

Homework 3 Solutions

ECON 5332 Government, Taxes, and Business Strategy
Spring 2008

Due Tuesday, February 5, 7:00 pm

1. Two firms are ordered by the federal government to reduce their pollution levels. Firm A's marginal cost of pollution reduction is given by $MC^A = 20 + 4Q^A$. Firm B's marginal cost of pollution reduction is given by $MC^B = 10 + 8Q^B$. The marginal benefit of total pollution reduction is $MB = 400 - 4Q^T$, where $Q^T = Q^A + Q^B$.

- (a) What is the socially optimal level of pollution reduction in total? How much pollution reduction does each firm contribute?

The social optimum must solve

$$MC^A = MC^B = MB,$$

or

$$20 + 4Q^A = 10 + 8Q^B = 400 - 4(Q^A + Q^B).$$

We can solve this in two steps. First, set $MC^A = MC^B$ and solve for Q^A in terms of Q^B , which yields $Q^A = 2Q^B - 2.5$. Next, set $MC^B = MB$, substitute for Q^A in terms of Q^B , and solve for Q^B :

$$10 + 8Q^B = 400 - 4((2Q^B - 2.5) + Q^B).$$

This calculation yields $Q^B = 20$. It follows that $Q^A = 37.5$ and the optimal quantity of pollution reduction is 57.5 units total.

- (b) Compare the total surplus generated by each of three possible public policies designed to generate the socially optimal quantity of pollution reduction: (1) require both firms to reduce pollution by the same amount, (2) charge a common tax per unit of pollution, or (3) require both firms to reduce pollution above levels for which they do not have a permit, and issue an equal number of tradeable pollution permits to each firm.

Total surplus is equal to total benefit minus total cost. The total benefit of pollution reduction will be the same in all three cases, because they all generate the same quantity of pollution reduction, $Q^o = 57.5$. The total benefit is equal to the area under the marginal benefit curve, $MB = 400 - 4Q^T$, from $Q^T = 0$ to $Q^T = 57.5$, which is 16387.5.

1. The same total reduction in pollution could be achieved by requiring each firm to reduce pollution by 28.75 units. The total cost to firm A of producing 28.75 units of pollution reduction is the area under firm A's marginal cost curve, $MC^A = 20 + 4Q^A$, from $Q^A = 0$ to $Q^A = 28.75$, which is 2228.13. The total cost to firm B of producing 28.75 units of pollution reduction is the area under firm B's marginal cost curve, $MC^B = 10 + 8Q^B$, from $Q^B = 0$ to $Q^B = 28.75$, which is 3593.75.

Total surplus is thus $16387.5 - 2228.13 - 3593.75 = 10565.6$.

We can tell that this would be less efficient than the social optimum, since it would be less costly for firm A to reduce pollution by more and for firm B to reduce pollution by less (since $MC^A < MC^B$ at 28.75 units).

2. A common tax could be used to achieve the social optimum. The marginal benefit of pollution reduction at the optimum is

$$MB(57.5) = 400 - 4(57.5) = 170.$$

In other words, the marginal external cost of *pollution* (not pollution reduction) is equal to 170 at the optimum. Thus, the Pigouvian tax on pollution (or, equivalently, the good whose production causes pollution) is 170 per unit. Setting a tax on *pollution* (not pollution reduction) of 170 would lead firm A (respectively, B) to reduce pollution to the point where $MC^A = 170$ (respectively $MC^B = 170$). In other words, each firm reduces pollution until the marginal cost of doing so exceeds the marginal benefit, which is the value of avoiding the tax. Solving gives $Q^A = 37.5$ and $Q^B = 20$.

The total cost to firm A of producing 37.5 units of pollution reduction is the area under firm A's marginal cost curve from $Q^A = 0$ to $Q^A = 37.5$, which is 3562.5. The total cost to firm B of producing 20 units of pollution reduction is the area under firm B's marginal cost curve from $Q^B = 0$ to $Q^B = 20$, which is 1800. It follows that total surplus in this case is $16387.5 - 3562.5 - 1800 = 11025$.

3. Requiring both firms to reduce pollution by 27.25 units but allowing them to trade pollution permits can also be used to achieve the social optimum. The value to firm B of being able to produce 1 more unit of pollution (i.e., MC^B) is higher than the cost to firm A of reducing pollution by one unit (i.e., MC^A) when $Q^B = 27.25 = Q^A$, so both can gain by trading a unit of pollution permits. This continues to be true as long as $Q^A < 37.5$ and $Q^B > 20$, so they will trade permits until $Q^A = 37.5$ and $Q^B = 20$.

Since total pollution reduction by each firm is the same as with the Pigouvian tax, total surplus must also be the same (11025).

We can see that total surplus is higher in cases 2 and 3 than in case 1.

2. Nordhaus (2007) talks about the "Westphalian dilemma." What is this dilemma and why does it make addressing global warming more difficult than addressing, say, acid rain?

