured by $e(x_p)$ for all $x_p > 0$.
- Both firms maximize their respective profits. In the competitive market each firm maximizes profits individually. 
  \[
  \max_{x_p} px_p - c_p(x_p)
  \]
  \[
  \max_{x_w} wx_w - c_w(x_w) - e(x_p)
  \]

**FOCs**

wrt $x_p : p - c_p'(x_p) = 0$

wrt $x_w : w - c_w'(x_w) = 0$
With externality: Is competitive equilibrium efficient?

- The water treatment plant takes the cost imposed on it by the output decisions of the paper mill as given.
- Both producers set price equal to marginal cost, but the paper mill ignores the cost that it imposes on the water treatment plant.
- Next we find out what the conditions are to maximize joint profits of the two firms.

\[
\max_{x_p, x_w} px_p + wx_w - c_p(x_p) - c_w(x_w) - e(x_p)
\]

**FOCs**

wrt \(x_p\): \(p - c_p'(x_p) - e_p'(x_p) = 0\)

wrt \(x_w\): \(w - c_w'(x_w) = 0\)
Competitive Equilibrium not socially optimal

- Each firm maximizing its own profit leads to a lower sum of profits than if we maximize joint profits.
- The competitive equilibrium is not efficient, because there is a way to make both firms better off without making anybody else worse off.
  - remember firms and consumers are price takers in the output markets; costumers are the same off whether these two firms maximize profits individually or jointly.
Social vs. Private Cost

• If we compare the two solutions, we see that the marginal cost of producing paper differs in the market solution and the joint profit solution.

• The market solution only recognizes the private marginal cost, the cost internal to the paper mill. By maximizing joint profits instead, we find the social marginal cost of producing paper.

• This cost includes the private marginal cost and the cost that it imposes on the water treatment center.

• The private marginal cost is different from the social marginal cost and the market solution is therefore not Pareto efficient.
How Can We Decrease Pollution?

• Pigouvian Tax
• Assigning Property Rights
• We will now focus on how we can decrease the amount of waste produced by the paper mill to achieve the socially optimal amount. We will first discuss a tax on waste and then the assignment of property rights.
Pigouvian Tax

- We have just seen that the paper mill does not face the social marginal cost of its production of paper.
- As far as the paper mill is concerned its production of waste costs nothing. But that neglects the costs that the waste imposes on the water treatment plant, the external cost.
- According to this view, the situation can be rectified by making sure that the polluter faces the correct social marginal cost of its actions by levying a tax on the waste that it creates.
Paper, Waste, and Clean Water

• We will continue with our example of the paper mill and the water treatment center.

• It will be useful for our analysis to distinguish between the two things that the paper mill produces: paper and waste.

• The paper mill can only control the waste that it produces by controlling its output – we assume there are no alternative technologies that allow the paper mill to produce paper environmentally friendlier.

• Therefore producing a certain amount of paper is associated with a certain amount of waste. Let $D(x_p)$ be the waste produced by the paper mill at a given amount of paper.
Paper Mill’s problem with tax

- Suppose we put a tax of $t$ dollars per unit of waste on the paper mill. Write down the profit maximization problem of the paper mill with the tax.

\[
\max_{x_p} \quad px_p - c_p(x_p) - tD(x_p)
\]
\[
\max_{x_w} \quad wx_w - c_w(x_w) - e(x_p)
\]

**FOCs**

wrt $x_p$ : \( p - c_p'(x_p) - tD'(x_p) = 0 \)

wrt $x_w$ : \( w - c_w'(x_w) = 0 \)
Optimal tax

- Recall that the socially optimal amount of paper was given by \( p = c' (x_p) + e'(x_p) \).
- Comparing this optimal condition with the profit maximization condition with the tax, we need \( t = e'(x_p^*)/D'(x_p^*) \). Where \( x_p^* \) denotes the efficient amount of paper.
Focus on waste, not paper

• Note that because of the relationship between paper and waste, we could also think about solving the same problem by focusing on waste instead of paper.

\[
\max_D px_p(D) - c_p\left(x_p(D)\right) - tD
\]

\[
\max_{x_w} wx_w - c_w\left(x_w\right) - e\left(x_p(D)\right)
\]

\(FOCs\ wrt D: px'_p(D) - c'_p\left(x_p\right)x'_p(D) - t = 0\)

\(wrt x_w: w - c'_w\left(x_w\right) = 0\)

\(FOC\text{(efficiency)}: px'_p(D) - c'_p\left(x_p\right)x'_p(D) - e'_p\left(x_p\right)x'_p(D) = 0\)

\(t = e'(x_p(D^*))x'_p(D^*) = e'(x_p^*)/D'(x_p^*)\)

\(t = e'(D^*)\)
Solving the problem for optimal amount of waste graphically

- More waste means more paper. At current market price $p$, the firm’s marginal profit decreases with more paper (as the marginal cost of producing paper is increasing) and hence more waste. $D_{\text{max}}$ denotes the amount of waste at which profit is 0.

