Problem Set Two
ARE 264: Environmental and Resource Economics: Spring 2022

Problem 1: Co-benefits and pre-existing policies

You are analyzing a carbon pricing policy. The policy will generate cobenefits in the form of reduced local air pollution. (I.e., a carbon tax will reduce the use of coal in the electricity market, which will reduce particulate matter.)

You know that local air pollutants are also subject to regulation. (I.e., the Clean Air Act limits ambient levels of particulate matter.) But, you think the regulation of the local air pollutants is imperfect and likely does not yield the optimal amount of abatement. The question you wish to investigate is how the cobenefits should figure into the optimal price on carbon, taking into account that there are some policies in place.

Write down a mathematical model that allows you to characterize the optimal carbon tax that takes into account cobenefits and the existence of imperfect policies regulating air pollution. Solve the model and describe how the results answer the question.

There are myriad ways of complicating this problem and a variety of interesting related questions. Your goal is to shed light on the issue in the bold text. Make your modeling choices accordingly.

This question is motivated by one of the critiques that I suspect hampered Knittel and Sandler. In their paper, they calculated the optimal second-best gasoline tax as if it were an instrument acting on local air pollution. There are already regulations impacting the local air pollution per mile of vehicles. Their discussion of welfare did not take those policies into account, and this made it harder to judge the welfare conclusions.

Problem 2: Externalities with monopoly

In "External Diseconomies, Corrective Taxation, and Market Structure" James Buchanan critiqued Pigouvian taxation in the presence of market power, which he argued constituted the bulk of relevant congestion and pollution problems. He presents a graphical argument of a monopolist whose production produces a negative externality on a second competitive industry, summarized by this quote: "The monopolist simultaneously imposes two external diseconomies...He 'pollutes' and hence increases costs of firms in the damaged industry. Also, however, he holds down output and hence increases costs of his product to buyers. So long as the second diseconomy is more highly valued than the former [at the margin], any levy of a per unit tax on the monopolist's output will decrease total welfare." That is, he concluded that the use of any corrective tax would cause a net decrease in social welfare.

Also, just to capture the flavor of the discourse, the article begins thusly: "This note is presented as a contribution to the continuing dismantling of the Pigovian tradition in applied economics, defined here as the emphasis on internalizing externalities through the imposition of corrective taxes and subsidies."

The optimal policy solution when there are two market failures is to have two corrective policies. If one fixes the competition failure, then the Pigouvian prescription will apply unaltered. (This point is made in the summary article by Cropper and Oates, as well as the Baumol and Oates text.) But, let us suppose that we must take the competition failure as given. The point of this exercise is to get you to consider how the Pigouvian tax is (or is not) altered by the existence of market power.

For ease, let us consider a monopolist who produces a good in quantity q. Production of q generates a constantly increasing externality, with net effect on welfare of ϕq. Write the inverse demand curve of consumers as $p(q)$. The production cost to the monopolist is $c(q)$. The planner's only available policy tool is a per unit of output tax, t.

Derive the optimal (second-best) tax rate t, and thoroughly interpret its economic meaning.

The following might be useful:

- The planner's optimization problem can be written as $\max_t \int_0^q p(w)dw - c(q) - \phi q$.
- The monopolist's optimization problem can be written $\max_q \pi = p(q)q - c(q) - tq$.

Please note that the analysis here for a monopolist need not extend directly to alternative models of imperfect competition. Such models are highly varied and are capable of delivering different results about the implications for externalities.

Also note that in this model, the only way to abate is to reduce quantity. The lessons are different when there is an abatement action that can be taken independent of quantity. You can see a more general version in Barnett (AER 1980).

Problem 3: Optimal subsidy for two goods

This problem asks you to consider results related to a second-best problem in which a planner wants to subsidize two products, but faces a revenue constraint. When revenue is costly, the optimal subsidies will depend on the number of inframarginal agents because of a marginal cost of funds consideration. If you just want to kick start a market for a new good with a limited budget, the logic of the relative subsidies here should be a useful guide. (Note, however, that this objective is not particularly well grounded in theory, but it does seem of practical relevance.) This is a version of the problem that we considered in Workshop 1, and it relates to the theory in DeShazo, Sheldon and Carson's article.
Consider a setup with two goods, 1 and 2, consumed in quantities x_1 and x_2. Each is produced at constant marginal cost, denoted c_1 and c_2, by a competitive industry. The utility of a representative consumer is denoted $u(x_1) + v(x_2) + n$, where u and v are increasing and concave. n is a numeraire good. Consumer income Y is exogenous.

Consumption of the **sum** of x_1 and x_2 has a marginal external benefit ϕ. That is, a positive externality is equal to $\phi(x_1 + x_2)$. You could think of x_1 and x_2 as two versions of a new technology, where the externality is a function of the total market demand for either product; the externality coming from network externalities that aid diffusion.

A planner can subsidize the two goods with marginal price subsidies s_1 and s_2.

1. Derive expressions for the optimal subsidies s_1^* and s_2^*, assuming that revenue from the tax is simply recycled lump-sum to consumers.

2. The setup assumes additive separability of the utility from x_1 and x_2. Suppose instead that utility is described by $w(x_1, x_2) + n$, with $w'_1, w'_2 > 0, w''_1 < 0, w''_2 < 0$ and, importantly, $w''_{12} < 0$—that is, x_1 and x_2 are substitutes. Would this modification change your answer to part (a)? Explain how, or explain why not.

3. Assume separability again (utility is $u(x_1) + v(x_2) + n$). Suppose that the government faces a binding revenue constraint R that limits the total amount that can be spent on subsidies: $s_1x_1 + s_2x_2 \leq R$. Derive expressions for the optimal subsidies, $\tilde{s}_1$ and $\tilde{s}_2$, that illustrates the additivity property of Pigouvian taxation, where the optimal subsidy is marginal damages plus some other term.

   (Hint: for the parts below, it is most useful to write the answer in terms of price derivatives and quantities, x and $\partial x/\partial s$, rather than to substitute in using the definition of the elasticity. Also, if you have the correct answer, your answer in part (a) should be a special case that is easy to see.)

4. Suppose that x_1 and x_2 both have the same constant own-price demand derivative $\partial x_1/\partial s_1 = \partial x_2/\partial s_2$. If good one is sold in higher quantities (at the second-best policy; $\tilde{x}_1 > \tilde{x}_2$), what does this imply about the relative subsidy for good one compared to good two?

   Answer the question in two parts. First, apply intuition from class lectures. Second, use your result from part (c), in particular take the difference between $\tilde{s}_1 - \tilde{s}_2$ and examine the expression. Use the theoretical intuition to make sure that your algebra signs are correct. Briefly state the intuition and algebra separately in your write up.

5. Suppose instead that x_1 and x_2 have the same quantities sold (at the second-best policy $\tilde{x}_1 > \tilde{x}_2$), but now x_1 is more price responsive, so that $|\partial x_1/\partial s_1| > |\partial x_2/\partial s_2|$. What does this imply about the relative subsidy for good one compared to good two?

   Answer the question in two parts. First, apply intuition from class lectures. Second, use your result from part (c), in particular take the difference between $\tilde{s}_1 - \tilde{s}_2$ and examine the expression. Use the theoretical intuition to make sure that your algebra signs are correct. Briefly state the intuition and algebra separately in your write up.