Lecture # 3 -- Modeling Pollution

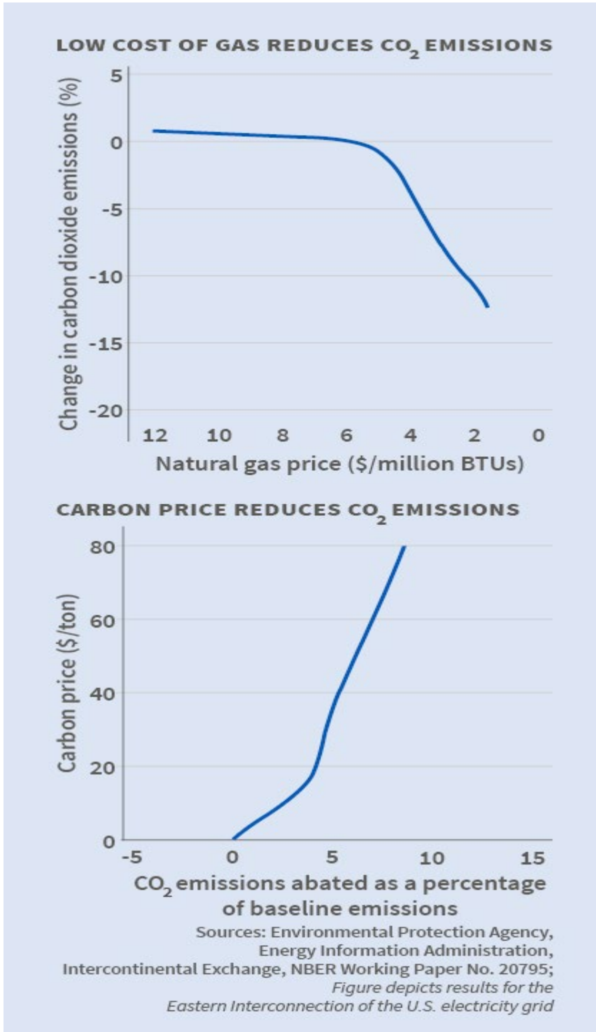
I. The Marginal Damage Function

- Our goal, of course, is to develop policies that lead to an optimal level of pollution.
    - Recall that the optimal level of pollution is not zero.
    - We need to consider the marginal costs and marginal benefits of pollution.
- The <u>marginal damage function</u> shows the damage done by an additional unit of pollution.
    - It is upward-sloping.
    - The slope normally gets steeper as emissions increase.
        - However, it may level off if there is a point where no more damage can be done (e.g. all the pond life is dead).
    - We can look at damage in one of two ways:
        - Emissions damage functions -- the marginal damage done by additional flows of emissions.
        - Ambient damage functions -- the marginal damage done by additional concentrations of pollution in the ambient environment.
    - The area under the marginal damage function shows the total damages.
- The type of pollutant affects the shape:
    - An example where it gets steep very suddenly is a *threshold effect*.
    - <u>Flow pollutant</u> – A pollutant that the environment can absorb. As a result, only the amount that occurs at a specific point in time matters (e.g. waste flowing into the river).
        - For a flow pollutant, the MDF does not change over time (if other things remain equal).
    - <u>Stock pollutant</u> – A pollutant that the environment cannot absorb. The level of the pollutant in the environment grows over time as the pollutant is accumulated.
        - Example: CO2 emissions (take 200 years to decay).
        - MDF is flat, and shifts up over time, because the stock keeps getting larger.
- Things that affect the position of the MDF include:
    - Population
    - Time of year

II. The Marginal Abatement Cost Curve

- Marginal abatement costs can be:
  - The costs of reducing pollution (e.g. costs of scrubbers, labor needed to maintain them, etc.).
  - The opportunity costs of lowering consumption or production.
- The marginal abatement cost curve is downward sloping, and equals zero at the level of unconstrained emissions.
  - Firms choose the easiest ways to reduce pollution first.
  - It may flatten if economies of scale are present.
- Things affecting the position of the MAC:
  - Technology
- Example of marginal abatement costs:
  - Recent work by Cullen and Mansur (NBER Working Paper #20795) uses changes in natural gas prices to estimate abatement costs for carbon dioxide
  - As gas prices fall, more utilities switch from coal to gas, lowering CO_2 emissions
  - They use data on prices, coal and gas consumption, and emissions to show how carbon emissions in the electric utility industry change as gas prices change.

