Economics 5250/6250 Dr. Lozada
Fall 2018 Final Exam

This exam has 67 points. There are eight questions on the exam; you should work all of them. Most of the questions are worth 8 points each but Questions 3, 4 and 5 are worth 9 points each.

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.

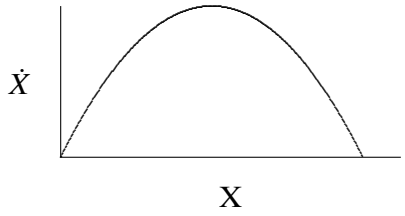
Good luck.

**Answer all of the following eight questions.**

1. **[8 points]** The logistic growth function

$$\begin{aligned}\dot{X} &= r\,X\,(1 - X/K) \\ &= r\,X - (r/K)\,X^2\end{aligned}$$

looks something like:




In class, we gave a mathematical interpretation of $r$, then inferred from that a graphical interpretation of $r$. Give these two interpretations of $r$, and state the name we give to $r$. (Hint: $\dot{X}/X$.)

2. **[8 points]** Below are two recent articles from the UK about the role fishing is playing in the Brexit controversies. Read them and then compare and contrast this situation with a different historical fisheries controversy. You should describe at least one way that the two controversies are similar from the viewpoint of economic theory and you should describe at least one way that the two controversies are different from the viewpoint of economic theory. (Saying "they are different because this is happening in the UK and the other controversy happened in Country XYZ" does not count as a difference "from the viewpoint of economic theory.")

> Brexit: Emmanuel Macron in EU customs union threat to Scottish fishing
> Paris Gourtsoyannis
> Published: 15:57 Sunday 25 November 2018
> `https://www.scotsman.com/news/brexit-emmanuel-macron-in-eu-customs-union-threat-to-scottish-fishing-1-4834797`
>
> Emmanuel Macron has put fishing at the heart of a fresh row over the future trade with the EU by threatening to keep the UK inside the customs union unless European fishermen keep the same rights in British waters after Brexit.
>
> The French President said that unless a new fishing agreement is agreed by the end of 2020, maintaining reciprocal access

to waters and imposing the same quotas as today, he would seek to trigger the 'backstop' included in the UK's divorce deal, keeping it under EU customs rules. [. . . ]

Brexit: Why is everyone talking about fishing?
By Philip Sim
BBC Scotland political reporter
28 November 2018
https://www.bbc.com/news/uk-scotland-scotland-politics-46372153

The fishing industry has found itself at the heart of the debate over Brexit and the prime minister's draft deal. But how did a sector which accounts for about 0.1% of the UK's economy become such a big issue? [. . . ]

So the actual fish-catching infrastructure is packed into a few small areas - particularly in Scotland, which has 53% of the entire UK industry. While it might make up a small sliver of the national workforce, the industry dominates some coastal communities in places like Peterhead. This means any changes in its fortunes have a very noticeable impact. . . . The fishing industry played a fairly major role in the Brexit campaign. . . . The industry became a symbol of dissatisfaction with the EU, an illustration of the "take back control" narrative of the Leave campaign. It was a tangible example that people could point to—the UK would literally be reasserting control over its waters by exiting the unpopular Common Fisheries Policy ["CFP"]. . . The Scottish Conservative MPs ["Members of Parliament"] wrote to Mrs May making clear that they could only support her deal if it protects the fishing industry and guarantees a speedy exit from the CFP. . . . Mrs May has managed to keep these concerns largely at bay, for now, by kicking the can down the road to future negotiations. But the topic continues to rear its head constantly. . . Only the Northern Irish backstop rears its heads as often when it comes to gripes about her draft deal. . . .

The symbolic value of fishing in the Brexit debate is chiefly about the catching of fish, given the ongoing row over whose boats will get to go where (and how much they'll be allowed to catch). But just as important as the catching of fish is the selling of it. For an example, let's look at the battered (or breaded) heart of the iconic British fish supper, cod and haddock. These fish only make up a small slice of the UK catch—5% is cod, 7% is haddock. And the majority of the stuff actually eaten here is actually imported—83% of the cod consumed in the UK is shipped in from abroad, alongside 58% of the haddock. What the UK fleet actually catches a lot of is herring - and 93% of it is

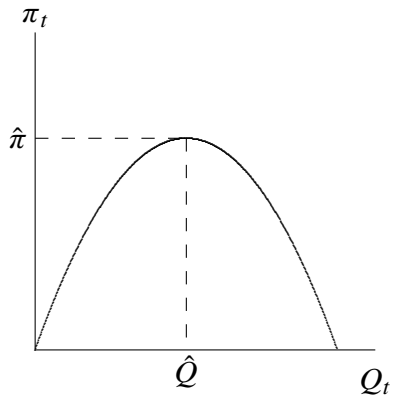



Figure 1

exported, mostly to Norway and the Netherlands, where people have much more of a taste for it. So, while the most regularly-cited issues are quotas and access, future trading arrangements are also going to be a big deal when it comes to fish. Basically, even if Mrs May's deal makes it through the Commons, we won't have heard the last of fishing.

