

EC371 – Environmental Economics, Fall 2010, Boston University

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First Mid-term Exam

Wednesday, October 20, 2010

This is a 46-minute exam, but you will have 51 minutes to complete it. There is a total of 46 points allocated across two questions. In addition, there is one bonus question at the end. Use the number of points allocated to each part as a rough guide to how long to spend on that part. I recommend that you use one minute per point *at most* until you have gotten through each question, then use your extra time to revisit parts you may have missed the first time through and to check your work.

Please read the questions carefully and write your answers in the space provided. You can use the backs of the sheets for scrap paper, but to get full credit you must show all relevant work in the space provided.

Please follow my instructions at all times.

Concentrate and think carefully, but try to relax too!

Student Number: SOLUTIONS

(Please do not include your name.)

1. [22 points total, 3 parts] A large corporation is considering building a desalination plant in a developing country. Once operating, the plant would take water in from the ocean and convert it to clean water for household and industrial use. This company requires the use of a 4% discount rate, which accurately reflects its outside investment opportunities. You are hired as a cost-benefit analyst to evaluate the following two proposals. You can use formulas from class without deriving them for this question, but be careful to write them down clearly and show your calculations.

a) [10 points] The first option that the company is considering is to build the plant without any support from the target country. The up-front costs (borne in year 0) are estimated to be \$3 billion. The revenues from selling the clean water (to be received annually starting in year one) are uncertain because they will depend on the degree of drought that the target country will suffer in a given year. The company estimates that there is a 25% chance that revenues will be \$400 million in a given year, a 35% chance they will be \$500 million and a 40% chance they will be \$600 million. The annual electricity costs for running the plant will be \$347 million. The company would plan to operate the plant for years 1 through 20, then to sell the plant at the beginning of year 21 for an anticipated price of \$1 billion. Calculate the net present value of this project.

answer:

$$\delta = 1/1.04 = 0.9615$$

$$EV(\text{revenue}) = 0.25*400 + 0.35*500 + 0.4*600 = 515 \text{ [4 points]}$$

$$NPV_1 = -C_0 + \frac{\delta - \delta^{21}}{1 - \delta} NB_{1-20} + \delta^{21} B_{21}$$

$$= -3000 + 13.5903*(515 - 347) + 0.4388*1000 \text{ [5 points]}$$

$$= -\$278.03. \text{ [1 point]}$$

b) [6 points] The alternative option that the company is considering is to enter a public-private partnership with the government of the target country. Under this partnership, the company would only have to pay \$1 billion of the estimated start-up costs in year 0. The government would buy the clean water from the company for a fixed amount of \$400 million annually, and grant the company a slightly discounted annual electricity cost of \$312 million. For its part, the company would be expected to turn the plant over to the government at the beginning of year 21 without further compensation. Calculate the net present value of this option.

answer:

$$NPV_2 = -C_0 + \frac{\delta - \delta^{21}}{1 - \delta} NB_{1-20}$$

$$= -1000 + 13.5903*(400 - 312) \text{ [5 points]}$$

$$= \$195.95. \text{ [1 point]}$$

c) [6 points] Does the partnership look attractive relative to the first option? Does it look attractive relative to not building the plant altogether? Explain. Without doing any further calculations, discuss briefly how your responses in this part might change if the company gained access to higher-yield outside investment opportunities and changed its required discount rate accordingly.

answer:

$NPV_2 > NPV_1$ so the partnership is more attractive than doing it alone.

$NPV_2 > 0$, so the partnership is more attractive than not building at all (where not building means investing in an outside option instead, which would have an NPV of zero because we have used a discount rate that appropriately accounts for the corporation's opportunity cost of funds).

(It would be fine to say that some sensitivity analysis would be desirable *in addition to* making statements like these, but you will only receive partial credit if your response focused exclusively on sensitivity and uncertainty. I would argue that these NPV estimates are “substantially” negative and positive respectively, and that their sign does not appear, on the surface, to be too sensitive to small changes in assumptions.)

[3 points]

If the opportunity cost of funds increases (i.e. the outside option becomes more valuable, or in other words, has a higher yield or rate of return), a higher discount rate should be used to reflect this. Using a *higher* discount rate means that *less* value is placed on benefits/costs received/borne in the future, so projects with benefits in the future will tend to look less attractive with a higher discount rate.