- Results

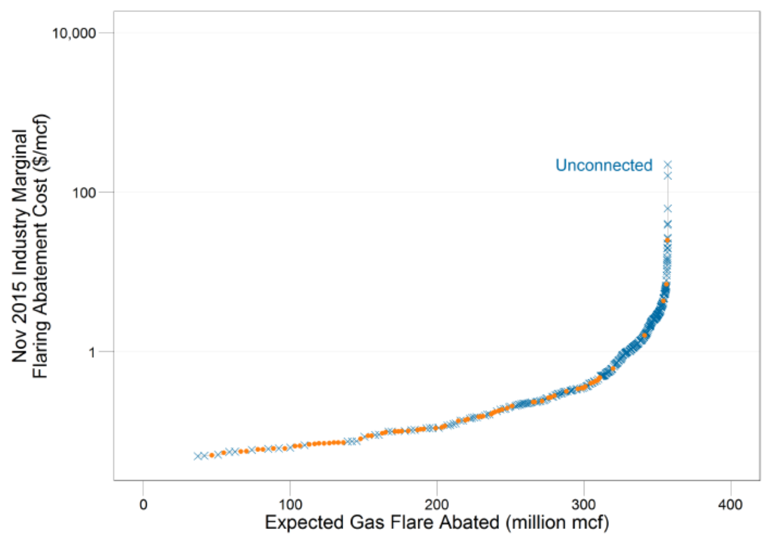


  - $10 per ton tax on CO2 would reduce emissions by 4%.
  - $60 per ton tax on CO2 would reduce emissions by 10%
  - Thus, it becomes increasingly more expensive to meet more stringent targets, resulting in a steep curve.

III. The Equimarginal Principle

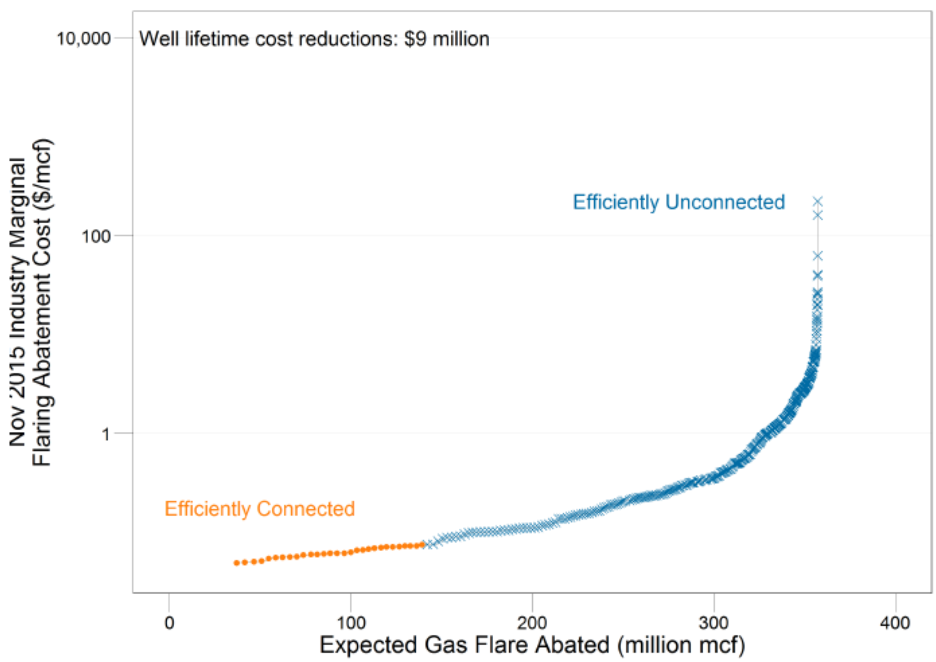
- To add together the MAC of individual firms, we use a horizontal summation. See Figure 5-5 in Field and the spreadsheet from today's class.
  - Note that this follows from what Field calls the equimarginal principle – to minimize total abatement costs, choose the lowest marginal abatement costs first, even if it means one firm does more than the other.
  - *Intuition*: we do the simplest (the cheapest) abatement first.
  - The *Economist* article "Giving up carbs" provides an example.
    - Aggregate marginal abatement costs for the whole economy are found by identifying the cheapest possible options first.
    - Note that these curves are uncertain, as the marginal abatement costs may vary in different places.
    - Also note how technologies interact. For example, by making electricity cleaner, adding renewable energy to the grid reduces the marginal abatement cost in the transportation sector, by reducing pollution from electricity used to power electric vehicles.
- The example below illustrates how violating the equimarginal principle increases costs. (source: Lade and Rudik, *Journal of Environmental Economics*, 2020)
  - Regulations in North Dakota address flaring of natural gas at oil wells
    - While oil is the main product in the Bakken shale formation, wells also produce natural gas.
    - If there is no infrastructure to capture the natural gas (e.g. pipelines), the natural gas is burned at the site (flared).
    - Natural gas pipeline infrastructure has not kept up with the expansion of oil wells, so much gas is flared.
    - In July 2014, the state passed a rule requiring each well operator capture 91% of gas produced by 2020.
  - Analysis
    - Since each firm must meet the same target, costs will be too high if marginal costs vary across firms.
    - Why might they vary?
      - Marginal abatement costs include on-site fixed costs and pipeline costs
      - Different wells produce different levels of natural gas
        - Thus, the cost per thousand cubic feet (mcf) of flaring reduced will depend both on the distance of the pipeline needed to connect to other infrastructure and the amount of natural gas produced at each well

