The Pigouvian Prescription:

(Or, What are Externalities and How Do We Fix Them?)

Lecture 1

ARE 264

January 18, 2022

What are the goals of this course?

1. Make you familiar with core, **canonical ideas**
2. Make you familiar with **cutting edge** research and methods
3. Give you a starting place for writing your own **models**, particularly those that pair with empirical analysis
4. Discuss the **research process** (e.g., how to select projects and how to execute them)
5. Discuss the **profession** (e.g., publication process)
6. Provide **broad exposure**, but also great **depth**
7. Shamelessly plug my own research

- Sadly, I am unable to execute all of these things in 14 lectures. There will be trade offs.

What is the plan of this course?

- **Part I.** Twelve standard lectures
  - Covering **canonical** topics on efficiency and equity of environmental policy

- **Part II.** Two non-standard class sessions
  - One research workshop (writing and idea development)
  - One modeling workshop

- **Part III.** Your work
  - Daily **bullet points** on reading or prompt
  - Two **problem sets** combining standard math problems and "build your own" math problems
  - Two **research skills** assignments

Before today's material

- I would normally start with a recap of last lecture. This may feel repetitive, but repetition is what makes you remember things, and it offers an opportunity for follow up questions

- **Preparing for lecture 2:**

- Before next class, upload your "instrument choice" exercise on bCourses
- Starred reading is Goulder and Parry review article on instrument choice; lots of other articles

Outline

1. **What is an externality, and how does it cause market failure?**
    - An externality affects costs or utility directly, not through prices
2. **How do we fix problems caused by externalities?**
    - The Pigouvian prescription is to set a tax equal to marginal damages at the optimum, which will restore market efficiency
3. **Are Pigouvian taxes efficient?**
    - Transitions are not Pareto improvements, but outcomes under a Pigouvian tax are Pareto efficient if the tax is at the right level. But it is hard to get the right tax, so the primary appeal of market based instruments is that they require far less information to achieve cost effectiveness than do other interventions.

How would you answer today's key questions?

- Today's material is all familiar concepts. So, let's just hear your version of these things before seeing mine.
- What is an externality? How would you define the idea?
- What is a Pigouvian tax?
- Is a Pigouvian tax efficient? What do we mean by that exactly?

What is an externality?

The externality is in some ways a straightforward concept: yet, in others, it is extraordinarily elusive. We know how to take it into account in our analysis, and we are aware of its many implications, but, despite a number of illuminating attempts to define the notion, one is left with the feeling that we still have not captured all of its ramifications. [Baumol and Oates (p. 14)]

Are these externalities?

- Beekeeper and orchard
- Neighborhood gentrification
- Carbon emissions
- I join Facebook
- I buy the only copy of a Wu Tang album
- I buy the first N solar panels

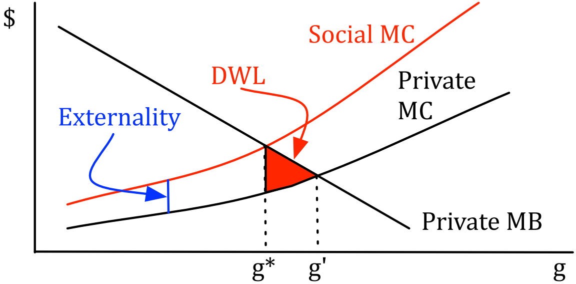
An externality is said to exist when the production or consumption of a good has a direct impact (i.e., not through prices) on consumption or production sets of another agent; that is, it alters their production or utility function.

- We are most interested in externalities as they rationalize policy intervention
- The existence of an uncorrected externality violates conditions of the First Welfare Theorem
- Market outcomes will not be Pareto efficient—there is a way to reorganize economic activity so as to make everyone better off

Outline

1. **What is an externality, and how does it cause market failure?**
    - An externality affects costs or utility directly, not through prices
2. **How do we fix problems caused by externalities?**
    - The Pigouvian prescription is to set a tax equal to marginal damages at the optimum, which will restore market efficiency
3. **Are Pigouvian taxes efficient?**
    - Transitions are not Pareto improvements, but outcomes under a Pigouvian tax are Pareto efficient if the tax is at the right level. But it is hard to get the right tax, so the primary appeal of market based instruments is that they require far less information to achieve cost effectiveness than do other interventions.

Undergrad version



- Consider: GHG from gasoline consumption
- According to this simple view, what is the optimal tax on gasoline?