- The damage to the WTC is captured by a function that increases in waste. The marginal damage (MEC) is assumed to increase in waste as well. In the next graph both the MP and the MEC function are assumed to be linear.
The optimal tax on waste

MP stands for marginal profit, \( e'(D) \) is the marginal cost caused by the externality, i.e. the marginal external cost.
Optimal Tax Is Named After Pigou

- A.C. Pigou argued that, when an externality exists, the government should tax the party causing the externality by the amount equal to the marginal external cost at the efficient level. We therefore call this tax Pigouvian tax.

- As we have seen, the marginal tax must equal the marginal external cost at the social optimum. This tax will force the paper mill to internalize the externality, that is, the paper mill will now take the waste it produces into account when deciding how much paper to produce.
The Weakness of the Pigouvian Tax

• The government must set the tax and in order to set it appropriately, it must know the optimal amount of the externality.

• But if we knew the optimal level of waste we could just tell the paper mill how much to produce and we don’t need the taxation scheme at all.
Assigning Property Rights

- With externalities property rights are not well defined, i.e. there is a missing market.
- We will next examine whether properly defining property rights over the cleanliness of the water, will help us achieve a Pareto efficient outcome.
- We can assign property rights either to the water treatment center (the right to clean water) or to the paper mill (the right to pollute the water to a certain degree).
Assigning the right to clean water to the WTC

• If the water treatment center has the right to clean water, it can also sell parts of this right to the paper mill, i.e. for each unit of waste dumped into the water the paper mill must pay the water treatment center a certain price. Let this price be equal to $q$. 
Finding the Paper Mill’s Demand for Waste

• Write down the profit maximization problem of the paper mill if the water treatment center can charge a price $q$ to the paper mill for any unit of waste dumped into the river.

$$\max_D px_p(D) - c_p \left( x_p(D) \right) - qD$$

FOCs wrt $D$:

$$px'_p(D) - c'_p \left( x_p \right) x'_p(D) - q = 0$$

since $MP(D) = px'_p(D) - c'_p \left( x_p \right) x'_p(D)$

$FOC : MP(D) = q$
Finding the paper mill’s demand for waste

- Profit of paper mill is maximized when marginal benefit (equal to marginal profit of waste from its production of paper) equals marginal cost of waste \( q = MP(D) \)

- This is also the inverse demand for waste. It tells us how much the paper mill would be at most willing to pay in order to be allowed to dump one more unit of waste into the river.
Finding the WTC’s supply of “waste”

- The water treatment plant has now two choice variables: its own output and how many units of waste it will let the paper mill dump into the water given that for each unit of waste it will receive $q$ from the paper mill, but each unit of waste also has an impact on its cost of producing clean water.

\[
\max_{x_w, D} w x_w - c_w(x_w) - e(D) + qD
\]

\[
\text{FOCs wrt } x_w : w - c'_w(x_w) = 0
\]

\[
\text{wrt } D : -e'(D) + q = 0
\]

\[
q = e'(D)
\]
Inverse supply of waste

- The equation $q = e'(D)$ is also the inverse supply for waste. It tells us by how much the WTC needs to be at least compensated in order to allow the paper mill to dump one more unit of waste into the river.
The market for waste

WTC receives this much in revenues from selling its rights

\[ q = e'(D) \]

Supply of WTC of permits to dump waste

Demand of Paper Mill to dump waste

\[ q = MP(D) \]
The right to dump waste into the water of the paper mill

• What if the paper mill had the right to pollute at the level of $D = D_{max}$ in the absence of any payment and the water treatment center needs to pay the paper mill to pollute less? Let $q$ be the price that the water treatment center pays to reduce the amount of waste produced by the paper mill.