[2 points]

Both options involve start-up costs followed by positive net benefits in the future, but this is true for the first option to a slightly greater degree because of the selling price. The first option is not going to look any better with a higher discount rate: its NPV is negative with a 4% discount rate so will definitely be negative with a higher one. The second option will look worse (its NPV will fall) as the discount rate increases, but we can't know, without checking, how far it would have to increase for the NPV to become negative.

In short, a higher discount rate should not affect the fact that the second option is preferred to the first, but a high enough discount rate could push us to prefer the outside investment (with the correspondingly high interest rate) over the second option.

[1 point]

2. [24 points total, 3 parts] Suppose that a wood pulp mill is situated on a bank of the Charles River. The private marginal cost (MC) of producing wood pulp, in \$ per ton, is given by $MC = 36Q$ where Q is tons of wood pulp produced. In addition to the private marginal cost, an external marginal damage (MD) is incurred due to harm from pollutant flows into the river, valued at $MD = 21Q$, in \$ per ton. This external cost is borne by consumers collectively. Even though we are concerned with a single mill, it behaves perfectly competitively. The aggregate inverse demand curve for wood pulp, in \$ per ton, representing both the private and social marginal benefits (MB) to consumers, is given by $MB = 2520 - 27Q$.

a) [12 points] Find the market equilibrium quantity of wood pulp. Find the socially efficient quantity of wood pulp. Calculate the Pigouvian per-unit tax to be collected from the mill that would achieve the socially efficient output level.

answer:

$$\begin{aligned} \text{market: } MB &= MC \\ 2520 - 27Q &= 36Q \\ 63Q &= 2520 \\ Q^* &= 2520/63 = 40. \text{ [4 points]} \end{aligned}$$

$$\begin{aligned} \text{efficient: } MB &= MSC \\ MB &= MC + MD \\ 2520 - 27Q &= 36Q + 21Q \\ 84Q &= 2520 \\ Q^{**} &= 2520/84 = 30. \text{ [4 points]} \end{aligned}$$

$$\begin{aligned} \text{Pigouvian tax: } t^{**} &= MSC(Q^{**}) - MC(Q^{**}) \\ &= (57 \times Q^{**}) - (36 \times Q^{**}) \\ &= (57 - 36) \times Q^{**} \\ &= 21 \times Q^{**} \text{ (which, of course, is equivalent to } MD(Q^{**})) \\ &= 21 \times 30 \\ &= \$630. \text{ [4 points]} \end{aligned}$$

b) [6 points] Now suppose that, as an alternative to a tax, independent analysts have suggested that a set of technologies should be installed to clean effluent from the river. Specifically, if this set of technologies were installed, the marginal damage from wood pulp production would become $MD^N = 9Q$, while there would be no effect on the benefits from consumption of wood pulp or on the private costs of producing it. If this set of technologies were installed and no other policy were in place, what would be the market equilibrium quantity of wood pulp, and what would be the associated efficiency loss relative to the socially efficient quantity? (Ignore any costs associated with installing the technologies.)

answer:

This is an example of a policy that does not attempt to achieve efficiency, but rather attempts to reduce the environmental damage that is associated with the market (or any other) quantity of output. With lower marginal damages, the efficient quantity will be closer to the market equilibrium quantity, but the market equilibrium quantity will still be too high.

What is the market equilibrium quantity? Since nothing has changed with private benefits and costs, unfettered private decisions will still lead to $Q^* = 40$, as in the previous part. [1 point]