The Pigouvian Prescription

Pigou's solution to the problems caused by an externality is to set a tax per unit of a good, with the tax set equal to the marginal externality at the optimal resource allocation

- A.C. Pigou (1912) posed a solution: "internalize the externality"
- This will restore conditions of First Welfare Economics and restore Pareto efficiency
- Importantly, this does not involve policy intervention in any other market

- I recommend that you think of this policy prescription as a **default**—it is a **null hypothesis** that you accept unless presented with compelling evidence
- We will discuss various cases where the Pigouvian Prescription needs to be modified, but I believe it is a useful starting place

- To illustrate the logic of the Pigouvian prescription, we will first present a very simple (undergrad style) model of an externality
- The model also gives us a chance to look at a more general algorithm that can be applied to a subset of problems
- The goal of this subsection is to illustrate some of practical challenges of implementing the Pigouvian prescription

Undergrad version

- Representative consumer with utility function $U(X_1, X_2)$
- X_1 is clean good
- X_2 is dirty good
- Externality linear in total dirty good consumption ϕX_2
- Exogenous income Y to be spent
- Producer prices fixed
- Planner can place taxes on X_1 and X_2; remitted by consumer
- Consumer faces prices $P_j = t_j + p_j$, where p_j is producer price
- Recycle revenue in lump sum transfer T
- Assume consumer "small"; does not recognize contribution to total dirty good consumption

Undergrad version

How do we write planner's problem?

$$\max_{X_1, X_2} SWF = U(X_1, X_2) - \phi X_2$$

$$\text{s.t. } p_1 X_1 + p_2 X_2 \leq Y$$

How do we find solution? (Planner chooses quantities)

$$\mathcal{L}_P = U(X_1, X_2) - \phi X_2 + \lambda(Y - p_1 X_1 - p_2 X_2)$$

$$\frac{\partial \mathcal{L}_P}{\partial X_1} = \frac{\partial U}{\partial X_1} - \lambda p_1 = 0$$

$$\frac{\partial \mathcal{L}_P}{\partial X_2} = \frac{\partial U}{\partial X_2} - \phi - \lambda p_2 = 0$$

Undergrad version

How do we write consumer's problem? (Consumer ignores externality; recognizes marginal tax rates; treats transfer T as exogenous)

$$\max_{X_1, X_2} U = U(X_1, X_2)$$
$$\text{s.t. } (p_1 + t_1)X_1 + (p_2 + t_2)X_2 \leq Y + T$$

How do we find solution?

$$\mathcal{L}_C = U(X_1, X_2) + \mu(Y + T - (p_1 + t_1)X_1 - (p_2 + t_2)X_2)$$

$$\frac{\partial \mathcal{L}_C}{\partial X_1} = \frac{\partial U}{\partial X_1} - \mu(p_1 + t_1) = 0$$
$$\frac{\partial \mathcal{L}_C}{\partial X_2} = \frac{\partial U}{\partial X_2} - \mu(p_2 + t_2) = 0$$

How do we get consumer's FOCs to match planner's FOCs? (If consumer's problem has same solution conditions as planner's, then consumer will choose first best allocation)

- Set $t_1 = 0$ and $t_2 = \phi/\mu$.
- Then, $\mathcal{L}_C = U(X_1, X_2) - \phi X_2 + \mu(Y - p_1 X_1 - p_2 X_2)$
- Consumer's problem now <u>same</u> as planner's (note $\mu = \lambda$, remember μ is a function, so we need μ at optimal allocation)
- FOCs will collapse to planner's

- First-best allocation is achievable (tax can achieve same outcome as planner who chooses quantities directly)
- There is <u>no tax</u> on the clean good

- One reason to show you this simple case is that it contains an algorithm for examining policy interventions that can fully restore the first-best allocation
  1. Derive the agents' choice conditions assuming a generic tax
  2. Derive the planner's choice conditions assuming omnipotence (can choose allocation directly)
  3. Find a tax rate that will make the agents' choice identical to the planner's

Observation 1: Willingness to pay

$

- Practically, we need to set the tax rate in <u>dollars</u>
- We usually think about “marginal damages” in dollars—i.e., the social cost of carbon, the VSL—which represent WTP for changes in externality

- But ϕ (the externality) is in utils
- Transforming ϕ by the marginal utility of income (for consumer μ or government λ) translates utils into dollars

Observation 2: Where are the elasticities?

