Lecture Note 11: Externalities

A major theme of this course is that an unregulated market economy won't always achieve socially efficient outcomes: there are **market failures**.

So far, we've looked at one such market failure: imperfect competition. Today we'll consider another, extremely important one: externalities.

An **externality** occurs when one person's behavior directly impacts someone else's welfare, either positively or negatively.*

Examples of **negative externalities**:

- Air pollution emitted by cars harms infant health.
- Secondhand smoke harms the people around you.
- Loud noise from a construction project reduces my productivity.

Examples of **positive externalities**:

- When I get a flu shot, you're less likely to get the flu.
- Innovations benefit many people/firms, not just the inventor.
- If a student points out a typo in the notes, the whole class benefits.

Two big questions:

- Why do externalities result in inefficiency?
- What can we do about them?

These questions are central to environmental economics and public health, and they appear in many other areas of economics as well.

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*Whenever we participate in a market, we also indirectly affect other people's welfare because our consumption and production decisions affect the prices other people will get/pay for various goods. Our focus here is on cases where behavior has a direct impact on others, not just through prices.

External costs and external benefits

Almonds are a water-intensive crop, and overuse of water contributes to California's drought and wildfire conditions. Just how costly is almond farming for society as a whole, and who bears those costs?

First, there is the cost of production, $C(Q)$. Since production costs are paid by the producers themselves, we often call them **private costs**. Each additional unit sold increases $C(Q)$ by the **private marginal cost**. In the context of externalities, I'll sometimes write $PC(Q)$ and $PMC(Q)$ instead of $C(Q)$ and $MC(Q)$ to clarify that these are *private* costs.

But because almond production hurts the environment, it also imposes an **external cost** $EC(Q)$ on society as a whole. If we take the derivative, we get the **external marginal cost**, $EMC(Q) \equiv EC'(Q)$.[†] These external costs are spread out across everyone in society.

Adding the private and external costs gives us the **social cost** of growing almonds, $SC(Q) \equiv PC(Q) + EC(Q)$. The **social marginal cost** is

$$SMC(Q) \equiv PMC(Q) + EMC(Q)$$

The main *benefit* of growing almonds is that consumers like to eat them. These are **private benefits**, $PB(Q)$—"private" because they apply to the market participants themselves. Since my willingness to pay equals the benefit I get from owning a product, the demand curve tells us the **private marginal benefit**, $PMB(Q) \equiv p(Q)$, from growing more almonds.

Some economic activities have **external benefits** $EB(Q)$ for the rest of society, with **external marginal benefit** $EMB(Q) \equiv EB'(Q)$. Adding the private and external benefits gives us the **social benefits**, $SB(Q) \equiv PB(Q) + EB(Q)$. The **social marginal benefit** is

$$SMB(Q) \equiv PMB(Q) + EMB(Q)$$

[†]The triple equal sign, "≡", is mathematical notation that simply means "is defined as".

Market participants ignore external costs and benefits

The crucial assumption we make when thinking about externalities is that *market participants ignore the external effects of their actions.*

If I go on a road trip, I make the environment a little bit worse for everyone, including me. But I only bear a negligible share of the total environmental cost myself. So, when deciding how many miles to drive each year, I just compare the private benefits I get from driving to the price I have to pay.[‡]

When an almond farmer is deciding how many almonds to grow each year, she compares her private costs to the revenue she gets from selling them.

And when Pfizer is deciding how much to invest in R&D, they just care about their own profits. They ignore the fact that their scientific discoveries might benefit the rest of society (in addition to Pfizer's shareholders).

A negative externality: almond production

Suppose the almond market is perfectly competitive, with demand given by $p(Q) = 18 - Q$ and supply given by $PMC(Q) = 6 + \frac{1}{2}Q$. Suppose that almond production imposes external costs $EC(Q) = 3Q$.

How much output will the market produce? How much should it produce?

- Since firms ignore external costs, the competitive quantity Q_c solves

$$p(Q) = PMC(Q) \implies 18 - Q = 6 + \frac{1}{2}Q \implies Q_c = 8$$

- The social optimum Q_s occurs where $SMB(Q) = SMC(Q)$:

$$18 - Q = \left(6 + \frac{1}{2}Q\right) + 3 \implies Q_s = 6$$

Since $Q_c > Q_s$, the market grows more almonds than is socially optimal.

