

# External effects, externalities, and pollution

briefly about grades

chapter 16 stuff:

Edward Morey: draft Dec 3, 2018

Externalities are a type of market failure - market failures are things inherent to the market that cause the market-equilibrium allocation to be inefficient.

## 1 Let's start by defining external effects (what KW call "side effects").

Reviewing, an external effect occurs when the actions of one economic agent directly affect, not indirectly through market prices, another economic agent.

Examples of external effects:

- I put plaster statues of Snow White and the Seven Dwarfs in my front yard, because it makes me better off, but doing so decreases or increases the utility of my neighbors—some like them, some don't
- —
- I smoke a cigarette and you are subjected to second-hand smoke, which makes you worse off.
- —
- I smoke weed and you are positively affected by the second-hand smoke: you are better off.
- —
- I take a bath because I can no longer stand the way I smell, which improves your life because you are assigned to sit next to me in class.
- —
- The factory producing widgets emits a lot of pollution, making a lot of people in the neighborhood sick.
- —
- I drive slowly to Vail on I-70 on a Saturday winter morning (I am a wimpy driver), slowing down everyone behind me.
- —

- You stand up at a concert so you can see better, making it harder for the guy behind you to see
- --
- You watch porn in your windowless basement. The neighbor somehow knows you are doing it, and is made worse off (better off)
- --
- My driving increases CO2 emissions, which makes future generations worse off.
- --
- You kiss Dayle on the lips? And she/he kisses you back. (double external effects?)
- --
- You run by me and steal my purse because you need money to feed the kids

All of these are examples of actions that cause external effects: some positive and some negative.

I prefer "external effect" to the KW "side-effect" because sometimes external effects are produced precisely because the intent is to affect others, making the adjective "side" a bit misleading.

Make sure you understand the difference between external benefits and costs, and internal benefits and costs. For example, if I smoke cigarettes, producing both second-hand smoke, and cancer in my lungs, the effects on others from my second-hand smoke are external costs, but the pain and suffering from the cancer are internal to me.

Like everything else, there is some efficient amount of every external effect. The question is whether the unregulated market will typically produce the efficient amount of the external effect.

The answer is **often**, NO.

Consider cigarette smoking:

cigarette, match, etc. WE DID THIS ALREADY, but think it through.

Like the consumption of everything, we, as a society, want cigarettes consumed up to the point where the marginal benefits to society from the last cigarette consumed just equals the marginal cost to society from the last cigarette consumed.

Edward will smoke cigarettes up to the point where  $mb_E(c_E) = mc_E(c_E)$ , the efficient amount from Edward's perspective

But if  $mc_s(c_E) > mc_E(c_E)$  Edward will smoke too many from society's perspective (an inefficient amount)

We also want the efficient amount of congestion on I-70 on Saturday morning in the winter.

It is very unlikely that zero is the efficient number of cigarettes smoked. And, the efficient amount of congestion on I-70 is not zero.

The cigarette smoker does not incur all of the benefits and costs of her smoking (there are external effects).

Remember that the smoker is typically a member of society, so their preference for smoking counts.

It is also unlikely that zero is the efficient amount of congestion on I-70 on a Saturday morning in the winter.

## 2 Before we consider cigarettes, consider a commodity with the following properties:

- Consumption of the product affects only the consumer, no one else
- And, production of the product by firms has no direct effect on other firms or consumers.

I have created a hypothetical product, a product whose production and consumption produces no external effect.

What would be an example of such a product? What should we call a product with these properties? A "purely private" good?

Are there good examples? How about you listening to your iPod? Wearing a dress in your private and personal closet? Reading a book, by yourself?

We can all think of reasons why there might be external effects associated with the consumption of these products.<sup>1</sup>

So, they are not pure examples.

Can you think of a better example, a good whose production and consump-

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<sup>1</sup>They both could affect your mood and outlook, so affect how you treat others.

tion has no external effects?

### 3 My example will be George's tattoos

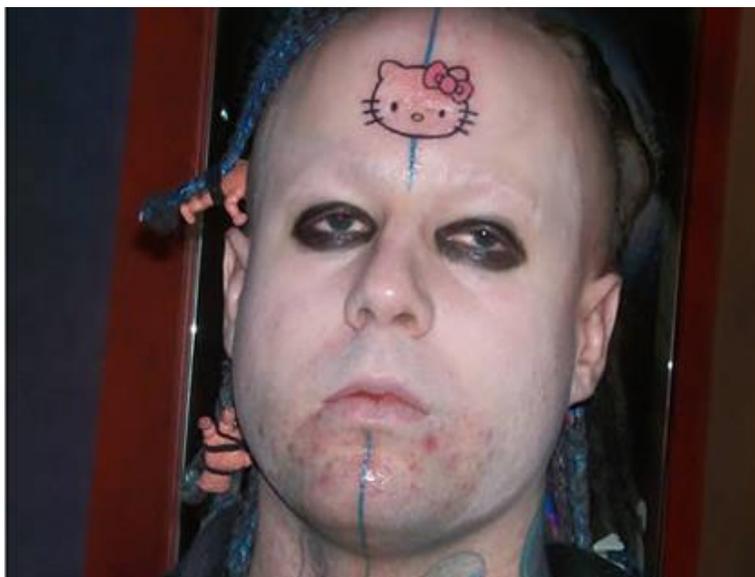
The follow is from from MSNBC, worst tattoos.