Under international law, based on the 1648 Treaty of Westphalia, obligations cannot be imposed on a sovereign state without its consent. Countries cannot be coerced into

participating in efforts to reduce negative externalities generated by the stock of greenhouse gases (GHGs), but instead must participate voluntarily. Voluntary participation requires that a country's benefits of participating are at least as great as the costs. While each country incurs its own costs, the benefits of reduced GHG emissions are shared by all countries, including those who do not participate. Thus, each country has an incentive not to participate and let other countries bear the cost of reducing GHGs, making voluntary participation unlikely. This dilemma is the "Westphalian dilemma."

The difference between global warming and, say, acid rain is that the geographic scope of damages generated by GHGs is global, whereas the geographic scope of damages generated by SO₂ emissions, the source of acid rain, are more likely national or regional. A national government can coerce decision-makers, such as lower-level governments, businesses, or households, who fall under its jurisdiction to participate in efforts to reduce SO₂ emissions. The ability of a national government to coerce participation by those who would not do so voluntarily makes addressing acid rain easier than addressing global warming.

3. Nordhaus (2007) identifies two types of efficiency that contribute to determining the efficient distribution of emissions reductions. Define these two types of efficiency and explain why they are important.

The two components of efficient distribution of emissions reductions are (1) *where efficiency* and (2) *when efficiency*. *Where efficiency* refers to the notion that efficient distribution of emissions reductions requires that the marginal cost of reducing emissions is equal across countries (i.e. across locations or across geographic space). *When efficiency* refers to the notion that the net present marginal cost of reducing emissions should be equal across time periods (i.e. years). Both components are important because efficiency requires that emissions reductions be distributed both where and when they can be produced at lowest cost.

4. According to Nordhaus (2007), are price-type approaches to addressing global warming more or less susceptible to corruption than quantity-type approaches? Why?

Price-type approaches, such as harmonized carbon taxes, are less susceptible to corruption than quantity-type approaches, such as a cap-and-trade scheme, because quantity-type approaches are likely to create valuable assets, whereas price-type approaches do not. For example, a cap-and-trade scheme creates a valuable asset in the form of tradeable emissions permits. Bureaucrats and elected officials may distribute these permits as rewards to their supporters, or may accept bribes to sell them at artificially low prices. Such practices may undermine public support for tradeable permits. Such practices may also generate an inefficient distribution of permits if permits are allocated to firms with low marginal costs of reducing emissions and trading permits is costly.

5. In Becker and Murphy's "rational addicts" model, smokers are perfectly aware of the potential for smoking to cause addiction, and they take this into account when deciding whether or not to smoke. Suppose a new technology – such as a nicotine patch – is

invented that makes quitting smoking much easier (less costly) for an addict. If Becker and Murphy's model is correct, what effects would you expect this invention to have on people's smoking behavior? Would your answer be different for young people than for older people?

Older people who are already addicted to smoking might suddenly find it worthwhile to quit, now that it is less costly to do so. This would lead to lower smoking rates. At the same time, people considering starting to smoke particularly young people would now find it less costly to become addicted to smoking because it would be easier to quit later. Since they take this cost into account when making their decisions, their smoking rates are likely to increase.

6. According to Gruber and Koszegi (2001), what two conditions are required for a good to be addictive? Why are cigarettes addictive?

The two components of addiction are (1) *reinforcement*, in that the more of a good you consume, the more of that good you want to consume, and (2) *tolerance*, in that increased consumption of a good today reduces your utility from consuming a given quantity of that good in the future. Cigarettes are considered addictive because the desire to smoke is increasing in the quantity of cigarettes smoked (reinforcement) and the utility you get from smoking one pack of cigarettes in the future is decreasing in the number of packs of cigarettes you smoke today (tolerance). In other words, the more you smoke, the more you want to smoke, and the more you smoke today, the more you have to smoke tomorrow in order to get the same pleasure you got from smoking today.

7. Caffeine is a highly addictive drug found in coffee, tea, and some sodas. Unlike cigarettes, however, there have been very few calls to tax it, to regulate its consumption, or limit its use in public places. Why the difference? Can you think of any economic arguments for regulating (or taxing) its use?

Unlike cigarettes, caffeine does not cause any obvious externalities (e.g., secondhand smoke). If we believe Becker and Murphy's rational addiction model, then addictiveness does not provide a motivation for regulating a good only externalities do. On the other hand, if people have self-control problems, then "internalities" could potentially provide a motivation for taxing or otherwise regulating caffeine. This is particularly true for children, who tend to be short-sighted and may not fully appreciate the long-term consequences of caffeine addiction. This might be a reason to regulate sales of sodas containing caffeine in schools, for example.

References

- Jonathan Gruber and Botond Koszegi. Is addiction rational? theory and evidence. *Quarterly Journal of Economics*, 116(4):1261–1303, November 2001. Available on EconLit.
- William D. Nordhaus. To tax or not to tax: Alternative approaches to slowing global warming. *Review of Environmental Economics and Policy*, 1(1):26–44, Winter 2007. Available at http://nordhaus.econ.yale.edu/nordhaus_carbontax_reep.pdf.