1 Water − 25 pts

Explain why water allocation between urban and agricultural users is inefficient. Discuss (in one paragraph) property rights, different demand by urban and agricultural users, the resulting difference in prices and the optimal price and quantity if water markets existed. Provide a graph to explain your answer.

25 points − 9 graph, 16 explanation (equal between property rights, demand, prices, optimal allocation).

Answer:

Agricultural users have the senior rights to water. Their demand is more elastic than urban users’ demand. Because agricultural users have the senior rights, they can use as much water as they need. That is, their use is where their demand meets supply. Urban users then look at residual supply (total supply minus the water used by agricultural users) and set that equal to their demand. The price for agricultural users is lower and the quantity is higher than that of the urban users. This means that the marginal benefits are unequal and the social welfare can be increased by reallocating water
from agricultural to urban users. The optimal (efficient) allocation (that is if trading is allowed) occurs where total demand (the horizontal sum of agricultural and urban demands) meets supply. This would result in a price between the urban and agricultural price under Riparian water rights. For the graph necessary for this problem, please refer to graph 16.2. on p.8 of Ch.16: “Surface Water Economics” at http://are.berkeley.edu/~zilber/EEP101/spring02/detailed_text/16.pdf.

2 Pesticides – 35 pts

Suppose a farmer can potentially produce 200 pounds of cotton. Due to pests, however, actual output is below potential output. To remedy the situation, the farmer uses a certain amount of pesticides (X). Due to weather differences across years, pest levels are high in some years and low in others. There is a 50% chance that weather conditions will be favorable for pests and 100 of them will attack the field. The rest of the time, conditions are less favorable and only 50 attack the field. If the farmer uses a preventive pest control program, she will choose the amount of pesticides that maximizes expected profits $E(\pi)$:

$$E(\pi) = \phi \left(pY (1 - D_h(X)) - wX_0\right) + (1 - \phi) \left(pY (1 - D_l(X)) - wX_0\right)$$

Where

- $\phi$ is the probability of facing a high pest year = 0.5
- $p$ Price of cotton = 5
$Y$ Potential cotton output = 200

$D_h$ Damage from pests, measured as the fraction of crops lost, in a high pest year. This depends on the amount of pesticides used.

$D_l$ Damage from pests, measured as the fraction of crops lost, in a low pest year. This depends on the amount of pesticides used.

$X_0$ Use of pesticides under a preventive pest management program

$w$ Per unit price of the pesticides = 10

(a) Interpret the above equation. Be specific as to the economic meaning of each part.

5 pts. **Answer:** $D_h(X_0)$ is the proportion of potential output damaged by pests in high pest year. Therefore $1 - D_h$ is the proportion of potential output not damaged and $y(1 - D_h)$ is the actual output. Actual output times price is the revenue and $wX_0$ is the input cost. Therefore the first term in brackets is the profit in a high-pest year. Similarly, $pY(1 - D_l(X_0)) - wX_0$ is the profit in a low-pest year. The expected profit is the probability of a high pest year ($\phi$) times the profit in a high-pest year plus the probability of a low pest year times the profit in a low-pest year.

(b) Write the condition for the optimal level of pesticide use under a preventive approach. The condition should be in general terms (using the notation above) and employ the concept of marginal benefit and cost.

8 pts **Answer:** Under a preventative approach, the farmer applies pesticides without knowing whether it is a high-pest year or a low-pest year. Therefore, he maximizes expected profit with respect to amount of pesticides $X_0$. To find the max, we take the first derivative of the expected profit $E(\pi)$
with respect to \( X_0 \) and set it equal to 0 (to make sure this is a max as opposed to a min we need to check that the second derivative is less than 0 but as in the rest of the class you are not expected to do that).

\[
\frac{\partial E(\pi)}{\partial X_0} = \phi \left( pY \left( - \frac{\partial D_h(X_0)}{\partial X_0} \right) - w \right) + (1 - \phi) \left( pY \left( - \frac{\partial D_l(X_0)}{\partial X_0} \right) - w \right) = 0
\]

We put on the left-hand side \( w \) and we get:

\[
w = pY \left( \phi \left( - \frac{\partial D_h(X_0)}{\partial X_0} \right) \right) + (1 - \phi) \left( - \frac{\partial D_l(X_0)}{\partial X_0} \right)
\]

The left-hand side is the marginal cost of an additional unit of pesticide. The right-hand side is the expected marginal benefit of one more unit of pesticide used because \( \frac{\partial D}{\partial X_0} \) is the reduction in the damage by using one more unit of pesticide. At the optimum, the marginal cost equals the expected marginal benefit.

(c) Suppose the amount of pesticides that maximized expected profits is \( X_0^* = 5 \). This amount of pesticides will reduce damage from pests to 2% of output \( (D_l(X_0^*) = .02) \) when pest levels are low, and to 10% of output when pest levels are high. Calculate expected profit.