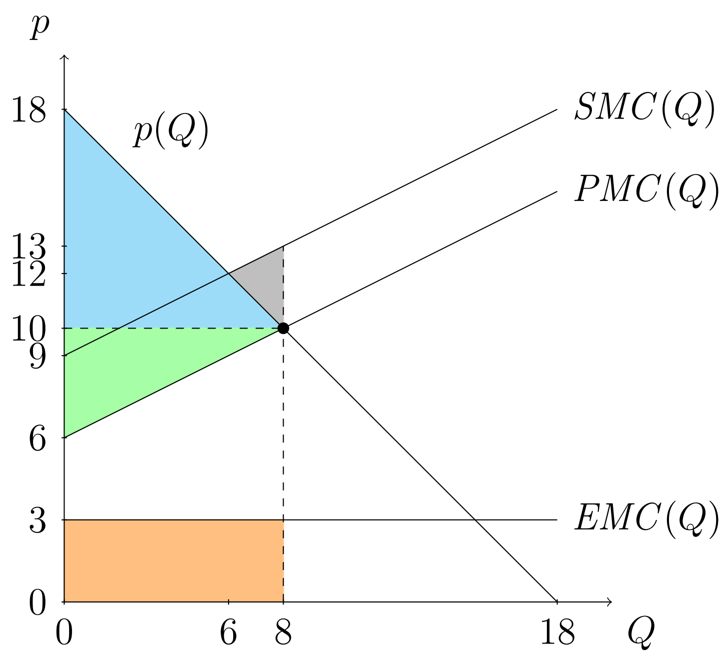
[‡]Of course, some consumers (even some economists) are eco-conscious and try to avoid activities that hurt the environment. Such attitudes are already reflected in the demand curve: environmentally conscious consumers will have low WTP for, say, SUVs because SUVs are bad for the environment.

Total surplus in the competitive equilibrium

In the presence of externalities, we redefine total surplus as

$$\text{TS} = \text{consumer surplus} + \text{producer surplus} + \text{net tax revenue} \\ + \text{external benefits} - \text{external costs}$$

(Of course, some of these components may not apply in any given problem.)



In the competitive equilibrium, we have $Q_c = 8$ and $p_c = 10$.

- Consumer surplus (blue) $= \frac{1}{2} \times 8 \times (18 - 10) = 32$.
- Producer surplus (green) $= \frac{1}{2} \times 8 \times (10 - 6) = 16$.
- Net tax revenue $= 0$.
- External costs (orange) $= 8 \times 3 = 24$.
- Deadweight loss (gray) $= \frac{1}{2} \times (8 - 6) \times (13 - 10) = 3$.

Total surplus $= \underbrace{32}_{CS} + \underbrace{16}_{PS} + \underbrace{0}_{TR} - \underbrace{24}_{D} = 24.$[§]

[§]We can also define total surplus as social benefits (here, just the area under the demand curve) minus social costs (here, just the area under the social marginal cost curve). The social benefits equal 112 and the social costs equal 88, so this calculation gives us $112 - 88 = 24$, as expected.

Regulating externalities

We use three main tools to mitigate (or eliminate) negative externalities:

1. Restricting the amount of pollution firms are allowed to produce, or requiring them to use cleaner production methods. Policies like this are often referred to as a **command-and-control** approach.
2. Imposing a **corrective tax** for each unit of pollution emitted.
3. Assigning **property rights** so that polluters and those harmed by pollution can negotiate about the appropriate level of pollution.†

We'll look quickly at command-and-control, then turn to corrective taxes. I won't be covering property rights (and they won't be on the exam).

Approach #1: command and control

In our almond example, the government could simply impose a **quota** making it illegal for the almond industry to produce more than $Q_s = 6$.

- This is a little more complicated in practice, because the government has to specify how much each almond farm can produce.
- To choose the optimal quotas, the government would need to know the demand curve, each firm's marginal cost curve, and the external marginal cost curve—all of which are hard to observe in practice.‡

Despite these challenges, governments do use command-and-control tools:

- Restricting the amount of water allocated to California farmers.
- Limiting the amount of SO_2 pollution coal plants can emit.
- Mandating the use of catalytic converters in cars.

†This is the idea behind the *Coase theorem*, which argues that (under some very strong assumptions) clearly defined property rights will get us to the social optimum, even without any regulation.