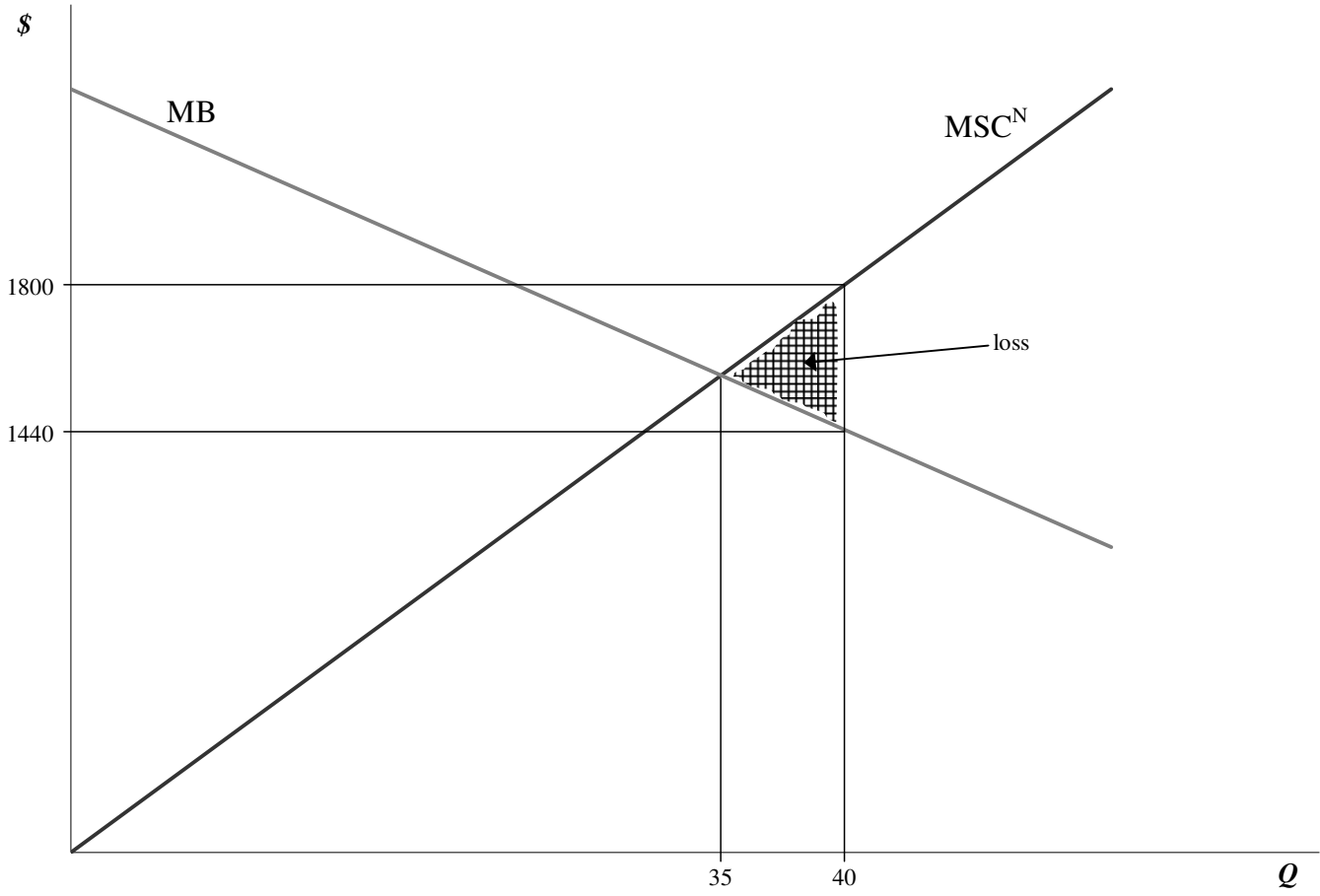
What is the socially efficient quantity? This has changed, and to find the new one, we will need to form $MSC^N = MC + MD^N = 36Q + 9Q = 45Q$ and equate it with MB:

$$\begin{aligned} 2520 - 27Q &= 45Q \\ 72Q &= 2520 \\ Q^{***} &= 2520/72 = 35. \end{aligned} \text{ [2 points]}$$

This is higher than before, which should make sense, because the external cost that is ignored by private actors is now smaller, and hence there is less of a divergence between private and social costs.