<http://now.msn.com/bad-tattoos-30-photos-of-the-worlds-worst-inkings>



Note that the suspenders are tattoos, also the strips on his thumbs.





back to George:

**3.1 George never takes off his clothes in the presence of other people, and there are no tattoos on his face, so no one else every sees his tattoos. The tattoos do not affect George's interactions with other people: George never talks about his tattoos, they never affect what he says or how he behaves in social situations.**

Also assume George does (produces) his own tattoos, and the production process has no effect on others: we are assuming George tattooing himself creates no pollution or other external effects<sup>2</sup>).

I have created a scenario where George's production and consumption of his tattos produce no external effects.

Let  $t$  be the number of tattoos on George

So, given my assumptions. the private benefits to George of adding an additional tattoo (marginal private benefit,  $MB_G(t)$ ) equals the marginal social benefit ( $MB_s(t)$ ) of an additional tattoo because George is a member of society and he is the only member who will see the tattoos.<sup>3</sup> Let's measure benefits and costs in dollars.

And, given my assumption about the production of George's tattoos, the marginal private cost of producing another tattoo,  $MC_G(t)$ , equals the marginal social cost of producing the tattoo,  $MC_s(t)$ .

Assume the marginal benefits George gets from his tattoos start positive, are downward sloping, and eventually go negative.

Assume his marginal costs are positive and upward sloping: George starts with the most accessible spot on his body, but it is damn hard to tattoo yourself on the middle of your back.

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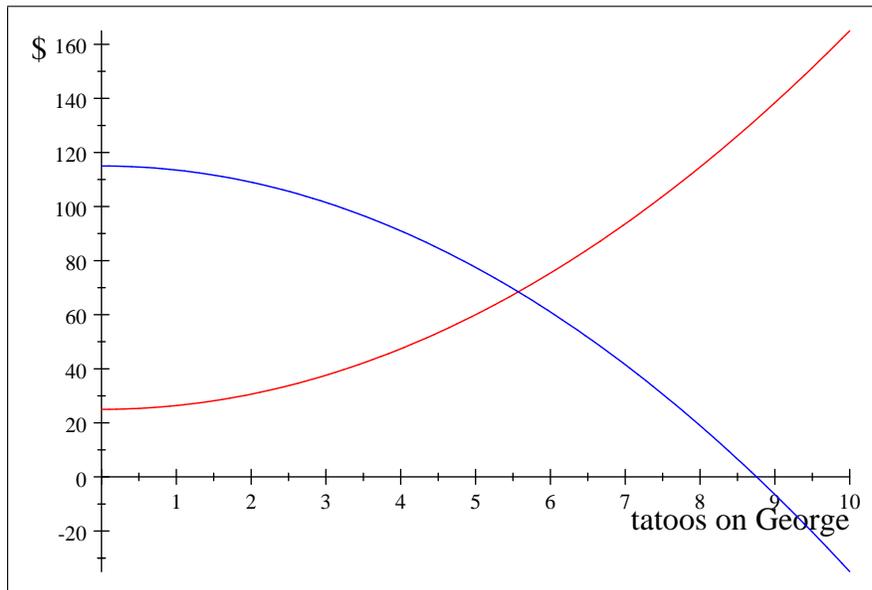
<sup>2</sup>Tattooing is painful but that is a cost internal to Geroge.

<sup>3</sup>Does it matter whether non-members see them? NO. This thought could produce a question for the final. In fact there was a question on this issue on an old final. Make sure to check it out.

**3.1.1 Draw a graph: number of tattoos on George on the horizontal axis, and \$ on vertical axis.**

label the curves  $MB_G(t)$  and  $MC_G(t)$

To draw the graphs, I will assume  $MC_G(t) = 25 + 1.4t^2$  and  $MB_G(t) = 115 - 1.5x^2$



George: marginal cost (red), marginal benefit to (blue)

George's wtp for his first tattoo is almost \$120.

What would explain the decreasing marginal benefit? He starts with the images he likes best? It is also difficult for George to see certain parts of his own body.

What is the efficient number of tattoos **from George's perspective** (his the number that maximizes his WB)?

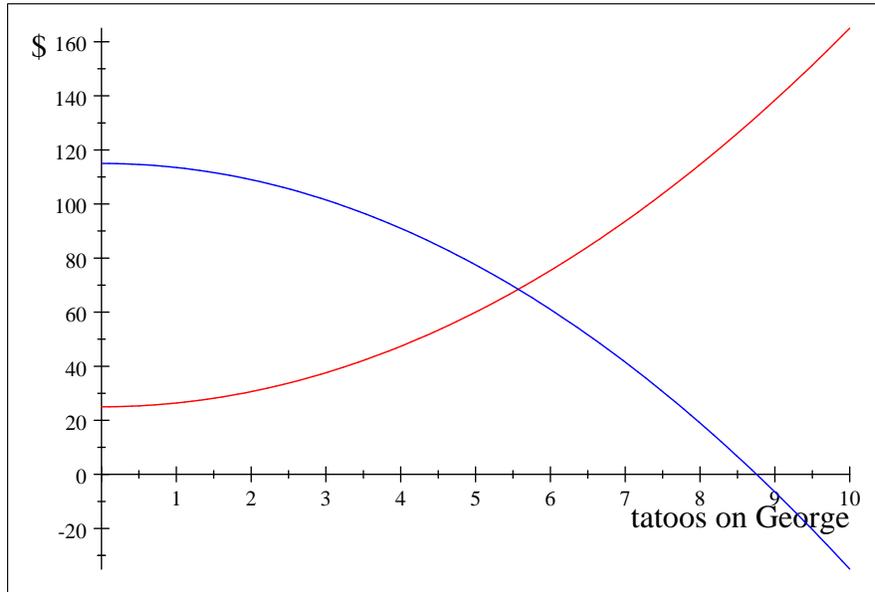
At equilibrium for George  $MB_G = MC_G$ , so  $MB_G(t) = 115 - 1.5x^2 = 25 + 1.4t^2$ , Solution 5.57 tattoos. George maximizes his utility by having 5.57 tattoos.