3. **[9 points]** Suppose the instantaneous profit of a mining firm is graphed in Figure 1.

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

      i. a strategy of "maximize short-run profit;" and, 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 the implications of:

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

      ii. a strategy following the Hotelling Rule.

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

4. **[9 points]** Table 19.1 of your textbook lists the "1972 exponential exhaustion indices" in years for many minerals, taken from *Limits to Growth*. Here are a few of them ("$S$" denotes the 1972 known global reserves):

| | $S$ | $5 \times$ S |
|---|---|---|
| Aluminum | 11 | 55 |
| Coal | 111 | 150 |
| Copper | 21 | 49 |
| Iron | 93 | 173 |
| Gold | 9 | 29 |
| Natural Gas | 22 | 49 |
| Tin | 15 | 61 |
| Zinc | 18 | 50 |

(a) What is an "exponential exhaustion index?"

(b) What do the $S$ and $5 \times S$ columns mean?

(c) Seen from the vantage point of today, what is the meaning, lesson, or importance of these numbers, and why? (If you think the answer is "nothing of importance," explain why.)

5. **[9 points]** Show, in a diagram, the loss in social surplus if a polluting firm fools a government regulator into thinking that its MNPB curve is higher than it actually is. Explain your answer, as always. ("MNPB" is "marginal net private benefit.")

6. **[8 points]** What difficulties might occur due to the fact that Willingness to Pay is not equal to Willingness to Accept?

7. **[8 points]** Describe what "acid rain" is, what damage it causes, and what economic policies have been undertaken to control it.

8. **[8 points]** This question concerns the expression

$$\sum_{i=1}^{T} \frac{\pi_t}{(1+\delta)^t}$$

where $T$ is a fixed number (a constant) and $\pi$ denotes profit.

(a) If $T = 1$, what does this expression represent (both mathematically and economically)? Be sure to explain the meaning of $\delta$. This part of this question applies to all of economics, not just to environmental and natural resource economics.

(b) If $T = \infty$, what does this expression represent (both mathematically and economically)? This part of this question applies to all of economics, not just to environmental and natural resource economics.

(c) What role or roles did this expression, with $T = \infty$, play in our discussion of environmental or natural resource economics this semester? That is, how did we use it, and why?

## Answers to Final Exam Econ. 5250, Fall 2018

1. The "growth" of the fish stock $X$ is $\dot{X}$ and the "growth rate" of the fish stock is $\dot{X}/X$. Since the growth rate is

$$\frac{\dot{X}}{X} = r - \frac{r}{K}X\,, \tag{1}$$

we observe that

$$\begin{aligned}\lim_{X\to 0}\frac{\dot{X}}{X} &= \lim_{X\to 0}\left[r - \frac{r}{K}X\right]\\ &= r\,.\end{aligned} \tag{2}$$

Also, since $X$, $r$, and $K$ are all positive, the growth rate

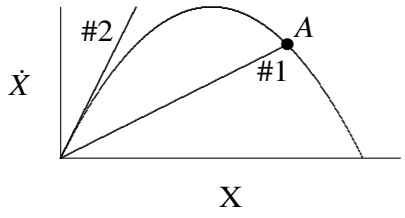
$$\frac{\dot{X}}{X} = r - \frac{r}{K}X \;< r\,.$$

So the growth rate is always less than $r$, but (2) says that it approaches $r$ in the limit as $X \to 0$. The name given to $r$ is the "intrinsic growth rate," and it is the maximum possible growth rate of the species, and it is attained only in the limit as $X \to 0$.

The growth of the fish stock as a function of $X$ is, multiplying both sides of (1) by $X$, the quadratic function

$$\begin{aligned}\dot{X} &= X\left(r - \frac{r}{K}X\right)\\ &= rX - \frac{r}{K}X^2\,.\end{aligned}$$

Its graph is:




Geometrically, $\dot{X}/X$ is the slope of a line from the origin to the function, such as the slope of the line marked "#1." In the limit as $X \to 0$, point $A$ goes to the origin, and lines such as #1 rotate until they look like the line marked #2. So the slope of line #2 is $\dot{X}/X$ in the limit as $X \to 0$. Since the latter is equal to $r$ from (2), the slope of line #2 must also be be $r$. This is $r$'s geometrical interpretation.

