Economics 3250 Dr. Lozada
Spring 2020 Final Exam

Instructions

Open Book. This is an open-book exam. You may use anything on the class web site, your notes, the textbook, the internet, and so forth, except that you must not communicate with anyone except for me during the exam. (I understand that if you are at home with young children, an unplanned communication with one of them could occur; the point is that you should neither give nor receive help on the exam from anyone, except that you may communicate with me.)

Point Breakdown. This exam has 50 points. There are ten questions on the exam, each worth 5 points.

Write Clearly. Since only a copy, not the original, of your exam is going to be graded, write your answers legibly and preferably in black ink; if you make a mistake, cross it out or use "white-out" or white correction tape. Put at least your last name on each sheet of your exam, because I may print them out and do not want to get them out of order.

Explain thoroughly. 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.

Reaching me during the exam. If you have a question for me during the exam, you may get in touch with me by sending an e-mail to

`lozada@economics.utah.edu`,

by calling **801-581-7650** (leave a message) or **801-883-0134**, or via Zoom (assuming its "breakout rooms" feature is working) at `https://lms-utah.zoom.us/j/95515016152`. (If you are reading this on a screen (not paper), the above e-mail address and URL are hyperlinks you can click on.)

Sending the exam to me by 4:15. You have 2 hours (that is, until 4:00 PM) to finish this test. Then scan (or photograph) your answers and send them back to me at

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before 4:15 PM. Be sure not to accidentally omit any of your answer sheets.

Internet problems with sending me your exam. If your internet service is not functioning around 4:00 PM today and so you cannot send me your final exam, either:

If you can send a FAX: Try to send a FAX of your answers to the CSBS Dean's office at (801) 585-5081, attention "Prof. Lozada of the Economics Department," before 4:15 PM. (This may fail if the Dean's office personnel has recently not been able to restock the paper in their FAX machine.) Then *call me*.

Otherwise (including if you don't know what a "FAX" is): Scan your exam answers or take pictures of them as soon as possible, so that the scan or photo file has a time stamp before 4:15 PM. Then *call me*.

Internet problems on my end. If my internet service is not functioning around 2:00 PM and so I cannot send you the final exam, I will send it as soon as I can, and extend your time to take it appropriately.

This is the end of the instructions.
Seven pages of questions follow.
Good luck.

Answer all of the following ten questions.

1. **[5 points]** Construct an argument supporting the following position: "the Hotelling Rule is unlikely to be observed in reality." (Of course, you need to explain the Hotelling Rule before attacking it.)

2. **[5 points]**

   (a) Is non-compliance (not following laws) a potentially more serious problem for command-and-control regulation of municipal solid waste than for command-and-control regulation of other types of environmental problems? Why or why not?

   (b) Is non-compliance (not following laws) a potentially more serious problem for "economic incentive instrument" regulation of municipal solid waste than for "economic incentive instrument" regulation of other types of environmental problems? Why or why not?

3. **[5 points]** On December 6, 2018, *Foreign Policy* magazine published an article by Jason Hickel with the title and subtitle "The Nobel Prize for Climate Catastrophe: The economist William Nordhaus will receive his profession's highest honor for research on global warming that's been hugely influential—and entirely misguided." Here are some excerpts:

> Using this logic, Nordhaus long claimed that from the standpoint of "economic rationality" it is "optimal" to keep warming the planet to about 3.5 degrees Celsius over preindustrial levels—vastly in excess of the 1.5 degrees Celsius threshold that the IPCC insists on.
>
> [. . .]
>
> So how do economists get away with believing that these extreme temperatures are somehow okay? Because the Nordhaus model tells us that even the worst catastrophes will not really hurt the global economy all that much. Maybe a percentage point or two at the most, by the end of the century—much less than the cost of immediate action.
>
> How do they figure this? Because if climate breakdown ends up starving and displacing a few hundred million impoverished Africans and Asians, that will register as only a tiny blip in GDP. After all, poor people don't add much "value" to the global economy. The same goes for things like insects and birds and wildlife, so it doesn't matter if global warming continues to accelerate

> mass extinction. From the perspective of capital, what most of us see as tremendous ethical and even existential problems literally don't count.
>
> What is more, Nordhaus reasons that the sectors most vulnerable to global warming—agricultural, forestry, and fishing—contribute relatively little to global GDP, only about 4 percent. So even if the entire global agricultural system were to collapse in the future, the costs, in terms of world GDP, would be minimal.[1]

(a) Under what circumstances would a *correct economic argument* end up *not* arriving at the conclusion that "poor people don't add much 'value' to the global economy"?

