Grading instructions ECON 2920 Spring 2020

Question 1. 40% (each sub question counts equally – 20pts)
Assume that there are two firms in an economy, each emitting respectively a quantity Q_1 and Q_2 of a uniformly mixed pollutant (in tons). Firm 1's marginal abatement cost (hereafter *MAC*) is given by $MAC_1 = 60 - 6Q_1$ and firm 2's MAC is given by $MAC_2 = 80 - 4Q_2$. The marginal social costs of damages from emissions are $MC_{damages} = 2Q$.

a. Find society's aggregate marginal abatement cost function MAC_s.

We need to add the MACs of the two firms horizontally. To do that, we have to solve for Q_1 and Q_2 and add them to find Q_{tot}.

$Q_1 = 10 - 1/6 * MAC_1$

$Q_2 = 20 - 1/4 * MAC_2$

→ $Q_{tot} = Q_1 + Q_2 = 30 - 5/12 * MAC_s$

(We can add MAC_1 and MAC_2 because the construction of this curve assumes that both firms are operating at the same MAC.)

Then we solve again for MAC_s:

$MAC_s = 80 - 4*Q_{tot}$ $\quad if \ 0 \leq Q_{tot} \leq \tilde{Q}$

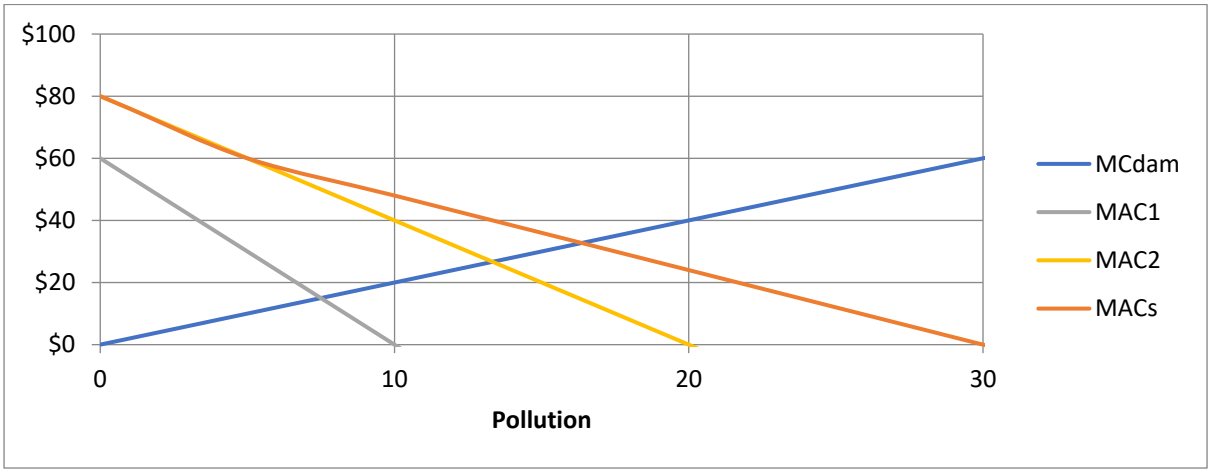
$= 72 - 12/5*Q_{tot}$ $\quad if \ Q_{tot} \geq \tilde{Q}$

To find $\tilde{Q}$ we solve the two portions of the MAC_s above for Q_{tot}:

$80 - 4*\tilde{Q} = 72 - 12/5*\tilde{Q}$

→ $\tilde{Q} = 5$

b. Plot MAC_1, MAC_2, MAC_s, and MC_{damage} together on a graph with pollution quantity on the horizontal axis.



c. What level of pollution will be generated without regulation? What is the efficient level of pollution?

The unregulated (business as usual) level of pollution occurs when each firm pollutes at the point where MAC is zero. So that means that firm 1 emits 10 tons and firm 2 emits 20 tons, giving 30 tons total.