What is the efficient number of tattoos from society's perspective?

In this case  $MB_G = MB_s$  because only one member of society gets benefits from George's tattoos, George

In this case  $MC_G = MC_s$  because only one member of society incurs any costs in the production of George's tattoos, George

There are not external effects (side effects)



George and Society: marginal cost, marginal benefit

So, in this case, selfish George maximizing his own WB achieves the efficient number of tattoos, on George, from society's perspective. Freedom to choose is working - the wonders of the invisible hand in the production of tattoos.<sup>4</sup>

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<sup>4</sup>Did Adam Smith have tattoos, and did his mother see them?

### 3.2 Now George decides the world will be a better place if he wears as few clothes as possible - George has been reborn and forsaken clothes: everyone else now sees his tattoos, and everyone is not pleased.

Assume that George gets the same pleasure/utility from his tattoos whether he does or not wear cloths: he is not going naked so others can see his tattoos. He goes naked simply because it make him feel free, and refreshed by the cool breezes.

To keep things simple, let's also assume that society does not care about his nakedness per se.; we only care that we can see the tattoos.<sup>5</sup> This is an important simplification; it implies that his nakedness is not a negative external effect: no one cares except for the tattoos that they see.

Seeing George's tattoos imposes a cost on society, so

$$MC_S(t) > MC_G(t)$$

where the  $MC_S(t)$  is  $MC_G(t)$  plus the cost his last tattoo imposes on the other members of society.<sup>6</sup>

$$MC_S(t) = MC_G(t) + MC_O(t), \text{ where } O \text{ is for "other"}$$

Specifically, I will assume  $MC_S(t) = MC_G(t) + 10t$ : George's tattoos make other people worse off.

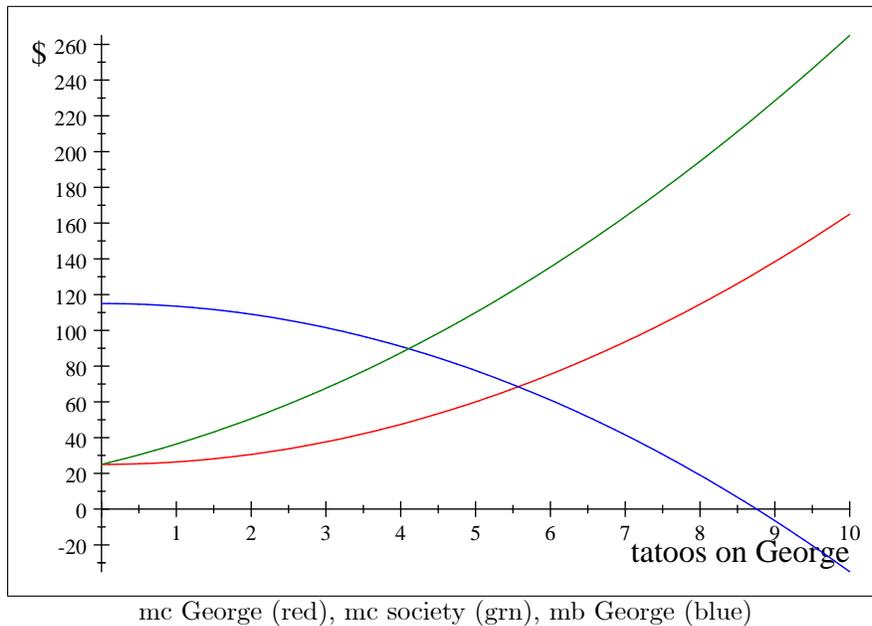
For example, his mother hates it when she sees them, and she hates seeing each additional tattoo, hates each one more than the previous one.<sup>7</sup>

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<sup>5</sup>See the related NYTimes reading on the web page, "The naked next door."

<sup>6</sup>Alternatively, I could have specified the problem as a wedge between  $MB_s(t)$  and  $MB_G(t)$

<sup>7</sup>E.g. She would pay \$10 to have his first tattoo disappear, \$20 to make his second tattoo disappear, etc.



In this case, the efficient number of tattoos **from George's perspective** is still 5.57 tattoos (the number he will get and show if society does not try to influence him). But the efficient number showing from society's perspective is where  $MC_s(t) = MB_s(t)$ , at that  $t$  where  $25 + 1.4t^2 + 10t = 115 - 1.5t^2$ . Solution is 4.11 tattoos on George. Efficiency dictates that he only show 4

Utility maximizing behavior on the part of George is good for George, but produces too many tattoos **showing** on George from Society's perspective : $5.57 - 4.11 = 1.46$  too many

George, when he decides how many tattoos to have, he does not appropriately take into account the negative external effects caused by him exposing his tattoos in public, so there is a negative-externality-type market failure. (I will formally define externalities in a page or two.)