(b) It is true that "the sectors most vulnerable to global warming—agricultural, forestry, and fishing—contribute relatively little to global GDP, only about 4 percent." Under what circumstances would a *correct economic argument* end up *not* arriving at the conclusion that "if the entire global agricultural system were to collapse in the future, the costs, in terms of world GDP, would be minimal"?

Hint: diamonds have a much higher "willingness to pay" than water for the *marginal* unit, but how about the total willingness to pay for diamonds versus for water?

4. **[5 points]** What is the environmental significance of the chemical equation

$$2\,O_3 \xrightarrow{Cl^-} 3\,O_2$$

and how successful has this environmental situation been dealt with? Briefly describe some reasons for the success or lack of success.

5. **[5 points]**

(a) Page 251 of your textbook contains the following passage:

> It is conceivable that the pursuit of self-interest within a regulatory framework will secure sustainable development. But the moral case for the environment remains, and it shows through in business approaches to the environment. It shows as *commitment*—which we might define as a concern for the

[1] From `https://foreignpolicy.com/2018/12/06/the-nobel-prize-for-climate-catastrophe/`.

> environment which cannot be explained in terms of the self-interested motives discussed previously. But it isn't easy to understand some corporate approaches to the environment unless commitment exists.

Critique this passage.

(b) Page 298 of your textbook contains the following passage:

> Biological diversity is important for both moral and economic reasons. But if the morality of conservation can be disputed, the economic case for conservation is becoming increasingly powerful. This means investigating the economic values of conservation and, above all, the economic factors that create diversity erosion.

Critique this passage.

6. **[5 points]** Label the lines and other important aspects of Figure 1 and thoroughly describe what it is illustrating.

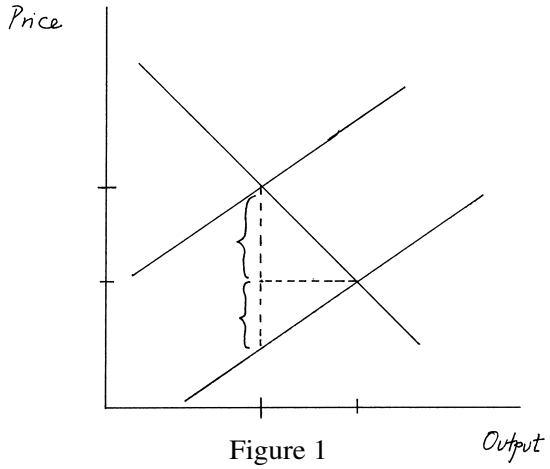

Figure 1

7. **[5 points]** Suppose there are only two polluting firms. One of them would have to spend $50 to clean up one ton of its pollution while the other would have to spend $100 to clean up one ton of its pollution. Construct an example, with numbers, showing that "command and control" regulation is not as good as "tradeable permits" (also known as "cap and trade") in this situation.

8. **[5 points]** Using a graph with fishing effort on the horizontal axis, illustrate the "tragedy of the commons." Discuss both the aspect of

the "tragedy of the commons" related to fishing firm profit and also the aspect related to the size of the exploited population of fish.

9. **[5 points]** The following excerpt appears on page 71 of the book *Valuing the Earth: Economics, Ecology, Ethics*, edited by Herman E. Daly and Kenneth N. Townsend (MIT Press, 1993); the authors are Paul Ehrlich[2], Anne Ehrlich[3], and John Holdren[4] (*Ecoscience*, W. H. Freeman and Co., 1977).

> ...one can state succinctly the subtle and overwhelmingly important message of the second law of thermodynamics: *all [real] physical processes, natural and technological, proceed in such a way that the availability of the energy involved decreases....*
>
> The statement of the second law given above is deceptively simple; whole books have been written about equivalent formulations of the law and about its implications. Among the most important of these formulations and implications are the following:
>
> (a) In any transformation of energy, some of the energy is degraded.
>
> (b) No process is possible whole sole result is the conversion of a given quantity of heat (thermal energy) into an equal amount of useful work.
>
> (c) No process is possible whose sole result is the flow of heat from a colder body to a hotter one.
>
> (d) The availability of a given quantity of energy can only be used once; that is, the property of convertibility into useful work cannot be "recycled."
>
> (e) In spontaneous processes, concentrations (of anything) tend to disperse, structure tends to disappear, order becomes disorder.