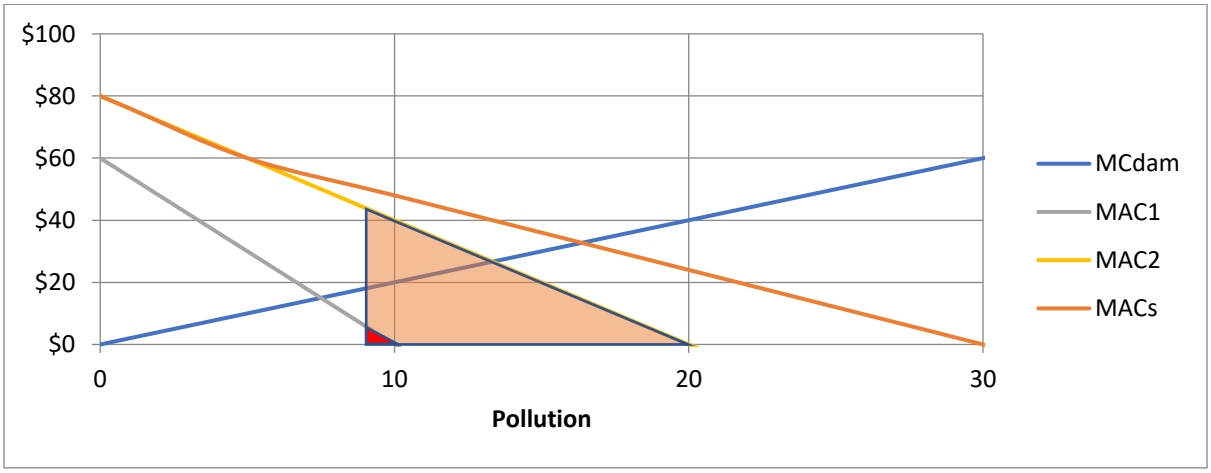
The efficient level of pollution Q^* occurs where *MCdamages* and MAC_s are equal. Be careful that MAC_s has two equations depending on the value of Q_{tot}. We can start with the case $Q^* \geq \tilde{Q}$ and verify ex post if this condition holds. This gives:

$72 - 12/5*Q^* = 2*Q^*$
→ $Q^* = 180/11$

We verify that $Q^* \geq \tilde{Q}$, thus we used the correct equation for MAC_s.

d. Assume the regulator wants to impose a uniform mandate across the two firms to achieve the efficient level of pollution Q^*. What would total abatement costs be? Draw them on a graph.

This would require each firm to emit Q^M equals to half of Q^*, i.e., 90/11 tons each. We can get total abatement costs for each firm by figuring out the area of the triangles between business as usual pollution and Q^M.



For firm 1, $MAC_1^M = 60 - 6*Q_1^M = 60 - 6*90/11 = \$120/11$,
With TAC_1^M area given by:
$TAC_1^M = ½\ (10-90/11)*\$120/11 = \$1260/121$.

For firm 2, $MAC_2^M = 80 - 4*Q_2^M = 80 - 4*90/11 = \$520/11$,
With TAC_2^M area given by:
$TAC_2^M = ½\ (20-90/11)*\$520/11 = \$33800/121$.
So total social abatement costs are $TAC_{tot}^M = TAC_1^M + TAC_2^M = \$35{,}060/121$.

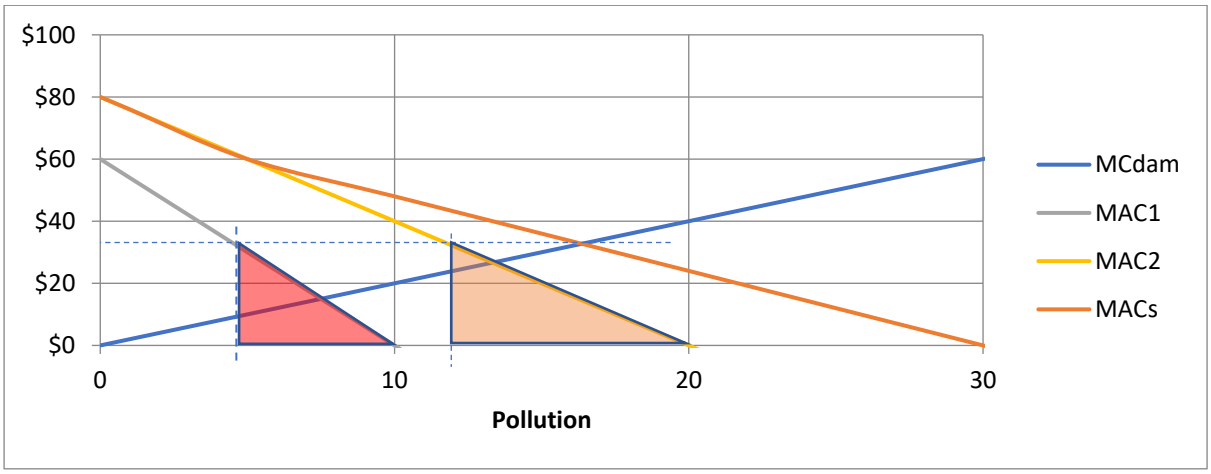
e. Assume the regulator wants to impose a cap-and-trade (CAT) between the firms to achieve the efficient level of pollution Q^*. Permits are distributed equally among the two firms and for free. What is the equilibrium permit price p^*? What would total abatement costs be under the CAT? Draw them on a graph. (<u>BONUS</u> (10pts): What are each firm

total abatement costs <u>net</u> of permit sales/purchases? Are the two firms better off with the CAT than with the uniform mandate. Explain.)