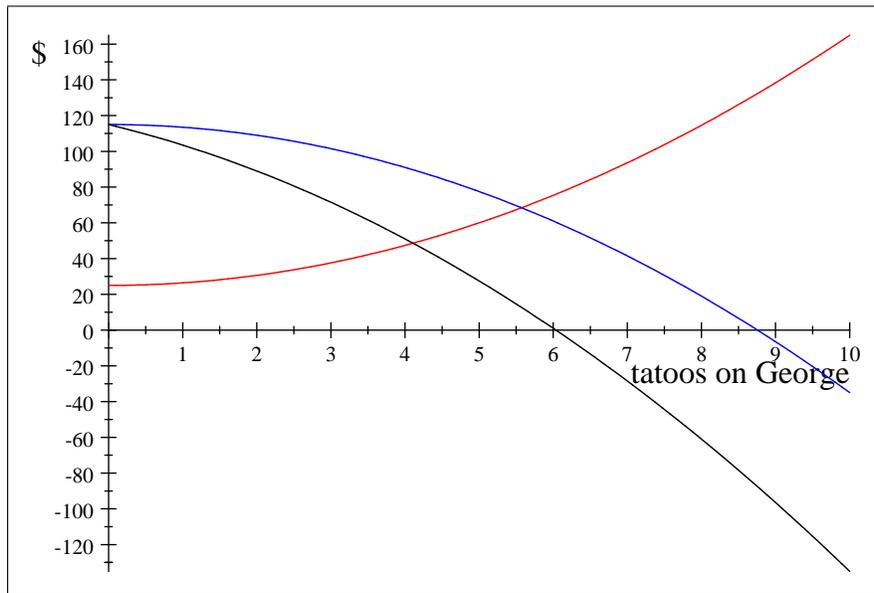
Make sure you understand and can explain why the efficient number of tattoos is not zero from society's perspective.<sup>8</sup>

We can think of George's tattoos as *visual pollution*: they are having a negative effect on others.

What are some other examples of visual pollution? Smog that reduces visibility, ugly things (buildings, the Blue Horse at DIA)

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<sup>8</sup>As noted in the last footnote, another way to recast the problem is that George's tattoos don't drive a wedge between marginal private cost and marginal social cost (as I did in the text) but they drive a wedge between marginal social benefit and marginal private benefit. One can express the problem either way, but not both at once. If one models the problem as a wedge between marginal social benefit and marginal private benefit. In which case,  $MB_S(t) < MC_G(t)$  where  $MB_S(t)$  is  $MB_G(t)$  minus the cost (negative benefit) his last tattoo imposes on the other members of society. The graph would look like



George and Society: marginal cost, marginal benefit

#### 4 **Inefficiency results because George does not take this negative effect into account when he decides how many tattoos to show in public.**

George does not get more pleasure from his tattoos by revealing them, nor does it bother him to reveal them, but he does get pleasure from them all of the time, at home, and in public.

His having an **inefficient number of tattoos** is caused by the combination of **two things**:

- George's actions (showing them) directly affect others (an external effect is occurring (a side effect))
- When George decides how many tattoos to show in public he is **not** compelled to take account of how he is affecting others

The first bullet simply says that one must have an external effect for it to be at an inefficient level.

Point two is why the external effect is at an inefficient level.

We have an negative externality market failure (too many tattoos are being shown from society's perspective).

Externality: An externality occurs when an external effect is being produced at an inefficient level.

Said another way: an externality occurs when one economic agent's actions **directly** affect another economic agent(s) (not through market prices) and the producer of the external effect does not have the correct incentive (not compelled) to fully take the influence of their actions into account.

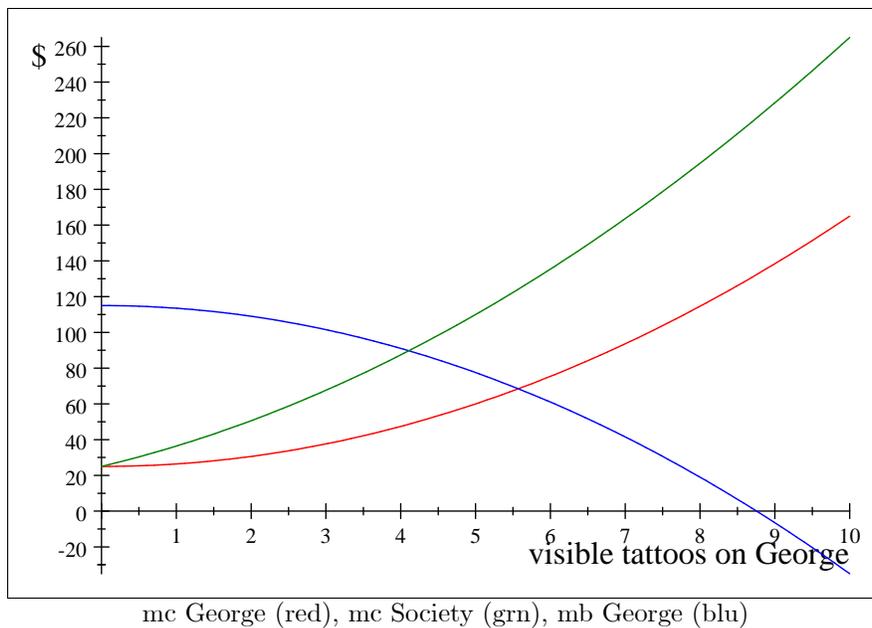
## 4.1 How to eliminate the inefficiency?

Think about the assumptions I made in setting up the problem. George's tattoos only cause a negative effect when they are seen in public, so the inefficiency is **not caused by the number of tattoos George has on his body, but rather the number showing in public.**

This is an important point; in this case governments wants to influence the number showing, not the number he has.

We simply want to force, compel, or entice George to have 4.11 tattoos showing, rather than 5.57 tattoos showing

Remember it is efficient for 4.11 to show, given that George enjoys walking around nude.