- Observe that if we are in the first-best, the Pigouvian prescription **does not (directly) depend on elasticities** (on how agents respond to the tax)
  - This limits greatly the amount of information we need to determine the Pigouvian prescription
  - In contrast, the welfare gain created by a corrective tax <u>does</u> depend on market responsiveness

  - Nuance: when marginal damages are non-constant, would need estimate of elasticity to locate optimal quantity, which is needed to determine marginal damages at optimum

Observation 3: At the optimum...

- A lot of bodies are buried in the phrase "at the optimum"—optimum is where <u>all</u> choices are made efficiently
- Suppose population of an area depends on air quality. Marginal damages of air pollution depends on population—Pigouvian tax on emissions is marginal damages assuming population is at optimal size

Observation 3: At the optimum...

- Adaptation and defensive investments also must be at optimum
- If optimal defensive expenditures are much less than the observed, then marginal damages at optimum may be much higher than observed
- Deschenes, Greenstone and Shapiro (2017): defensive investments $\approx 1/3$ WTP estimates

Observation 4: Empirical objects of interest

- The major goal of this class is to foster your ability to think about the relationship between empirical analysis and theoretical models around the issue of externalities

- What does this discussion suggest are important things to estimate?
  - Marginal damages (to identify optimal policy)
  - Behavioral responses (to calculate welfare gains)
  - Defensive investments or abatement (including sorting)
  - Others?

Collective Think Aloud

- The main point of the preceding is that **even though the Pigouvian prescription is a clear idea in theory, in practice it is quite difficult to implement it because it is difficult to estimate damages at the optimum**

- Here is a second challenge/question:
  - Is the Pigouvian prescription *always* a good idea?
  - Why might we ever want to do something different? How many reasons can you come up with for modifying the prescription?

Outline

1. **What is an externality, and how does it cause market failure?**
   - An externality affects costs or utility directly, not through prices
2. **How do we fix problems caused by externalities?**
   - The Pigouvian prescription is to set a tax equal to marginal damages at the optimum, which will restore market efficiency
3. **Are Pigouvian taxes efficient?**
   - Transitions are not Pareto improvements, but outcomes under a Pigouvian tax are Pareto efficient if the tax is at the right level. But it is hard to get the right tax, so the primary appeal of market based instruments is that they require far less information to achieve cost effectiveness than do other interventions.

Is a Pigouvian tax efficient?

- Does implementing a Pigouvian tax create a Pareto improvement?
- No. But the resulting equilibrium is Pareto efficient, assuming that the externality was the only market failure, and the tax is set at exactly the right amount.
- But it is rare that we believe we know marginal externality at the optimum with any precision, as argued above
- So are Pigouvian taxes all that great?

- It is rare that we believe we know marginal externality at the optimum with any precision

- Thus two questions present themselves:
  1. If we are uncertain of the externality, might we prefer some other **type** of policy? (instrument choice)
  2. If we want to stick with a tax even though we are uncertain, what level of tax should we choose?

- A key observation related to the first question is that the **cost effectiveness** of a tax does not depend on having set it at the optimal level

A Cherry Tree: hard to get the ones at the top

- My favorite metaphor for cost effectiveness is low-hanging fruit
- A cost effective policy is one that harvests the low-hanging fruit
- Corrective taxes (or tradable permit systems) are cost-effective because they give everyone the same marginal incentive to reduce emissions across all relevant margins
- Slides present simple model to illustrate; will just hit high points in class; you will work through notation and extend on homework

Abatement cost model

- Heterogeneous producers: $j = 1, ..., J$
- Homogeneous good: x_j; $X \equiv \sum_{j=1}^{J} x_j$
- Production cost is $c_j(x_j)$, $c_j' > 0, c_j'' < 0$
- Representative consumer, utility: $U(X)$, $U' > 0$, $U'' \leq 0$
- Production creates emissions: $e_j(x_j)$, $e_j' > 0$, $e_j'' \leq 0$
- Firms can abate emissions a_j, at cost $g_j(a_j)$, $g_j' > 0$, $g_j'' < 0$
- Net emission from production is $e_j(x_j) - a_j$
- Total externality is $\phi \sum_{j=1}^{J}(e_j(x_j) - a_j)$

- **Given this setup, what characterizes optimal emissions/abatement, and how do we verify that the Pigouvian prescription induces that allocation?**

Points illustrated by model

- Efficient allocation features equimarginal principle
  - All methods of mitigation should have same marginal cost
  - All agents (firms) should have same marginal cost
- Any tax rate (not just the optimum) preserves equimarginal principle and is therefore cost effective