The permit price is determined by where MAC_s equals MCdamages, i.e., where total pollution is Q^*. We know that $Q^* \geq Q^{\sim}$ so we should use the second equation of the MAC_s. $p^* = 72 - 12/5*Q^* = \$360/11$. So the permit price should be about \$33 per ton. (Note, this is also the level of the Pigouvian tax.)

To find the total abatement cost, we first need to find how much each firm will choose to pollute under the CAT. We know they will equate their MAC to the permit price.
$Q_1^{CAT} = 10 - 1/6* p^* = 50/11$
$Q_2^{CAT} = 20 - 1/4* p^* = 130/11$
We further know (and verify here) that $MAC_1^{CAT} = MAC_1^{CAT} = p^*$:
Indeed, $MAC_1^{CAT} = 60 - 6* Q_1^{CAT} = 60 - 6*50/11 = \$360/11$,
With TAC_1^{CAT} area given by:
$TAC_1^{CAT} = ½ (10-50/11)*\$360/11 = \$10800/121$.

For firm 2, $MAC_2^{CAT} = 80 - 4*Q_2^{CAT} = 80 - 4*130/11 = \$360/11$,
With TAC_2^{CAT} area given by:
$TAC_2^{CAT} = ½ (20-130/11)*\$360/11 = \$16200/121$.
So total social abatement costs are $TAC_{tot}^{CAT} = TAC_1^{CAT} + TAC_2^{CAT} = \$27{,}000/121$.



To determine revenue /cost of permits sales / purchases, we need to determine how many permits each firm will buy/sale. Each firm receives 90/11 permits:
For firm 1: $90/11 - Q_1^{CAT} = 90/11 - 50/11 = 40/11$ → it sells permits
For firm 2: $90/11 - Q_2^{CAT} = 90/11 - 130/11 = -40/11$ → it buys permits
Permit price p^* is $\$360/11$, which gives permits revenue / expenses of
$40/11*\$360/11 = \$14400/121$.

TAC_1^{CAT} net of permit sales revenue is $TAC_1^{CAT} = \$10800/121 - \$14400/121 = -\$3600/121$.
TAC_2^{CAT} net of permit sales expenses is $TAC_2 = \$16200/121 + \$14400/121 = \$30600/121$.

The two firms are clearly better off with the CAT. Firm 1's total costs went down by *$1260/121-(-$3600/121)= $4860/121,* and firm 2's: *$33800/121-$30600/121=$3200/121.* Gains from permit trading makes both firms better off.

Question 2. 60% (each essay counts equally)
In this question, you'll give detailed but concise answers to the two essay prompts below. Your answers must be 500 words or less per essay prompt, and will often need to be nearly that to be complete. Although there is a word limit, your answers must have sufficient detail to fully answer the question and get full credit. Your responses should be well-written, carefully considered and refined. Please cite your sources if you use any (you need not cite lecture).

Each essay is graded out of 100 pts. Students lose 5pts on each essay for which they go over the 500-word limit by less than 50 words; 10 if they go over more than that.

> **Part 2.A. Describe a technology that increases energy efficiency. Why might or might not people voluntarily make the economically efficient choice to adopt or not adopt this technology? If they do not adopt it efficiently, suggest a policy that could rectify the problem. Finally, describe precisely how the rebound effect could occur in this situation.**

Home appliances are available on the market with a range of energy efficient technology. Examples include among others fridges, washing machines, and dryers. To fix ideas, let us focus on fridges.

To achieve economic efficiency, the energy-efficient fridges should be used when the total social costs of buying and operating them over their lifetimes is less than those of less-energy-efficient fridges. Efficient fridges have a larger up-front cost but save on electricity and are less expensive to run. So **if the difference in up-front costs is not too large, the monthly energy savings is sufficiently large, the social discount rate is not too large, and the fridges last long enough, it's efficient to use the energy-efficient; otherwise, the less-energy-efficient fridges are more economically efficient**.

