Economics 5250/6250 Dr. Lozada
Fall 2021 Final Exam

This exam has 67 points. There are eight questions on the exam; you should work all of them. Five of the questions are worth 8 points each and three of the questions are worth 9 points each. You have two hours to take the exam.

Put your answers to the exam in a blue book or on blank sheets of paper.

Answer the questions using as much precision and detail as the time allows. Correct answers which are unsupported by explanations will not be awarded points. Therefore, even if you think something is "obvious," do not omit it. If you omit anything, you will not get credit for it. You get credit for nothing which does not explicitly appear in your answer. If you have questions about the adequacy of an explanation of yours during the exam, ask me.

Good luck!

Answer all of the following eight questions.

1. **[9 points]** In class, we discussed the equation

$$\delta = F' + \frac{1}{M\Pi}\frac{\partial \Pi}{\partial X} .$$

   (a) What do the symbols in this equation stand for?

   (b) What economic problem is this equation a solution for? State the problem in mathematical form; you will lose some (but not all) points for stating it in a correct non-mathematical form.

   (c) What does this equation simplify to in the case of a Schooling Fishery? Why?

   (d) Suppose in this equation we can take $\partial\Pi/\partial X$ to be zero.

      i. Graph this equation in the case of logistic growth. (Do not forget to explain why your graph answers this question.)

      ii. In the graph you just drew, what happens to steady-state stock size as the discount rate rises?

2. **[8 points]** Discuss why regulators might adopt "season length regulation" in a fishery. Also discuss the problems that type of regulation can create, and what one better alternative would be. (Be sure to define what you mean by "better.")

3. **[9 points]** When the parts of this question have sub-parts (i) and (ii), you need to answer both (i) and (ii).

   Suppose the instantaneous profit of a mining firm is graphed in Figure 1.

   (a) On a copy or copies of this graph, show (and explain thoroughly) what would happen as time goes on if the industry adopted:

      i. a strategy of "maximize short-run profit;" or, by contrast,

      ii. a strategy following the Hotelling Rule.

   (b) Make a graph with time on the horizontal axis and **profit earned** per period on the vertical axis. On this graph, show (and explain) the implications of:

      i. a strategy of "maximize short-run profit;" or, by contrast,

      ii. a strategy following the Hotelling Rule.

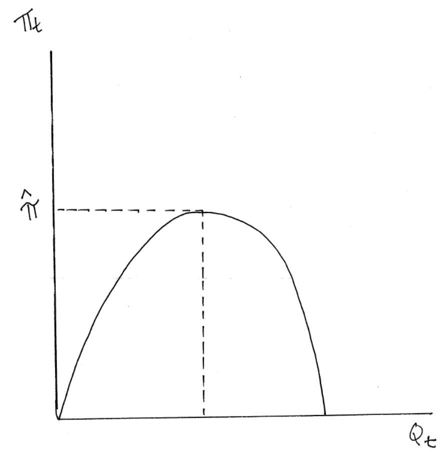

Figure 1. Here π_t is profit at date t and Q_t is the output of a mining industry at date t.

(c) Make a graph with time on the horizontal axis and **quantity extracted** per period on the vertical axis. On this graph, show (and explain) the implications of:

i. a strategy of "maximize short-run profit;" or, by contrast,

ii. a strategy following the Hotelling Rule.

(d) Make a graph with time on the horizontal axis and **price** on the vertical axis. On this graph, show (and explain) the implications of:

i. a strategy of "maximize short-run profit;" or, by contrast,

ii. a strategy following the Hotelling Rule.

(e) Argue that strategy (ii) is more plausible than strategy (i). Then argue the opposite.

4. **[8 points]** What is the connection in some developing countries between deforestation and dung? What are the consequences of this connection?

5. **[9 points]** Economist George Stigler postulated a result he called "The Coase Theorem" (named after economist Ronald Coase). It implies that, in a world of costless bargaining and no strategic behavior, private bargains between a polluter and a pollution victim will result in the socially-optimal amount of a polluting output being produced,

regardless of whether the polluter or the pollution victim own the property right to the air (assume pollution of air is the situation). Argue that this is not true. In other words, argue that, in a world of costless bargaining and no strategic behavior, private bargains between a polluter and a pollution victim will *not* "result in the same amount of a polluting output being produced, regardless of whether the polluter or the pollution victim own the property right to the air."