All of these "formulations and implications" is correct except for one. Which one is wrong, and why?

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[2]Author of *The Population Bomb* and Bing Professor of Population Studies (Emeritus) and President of the Center for Conservation Biology at Stanford University.

[3]Senior Research Scientist, Department of Biology, Stanford University.

[4]The Teresa and John Heinz Professor of Environmental Policy at the Harvard's Kennedy School of Government, Professor of Environmental Science and Policy in Harvard's Department of Earth and Planetary Sciences, and Faculty Affiliate in Harvard's Paulson School of Engineering and Applied Science; from January 2009 to January 2017, he was President Obama's Science Advisor and Senate-confirmed Director of the White House Office of Science and Technology Policy. His Ph.D. is from Stanford University in aerospace engineering and theoretical plasma physics.

10. **[5 points]** The following excerpt appears starting on page 103 of the book *Valuing the Earth: Economics, Ecology, Ethics*, edited by Herman E. Daly and Kenneth N. Townsend (MIT Press, 1993); the author is Nicholas Georgescu-Roegen and it was part of his article "Energy and Economic Myths," *Southern Economic Journal*, 41/3, Jan. 1975.

> It would be foolish to propose a complete renunciation of the industrial comfort of the exosomatic evolution. Mankind will not return to the cave or, rather, to the tree. But there are a few points that may be included in a minimal bioeconomic program.
>
> *First,* the production of all instruments of war, *not only of war itself,* should be prohibited completely. It is utterly absurd (and also hypocritical) to continue growing tobacco, if avowedly, no one intends to smoke. The nations which are so developed as to be the main producers of armaments should be able to reach a consensus over this prohibition without any difficulty if, as they claim, they also possess the wisdom to lead mankind.
>
> Discontinuing the production of all instruments of war will not only do away at least with the mass killings by ingenious weapons but will also release some tremendous productive forces for international aid without lowering the standard of living in the corresponding countries.
>
> *Second,* through the use of these productive forces as well as by additional well-planned and sincerely intended measures, the underdeveloped nations must be aided to arrive as quickly as possible at a good (not luxurious) life. Both ends of the spectrum must effectively participate in the efforts required by this transformation and accept the necessity of a radical change in their polarized outlooks on life.[5]
>
> *Third,* mankind should gradually lower its population to a level that could be adequately fed only by organic agriculture.[6] Naturally, the nations now experiencing very high demographic growth will have to strive hard for the most rapid possible results in that direction.
>
> *Fourth,* until either the direct use of solar energy becomes a general convenience or controlled fusion is achieved, all waste of

[5] At the Dai Dong Conference (Stockholm, 1972), I suggested the adoption of a measure which seems to me to be applicable with much less difficulty than dealing with installations of all sorts. My suggestion, instead, was to allow people to move freely from one country to any other country whatsoever. Its reception was less than lukewarm. See [Tom Artin, *Earth Talk: Independent Voices on the Environment*, Grossman press, 1973, p. 72].

[6] To avoid any misinterpretation, I should add that the present fad for organic foods has nothing to do with this proposal. . . .

energy—by overheating, overcooking, overspeeding, overlighting, etc.—should be carefully avoided, and if necessary, strictly regulated.

Fifth, we must cure ourselves of the morbid craving for extravagant gadgetry, splendidly illustrated by such a contradictory item as the golf cart, and for such mammoth splendors as *two-garage* cars. Once we do so. manufacturers will have to stop manufacturing such "commodities."

Sixth, we must also get rid of fashion, of "that disease of the human mind," as Abbot Fernando Galliani characterized it in his celebrated *Della moneta* (1750) . It is indeed a disease of the mind to throw away a coat or a piece of furniture while it can still perform its specific service. To get a "new" car every year and to refashion the house every other is a bioeconomic crime. Other writers have already proposed that goods be manufactured in such a way as to be more durable.... But it is even more important that consumers should reeducate themselves to despise fashion. Manufacturers will then have to focus on durability.

Seventh, and closely related to the preceding point, is the necessity that durable goods be made still more durable by being designed so as to be repairable. (To put it in a plastic analogy, in many cases nowadays, we have to throw away a pair of shoes merely because one lace has broken.)