#### 4.1.1 There are numerous ways to do this:

- Pass a law saying that George must have 4.11 tattoos showing - sounds un-American (the government is restricting freedom and saying he has to have at least 4.11 tattoos, and show this many)
- —
- Pass a law saying that George cannot have more than 4.11 tattoos showing (and George then "chooses" to show 4.11)
- —
- Tax George for every tattoo showing, and set the tax so George "voluntarily chooses" to have 4.11 tattoos showing. This tax rate is the tax rate that eliminates the wedge between marginal private costs,  $MC_G(t)$ , and marginal social costs,  $MC_s(t)$ , of his exposed tattoos. It is a visual-pollution tax. Put simply, if George is paying the complete social costs of his actions, he will do the efficient thing from society's perspective.

Note that George can respond to the tax or regulation by either not getting an additional tattoo, or getting it and then covering part of his body when he goes out in public.

Regulating/taxing **exposed** tattoos is more direct than regulating/taxing tattoos because the former gives George an additional way to achieve the goal: get the tattoo, but not show it in public.<sup>9</sup>

#### Less practical ways to achieve 4.11 tattoos showing

- Pass a law clarifying property rights, a law that says that George cannot have tattoos showing unless everyone else is OK with it. In this case, society could potentially end up with 4.11 exposed tattoos on George because George has an incentive to bribe people so can go naked, or at least partially naked.<sup>10</sup>
- —
- Pass a law clarifying property rights, a law that says that George can have as many tattoos as he wants. In this case, society could potentially end up with 4.11 tattoos on George because other people have an incentive to bribe George to not get show his tattoos.

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<sup>9</sup>If George prefers to get more than 4.11 tattoos and then wear some cloth in public to only having 4.11 tattoos on his body, the regulation/tax on **exposed** tattoos is more efficient than a direct regulation/tax on tattoos.

<sup>10</sup>This will be tough if George lives in a big city and walks around a lot.

These last two ways of eliminating the inefficiency are *Coasian* solutions (mentioned in chapter 17): clearly define the property rights and let the players work out the trades that would get society to efficiency. Such a process **won't work** in this case because George's tattoos are affecting a lot of people.

That is, Coasian solutions are unlikely to work if there are a lot of players involved.<sup>11</sup>

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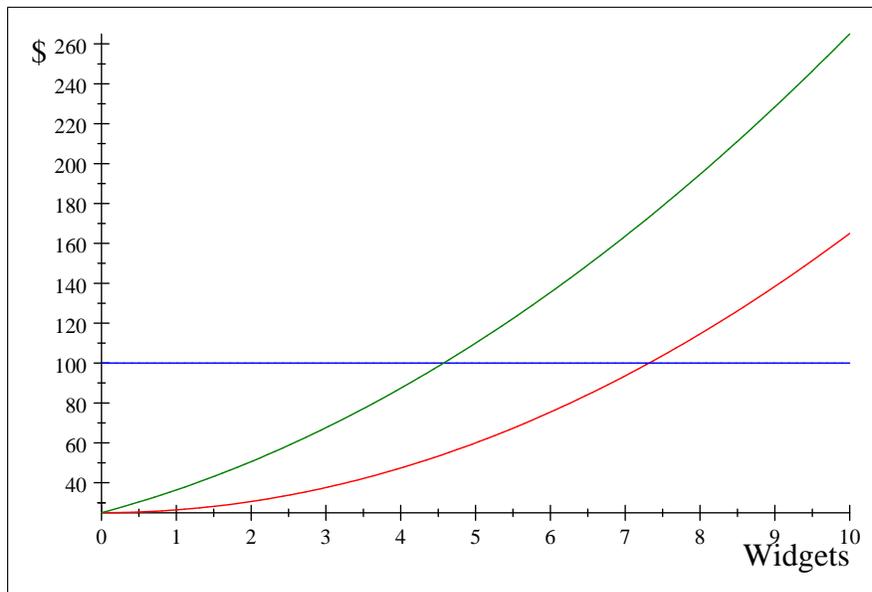
<sup>11</sup>For example, if George has the property rights, the rest of us have to bribe him to show fewer tattoos. The problem is that I would prefer you pay the bribe so that I get the benefit at zero cost to me, and you prefer that I pay the bribe and you get the benefit at zero cost. So, there won't be enough bribing.

## Let's relate all of the above to polluting by a firm

When a firm produces a product to sell there are by-products in the production process; there is waste. Water, air, and solid-waste pollution are examples. The firm needs to get rid of these pollutants, and, to maximize its profits, will get rid of them in the minimum-cost way from its perspective.

If the cost to the firm (private costs) of getting rid of these pollutants is less than the marginal cost to society (the social cost), there is a wedge between the private and marginal costs of polluting, and the firm will pollute an inefficient amount (too much) from society's perspective.

Consider a competitive firm selling widgets at  $p_w = \$100$ , where  $W_f$  is the number of widgets the firm produces. The distance between  $MC_F(W_F)$ , the marginal cost curve for the firm to produce widgets, and  $MC_S(W_F)$  is the gap between the firm's cost and society's cost to produce another widget.



Comp firm with gap between mcf cost (red) and mcs (grn),

The firm maximizes its profits by setting  $p_w = 100 = MC_F(W_F)$  and produces approximately 7 widgets.

But at 7 widgets, the cost to society of producing the 7<sup>th</sup> widget,  $MC_S(7)$ , is much greater than 100, the benefit society is getting from that widget.

That is, firm is producing too many widgets from society's perspective (too many of society's resources are being allocated to produce widgets: the cost to society of the last widget produced is higher than then benefit to society).

The efficient number of widgets for societys perspective is, in this example, 4.5 widgets.

One could get the firm to choose to produce 4.5 widgets, by taxing widget production such that  $p_w = 100 = MC_F(4.5) + tax_w$

That is, set the tax so that price equals marginal cost at 4.5 widgets, where marginal cost includes the widget tax.