• Write down the profit maximization problem for both the paper mill and the water treatment center. Note that since the paper mill is selling “reduction in waste”, it sells $(D_{max} - D)$ to the water treatment center. $(D_{max} - D)$ is called the waste abatement.
The Paper Mill’s Problem

$$\max_D px_p(D) - c_p(x_p(D)) + q(D^{\text{max}} - D)$$

**FOCs wrt** $D$: $px'_p(D) - c'_p(x_p)x'_p(D) - q = 0$

since $MP(D) = px'_p(D) - c'_p(x_p)x'_p(D)$

**FOC**: $MP(D^{\text{max}} - (D^{\text{max}} - D)) = q$
Market for waste abatement

- Profit of paper mill is maximized when marginal benefit (equal to marginal profit of waste from its production of paper) equals marginal cost of waste (the loss of receiving $q$ from WTC for waste reduction by one unit): $MP(D) = q$

- The paper mill is a supplier of waste abatement ($D^{max} - D$) and the WTC is a demander of waste abatement.
WTC’s Profit MAX Problem

$$\max_{x,w,D} wx_w - c_w(x_w) - e(D) - q(D^{\text{max}} - D)$$

**FOCs wrt** $x_w$:

$$w - c'_w(x_w) = 0$$

**wrt** $D$:

$$-e'(D) + q = 0$$

$$q = e'(D)$$

$$q = e'(D^{\text{max}} - (D^{\text{max}} - D))$$
Market for waste abatement

Paper mill receives this much in revenues. from polluting \( D_{max} - D^* \) units less.

Supply of waste abatement by Paper Mill \( q = MP(D_{max} - D) \)

Demand for waste abatement by WTC \( q = e'(D_{max} - D) \)

Waste abatement

\( D_{max} \)

\( D^* \)

\( D=0 \)
Same efficient amount of waste

- The different solutions have all yielded the same amount of waste.
- In the case of production externalities affecting other firms, the optimal production pattern does not depend on the assignment of property rights.
- Of course, the distribution of profits will depend on the assignment of property rights and if the government were to decide to whom to give the property rights one can imagine massive lobbying of both the paper mill and the water treatment center.
The Coase Theorem

- In markets with externalities, if property rights are assigned unambiguously and if the parties involved can negotiate costlessly...
- Broad interpretation: ...then the parties will arrive at a Pareto efficient outcome regardless of which owns the property rights.
- Narrower interpretation: ...then the allocation of resources will be efficient and invariant with respect to the legal rules of entitlement.
Why not always rely on the Coase Theorem?

• The Coase Theorem only works if transaction costs are negligible.
• Suppose there is an airport and 2000 residents live near the airport. It will take a lot of energy and time to negotiate with all the residents – transaction costs will be huge.
• There is a role for government other than just defining property rights if there are externalities and transaction costs are substantial.
Public Policies to Decrease Negative Externalities

• Standard and Charges
  – BC Carbon Tax

• Cap and Trade
  – Competitive Market w/ permits
Standards and Charges

• We are now deviating from the assumption that the government knows the socially optimal level of waste and instead we assume that it tries to decrease pollution to a level that it deems acceptable.

• Standards: The government tells each firm by how much to cut pollution.

• Charges: The government announces that firms have to pay an environmental fee – a charge – for each unit of pollution. By making polluting more costly the government hopes to decrease pollution to the acceptable level.
Costs of abatement

- We have seen in the example of the paper mill and WTC how we can derive the supply of pollution abatement of a firm when it has the right to pollute.
- We can interpret the same curve as the firm’s marginal cost curve of abating pollution.
- If a firm has the right to pollute then in order to abate pollution by 1 unit it must be compensated for this abatement by at least the cost it incurs of cutting pollution by 1 unit.
- In what follows we will just take a firm’s total and marginal cost of pollution abatement as given.
Example: Setting Standards

• 2 firms, denoted by A and B, in a community pollute the environment.

• The government has decided that $Q$ units of pollution must be abated and that each firm must cut pollution by $Q/2$ units.

• The cost functions of pollution abatement are:

\[ c_i(R_i) > 0, i = A, B \]

\[ c'_i(R_i) > 0, c''_i(R_i) > 0 \]
Question a)

• Will this lead to a cost efficient solution in general? Explain why or why not.

• To answer this question, suppose that the cost functions of the two firms are different. Moreover assume that

\[ c_A' \left( \frac{Q}{2} \right) > c_B' \left( \frac{Q}{2} \right). \]
Answer a)

$$\min c_A(R_A) + c_B(R_B) \text{ s.t. } R_A + R_B = Q$$

$$\min_{R_A} c_A(R_A) + c_B(Q - R_A)$$

$$FOC : c'_A(R_A) = c'_B(Q - R_A)$$

• For cost efficiency, we need that all firms’ marginal costs of abatement are the same and that the total amount abated adds up to $Q$. 
Answer to a) ctd

• We see that if

\[ c_A'(Q/2) > c_B'(Q/2) \]

having each firm abate \( Q/2 \) is not cost efficient.
Question b)

- Suppose instead of standards the government imposes a pollution charge $t$.
- Show that the firms will abate pollution in a cost efficient manner.
Answer b)