Since actual output (40) will be higher than what is efficient, there will be an efficiency loss equal to the total social costs net of total benefits associated with the excess units. On a graph, this will be given by the area of a triangle with a “height” of the quantity difference and “base” given by the difference between the height of MSC^N and the height of MB at the higher quantity:

$$\begin{aligned} \text{loss} &= [MSC^N(40) - MB(40)] * [40 - 35] / 2 \\ &= [(45 * 40) - (2520 - 27 * 40)] * 5 / 2 \\ &= [1800 - 1440] * 5 / 2 \\ &= 180 * 5 \\ &= \$900. \end{aligned} \text{ [3 points]}$$



A graph was not necessary to get full credit, but it is possible to get partial credit for identifying the loss accurately on a graph even if you were not successful in calculating the dollar value.

c) [6 points] Consider two politicians running for governor. Politician A states that, if elected, he will implement the Pigouvian tax on the mill at the rate you found in the first part. Further, he will take half of the tax revenue raised and reimburse it to consumers as a lump-sum payment. (The other half of the revenue must be remitted to an outside body.) Politician B states that, if elected, she will have the set of technologies discussed in the second part installed. (The cost of installation will be covered by an outside body.) Would consumers, as a collective group, tend to vote for Politician A or Politician B (assuming both can be equally trusted to follow through on their campaign promises)? (Well-argued written responses will receive partial credit, but for full credit you should support your argument with appropriate calculations.)

answer:

The tax policy, by design, will achieve efficiency, in the sense that it ensures that total net social benefits are maximized in the present “state of the world”. The technology policy, on the other hand, will not achieve efficiency (as demonstrated in the previous part), but it does change the “state of the world” in a positive way: by reducing the environmental damage that is caused by a given amount of production, *potential* total net social benefits increase. The question from the overall perspective of social efficiency (if restricted just to the two alternatives) is whether it would be more desirable to be efficient in one state of the world or suffer some degree of inefficiency in a “better” state of the world.

However, this question doesn’t ask about the overall efficiency perspective, but rather about the perspective of consumers only. My motivation for this is to get you considering how average voters probably don’t think much, if at all, about this rather arcane concept of economic efficiency when making their electoral choices, and how we therefore probably need to go well beyond these simple partial equilibrium models to get better insights on what types of policies get votes. That said, there is some relevant information we can try to get out of even such a simplified example as this one. What do consumers in the model care about? They care about consuming wood pulp in whatever form, for one thing, and when they value a given unit of it more than the price they have to pay to get it, they get some consumer surplus. They also care about pollution: there is an analogy between consumer surplus for a good and total damages from a “bad” because, as was mentioned in class, MD could be derived theoretically from consumer preferences and the subsequent vertical (because of non-rivalry) summation across individuals of marginal willingnesses to pay for a clean river (and could be estimated empirically using the valuation techniques discussed during the cost-benefit analysis unit). Finally, they certainly wouldn’t complain if a tax rebate check fell out of the sky and into their pockets. How would each politician’s plans affect these three factors?

Politician A

$$CS_A = (2520 - 1710) * 30 / 2 = \$12,150.$$

$$TD_A = 630 * 30 / 2 = \$9,450.$$

tax revenue = $30 \times 630 = \$18,900$;
consumers' share = $18900/2 = \$9,450$.

Net consumer benefits under A = $CS_A - TD_A + \text{share of revenue} = 12150 - 9450 + 9450 = \$12,150$.

Politician B

$CS_B = (2520 - 1440) \times 40/2 = \$21,600$.

$TD_B = 360 \times 40/2 = \$7,200$.

tax revenue = 0.

Net consumer benefits under B = $CS_B - TD_B + \text{share of revenue} = 21600 - 7200 + 0 = \$14,400$.

Summing Up

Based solely on these things that we can measure within the model, it looks like consumers would prefer Politician B's plan. Under it, they get to buy more wood pulp at a lower price, and the effluent-cleaning technology is so good that, even though there is more production, the total pollution damage from that production is lower as well.

Are there things outside the model, or at least beyond the information we have, that might change this? Still staying in the realm of efficiency, remember that there are other markets that these same consumers participate in that we haven't considered. Some consumers might be employed by the mill, and some may also buy products that use wood pulp as an intermediate input in production; the higher quantity and lower price of wood pulp under B's plan is likely extra good news for consumers on that front. On the other hand, industries producing close substitutes to wood pulp and associated products would be at a competitive disadvantage under B's plan, to the potential detriment of consumers of those products. Also, not much information has been given about the technology, and regulators themselves may not have full information about it. It's possible that the effluent cleaning comes at the expense of some geological damage to the river bed, or interferes with some downstream floodplain or ecosystem services that the river currently provides and consumers derive some benefit from. Under these last two scenarios, the balance might swing in favor of A's plan. There might be further general equilibrium and longer-term effects associated with either plan that are quite salient, such as the tax giving the mill private incentives to invest in clean technology on its own, which is something we'll discuss more in the context of air pollution regulation. Finally, the aggregate demand curve could mask a lot of heterogeneity across consumers, and it's therefore possible that the overall direct and indirect consumer benefits make one plan look favorable, while the other plan might actually be the one that makes a majority of individual consumers better off.