6. **[8 points]** Suppose that producing output also generates pollution. Draw a graph with "output" on the horizontal axis showing how an optimal (linear) "pollution tax" (really an output reduction tax) would work.

7. **[8 points]** Briefly define and contrast:
   (a) use value (consumptive and non-consumptive);
   (b) option value;
   (c) existence value;
   (d) bequest value; and
   (e) quasi-option value.

8. **[8 points]** On March 13, 2001, the office of the press secretary of then-President George W. Bush issued the text of a letter the president had written to several senators. It said in part:

   > As you know, I oppose the Kyoto Protocol *because it exempts 80 percent of the world, including major population centers such as China and India, from compliance*, and would cause serious harm to the U.S. economy. The Senate's vote, 95–0, shows that there is a clear consensus that the Kyoto Protocol is an *unfair* and ineffective means of addressing global climate change concerns. [emphasis added]

   Figure 2 shows greenhouse gas emissions. Explain how one half of Figure 2 could be used to support President Bush's argument that the Kyoto Protocol was unfair and how the other half of Figure 2 could be used to attack that argument. (The figure comes from `http://www.columbia.edu/~mhs119/CO2Emissions/Emis_moreFigs/` and shows carbon dioxide emissions.) You do not need to mention Figure 3 in your answer, but I include it because it appeared on a previous exam; it has data through the year 2010.

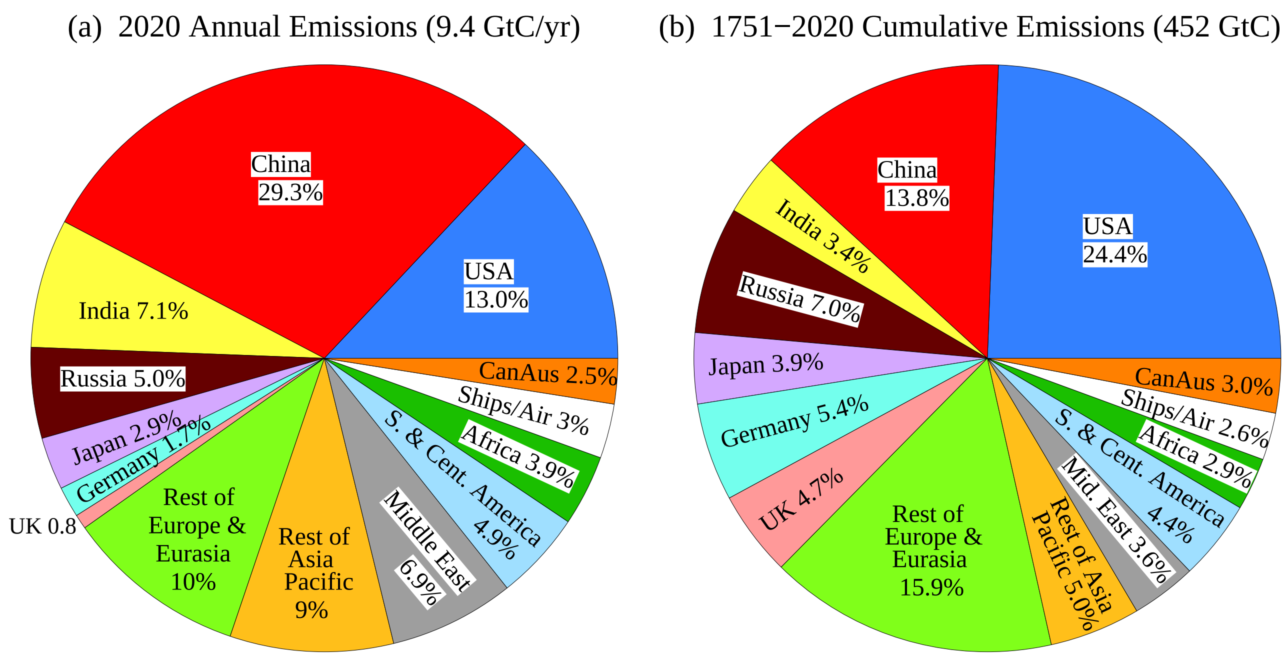

Figure 2. Data through 2020; “GtC” means “gigatons of carbon.”