- Each firm needs to figure out the amount of abatement that minimizes costs overall for the firm. On the one hand it incurs costs by abating, on the other hand it incurs costs by not abating because each unit not abated costs $t$. Let $D$ be the amounts of pollution if abatement is zero.

$$\min_{R_i} c_i(R_i) + t(D - R_i)$$

$$FOC : c_i'(R_i) - t = 0$$

$$\Rightarrow c_i'(R_i) = t \ \forall i = A,B$$

$$\Rightarrow c_A'(R_A) = c_B'(R_B) = t$$

- In words, choose an abatement level that minimizes the sum of costs that the firm is facing.
- Costs are minimized when marginal cost of abatement equals the cost of polluting.
Answer to b) ctd

• Note that each firm will behave in this way, and hence firms will all face the same marginal cost of abating.
• This is cost efficient.
Weaknesses of Standards and Charges

• In the case of charges, govt must have a good idea by how much pollution will decrease once the charges are in place. If it estimates the costs of abatement incorrectly, firms may decrease pollution by not enough or by too much.

• On the other hand, using charges rather than setting emission standards is cost efficient.
BC Carbon Tax

• Tax consumption of products that produce negative externality
• Use revenues to decrease provincial income tax.
Analyzing a Revenue Neutral Tax and Rebate Scheme

- In order to analyze the distributional impact of BC’s Carbon tax, we’ll look at a benchmark case.
- Assume consumer doesn’t care about CO$_2$ emissions … otherwise there wouldn’t be the need for the tax.
- Consider two-good model with gas on the x-axis and all other goods on y-axis.
- Assume rebate is in the form of a lump-sum transfer.
- Government revenue from tax on gas is equal to government expenditure on rebates…so tax is revenue neutral.
Is this program leaving consumer as well off as she would be w/o the program?

• This analysis is replicated from ECON500 lecture notes. You have all seen this before.
• We are interested how big the rebate would have to be in order to make the consumer with the Carbon tax as well off as without the Carbon tax.
Finding welfare neutral rebate

Original budget line: red & solid

Budget line with Carbon tax: green and dashed

Assume price of “other goods” is equal to 1.

Price of gas increases due to Carbon tax

Utility w/o Carbon tax
Finding welfare neutral rebate

CV = rebate to keep consumer as well off as before

Other goods

Need to reach original utility level with new price ratio: parallel shift green dashed line until you reach original utility level

Utility w/o Carbon tax
Is CV equal to revenue neutral rebate?

- Revenue neutral rebate is equal to government revenue from Carbon tax.
- Suppose government rebates |CV| to consumers, then $h_g(u^0, p^1)$ is the optimal choice of gas given Carbon tax and rebate.
- Then tax revenue = $t^* h_g(u^0, p^1)$
- Use area representation of CV to see if this is feasible.
Other goods $M^0$

Original budget line: blue
“new” budget line with tax and rebate $= |CV|$: red

Even if rebate $= |CV|$, tax revenue $< |CV|$!
Welfare Analysis of Tax and Rebate Scheme

• In order to keep consumers as well off as before the tax-and-rebate scheme, government would have to give to consumers more than what it is receiving in tax revenues. Put differently, a revenue-neutral tax-and-rebate scheme leaves consumers worse off.

• But Carbon Tax corrects for externality, we don’t really reduce social welfare by the amount current consumers are worse off.

• Future generations’ external cost is reduced and this benefit needs to be weighed against the welfare loss of current consumers.
“DWL” offset by decrease in negative externality

- Note that we can generate the graph from previous slide by assuming quasi-linear preferences. In this case Hicksian and Marshallian demand are the same.
- Suppose there are two consumers, and marginal external costs measure the harm that CO emissions cause for future generations.
- For simplicity, assume that the MEC is constant.
- Recall our assumption that tax is passed on to consumers, so firms face constant marginal cost.
Blue rectangle shows reduction in TEC due to Carbon tax; “DWL” of consumers is smaller
Orange area: efficiency gain compared to eqm.
Cap and Trade

- Marketable pollution permits have been in the news as a solution to reduce CO$_2$ emissions.
- How do they work?
- Govt wants to reduce emissions by say 25%. There is a cap on emissions on every firm in the same amount (or the same percentage), so that these pollution permits add up to 75% of the amount previously emitted.
- But firms are allowed to pollute more than their share of permits if they can find another firm that will pollute less than their share of permits so that their combined pollution will still be equal to their combined amount of permits.
- This means firms can trade the amount of pollution they are granted from the govt among themselves.
Marketable Permits