This example makes the simplifying assumption that there is a fixed relationship between the amount of pollution produced and the amount of widgets produced (the only way to change the amount of pollution produced is to change the number of widgets produced. So, in this case one could tax (or regulate) either the production of pollution or the production of widgets. Things are more complicated if this simplifying assumed is dropped. In general, efficiency requires that we tax the pollution directly, not the output of the firm.<sup>12</sup>

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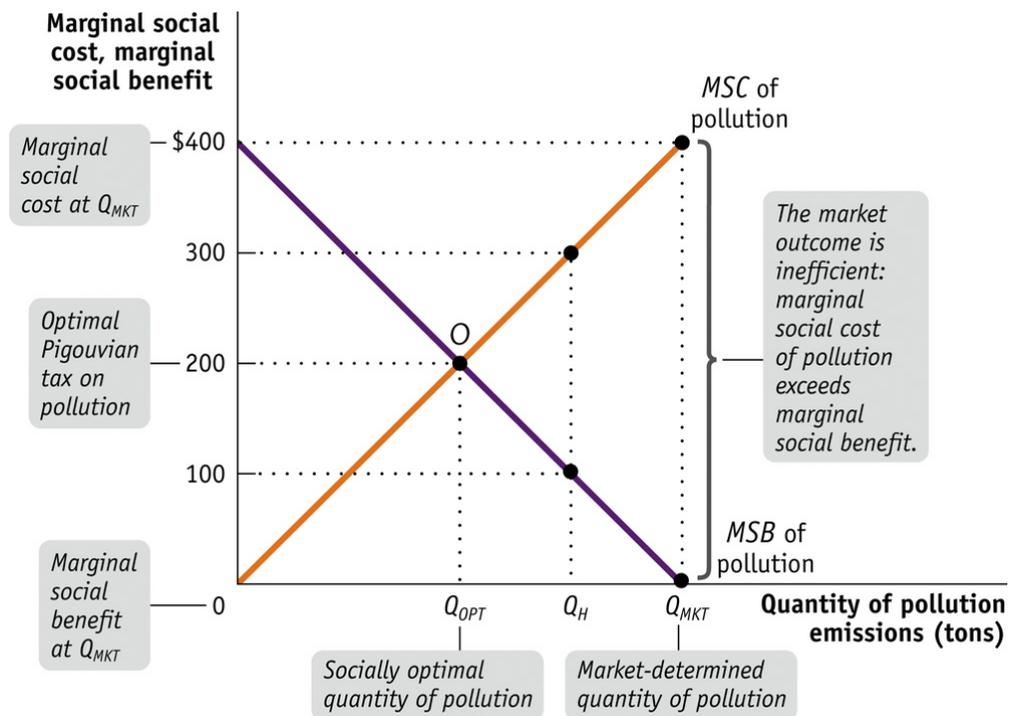
<sup>12</sup>In terms of George, we wanted to tax not his number of tattoos, but the number showing.

## 4.2 KW (Chapter 17) look at pollution external effects and externalities from an aggregate perspective

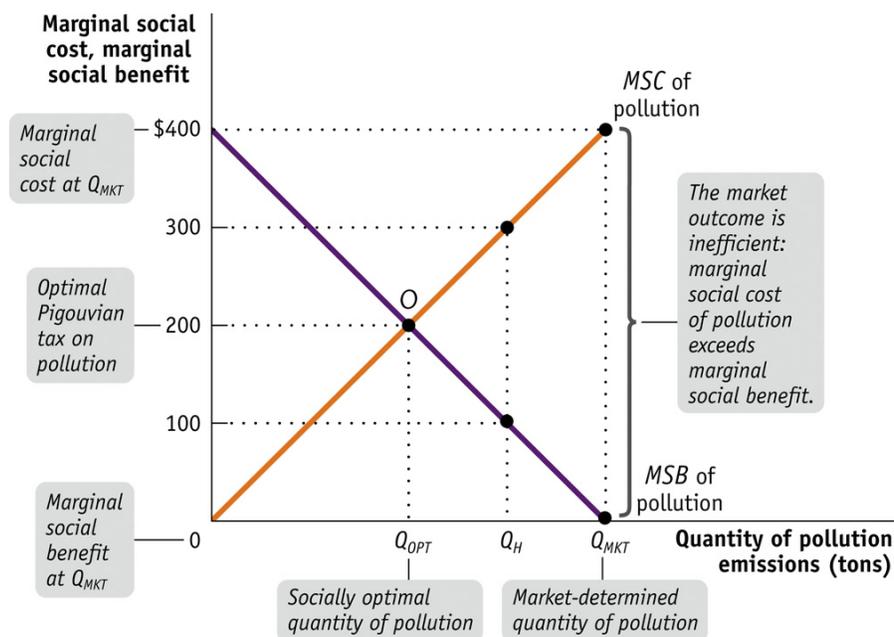
This is in contrast to how I presented it above. Above I first looked at a single person and then I looked at a single firm.

KW are looking at aggregate pollution from all sources. They are also expressing everything directly in terms of pollution rather than in terms of units of the product whose production produces the pollution (the widgets).

It is a different way of looking at the same issues.



### 4.3 I find the KW graph difficult to decipher. Let's try to explain it.



The commodity being graphed by KW is pollution, so they are graphing only the external effect (the side effect). The level of pollution in the atmosphere is increasing as one moves to the right.<sup>13</sup>

The downward-sloping purple line in the KW graph is what they call a *marginal cost curve for reducing pollution* (pollution abatement)—remember that pollution is reduced as we move to the left.<sup>14</sup>

Reading the purple line right to left (as one moves towards the axis, there is less and less pollution). What the purple line conveys is that there is a cost to reducing pollution, and the cost of reducing another unit starts low and increases as pollution is reduced more and more. That is, on the margin it costs

<sup>13</sup>Implicitly there is some good that is being produced and the pollution/emissions are a side effect of producing that good. In the tattoo example, George is producing tattoos on his body, and the external effect is others seeing them.