- The figures below show the impact of inefficient regulation
  - Figure A is the observed MAC, with sites sorted from lowest to highest costs.
    - Orange dots represent sites connected to pipelines.
    - Blue X's are unconnected sites that continue to flare gas
    - Note that orange dots continue well up the MAC



(a) Observed Industry MAC Curve

- Figure B is the efficient MAC.
    - Here, only the lowest costs sites are connected. All orange comes first.

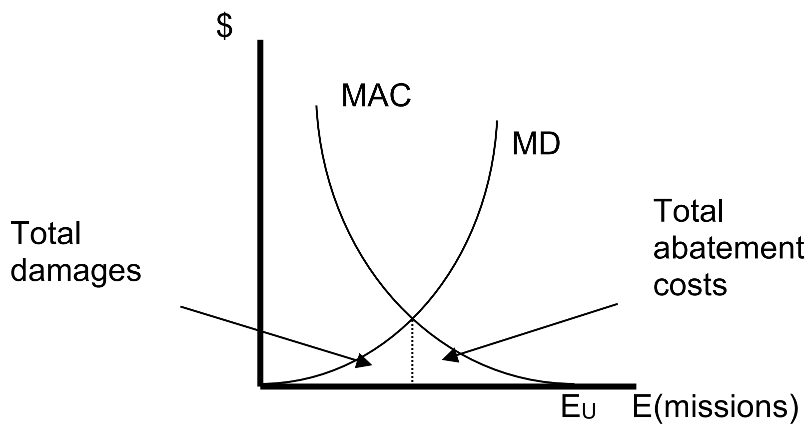


(b) Efficient Industry MAC Curve

- The authors' calculations show that if the efficient allocation were used, costs would fall by $96 million. This is a cost savings of 20%.

IV. The Efficient Level of Pollution

- The optimal level of pollution is where the MDF and the MAC curves intersect. Here, the additional benefits from pollution control are just equal to the additional costs.
  - In these examples, the marginal benefits are the marginal damages *avoided* by increased abatement.
  - Note that this is not where *total* benefits equal *total* costs. If that were the case, net benefits would be zero. Rather, we maximize *net* benefit by equating marginal benefits and marginal costs.



  - Some examples:
    1. How would the desired level of pollution control change if a new technology is discovered that improves the efficiency of scrubbers for power plants?
       - A new technology lowers the marginal abatement costs curve. Since abatement is cheaper, we should do more of it. The efficient level of pollution falls.
    2. How does the desired level of pollution change between summer and winter if the pollution leads to greater problems in the summer (e.g. ground level ozone)?
       - Here, the marginal damage function is higher in the summer than in the winter. As a result, we want less pollution (e.g. more abatement) in the summer.