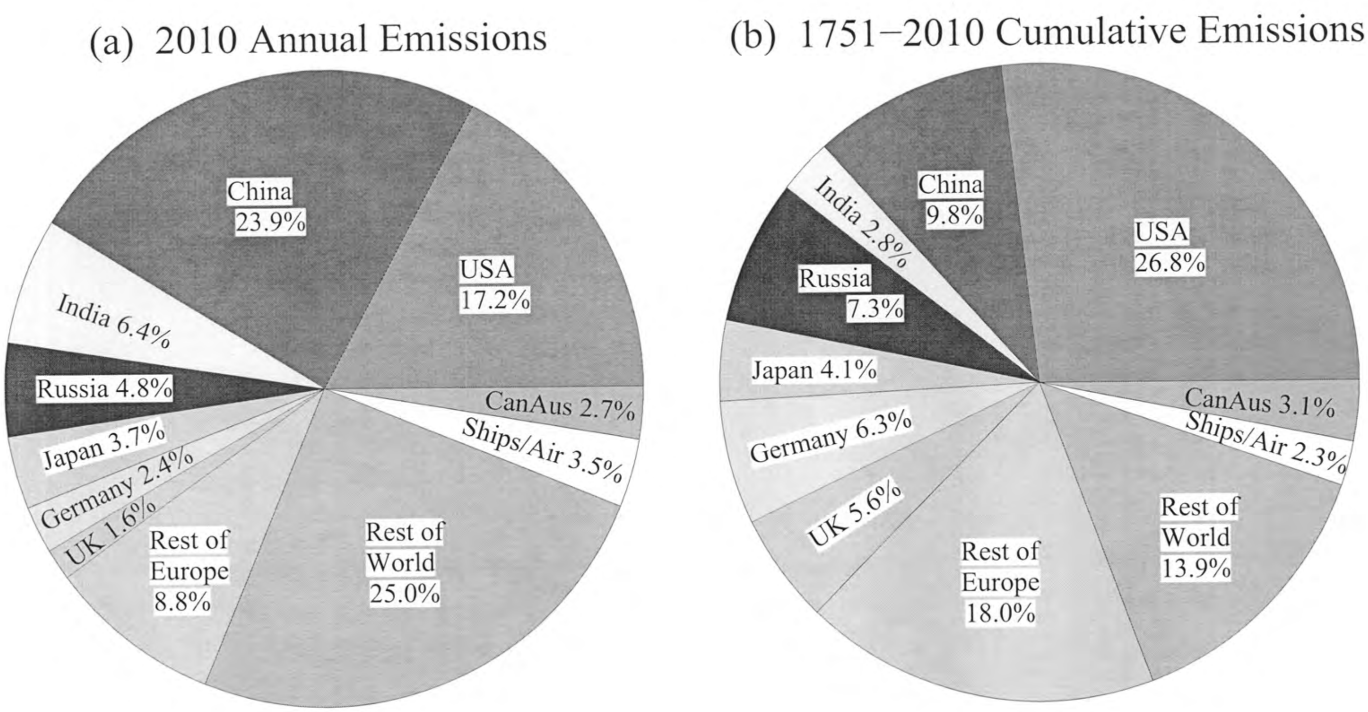

Figure 3. Data through 2010.

Answers to Final Exam, Econ. 5250, Fall 2021

1. **[9 points]** [Chapter 16]

   (a) The discount rate is δ. The excess of births over natural deaths is $F(X)$ where X is stock size (or biomass), and F' is the derivative of F with respect to X. Firm (instantaneous) profit is Π. The derivative of profit with respect to output—output is usually denoted by h or H for "harvest"—is $M\Pi$. The derivative of profit with respect to stock size is $\partial\Pi/\partial X$.

   (b) The problem facing the private-property fishing firm is to maximize its present discounted value of profit (or "the net present value of profit") subject to the growth of the fish stock:

   $$\max \sum_{t=0}^{\infty} \frac{\Pi_t}{(1+\delta)^t} \quad \text{s.t.} \tag{1}$$

   $$X_{t+1} - X_t = F(X_t) - H_t\,. \tag{2}$$

   (2) represents an infinite number of constraints on (1), one for each date $t = 1, 2, 3, \ldots$. (2)'s right-hand side is "births minus natural deaths" (namely, F) minus the extra deaths caused by humans (namely, H); its left-hand side is the change in the number of fish from the beginning of time period (such as a year) to the beginning of the next time period.