2. Most fisheries conflicts we studied concern, as the second article states, "whose boats will get to go where (and how much they'll be allowed to catch)." Examples include: fishing between the Ecuadorian mainland and the Galápagos Islands in the 1960's and 1970's; fishing around Iceland in the "Cod Wars" of the 1960's and 1970's, where the conflict was primarily between Iceland and the UK (https://en.wikipedia.org/wiki/Cod_Wars); the collapse of the Atlantic northwest cod fishery off the coast of Canada in the early 1990's (https://en.wikipedia.org/wiki/Collapse_of_the_Atlantic_northwest_cod_fishery) and the resulting "Turbot War" between Canada and the European Union (https://en.wikipedia.org/wiki/Turbot_War); and fishing off the coast of Somalia (http://www.risetopeace.org/2018/03/25/how-overfishing-led-to-piracy/). What is different is also mentioned in the second article: "But just as important as the catching of fish is the selling of it." The UK exports lots of fish of species abundant near the UK but liked more by the people of continental Europe, and the UK imports lots of fish of species liked by its inhabitants. With Brexit, this exporting and importing of fish may decline. In particular, Brexit may hurt the UK fishing industry by limiting its export markets. Difficulty in exporting fish that one can catch has not been an issue in past fishing disputes.

3. See Figure 2 and the Figures A and B on the next page. The strategy of maximizing short-run profit entails staying at the highest point in Figure 2, namely point $(\hat{Q}, \hat{\pi})$, for as long as possible—that is, until the resource runs out. After the resource runs out, $Q = 0$ so $\pi = 0$. In Figure A, this is shown by quantity staying at $\hat{Q}$, a horizontal line, until it falls to zero, where it stays from then on. In Figure B, this is shown by profit staying at $\hat{\pi}$, a horizontal line, until it falls to zero, where it stays from then on.

   Following the Hotelling Rule strategy entails having marginal profit rise at the rate of interest. Marginal profit is represented by tangent lines to the total profit graph of Figure 2. Moving from point $M$ to point $N$ corresponds to moving to a steeper tangent line and therefore a higher marginal profit, which is the direction the Hotelling Rule says to go. Moving from $M$ to $N$ corresponds to moving from $Q_1$ down to $Q_2$, as shown in Figure A, and moving from $M$ to $N$ corresponds to moving from $\pi_1$ down to $\pi_2$, as shown in Figure B.

   For part (c), "(ii) is more plausible than (i)": At time $\hat{t}$ of Figure A, quantity takes a large jump down. In competitive equilibrium this fall

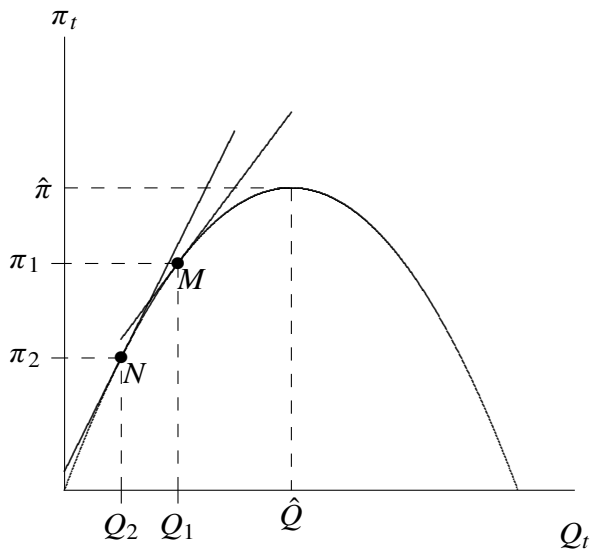



Figure 2

in quantity supplied (to zero) must go along with a fall in quantity demanded (to zero). The only way to get quantity demanded to fall to zero would be for price to rise a lot. But if price at $\hat{t}$ rises a lot, it makes no sense for the firm, which is assumed to know the future, to choose to mine its last ton of resource just before, rather than just after, the price jump. So this is not a dynamic competitive equilibrium.

"(i) is more plausible than (ii)": Following (i) maximizes short-run profit. The firm which does this beats all other firms every year until year $\hat{t}$. During the many years before $\hat{t}$, this persistent earning of higher profits by this firm would probably enable it to take over other, lower-profit-earning, Hotelling-Rule firms, or run them out of business. (After time $t'$, everyone knows that following the Hotelling Rule would have been a better strategy, but $t'$ is probably many years in the future, and by then it's too late: the resource along the $\hat{Q}$ path is already exhausted at $\hat{t}$, which is before $t'$.)