Eighth, in a compelling harmony with all the above thoughts we should cure ourselves of what I have been calling "the circumdrone of the shaving machine," which is to shave oneself faster so as to have more time to work on a machine that shaves faster so as to have more time to work on a machine that shaves still faster, and so on *ad infinitum.* This change will call for a great deal of recanting on the part of all those professions which have lured man into this empty infinite regress. We must come to realize that an important prerequisite for a good life is a substantial amount of leisure spent in an intelligent manner.

Considered on paper, in the abstract, the foregoing recommendations would on the whole seem reasonable to anyone willing to examine the logic on which they rest. But one thought has persisted in my mind ever since I became interested in the entropic nature of the economic process. Will mankind listen to any program that implies a constriction of its addiction to exosomatic comfort? Perhaps, the destiny of man is to have a short, but fiery, exciting and extravagant life rather than a long, uneventful and vegetative existence. Let other species—the amoebas, for example—which have no spiritual ambitions inherit an earth still bathed in plenty of sunshine.

(a) What economic problem was Georgescu-Roegen addressing in his first footnote (footnote 5)? What did he mean by "installations of all sorts"? Would this suggestion have solved the problem he was considering, and if so, would it have generated other problems?

(b) How compelling do Georgescu-Roegen's thoughts in his concluding paragraph appear from the viewpoint of today?

Answers to Final Exam Econ. 3250, Spring 2020

1. [Ch. 16] The Hotelling Rule says that in an exhaustible resource industry, marginal profit rises at the rate of interest (or rate of discount). It arises from assuming exhaustible resource extracting firms which maximize the discounted present value of profit.

   Consider Figure 2, which comes from Question 4 of Exam 2 of Spring 2017. According to the Hotelling Rule, marginal profit has to rise;

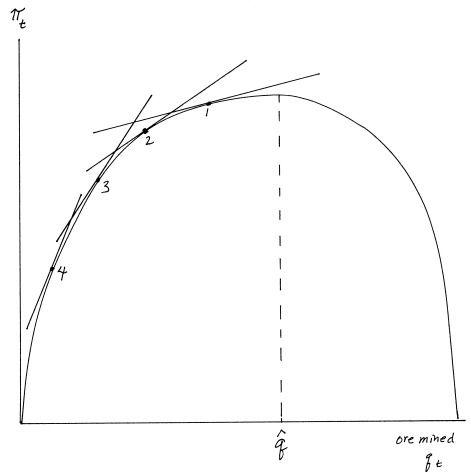

Figure 2

   this results in positions on the graph that begin at the point labeled 1, then going to 2, then 3, then 4. The slopes of the straight tangent lines are the respective marginal profit, which rises. Yet following such a program sacrifices the short-run greater profit which could be gained from producing at $\hat{q}$. If firms are more concerned about maximizing short-run profit than about maximizing the present value of profit, they would not follow the Hotelling Rule, instead they would produce at $\hat{q}$.

   Clearly they could not do this forever (they'd run out of resource at some date), and taking that end date into account, we reasoned in class that at this date quantity supplied would jump down to zero at the same moment that price jumped up (in order to choke off demand so that quantity demanded would also equal zero)—but no firm would voluntarily make its quantity jump to zero at the same moment price jumped up, but rather it would hold off on extracting the last ton of

resource until after the price upward jump. So the plan to extract at $\hat{q}$ as long as possible is not a perfect-foresight competitive equilibrium.

However, if firms are not thinking concretely about such a far-off occurrence, in the short run the best thing to do is to produce $\hat{q}$ instead of following the Hotelling Rule. In the real world, it's reasonable to argue that firms and investors pay far more attention to what is happening now than they do to what might happen around the future date of resource exhaustion, so in the real world firms are likely to ignore the Hotelling Rule.

2. [Ch. 18]

   (a) Non-compliance is potentially a more serious problem for command-and-control regulation of municipal solid waste ("MSW") than for command-and-control regulation of other types of environmental problems because it is rather easy to illegally dump garbage without being caught. Potential perpetrators are large in number (almost anyone could throw garbage away illegally) and potential dumping sites are many and widely dispersed, so are hard to police. Many other pollution problems could only be created by specific firms, which are few in number and so easier to police. Also, detecting illegally-disposed-of MSW is hard because there are so many places it could be put. Detecting illegal pollution of other types is sometimes as easy as monitoring a few smokestacks.