• Marketable permits combine the advantages of standards and charges:
  – The government issues permits in the amount it will tolerate pollution and hence removes all the uncertainty about whether or not the target level of pollution is reached. This is the advantage over charges.
  – On the other hand, by having firms bid for permits, the firms will set a price of the permit equal to the marginal benefit of polluting one more unit. Therefore the cost inefficiency caused by standards (see example below) does not apply to marketable permits.
Example: Trading Permits
• We continue with the previous example of firm A and B. Suppose now that firms can trade pollution permits.
• Suppose the government tells firms to cut pollution by $Q/2$ units or trade with another firm so that in total pollution is cut by the desired amount.
• If there is a competitive market for pollution abatement, what would be the price for each unit a firm abates beyond its $(Q/2)^{th}$ unit?
Answer

• Let $X$ be the additional amount beyond $Q/2$ units by which a firm is considering cutting pollution if it gets paid $p$ for each additional unit of pollution abated. A firm’s problem if it offers to cut pollution by more than $Q/2$ units is given by

$$\text{Max}_x pX - \left[ c_i\left(\frac{Q}{2} + X\right) - c_i\left(\frac{Q}{2}\right)\right]$$

$$\text{FOC}: p - c_i'\left(\frac{Q}{2} + X\right) = 0$$

• In words: maximize the difference between the revenues of cutting pollution for another firm by $X$ units and the cost of cutting pollution by an additional amount $X$.

• Profits are maximized when marginal revenue beyond $Q/2$ units equals marginal cost of abating an additional unit.
Answer cont’d

• A firm buying a permit from another firm to pollute more, solves the following problem:

\[ \text{Max}_X \left[ c_i \left( \frac{Q}{2} \right) - c_i \left( \frac{Q}{2} - X \right) \right] - pX \]

\[ \text{FOC: } c_i \left( \frac{Q}{2} - X \right) - p = 0 \]

• In words: maximize the difference between the cost saving from abating \( X \) units less and the payment to the other firm who will now abate \( X \) units more.

• Profits are maximized when the cost savings of the last unit not abated is equal to the price that the firm has to pay the other firm for abating the last unit on its behalf. Here again marginal benefit (cost savings of not abating last unit) equals marginal cost (paying other firm to abate last unit).
Answer cont’d

• We can now find the equilibrium with tradable permits.

• The only question that remains is which firm will abate more than $Q/2$ units and which firm will abate less?

• The firm with a cost advantage of abating the $(Q/2)^{th}$ unit abates more and becomes a supplier of permits and the firm with higher costs of abating the $(Q/2)^{th}$ unit becomes the demander of permits.

• Trading permits is cost efficient, because at the equilibrium price $c_i\left(\frac{Q}{2} + X\right) = p, c_j\left(\frac{Q}{2} - X\right) = p$

\[\Rightarrow c_i\left(\frac{Q}{2} + X\right) = c_j\left(\frac{Q}{2} - X\right)\]
Using Auctions to Allocate Permits

• Instead of distributing permits for free to private firms, the government could auction the permits

• There are different auction mechanisms

• Problem Set walks you through a problem with a second-price auction

• Auctioning permits is cost efficient
Potential Problems of Pollution Permits, Carbon Taxes

• One problem with pollution permits is that there is an assumption that a ton of pollution is the same regardless of where it is emitted
  – Might want regional permit programs, if you think it is more important to reduce pollution in highly populated areas, or near particularly valuable or sensitive wilderness areas
Transboundary Pollution

• Another problem of correcting externalities is that the local govt may not have authority to do so!
• Take the problem of acid rain in Eastern Canada.
  – Pollution is caused by US firms operating on US territory
  – Measuring the cost in one country only is not reflecting the true social cost of the pollution
  – International cooperation is required to formulate environmental policies
Externalities and Fairness

• Studies have shown that poor are disproportionately subject to pollution
  – Not surprising, if clean air is a normal good
  – Rich may pay real estate premium to live in areas with clean air and water
  – May be concerned that clean air is “fundamental right”, not commodity

• Interventions can reduce or increase fairness
  – Giving a rich factory owner rights to pollute increases his/her wealth
  – But taxing factory owner will raise price of the product sold--what if poor are primary consumers?
Externalities and Fairness

• Interventions that lead to reductions in output (in case of negative externalities) may lead to workers being laid off
  – Difficult to assess the distributional impacts of these attempts at achieving efficiency
  – Poor spend a large fraction of income on transportation; so gas tax or carbon tax is likely to hurt poor more than rich
  – This is not to say it shouldn’t be done. Other redistributive measures could be combined with correction of the externality to neutralize distributional effects of correction