   (c) In a Schooling Fishery, $\partial\Pi/\partial X = 0$ because when X is small, fishing costs do not increase, because it is just as easy to find the fish as when X is large: the fish occur in "schools" which are easy to locate, for example using sonar, even if few schools exist. In this situation, the equation simplifies to $\delta = F'$.

   (d) In this part of the question, $\delta = F'$. (So this is for a Schooling Fishery.)

      i. See Figure 4, which equates δ and F'. The graph of F is quadratic, which represents logistic growth.

      ii. See Figure 5, which shows that when δ rises, which is shown by the steeper red line, then the steady-state stock size X_{SS} falls.

2. **[8 points]** [Chapter 17]

   Season-length regulation—which places legal limits on the number of days a species can be harvested—has been used for many years to

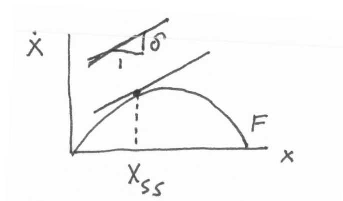

Figure 4. The steady state net-present-value maximizing solution for a schooling fishery.

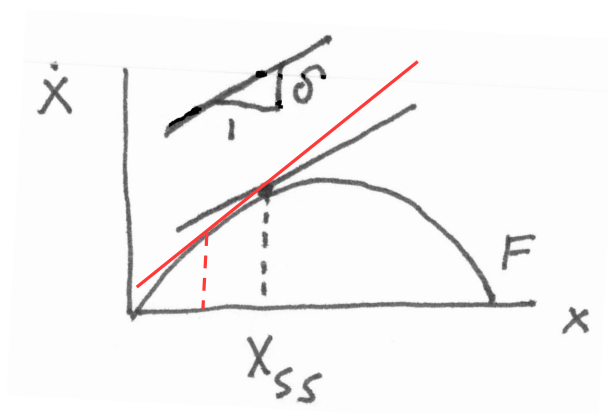

Figure 5. When δ rises, X_{SS} falls.

regulate the hunting of wild game such as deer. Therefore, regulators are familiar with it. In addition, superficially, if the season length is shortened, it would seem that harvest would fall; and indeed *if effort were kept constant*, then when season length was shortened, harvest *would* fall. The problem is that when season length is shortened, profit-maximizing firms exploiting the resource have an incentive to increase effort. This might actually cause harvest to rise; or, in any case, causes harvest to fall by a lesser extent than the regulators probably anticipated. If the regulators respond by shortening season length further, a vicious cycle can be established, where each year the industry responds to the shorter season by increasing effort, which induces the regulator to shorten the season even further the next year, which induces the industry to further increase effort. An infamous example of this occurred in the Alaskan halibut fishery.

An alternative is a cap-and-trade system of marketable permits, called "individual transferable quotas" ("ITQ's") in fisheries economics. ITQ's allow the regulator to set a desirable quota, and allow the industry to fish for that quota under no time constraints, leading to: safer fishing, because there is no "race to fish," so no hurry to fish quickly; less costly fishing, because elimination of a "race to fish" means that capital equipment does not have to be as large; and production of more fresh (as opposed to frozen) fish, since processing plants are not inundated with a huge amount of fish at one time—leading to higher industry profits, since fresh fish sell for a higher price than frozen fish.

3. **[9 points]** Chapter 18; Fall 2008 Final Qu. 6, extended with two new parts, (a) and (d).

   (a) The strategy of "maximize short-run profit" results in earning profit $\hat{\pi}$ for as long as possible, by producing the value of Q corresponding to the vertical dashed line in Figure 1, and then, when the resource is exhausted, producing nothing, and making zero profit, from that time onwards.