4. (a) It is a prediction of how many years left of a resource exists in the earth if the amount of that resource which is mined every year increases exponentially with time.

   (b) The $S$ column is the exponential exhaustion index assuming the 1972 level of reserves $S$ does not go up (that is, that there are no

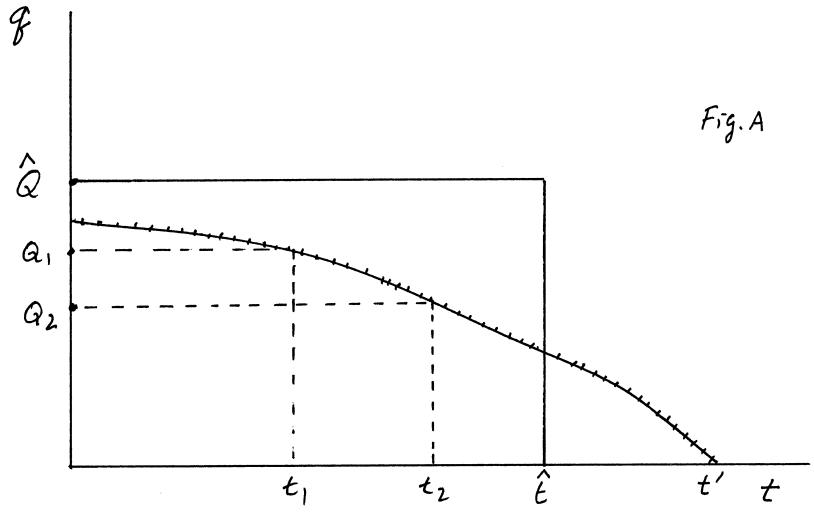



Fig. A

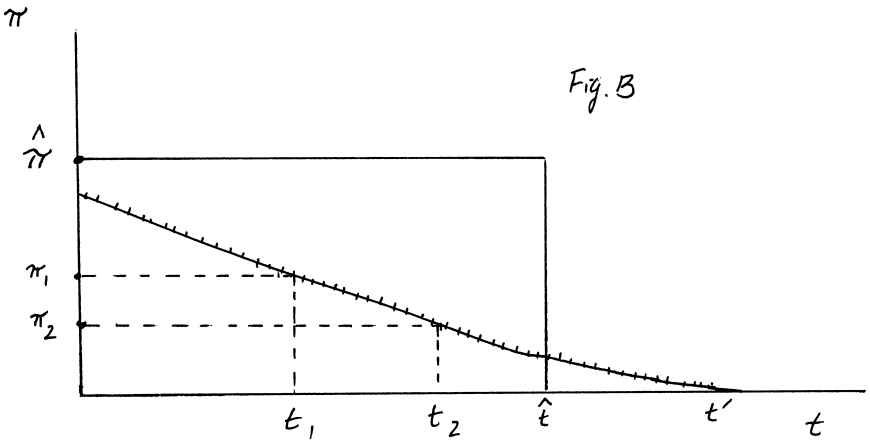



Fig. B

more resource discoveries). The $5 \times S$ column is the exponential exhaustion index assuming the total amount of new discoveries over time will increase reserves from $S$ to five times $S$.

(c) In the table below I have added the original year, 1972, to each of the exponential exhaustion indexes.

| | $S$ | $5 \times$ S | $S$ | $5 \times$ S |
|---|---|---|---|---|
| Aluminum | 11 | 55 | 1983 | 2027 |
| Coal | 111 | 150 | 2083 | 2122 |
| Copper | 21 | 49 | 1993 | 2021 |
| Iron | 93 | 173 | 2065 | 2145 |
| Gold | 9 | 29 | 1981 | 2001 |
| Natural Gas | 22 | 49 | 1994 | 2021 |
| Tin | 15 | 61 | 1987 | 2033 |
| Zinc | 18 | 50 | 1990 | 2022 |

Clearly most of the predictions in the $S$ column were wrong because those dates have passed without those resources being exhausted. Some of the dates in the $5S$ column are also in the past or are so close to us now that exhaustion by then is not going to happen. So, the predictions were too pessimistic. As for the future, it's hard to say. Just because we did not run out of these resources in the past does not mean we will not run out of them in the future. When, however, is hard to say.