People will make the economically efficient choice **if they understand this logic, know (and bear) all costs, and have a discount rate close to society's discount rate**. However, there are many situations when people may not make the economically efficient choice. For example, **if the owner purchases the appliances and the renter pays the electricity bill (principal-agent problem**), the owner might not choose the economically efficient option because she doesn't pay the energy use cost; this might cause her to buy less-energy-efficient fridges when energy efficient ones are more economically efficient. There may also be **externalities from energy use, e.g. greenhouse gas emissions and/or local pollutants, so some costs of regular operation are not borne by the users**; this would make the users inefficiently choose the less-energy-efficient fridge. People purchasing appliances **might also be more shortsighted than society and thus underweight the long-term costs and**

benefits, and thus choose the energy inefficient fridge too much. Similarly, they **might be credit constraint and not able to afford the higher upfront cost**. Finally, people might simply **not know the differences in energy consumption** (in particular if there is a principal-agent problem and they do not have an incentive to learn), and this could cause the incorrect choice in either direction. *(50pts)*

Minimum energy standards (**mandates**) could be used to force more energy efficient fridges into people's choice set. But requiring everyone to buy efficient fridges might be unpopular and unfair. We could make a policy of **spreading information about the more efficient fridges to make their long-term cost savings more salient**, or make recommendations and **appeal to social norms**. If some people simply do not know about efficient fridges, they might be amenable to a **behavioral "nudge"** suggesting that they do this or that others choose those fridges. *(20pts)*

The rebound effect could occur **if after purchasing an energy efficient fridge, one's energy expenditures go down, thereby generating an income effect, and a greater demand for energy use, which may somewhat offset (and in some cases even completely eliminate) the energy savings**. For example, people may leave the fridge door open more, or store more food and drinks in the fridge, or buy a bigger fridge than they would if the fridge was less energy efficient. *(30pts)*

Part 2.B. Consider the value of a statistical life (VSL). Describe specifically how you could use data to estimate VSL for a population in a hypothetical situation (i.e., give a concrete example of data and population; feel free to choose your own example or one that we covered in class). What assumptions must hold for this estimate to be correct? Give a specific example of how you might use this VSL estimate to inform policymaking in a domain other than that in which the VSL was estimated. Give at least two critiques of this use of VSL.

You could choose among one of the examples that we used in the seminars, including the use and maintenance of smoke alarms in homes to reduce mortality risk, or salary premiums to accept to work in sectors with higher mortality risk. Other examples include paying a premium for living in neighborhoods with lower mortality risk (e.g., lower crime or lower levels of pollution), purchasing travel/repatriation insurance when traveling to places with a higher mortality risk, purchasing cars with higher safety features, etc. The data you collect will be specific to a **particular population**, e.g., households in Oslo or across all Norway, students, retirees, engineers, or all working professionals.

For example, consider the population of households in Oslo. Some houses are safer than others. We must **identify a difference between houses that makes one house safer than another without otherwise changing the costs or benefits of living there**. We can use fire safety measures, since those cost money but we can assume that they don't affect everyday life in the house.

Assume that households typically have smoke detectors in their houses. We could find out the **reduction in risk of death from having smoke detectors** (*p* percentage points in a year) and the annual cost of owning and maintaining smoke detectors ($*X*). **Households' value for mortality risk reduction must be at least $*X* / *p*** since they're willing to give up this money to reduce the risk by that amount. In a competitive market for smoke detectors, the price would be competed to precisely the marginal value, so that the value for statistical life would be exactly $*X* / *p*. *(40pts)*

For this estimate to be correct, **households must know the risk reduction** and **the cost of the smoke detectors**. The alarms **must also not provide any additional costs** (e.g. beeping all night) **or benefits** (e.g. impressing friends by showing off the resident's safety-consciousness). The smoke detectors **must also be installed at households' choosing**; for example, if they were government mandated or the choice of a landlord, we probably couldn't learn about values for risk reduction from them. *(30pts)*

We might use this VSL estimate to **inform government's decisions regarding health policy**. Imagine that the government can pay $*Y* per year to ensure that a new disease doesn't get into Norway, and that this would reduce Norwegian household deaths by *q* (which, we hope, is a small number less than 1) per year. We would **recommend that the government undertakes this policy if *q* times the VSL was greater than $*Y***, because that would mean that the value of lives saved was worth the cost. *(10pts)*

This use of VSL could be considered problematic because **Oslo households may be different from the rest of Norwegian households**, e.g., they may earn more than households outside the capital. Since willingness to pay for safety is positively correlated with income, this means that because we're estimating this VSL for Oslo in particular, we will come up with a higher VSL than we would if we did this for another, more rural population. This would make us be more likely to recommend the policy fighting this new disease for all norwegians than we would be if we had used data for a poorer population, say, students.

Another critique is that **many of the assumptions under which the VSL is valid are unlikely to hold**. People **know very little about risks in their own lives, and they often overestimate the likelihood of low-probability events**. Therefore, they probably overestimate the likelihood that a fire will happen and thus they overestimate the benefit provided by the alarm. This would lead us to overestimate the VSL and make us too likely to recommend the health policy to fight the new disease. *(20pts)*