- Use same algorithm—show planner's FOC and demonstrate Pigouvian tax decentralizes same allocation

- The slides below (which we will skip over for class) attempt to use this model to illustrate these key points

To characterize the first best, solve planner's problem assuming planner maximizes total surplus and can choose all actions directly:

$$\max_{a_j, x_j} SWF \; = U(X) - \sum_{j=1}^{J} (c_j(x_j) + g_j(a_j)) - \phi \sum_{j=1}^{J} (e_j(x_j) - a_j)$$

FOCs imply that optimal allocation requires:

$$U' = c_j' + \phi e_j' \qquad \forall j$$
$$\phi = g_j' \qquad \forall j$$

Things to note about optimal allocation:

- Marginal cost of abatement (g_j') equal across firms = **equimarginal principle**
- Two margins for reducing pollution: scale (reduce X) and abatement (increase a_j)
  - These margins have equal marginal cost per unit reduced: $(U' - c_j')/e_j' = g_j'$

With no policy, price of good P will equal U' and firm FOC will be:

$$\begin{aligned} U' &= c_j' && \forall j \\ 0 &= g_j' && \forall j \end{aligned}$$

Optimum decentralized by Pigouvian tax; firm j's problem is:

$$\max_{a_j, x_j} \pi \; = P x_j - \left(c_j(x_j) + g_j(a_j)\right) - \tau \left(e_j(x_j) - a_j\right)$$

Firm's FOCs are:

$$\begin{aligned} P &= c_j' + \tau e_j' && \forall j \\ \tau &= g_j' && \forall j \end{aligned}$$

If $\tau = \phi$, then decentralized FOC match optimum

What if $\tau \neq \phi$? Firm FOC's still satisfy:

$$
\begin{aligned}
P &= c_j' + \tau e_j' & \forall j \\
\tau &= g_j' & \forall j
\end{aligned}
$$

- Marginal cost of abatement still equalized across all firms ($=\tau$)
- Marginal cost of emissions reduction equalized across margins (scale and abatement)

$\Rightarrow$ Such a tax is cost effective; for a given level of emissions reductions, it minimizes the cost to society

- This accords with equimarginal principle: efficiency requires that everyone's marginal cost of emissions reductions is equal

  (This is the same reason that markets are efficient in general)

To see why the tax is cost effective, consider the related problem of maximizing welfare subject to an emissions cap E:

$$\max_{a_j, x_j} SWF \;= U(X) - \sum_{j=1}^{J} (c_j(x_j) + g_j(a_j)) - \phi E$$

$$\text{s.t.} \;\; \sum_{j=1}^{J} (e_j(x_j) - a_j) \leq E$$

$$\mathcal{L} = U(X) - \sum_{j=1}^{J} (c_j(x_j) + g_j(a_j)) - \phi E - \lambda \left(-E + \sum_{j=1}^{J} (e_j(x_j) - a_j) \right)$$

$$\frac{\partial \mathcal{L}}{\partial x_j} = U' - c_j' - \lambda e_j' = 0$$

$$\frac{\partial \mathcal{L}}{\partial a_j} = -g_j' + \lambda = 0$$

FOC from tax match exactly the FOC from the cap problem whenever $\lambda = \tau$:

$$\begin{aligned} &\underline{\text{Tax}} \\ U' &= c_j' + \tau e_j' \\ \tau &= g_j' \end{aligned} \qquad\qquad \begin{aligned} &\underline{\text{Cap}} \\ U' &= c_j' + \lambda e_j' \\ \lambda &= g_j' \end{aligned}$$

- The cap problem is, by definition, cost effective—it maximizes welfare (minimizes cost) of achieving a specific emissions level (or emissions reduction)
- The tax produces the same allocation; ergo it is cost effective
- The key to cost effectiveness is satisfying equimarginal principle

Outline

1. **What is an externality, and how does it cause market failure?**
   - An externality affects costs or utility directly, not through prices
2. **How do we fix problems caused by externalities?**
   - The Pigouvian prescription is to set a tax equal to marginal damages at the optimum, which will restore market efficiency
3. **Are Pigouvian taxes efficient?**
   - Transitions are not Pareto improvements, but outcomes under a Pigouvian tax are Pareto efficient if the tax is at the right level. But it is hard to get the right tax, so the primary appeal of market based instruments is that they require far less information to achieve cost effectiveness than do other interventions.