   The strategy of following the Hotelling Rule, which says that "marginal profit should rise at the discount rate," results in the behavior shown in Figure 6, which is from the answer to Question 2 of the final exam of 2017. Marginal profit is the slope of lines such as the ones marked 1, 2, and 3. To make these slopes rise with time, quantity has to be, not at the short-run

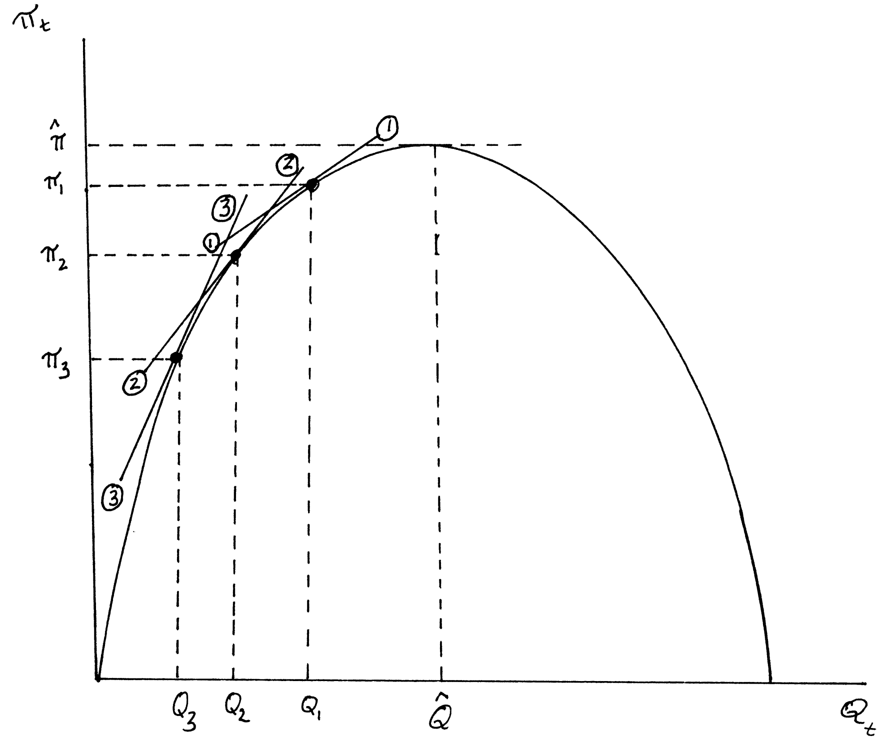

Figure 6

profit-maximizing level of $\hat{Q}$, but rather at the levels Q_1, Q_2, and finally Q_3. So quantity has to fall with time, and profit will fall with time also.

(b) See the top graph of Figure 7. As discussed in part (a), for strategy (i), profit remains at $\hat{\pi}$ until the resource is exhausted, which in this figure occurs at time t_1; from then on, profit is zero. For strategy (ii), profit will continuously fall, until it hits zero at a time marked t_2.

(c) As discussed in part (a), for strategy (i), quantity remains at $\hat{q}$ until the resource is exhausted, which in this figure occurs at time t_1; from then on, quantity is zero. For strategy (ii), quantity will continuously fall, until it hits zero at a time marked t_2. Since before t_1, quantity along the solid line (strategy (ii)) is always below quantity along the dashed line (strategy (i)), after t_1, quantity along the solid line needss to be above quantity along the dashed line (zero) at least for a while, because total quantity eventually extracted has to be the same for both strategies. (Geometrically, the area under the dashed curve has to be equal to the area under the solid curve. I should have drawn the solid curve somewhat higher, and I should have increased the value of t_2, in order to make this graph more plausible.)