We can also leave efficiency aside altogether. Some people may be philosophically opposed to the technology plan on the grounds that it doesn't "make polluters pay" and could be interpreted as somehow condoning "bad behavior". Such people could be tempted to vote for A on that basis, even though the economic function of a Pigouvian tax is simply to align private incentives with what is socially desirable, *not* to impose a punishment for some perceived moral wrongdoing. (It's also been pointed out – and is underlined in the bonus question – that, even though a Pigouvian tax is typically assessed on the "bad" producers, consumers end up suffering at least part of the burden of "internalizing the externality" through higher prices. Perhaps this should counteract such voters' alacrity for exacting their perceived punishment, but it's not clear that many voters realize or accept this.) On the other hand, some people may be philosophically opposed to the government collecting revenue in any way, regardless of the primary environmental motivation, while others could be opposed to the government attempting to address environmental issues at all. Such people might opt for the seemingly less meddlesome plan of B, or might abstain from voting for either politician. Just because such philosophical notions as these can often be quite misguided from a purely economic perspective doesn't mean that they can't be powerful factors in garnering voter support.

For grading, roughly half of the points are for identifying things that consumers care about, and the other half are for, where possible, getting numbers for these things out of the model for each politician's plan. Full points requires a fairly thorough treatment of what can be gotten out of the model, and at least some brief recognition that there are things outside the model that might matter. It's not possible to get more than 4 points for focusing on things completely outside the model, and it's not possible to get more than 2 points if you ignored the economic perspective altogether. You'll also lose a point or more if you think "too broadly" by including benefits to firms or outside parties, since the question specifically asked you to focus on consumers.

It should also be mentioned that there are a lot of things made artificially rigid in the question's set-up that are not necessarily so in real life. There's of course nothing to stop a governor from installing the set of technologies and then imposing the appropriate tax to achieve the new socially efficient output level. More generally, one could always dream up a Politician C that would do something better than either A or B. Also, government funding issues have been completely trivialized: in reality, the government would have to pay for the technology somehow, which would eventually have some negative effect on consumers through taxation; and part or all of the revenue from a pollution tax could be used to reimburse consumers (preferably in a way that's "de-linked" from their behavior and so leaves the appropriate incentives intact, and possibly targeted at specific income quantiles to address equity objectives), or it could be used to address other market failures to the benefit of consumers in other markets, or it could be completely squandered on some "bridge to nowhere" scheme by an influential local politician. These things are all well and good to consider in a larger sense, but you will lose points if you focus too much on things that require you to alter conditions that the question tells you to take as given.

BONUS QUESTION [3 points maximum – no penalty for guessing]: Calculate the “effective burden” on consumers of the Pigouvian tax from 2a). What would this effective burden be if the tax were collected from consumers rather than the mill?

answer:

The effective burden on consumers is defined as the increase in the effective price that consumers pay for wood pulp with the tax relative to without, as a proportion of the total per-unit tax.

$$\text{burden} = (1710 - 1440)/630 = 42.86\%.$$

[2 points potentially – 0 for nonsense or pure guessing, 1 for the general formula or graphical representation or at least getting close, 2 for completing the calculation correctly]

The effective burden is not affected by which side bears the administrative burden. With a tax imposed on consumers, the MB curve would shift left, and the “cash register” price would be determined by the intersection of this shifted MB curve with MC. However, consumers would then need to remit the tax for each unit purchased at that price, so the effective price would be the cash register price plus the per-unit tax rate, and would come to 1710 just as with the tax on producers.

[1 point potentially, no explanation necessary, no calculation of the burden under either scenario necessary]

Draw a graph to see all of this! That goes for all of the calculations in 2c) as well.