<sup>14</sup>This is a marginal cost curve, but not the marginal-cost curve for producing a product (widgets). Rather it is the cost of reducing the amount of pollution. Reducing the amount of pollution can be achieved by either reducing the amount produced of the good that had the pollution as its by-product or by reducing the amount of pollution associated with each unit of production.

little to reduce pollution by one unit starting from its current high level (at the very right), but that the cost of abating additional units increases as one abates more and more units of pollution (the curve rises as one moves from right to left).<sup>15</sup>

KW calls it a "marginal social benefit curve" because **increasing** pollution (left to right) releases resources from abating pollution so can be used to produce other things; so, in that sense there is a "benefit" to polluting—resources that could have been used to clean up pollution are available for other uses. (A benefit as in "we can have a bigger TV screen because we did not reduce pollution more."). The more pollution has already been reduced, the greater the "benefit" of not reducing it further.

Notice that it is expensive to completely abate all of one's pollution. (It is too expensive to eliminate all pollution.)<sup>16</sup>

The marginal social benefits of polluting curve (purple) shows that if no one regulated how much this firm or industry pollutes, the equilibrium level of pollution (the efficient level for the firm/industry) is  $Q_{mkt}$ : this is how much pollution the firms produce if no one penalizes them for polluting or restricts how much they can pollute.

**The upward-sloping red line** identifies the marginal damage to society at different levels of pollution. Damages are what people would pay not to incur the physical injuries that the pollution causes. Damages are in \$. The damages are caused by the injuries the pollution generates (e.g. health effects, damages to structures, loss of visibility, etc.)

The curve indicates that if there is no pollution, there are no damages to society from pollution, but that as pollution increases the marginal damage (cost) increases.<sup>17</sup>

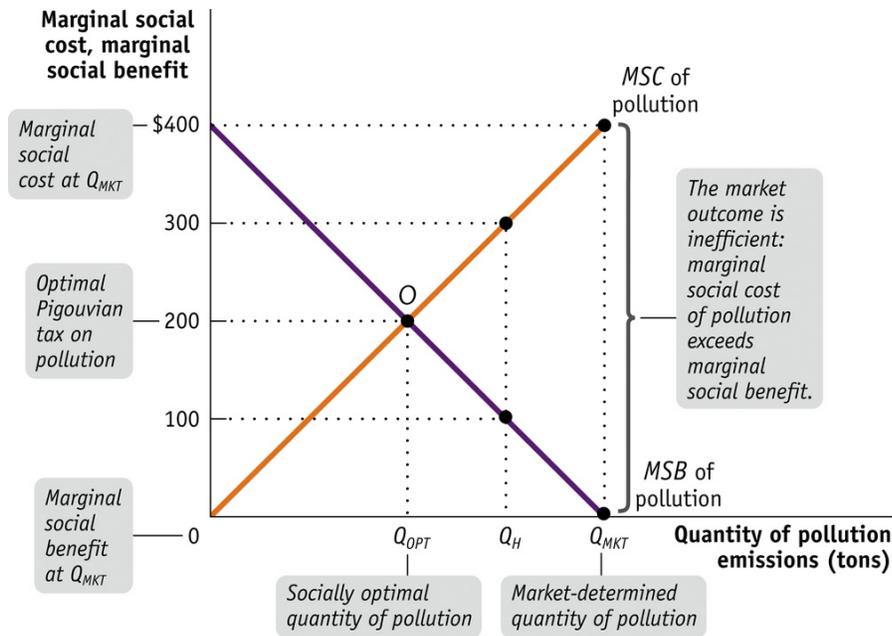
If the marginal damages from additional pollution are increasing the marginal-damage curve will slope upward, as it does in this example (the orange line).

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<sup>15</sup>If one reduces pollution, one typically starts by reducing where the cost is lowest. For example, if you were a company with many factories and were required to reduce total pollution by 100 units, you would minimize the cost of the reduction by reducing at the locations where it could be done the cheapest.

<sup>16</sup>So, the efficient amount of pollution is not zero.

<sup>17</sup>Total damages from pollution are increasing at an increasing rate.



What is the efficient amount of pollution from the perspective of the industries doing the polluting?  $Q_{mkt}$ .

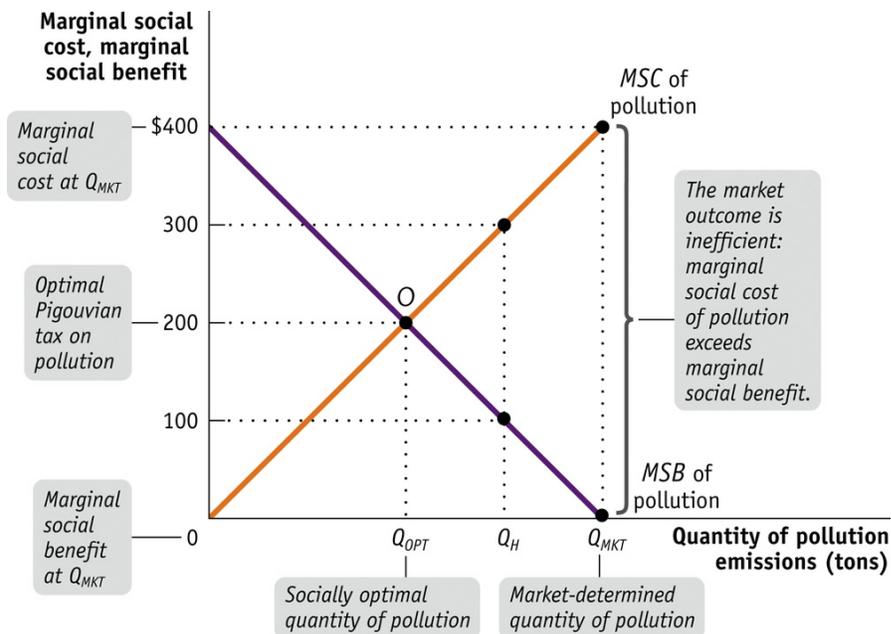
But from society's perspective it is  $Q_{opt}$ : the unregulated market is failing - there is more than the efficient amount of pollution.