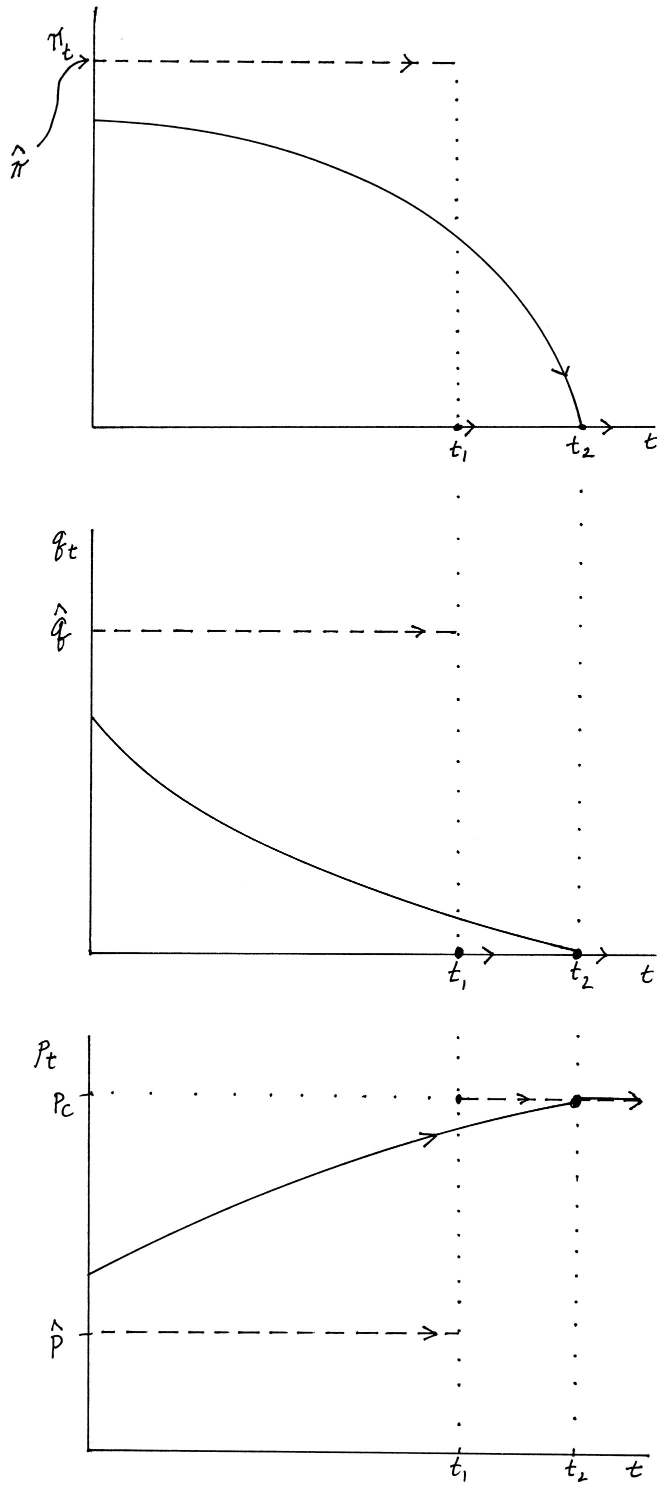

Figure 7. The dashed lines are for strategy (i), maximizing short-run profit. The solid lines are for strategy (ii), following the Hotelling Rule.

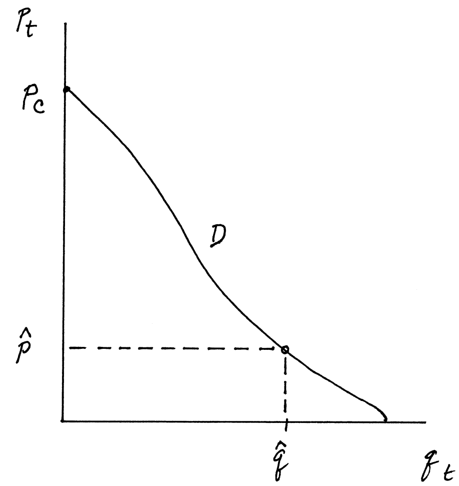

Figure 8. The demand curve.

(d) To relate the quantity path to a price path, we need a demand curve; suppose it looks like in Figure 8. For strategy (i), $\hat{q}$ corresponds to $\hat{p}$, for $t < t_1$. For $t > t_1$, quantity is zero, so price is equal to the "choke price," p_c. For strategy (ii), as q smoothly falls, equilibrium price has to smoothly rise, until at t_2, quantity reaches zero and price reaches p_c.

(e) The argument for Strategy (ii) is that it maximizes the net present value of profit (also known as the present discounted value of profit). Strategy (ii) implies a richer firm for all dates sufficiently far into the future. In addition, Strategy (i) has the shortcoming that at time t_1, price jumps up, just when the firm desires to exhaust its resource. We assume firms know all prices, so it makes no sense for the Strategy (i) firm to choose to run out of resource just before the large price jump at t_1; it ought to keep at least some resource in the ground at t_1 so it can sell it just after t_1. There is no such shortcoming along Strategy (ii) because its price path is continuous.