‡A potentially better approach is **cap-and-trade**, in which the government auctions off a fixed number of "pollution permits" that firms can buy/sell from each other. This approach was famously used in the United States's 1990 Clean Air Act Amendments, which regulated SO_2 emissions.

Approach #2: corrective (or "Pigouvian") taxes

Basic problem: a competitive market will overproduce goods that create negative externalities, because market participants ignore external costs.

If we want to discourage production of these goods, one solution is to impose a per-unit tax on firms that make them (or people who buy them).

These are called **corrective** or **Pigouvian taxes** (after Arthur Pigou).

Here, again, is the market for almonds:

- Demand curve: $p(Q) = 18 - Q$.
- Private marginal costs: $PMC(Q) = 6 + \frac{1}{2}Q$.
- External marginal costs: $EMC = 3$.

What tax should we impose on each unit produced?

An optimal corrective tax gets firms to **internalize the externality**, meaning that they bear the cost of the harm they are inflicting on others.

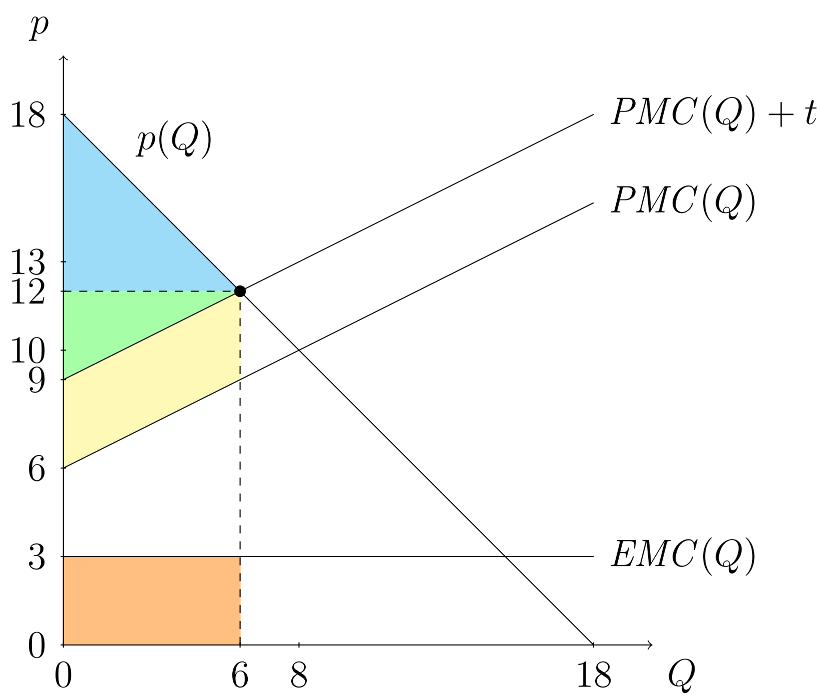
- With a per-unit tax, producing an extra unit costs $PMC(Q) + t$.
- Suppose we set the tax to $t = EMC$.
- So, a producer's marginal cost is now $PMC(Q) + EMC = SMC(Q)$.
- Under this corrective tax, competitive firms will set $p = SMC(Q)$.
- Result: we get the socially optimal level of production.

The optimal corrective tax is equal to the external marginal cost: $t = 3$.*

*If the external marginal cost is an increasing function of Q, then the optimal corrective tax equals the external marginal cost *evaluated at the socially optimal quantity*: $t = EMC(Q_s)$. Such a tax ensures that firms have the right incentives not to produce more than is socially optimal.

Total surplus with an optimal corrective tax ($t = 3$)

The corrective tax effectively shifts the supply curve up by \$3.



Under the optimal corrective tax, $Q^{\text{tax}} = 6$. For each unit sold, consumers must pay \$12 but producers only get \$9 (since \$3 goes to the government).

- Consumer surplus (blue) $= \frac{1}{2} \times 6 \times (18 - 12) = 18$
- Producer surplus (green) $= \frac{1}{2} \times 6 \times (12 - 9) = 9$
- Tax revenue (yellow) $= 3 \times 6 = 18$
- External costs (orange) $= 3 \times 6 = 18$

Total surplus $= \underbrace{18}_{CS} + \underbrace{9}_{PS} + \underbrace{18}_{TR} - \underbrace{18}_{D} = 27.$

The optimal corrective tax has increased total surplus from 24 to 27. Notice that the increase in total surplus (\$3) exactly equals the deadweight loss we found earlier, which has now been eliminated.