5. Refer to Figure 3. The socially-optimal point is $B$, where the true "marginal net private benefit" ("*MNPB*") curve intersects the "marginal external cost" ("*MEC*") curve. However the government is fooled into thinking that the socially-optimal point is $A$, where the false *MNPB* curve intersects *MEC*. As a result, too much output is produced (output beyond $q_{\text{right}}$). The output between $q_{\text{right}}$ and $q_{\text{wrong}}$ generates total external costs which are the area under $AB$ in the graph, while only adding the area under $BC$ to private benefits. The net change in social surplus is a loss of the triangle below $AB$ and above $BC$, so the triangle $ABC$.

6. **[8 points]** See the answer to Fall 2013 Exam 1 Question 4.

7. **[8 points]** See the answer to Fall 2011 Exam 1 Question 5.

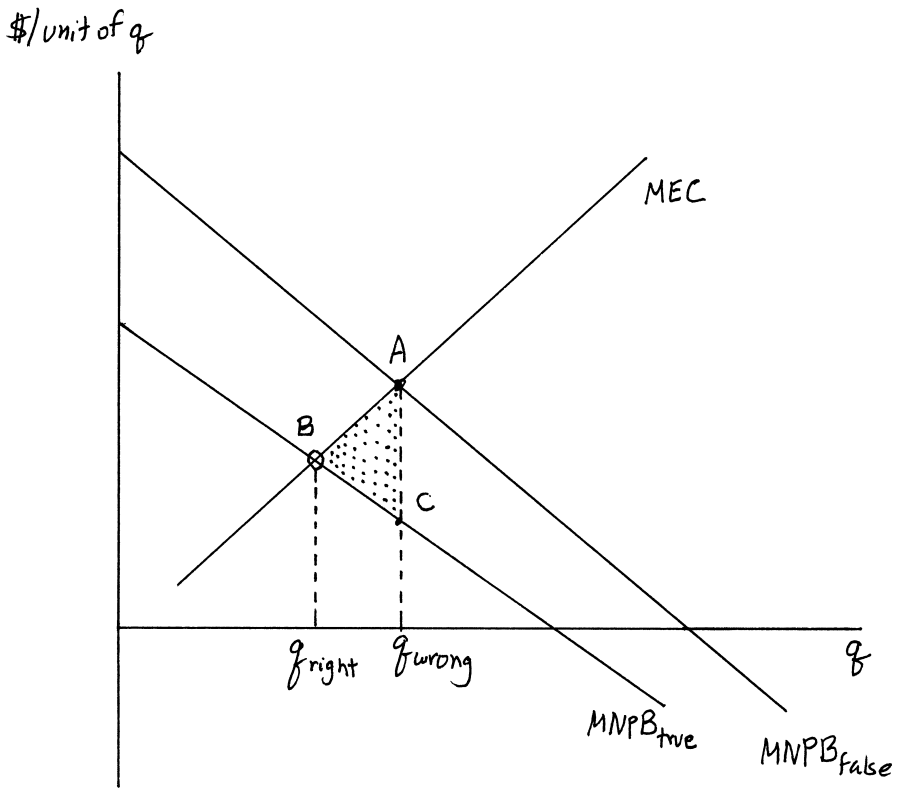



Figure 3

8. **[8 points]** This question concerns the expression

$$\sum_{i=1}^{T} \frac{\pi_t}{(1+\delta)^t}$$

(a) Mathematically, if $T = 1$ then the expression is just

$$\frac{\pi_1}{1+\delta}.$$

Economically, this is the profit earned at time 1 (at the end of time 1) divided by one plus the "rate of time discount" (often we say "the rate of interest," though there are subtle distinctions between the two). It is the present value of $\pi_1$, that is, the value now of $\pi_1$ at the end of period 1.

(b) Mathematically, it is

$$\frac{\pi_1}{1+\delta} + \frac{\pi_2}{(1+\delta)^2} + \frac{\pi_3}{(1+\delta)^3} + \frac{\pi_4}{(1+\delta)^4} + \cdots .$$

Economically, it is the present value (that is, the value today) of the future stream of profits $\pi_1$, $\pi_2$, $\pi_3$, $\pi_4$, .... "Present Value"

is also called "Present Discounted Value." The "undiscounted sum" would be just $\pi_1 + \pi_2 + \pi_3 + \pi_4$, which is what the above expression would equal if $\delta$ were zero.

(c) We modeled both the exhaustible-resource-extracting firm and the private-property fishery as maximizing this present discounted value of profit. It was the main behavioral assumption underlying those analyses. (One of the implications was the Hotelling Rule.)