The argument for Strategy (i) is that it maximizes short-run profit, and so the accumulated profit along Strategy (i) is certainly higher than the accumulated profit along Strategy (ii) for $t < t_1$ (see the top graph of Figure 7). This Strategy (i) "head start" means the value of the firm's bank account as time increases (called the "current value" as opposed to the "present value") will exceed the value of the Strategy (ii) bank account until quite some time after t_1. If foresight is imperfect, the fact that Strategy (i) beats Strategy (ii) for a very long initial period means that the very-long-run superiority of Strategy (ii) will be unimportant, and Strategy (i) will look better. This is particularly true if some

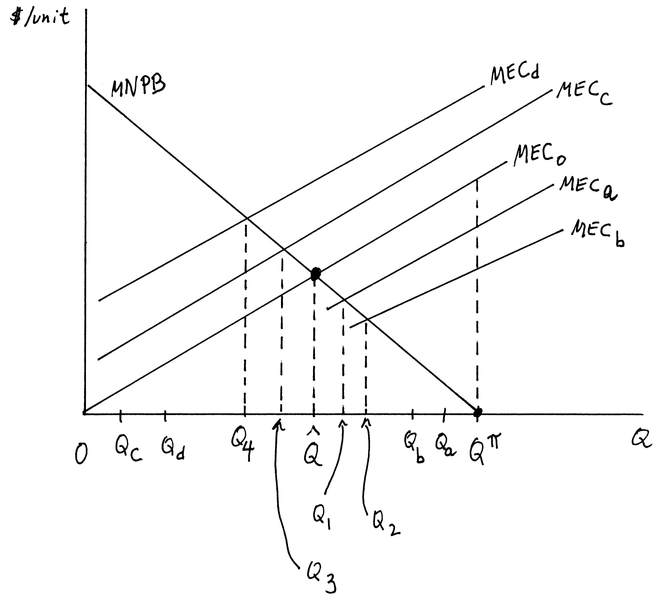

Figure 9.

market participants, such as Wall Street traders and investment banks which finance mergers and corporate takeovers, pay attention only to short-run and medium-run profits.

4. **[8 points]** Chapter 22; Qu. 3 of Fall 2007 Final, with the word "some" added.

5. **[9 points]** [Chapter 5.]

   Figure 9 shows a marginal net private benefit curve, MNPB, and an initial marginal external cost curve, MEC_0, as a function of production of a polluting output Q. At this initial position, the socially-optimal output level is $\hat{Q}$.

   Coase argued that in a fictional world with no transactions costs and no strategic behavior—a setting he did not believe was relevant to the real world, but Stigler did believe was relevant to many real-world situations—an output level of $\hat{Q}$ would be achieved without government action, merely by private transactions between the firm and the pollution victims. If the firms had the property right, output would start at Q^{π}, but since MEC measures willingness and ability to pay—well, or maybe willingness to accept, but let's ignore the important differences between them to make this argument simpler—pollution victims can and will want to pay the firm to reduce output to Q_a, and then to Q_b, and then to $\hat{Q}$, as long as what they have to pay the firm is less than MEC. The firm will demand MNPB or more in payment. Therefore, Coase said, decreasing Q can be mutually beneficial all the way from Q^π to $\hat{Q}$.

Similarly, Coase said, if the pollution victims had the property right, output would start at zero, but the firm will want to pay victims for the right to increase output to Q_c, and then to Q_c, and then to $\hat{Q}$, as long as what they have to pay the firm is less than MNPB. The victims will demand MEC or more in payment. Therefore increasing Q can be mutually beneficial all the way from zero to $\hat{Q}$, because along the way, what firms are willing to pay (MNPB) is more than what pollution victims demand in payment (MEC).

To see why this argument is wrong, assume firms have the property right, and a bargain is struck to reduce output to Q_a. Pollution victims have to pay the firm. This reduces their income. This reduces their MEC (assuming clean air is a normal good), say to MEC_a. This increases the socially-optimal level of pollution to $Q_1 > \hat{Q}$. So the process will never reach $\hat{Q}$. A further bargain can be struck to decrease output to Q_b, because MEC_a is still higher than MNPB around Q_b, even though MEC_a is less than MEC_0. But paying for this Q_b bargain will reduce the pollution victims' incomes further, so their MEC will fall again, now perhaps to MEC_b. This increases the socially-optimal level of pollution even more, to Q_2. The final bargain will be between Q_2 and Q_b, well to the right of $\hat{Q}$.