If the level of pollution is greater than  $Q_{opt}$ , reducing pollution by a unit will decrease the damages from pollution (in \$) more than what it costs (in \$) to reduce pollution by that unit. (The marginal damages caused by the pollution are greater than the marginal value of the goods and services associated with that pollution). That is the marginal improvement in environmental quality is greater than the value of the goods and services that would be lost because resources are shifted from their production to pollution abatement.

Without any government interference, there is an externality-type market failure as there was with the unrelated production of widgets and Fred's tattoos.

#### 4.4 How might the government eliminate the inefficiency in the KW graphical example

- Impose a pollution tax of \$200 per unit of pollution (see the graph). A tax of this amount will induce the firm/industry to produce  $Q_{opt}$  of pollution.
- Each firm has a profit incentive to reduce pollution down from  $Q_{mkt}$  as long as their cost of abating the marginal unit is less than \$200 (as long as the purple line is below \$200.) Firm's will reduce pollution by another unit as long as the cost of doing so (the purple line) is less than the tax, which in this case is \$200.
- If all of the pollution is coming from one firm, the government could simply pass a law saying the firm cannot pollute more than  $Q_{opt}$
- Instead of a tax, the government could issue  $Q_{opt}$  pollution permits and let firms buy and sell them



## 5 When it comes to environmental resources (like the atmosphere), many environmental resources are not efficiently used from society's perspective.

There are lots of external effects that are currently produced at inefficient levels (externality-type market failures)

- Global warming. When you decide how much  $CO_2$  to emit, you do not take into account the cost you are imposing on future generations because of your emissions, because you are not required to.<sup>18</sup> None of us are required to. We drive, for example, the efficient amount from our own perspective, but we each emit too much  $CO_2$  from society's perspective.
- -
- Excess air pollution and excess congestion from driving. Correct congestion by charging tolls (e.g. by turning I-70 into a toll road?)
- -
- We over-use our public parks and natural areas (but not the privately-owned Disneyland) because users are not required to pay for the costs they impose on others, others today, and others in the future.
- -
- We are overfishing many of the world's fish stocks because of the gap between the private costs and social costs of harvesting fish.
- -
- Firms emit too much junk into our air and water because the marginal private cost of polluting is less than the social cost.
- -
- We pump water out of our aquifers too quickly from society's perspective because those who pump the water do not consider the opportunity cost of their pumping on other potential users of the water.

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<sup>18</sup>Note that I am assuming that  $CO_2$  emissions contribute to global warming, a position held by the vast majority of environmental scientists, but not by many Republican politicians.

To be clear: If the production of these things are efficiently taxed or regulated, external effects will remain but there will be no market failure (no inefficiency in their production).

For example, the efficient amount of pollution is not zero, and the efficient amount of congestion is not zero, neither is the efficient amount of drunk driving nor sexual harassment. For example, to eliminate sexual harassment we would like have to shoot most men.<sup>19</sup>

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<sup>19</sup>Note that recently the private cost of sexually harassing has increased (increased probability of losing one's job, etc.). This will cause potential harassers choose to harass less, so likely make the amount of harassing in the future closer to the efficient amount.

There is, potentially, a big role for the government(s) to play in the allocation of our scarce natural and environmental resources, to correct externality-type market failures.

**Why do many object to a bigger role for the government in the management of external effects?**

Possible reasonable reasons:

- They do not believe that there are significant external effects in production or consumption.
- -
- They believe Coasian-type bargaining, with no government action, will eliminate the inefficiencies associated with external effects.
- -
- Even if market failures exist, they believe that government intervention will just screw things up more from an efficiency perspective. (the government is stupid argument)
- -
- They do not accept efficiency as the goal. For example, some people believe freedom to do as one pleases is the primary objective: liberty is more important than increased efficiency.<sup>20</sup>

Note that the problem of the market not achieving efficiency is one of property-rights not being well specified. And, as we learned earlier, if a resource is scarce but does not have well-defined property rights, the market will not efficiently allocate it.

An issue with the liberty goal/objective (more liberty is always better than less) is that you being allowed to do whatever you want often results in you doing things that affect others negatively.

That is, giving you more freedom to do as you please often reduces the freedom of others. E.g. if you are free to run around shooting off guns in the pursuit of critters, my freedom to safely mountain bike in the woods is reduced.<sup>21</sup>

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<sup>20</sup>There is nothing illogical about rejecting efficiency as a primary goal. Many members of the Tea Party would be in this camp. So would many libertarians, whose goal is more liberty/freedom, not more efficiency.

<sup>21</sup>Note that the amount of gun ownership in the U.S. is not determined on efficiency grounds, it is determined by an amendment to the U.S. constitution. The writer of our Constitution and Bill of Rights were not efficiency-obsessed economists.