   (b) The same considerations for enforcing command-and-control regulations apply to enforcing "economic incentive instrument" regulation. Both types of regulation only work well if their mandates are followed, but the nature of MSY makes it easier to behave illegally than to behave illegally with respect to other environmental problems. Enforcement would seem to be no easier or harder with command-and-control than with economic incentive instruments. Both equally require accurate information on where MSY is disposed of and what type of MSY it is.

3. [Ch. 19]

   (a) One argument would be that some (more than zero) people in the rich part of the world care about the welfare of poor people, in the sense that the richer people would be willing to pay to increase the welfare of poor people. Hurting poor people would

then also hurt this subset of richer people, which means the willingness-to-pay ("WTP") to avoid a policy hurting poor people from going into effect includes money coming from some rich people. The resulting total WTP might not be small.

(b) The "diamond-water paradox" (see `https://en.wikipedia.org/wiki/Paradox_of_value`, which has a nice dicussion) is that diamonds have a high price (and so a high weight in GDP) and water has a low price (and so a low weight in GDP) even though diamonds are much less useful than water. The resolution of the "paradox" is that price is determined by the value of the *marginal* unit of a commodity. We use so much water (for example, to water lawns) that the marginal value of the last gallon is quite low. Hence the price of water is low. This low price, times the total amount of water, could result in a value of "price times quantity" which is still small. "Price times quantity" is what goes into GDP (because it's what comprises water's contribution to "national income," that is, it's what water producers get paid). The marginal value of one more diamond is quite high; even though the amount of diamonds produced is low, "price times quantity" (which equals the (gross) income of diamond sellers) could be high.

However if water supply were to fall drastically, the *remaining* gallons of water would fetch much higher prices than the current marginal unit fetches. This reveals that the true "value" of water to society is not "price times quantity," that is "the value of the last unit times quantity," but rather the value of *every* gallon of water. The value of every gallon of water used is surely *larger* than the value of every diamond used.

So Nordhaus's fallacy is to confuse the true value of a commodity with the market value of the commodity. Water's total value (the value for all units, not just the marginal unit) is higher than diamond's, but water's market value is lower. The much more important concept is total value, not market value.

4. [Ch. 20] This is the chemical reaction decomposing ozone $2\,O_3$ into oxygen O_2 with a chlorine ion as a catalyst. The anthropogenic introduction of chlorine ions thus causes a "hole" (or thinning) of the "ozone layer," which is a protective layer of ozone (or high concentration of ozone) in the upper atmosphere. Most of the chlorine ions come from chlorofluorocarbons ("CFC's"), mostly from refrigerants;

there are some other sources of CFC's as well. The ozone layer in the upper atmosphere stops some wavelengths of ultra-violet light from penetrating to the earth's surface. The wavelengths of ultra-violet light would cause skin cancers and other environmental problems.

The Montreal Protocol of the 1980's was an international agreement to curb emissions of CFC's and other ozone-destroying chemicals. It has been generally considered a success. This is largely because it has been possible to find relatively inexpensive substitutes for older refrigerants; other ozone-destroying chemicals, for example aerosol can propellants, have been even easier to find cheap substitutes for. Another factor in the success of the Montreal Protocol is that it was perceived as treating all nations fairly, and in particular it treated developed nations and developing nations almost the same, with a slightly relaxed timetable for developing nations.

5. [Chs. 17, 21]

   (a) We generally assume that firms' only desire is to maximize profits. A justification for this resembles a Darwinian argument: if one firm does not maximize profit and another one does, the second will out-compete the first, so the first will either go out of business or be bought out by the second. To the extent that this argument is correct—and one might object that it is not correct in the short run, and that since the long run is just a succession of changing, new short runs, the argument is never correct—firms would not separately care about something such as the environment. Any appearance of caring for the environment would be strictly in the service of increasing profit, perhaps by creating a "green" image to attract customers or good employees.

   By the way, "the moral case for the environment" is already reflected "within a regulatory framework" because such a framework ought to be taking "willingness to pay to help the environment" into account, and that WTP could well have moral roots.

   (b) The second sentence is quite misleading because "the morality of conservation" ought to be *part* of "the economic case for conservation." As in part (a) of this question, the morality of conservation affects willingness to pay for conservation, which in turn feeds in to the "economic case for conservation." This sentence seems to use the word "economic" as a synonym for narrowly pecuniary aspects, but one of the main points of this course is

that "economic" means much more than just narrow pecuniary concerns.