Furthermore, if the pollution victims have the property right, one also does not end up at $\hat{Q}$. Starting with this assumption, quanity begins at zero, and suppose a bargain is struck to increase output to Q_c. Pollution victims receive money from the firm. This increases their income. This increases their MEC (assuming clean air is a normal good), say to MEC_c. This decreases the socially-optimal level of pollution to $Q_3 < \hat{Q}$. So the process will never reach $\hat{Q}$. A further bargain can be struck to increase output to Q_d. But receiving payment for this Q_d bargain will increase the pollution victims' incomes further, so their MEC will rise again, now perhaps to MEC_d. This decreases the socially-optimal level of pollution even more, to Q_4. The final bargain will be between Q_d and Q_4, well to the left of $\hat{Q}$.

The conclusion is that private bargaining will result in a pollution level higher than $\hat{Q}$ if the firms have the property right, and will result

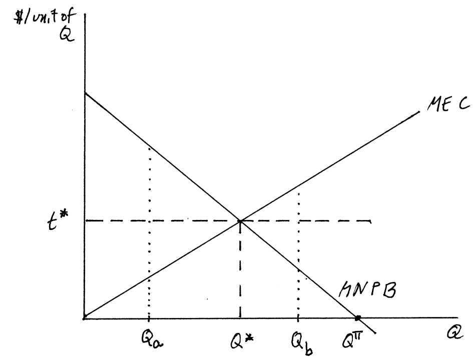

Figure 10.

in a pollution level lower than $\hat{Q}$ if the pollution victims have the property right.

Note 1: A less satisfactory answer points out that if the firm has the property right, the pollution victims' MEC reflects their "willingness and ability to pay" valuation ("WATP"), whereas if the pollution victims have the property right, the pollution victims' MEC reflects their "willingness to accept" valuation ("WTA"), which is different than their WATP. This generates two MEC curves, one based on WATP and one based on WTA, but it does not show how these shift when the bargains are made and money changes hands.

Note 2: A more satisfactory answer takes Note 1 into account, therefore starting with two MEC curves, not one MEC curve. Realizing this, even before bargaining begins there are two "socially optimal" levels of Q, not just one. Then as bargains are made and money changes hands, the relevant MEC curve would shift.

6. **[8 points]** [Chapter 7]

   Figure 10 shows a marginal net private benefit curve, MNPB, and a marginal external cost curve, *MEC*, as a function of production of a polluting output Q. We will demonstrate how the firm will react to a tax t^* on Q.

   Once the tax has been imposed, the firm will no longer wish to produce output levels such as Q_b and Q^π because producing them means the firm has to pay t^* in addition to all its previous costs, while he benefit to the firm of producing those output levels is MNPB, which is less than t^*. In other words, the firm will no longer wish to produce where MNPB is less than t^*. On the other hand, the firm will still want to produce output levels such as Q_a, because its MNPB is larger than t^*: where MNPB is larger than t^*, the firm still makes a net profit from producing, even after paying t^*.

Since we have concluded that the firm will want to produce where MNPB is greater than t^*, and the firm will not want to produce where MNPB is less than t^*, the firm will produce exactly where MNPB is equal to t^*.

Optional: In Figure 10, this means that the government can induce the firm to produce the socially-optimal level of quantity, Q^*, by imposing a tax level of t^*.

7. **[8 points]** Chapter 9; Fall 2015 Ex. 1 Qu. 4.

8. **[8 points]** Chapter 13; Fall 2011 Final Qu. 1 with an updated figure and some grammatical changes.

   To add to the old answer: Since the U.S. population is much less than that of China or India, converting the pollution amounts into per-capita figures would further weaken President Bush's argument, because it would show high per-capita emissions by the U.S., both currently and historically.

   Optional: Comparing Figures 2 and 3, the argument against President Bush's position has weakened between 2010 and 2020 (and certainly has weakened between 2001, when he wrote, and 2020). China and India's high current emissions mean they are catching up to the U.S. even in cumulative emissions, though have not reached the U.S.'s level yet. Panel (b) in 2010 was 26.8%, 9.8%, and 2.8% for the U.S., China, and India, whereas in 2020 it was 24.4%, 13.8%, and 3.4%. On the other hand, if one calculated per-capita figures, the U.S. would still be a far greater polluter.