2 pts. Answer: Plug the numbers in the equation for expected profit.

\[
E(\pi) = \phi \left( pY(1 - D_h(X_0)) - wX_0 \right) + (1 - \phi) \left( pY(1 - D_l(X_0)) - wX_0 \right)
\]

\[
E(\pi) = .5(5 \times 200 \times (1-.1) - 10 \times 5) + (1-.5)(5 \times 200 \times (1-.02) - 10 \times 5) = .5 \times 850 + .5 \times 930 = 890
\]

(d) The farmer could also invest in an integrated pest management (IPM) system that monitors the severity of pests and tells her to use less pesticides.
in low years and more pesticides in high years. Under this system the optimal levels of pesticides \((X_h^*, X_i^*)\) maximize profit:

\[
E(\pi) = \phi \left( pY(1 - D_h(X_h)) - wX_h \right) + (1 - \phi) \left( pY(1 - D_i(X_i)) - wX_i \right)
\]

Write the conditions for the optimal use of pesticides in a high pest year and in a low pest year.

8 pts **Answer:**

Under IPM, the uncertainty is eliminated. Before applying pesticides the farmer knows if it is a high-pest year or a low-pest year. Therefore, depending on the type of year, she will apply \(X_h\) or \(X_i\).

In a high-pest year, the farmer knows that \(\phi = 1\) and is maximizing the profit for a high-pest year.

\[
\max_{X_0} \pi_h = pY \left( 1 - D_h(X_h) \right) - wX_h
\]

We take the first derivative with respect to \(X_h\) and set it equal to 0. We get \(w = -pY \frac{\partial D_h(X_h)}{\partial X_h}\). The marginal cost is equal to the marginal benefit of an additional unit of pesticide.

Similarly, in a low-pest year, \(\phi = 0\) and the farmer maximizes profit with respect to \(X_i\). The condition is \(w = -pY \frac{\partial D_i(X_i)}{\partial X_i}\).

(e) Under this IPM system, the farmer uses \(X_h^* = 6\) and \(X_i^* = 1\). This reduces damage from pests to 5% in all years. How much is the farmer willing to pay for the IPM system?

**Answer**

6 pts - 2 for calculation of \(\pi\) under IPM, 4 for calculating willingness to pay.
We plug in the numbers into the equation and the average profit under IPM is:

\[
\text{average } \pi = \phi \left( pY(1-D_h(X_h)) - wX_h \right) + (1-\phi) \left( pY(1-D_l(X_l)) - wX_l \right) = 915
\]

The farmer is willing to pay for an IPM system at the maximum the additional profit that the IPM brings. The farmer is willing to pay \( \pi(\text{IPM}) - \pi(\text{preventive}) = 915 - 890 = 25 \) to switch to the new technology of IPM.

(f) Which program (preventive or IPM) leads to less use of pesticides?

**Answer:**

6 pts.

*On the average, the preventative approach uses* \( X_0^* = 5 \) *and the IPM uses* \( X_{\text{aver}} = \phi X_h + (1-\phi)X_l = 3.5 \). *Therefore, the IPM uses less pesticides.*

## 3 Intellectual Property Rights – 15 pts

Explain how patents differ in developed and developing countries. Give three differences with examples.

*5 pts for each difference. Many answers are possible to this question and any well justified and reasonable response will be given credit.*

**Answer:** Three of the main differences in how patents work in developing and developed countries are (1) institutions for protection of patents; (2) goals of the patents; (3) capacity to bring about patentable technology (human and financial capital to undertake research that will lead to patents). Institutions for protection of patents are vastly different, with the developed
countries having a good system for establishment of patents and their protection. In developing countries, the system for establishing of patents might be non-existant and the protection it provides can be weak. The patents in developed countries usually concern issues in developed countries (e.g. northern crops or drugs for chronic diseases). The goal of research in developing countries is to meet the social priorities in those countries. Thirdly, developing countries lack capital to invest in research and development. Additionally, this problem is compounded by “brain drain”, which does not allow those countries to build strong human capital necessary for innovation.

4 Environmental Services – 25 pts

Suppose there is a new policy under consideration in the Bay Area aiming to improve air quality and reduce greenhouse gases. The policy suggests that car commuters are to be paid not to commute by car but by public transportation. Discuss how you would design the policy in terms of its implementation, transaction costs, monitoring, and enforcement.

*Credit is given for proposing a policy, and/or outlining possible problems in terms of its implementation, transaction costs, monitoring and enforcement.*

**Suggested Answer:** Commuters currently have the de facto rights to drive their cars and pollute the air. The proposed policy will provide for subsidies for commuters to change their behavior and engage in more sustainable practices.
A possible policy might be a subsidy (or a tax break) to people who provide a proof of using public transportation for commuting. A proof might be tickets, employment address and home address. This will involve updating ticket reading machines at BART to stamp the time and dates on tickets and provide them back to commuters. There is the problem of not knowing who used to drive and who used to BART, however this might not be a big concern because such a program will provide a continuing incentive for people who already use public transportation to continue to do so. Since there is currently a similar policy in place (the commuter check, i believe, which gives a tax benefit) that is obviously not sufficient and the proposed subsidy needs to be of much higher value to foster a change in behavior. The transaction costs of running this policy is expected to be very high if it involves commuters sending materials and government bureaucrats making sure that the restriction of the policy are met. The initial costs of overhauling the ticket reading at BART can be very expensive. Monitoring involves checking the sent-in tickets, etc. and is costly. Enforcement of such a policy can be very straight-forward unless we are concerned with not paying people who were using BART even before the program.