6. [Ch. 12] See Figure 3. If a tax is imposed on output, the effect is the

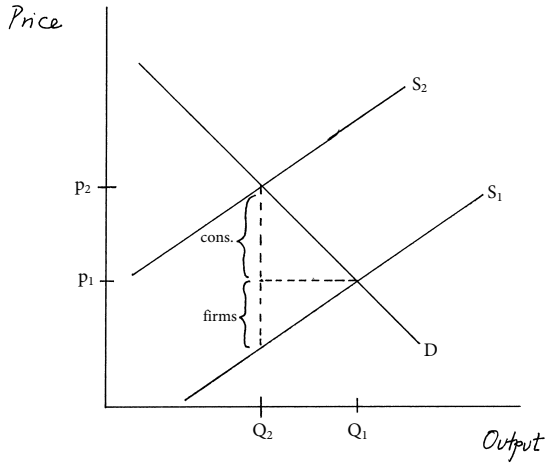

Figure 3

same as if marginal cost of production were to rise: the supply curve shifts back (geometrically up) by the amount of the tax. So the height of the vertical dashed line in the figure is the total amount of the tax per unit of output sold.

Equilibrium price goes up from p_1 to p_2, so the consumers bear some of the tax, and in particular, the gap between p_1 and p_2 is how much of the tax consumers really pay, once price changes are taken into account. Hence the "cons." portion of the vertical dashed line. The rest of the vertical dashed line must be borne by firms since there is no one else to bear it. Hence the "firms" portion of the vertical dashed line.

7. [Ch. 13] Posit an initial situation in which both firms are producing, for example, 10 tons of pollution each, so 20 tons in total. (You can come up with your own numbers; this is just one example.) Suppose the socially optimal amount of pollution is 18 tons (again, you could pick a different number).

   A command-and-control way of getting aggregate pollution to fall from 20 tons to 18 tons is to make each firm reduce its pollution

from 10 tons to 9 tons. This reduction would cost the low-abatement-cost firm ("LACF") \$50 and the high-abatement-cost firm ("HACF") \$100, for a total of \$150.

A tradeable permits system with grandfathering would give each firm 9 permits (each permit allowing the emission of 1 ton of pollution). If the firms neither buy nor sell permits, each firm has to reduce pollution by 1 ton, from 10 tons to 9 tons, for a total abatement cost of \$150 as explained in the previous paragraph. However, next suppose the LACF sold one of its permits to the HACF. The HACF now has 10 permits, so it just produces as it did before pollution regulation was imposed, and incurs no abatement costs. The LACF now has 8 permits, so it's required to pollute less than it did before pollution regulation was imposed (since $8 < 10$), and so it has to incur abatement costs of \$50/ton times 2 tons ("2" comes from comparing the old emissions of 10 to the new emissions of 8). Total abatement costs would be $\$50/\text{ton} \times 2 \text{ tons} = \$100$, all from the LACF because the HACF keeps its pre-regulation level of pollution. This is quite a bit less than the cost of achieving the same level of emissions via command-and-control (namely \$150). So tradeable permits are better in this example than command-and-control.

There are two more steps necessary for this argument to work. The previous paragraph says "next suppose the LACF sold one of its permits to the HACF"—but would the LACF really be willing to sell and would the HACF really be willing to buy? Suppose the permit price is $\$x$ and suppose that $50 < x < 100$.

If the LACF does not sell, its pollution is 9 tons and its abatement costs are \$50. If the LACF does sell, its pollution is 8 tons and its abatement costs are \$100, but it receives $\$x$ from the HACF, and since x is between 50 and 100, the LACF's net cost is less than \$50. So the LACF is better off selling.

If the HACF does not buy, its pollution is 9 tons and its abatement costs are \$100. If the HACF does buy, its pollution is 10 tons and its abatement costs are \$0, but it pays $\$x$ to the LACF, and since x is between 50 and 100, the LACF's net cost is less than \$100. So the HACF is better off buying.

