Answers to Problem Set #3

1. [3 points] Conventional wisdom holds that a price ceiling \( p_c \) does not affect the market (i.e. price and quantity produced) if the current market equilibrium price \( p \) is below \( p_c \). Show that this is not true if a permanent price ceiling is imposed on a nonrenewable resource that is extracted over many (possibly infinite) periods of time. In particular, what happens to the price and quantity extracted in the short run and in the long run?

If a permanent price ceiling is imposed, there will be a time in the future when the price ceiling will be binding. At that time, the marginal benefit of extracting the resource will be reduced. Anticipating this, the owner of the resource will increase extraction since the marginal user cost is lower (that is, the opportunity cost of extracting the resource now becomes lower). That is, in the short run, quantity supplied increases, and price thus decreases. In the following graph, initially quantity extracted is at \( q_0 \). When price ceiling is imposed, the quantity goes up to \( q_1 \).

Increased current extraction means that the resource will be depleted faster. As the resource depletes, extraction also goes down. Eventually, extraction, or the quantity supplied will be so low that price ceiling starts to be binding. This happens when the extraction is at \( q_2 \). After this, for example at \( q_3 \), there will be a shortage.
2. [3 points] It has been argued that countries other than OPEC have more incentive to conduct oil exploration. For example, North Sea was discovered after the energy crisis, and currently, countries such as the U.S., Norway, and China are all exploring intensively for offshore oil fields. On the other hand, oil explorations by OPEC countries are less intensive. Based on the cartel (OPEC) and competitive fringe argument, can you explain this difference in exploration efforts?

The major reason is that the cartel has market power and the fringe countries are price takers. Note that cartel members have to cut back production in order to raise prices, while the fringe countries actually increase their production as the price increases. Consequently, the cartel members do not want to do too much exploration since even if they discover more reserves, they do not want to extract much more since they have to maintain the high price. The fringe firms, however, are ready to increase their extraction if additional reserves are discovered, since their action does not significantly affect the price. That is, at the margin, the fringe's reserves are more valuable than those of the cartel members.

3. [4 points] Consider a water project in a region that supplies water to both industrial and agricultural use. Their demand functions for water are respectively:

\[
\begin{align*}
q_u &= 6 - p \\
q_a &= 12 - p
\end{align*}
\]

The water project has a capacity limit of \( S = 18 \), and the marginal cost of water supply is constant at 1.

a) What is the efficient price of water? What are the quantities of water allocated to agricultural and industrial use? What is the marginal scarcity rent of water?

We first check whether the water is scarce. Suppose not. Then water is priced at its marginal cost of supply, \( p = MC = 1 \). Then urban demand is \( q_u = 6 - 1 = 5 \), and agricultural demand is \( q_a = 12 - 1 = 11 \). The total demand is thus \( 5 + 11 = 16 < 18 \). Therefore, water is not scarce and both urban and agricultural water demands are fully satisfied. Since water is not scarce, the marginal scarcity rent is zero.

b) Suppose that a new government regulation requires that the environmental value of water is considered in making water allocations. The marginal benefit of environmental use is

\[ q_e = 6 - p \]

What are the new efficiency water price and the new allocation of water between agriculture and the industry? How much water is left for environmental use? What is the new marginal scarcity rent of water?

First, it is easy to check that now water is scarce. If \( p = 1 \), the total demand will be \( 5 + 11 + 5 = 21 > 18 \).
To calculate the allocation with scarcity, we need to figure out the total demand function for water. Note that there are two "jump" points at p=6 and p=12. If p<6, all three demands are nonzero, and summing them up, we get the total demand as \( q = (6-p) + (12-p) + (6-p) = 24-3p \). If \( 6 \leq p < 12 \), only agricultural demand is nonzero. Thus the total demand is \( 12-p \). In summary, the total demand function is

\[
q = \begin{cases} 
24 - 3p & \text{if } p < 6 \\
12 - p & \text{if } 6 \leq p < 12 \\
0 & \text{if } p \geq 12 
\end{cases}
\]

The total capacity of water is 18. Now suppose p<6. Then "demand = supply" implies that

\[
24 - 3p = 18,
\]

or p=2. Since this price is less than 6, we know this is the equilibrium price of water.

At p=2, we know \( q_a = 12-2 = 10 \), and \( q_e = 6 - 2 = 4 \). The marginal scarcity rent of water is "price - marginal cost" = 2-1=1.