8. [Ch. 23] See Figure 4, which comes from the answer to Question 3 of Exam 2 of Spring 2018. The tragedy of the commons is actually the tragedy of open access. The open-access equilibrium is at E_2,

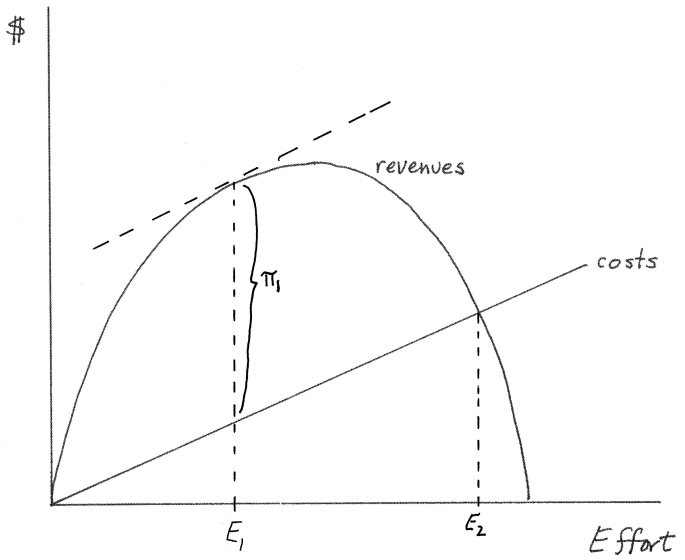

Figure 4

because there, costs are equal to revenues, so profit is zero, so there are no incentives to enter or exit the fishery. (Recall that if profit is not zero, then it's either positive—giving an incentive to enter the industry, which no one can prevent because of the openness of the access—or profit is negative, giving an incentive to leave the industry.) This is "tragic" because E_2 is a much better point. It's better for the fishing industry because it gives profit of π_1, which is much bigger than the zero profit earned at E_2. It's also better for the fish (the natural environment) because fishing effort is much less at E_1 than at E_2.

9. [Ch. 1] The last one is wrong. In particular, consider "concentrations (of anything) tend to disperse." There are examples where this is true: if a drop of ink is put into a cup of water, the concentrated ink tends to disperse. However if oil is put into water, even if the mixture is agitated so that the oil disperses, once the agitation stops the oil becomes concentrated at the top of the water. So in that case, the concentration has no tendency to disperse.

   "Structure tends to disappear" is a vague statement; how is "structure" measured?

   "Order becomes disorder": how is "order" measured? Furthermore, the Second Law of Thermodynamics intrinsically involves tempera-

ture. If the system whose "order" is being considered does not involve temperature, the Second Law is not relevant. So the "order" of books in a library or cards in a card deck has nothing to do with the Second Law.

Optional: This error in interpreting the Second Law began with Ludwig Boltzmann (who extended "Classical Thermodynamics" to "Statistical Mechanics" near the end of the 19th century). This error grew more widespread after being advocated by Erwin Schrödinger (who famously discovered Quantum Mechanics, which is in a different branch of physics than thermodynamics, several decades before his advocacy of the error).

Optional: Statement (a) is not wrong. While the First Law of Thermodynamics says that energy is neither created nor destroyed, the authors were well aware of the First Law (as might be inferred by their brief résumés which I gave in the footnotes), and they did not intend Statement (a) to contradict the First Law. By "degraded" they did not mean that the energy was destroyed, only that it had less "ability to do work." Not all energy as equal "ability to do work." For example, there is lots of heat energy stored in the oceans, but it can't be used to propel a ship across the water, so that energy has no ability to do work. (Caveat: over scales of hundreds of miles, there are ocean water temperature differences, which do do work by propelling ocean currents; and vertically in the ocean there are also temperature differences which can do work.)

10. [Ch. 3]

    (a) In his footnote 5 Georgescu-Roegen is concerned with international income inequality, particularly the existence of countries where most people are very poor. By "installations of all sorts" he means foreign aid programs (which exist not only in the US but in many other richer countries) and the many international organizations and charities set up to help poor countries. Georgescu's suggestion of allowing free movement of people across national borders was typical of countries before the late 19th century. It might work in equalizing wage rates around the world, though wage rates also depend on how productive the machinery is that people work with, and their educational level. However, there is significant within-country inequality, and it would likely remain (or perhaps even increase). In terms

of problems it might create, there would probably be ethnic tensions such as the ones in the US in the late 19th century, with discrimination against immigrants from Ireland, from southern and eastern European nations, and from China.

(b) In his last paragraph Georgescu-Roegen suggests most people will not want to sacrifice much in order to aid future generations. (One could say their intergenerational discount rate is high.) This is quite consistent with the great reluctance of many people around the world to take painful steps now in order to ameliorate global climate change for future generations.