Study Questions to Accompany International Energy Markets

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Chapter 5. Natural Monopoly and Electricity Generation

5.1 Suppose that a 500 megawatt hydro power plant including the dam costs $2500 per kilowatt of capacity.

5.1a What is the total cost of building the plant?

5.1b What is the maximum amount of electricity this plant could produce in 40 years if it could operate 24 hours a day, 365 days a year for 40 years? To produce more electricity the operator on duty opens a sluice and allows more water to fall under the dam. Assume the operating cost of a kilowatt-hour of electricity is 0 for this plant.

5.1c. Write a total cost function for building and operating this plant for 40 years. Assume that the interest rate is zero so we can ignore time costs of money. (We will do more realistic examples of capital costs in chapter 15 using a positive interest rate.)

5.1d Assuming no time costs of money and the plant runs at full capacity over 40 years, what is the short run average cost function per kWh?

5.1e What is the short run marginal cost function? Measure your output in kilowatt-hours.

5.1f The following table gives information from the EIA on costs for five types of power plants for some of their modeling work. Assuming no time cost of money, compute the cost information in the subsequent table.

	Capacity Cost	Plant Size	Operating Cost	% Time	Plant life
Type Plant	**$/kW**	**MW**	**$/kWh**	**Operate**	**years**
Coal	1000	500	0.024	90%	40
Coal	3500	500	0.046	90%	40
Gas Combined Cycle	975	500	0.035	90%	40
Nuclear	5000	500	0.021	90%	40
Gas Turbine	1000	500	0.035	45%	40
Hydro	3000	500	0.000	100%	40

5.1g If capital is paid for upfront, it takes 2 years to build the hydro plant, it then operates for 40 years at 100% of capacity, and the interest rate is 15%, compute the levelized cost of capital? Assume all capital is paid for up-front at time 0, electricity is all paid for at the end of the year. Thus, payments start at the end of year 3 and commence for 40 years.

5.1h How would your answer to 5.1g change if the half of the cost of the plant was paid at year 0 and the balance was paid at the end of the first year?

5.2 Suppose demand and cost of electricity generation industry are

$Q = 24 - (1/6)P$

$TC = 34Q - 0.5Q^2$

Where Q is measured in megawatt hours, price is measured in dollars per megawatt hour, and total costs are measured in dollars.

5.2a What is the socially optimal price and quantity in this market? What are profits at this level of price and quantity? (Remember to invert demand curve to set P = MC.)

5.2b Should this market be treated as a natural monopoly? Why or Why not? (Hint observe the shape of the average cost function.)

5.2c What would you expect to happen in this industry, if the industry was allowed to develop with no interference? What is the long run price and quantity with no interference in the market? What is the total welfare in the no interference case? What are the social losses from this case compared to the optimum in case a?

5.2d What are the economies of scale at the price and quantity in part c? (Check whether $\partial ATC/\partial Q$ ><=0 indicating diseconomies, economies, or constant economies of scale. (Note: Industries with these properties can be called increasing, decreasing of constant cost industries.)

5.2e Now suppose that this utility is connected to a power grid and people are free to choose any supplier. Power can be wheeled (purchased on the wholesale market) for 17 dollars per megawatt kilowatt hour. Thus any buyer would not buy from this utility if they charged a price higher than 17 dollars but would buy off of the grid. This makes this utility's demand curve flat at 17 dollars and above, but they face their downward sloping demand at prices below 17 dollars.

5.2e1. Draw their new demand curve?

5.2e2 What is marginal revenue for the flat area of the demand curve?

5.2e3 For the downward sloping portion of their demand curve?

5.2e4 What price and quantity would a profit maximizing monopoly be at?

5.2f What would happen if a $2 tax were placed on electricity? Be sure to be able to do this for a subsidy as well.

5.3 Suppose you are on a state utility commission and you have to make a decision on a rate case for Power Galore Utility (PGU). The legally established rate of return for the utility is s = 10%. PGU sells to two customer classes – residential and business – and is requesting the following prices for each class. They estimate sales in each rate class to be qi, their rate base is $750,000, the estimate fuel costs per kwh to be ci and other operating costs per kilowatt hour to be oi.

	P_i	Q_i	C_i	O_i	RB
i = 1	0.08	1,966,667	0.02	0.03	750,000
i = 2	0.05	799,999	0.02	0.01	

5.3a Based on the above table would you approve the rates requested? Why or why not?

5.3b Now suppose you have hired an independent contractor to estimate the demand equations for the two customer classes.

$$Q_1 = 2{,}000{,}000 - 100{,}000P_1 \qquad (5.40)$$

$$Q_2 = 900{,}000 - 100{,}000P_2 \qquad (5.41)$$

5.3c Would you be willing to give the utility lower or higher prices than proposed based on this new information and the costs and RB presented above? Why or why not?

5.4 Suppose a utility owns a coal mine. It sells 100 tons of coal to itself per year at $29 per ton and produces and sells 222,000 kilowatts of electricity at $0.06 per kilowatt hour. Coal mining has a 10% Federal depletion allowance, which allows them to deduct 10% of their revenues for tax purposes. Deductible costs are shown in the example below. Taxable income for the combined mine and utility are $2260 + $2420 = $4680.

Mine	
Sales Revenue = 29*100 =	**$ 2,900.00**
Operating Costs	**$ 300.00**
Depreciation	**$ 50.00**
% Depletion Allowance (10%)	**$ 290.00**
Taxable Income	**$ 2,260.00**
Utility	
Sales Revenue = 0.06*222000	**$ 13,320.00**
Fuel Cost	**$ 2,900.00**
Other operating costs	**$ 5,000.00**
Depreciation	**$ 3,000.00**
Taxable Income	**$ 2,420.00**

What happens to taxable income in the above example if the utility pays its mine $40 per ton? Explain why the tax changes?

5.5 Because money can earn interest if invested, a dollar now is worth a different amount than a dollar in a year. Thus economic decisions require that we can compound money to see its future value or discount future payments to see what they are worth now.

5.5a What is $5 worth in 50 years with annual compounding, if the interest rate is 10%?

5.5b What is $100 in 7 years worth today, if the interest rate is 10%?

5.5c What is $100 in 7 years worth today, if the interest rate is 20%?

5.5d Are future values worth more or less today as the interest rate goes up? Justify your answer mathematically. Try to give an intuitive explanation of why this is?

5.5e If interest rates are compounded p times per year, the value of A in t years is (1+r/p)tp*A. Redo part a if interest is compounded quarterly or p=4 times per year.

5.5f If we take the limit as p goes to ∞ we have continuous compounding and the formula becomes lim (1+r/p)tp*A = ertA, where e is the exponential function. Recompute part a for continuous compounding. Does it make much difference whether we compound annually or continually?

5.6 Suppose your interest rate is 15%, interest is compounded annually and you build a power plant costing 200 in year one (assume all the money is paid out on day 1) and it pays out a stream of income at the beginning of years 2 through 10 as shown below. Decommissioning costs are 20 and they occur at the beginning of year 11. This makes your stream of income

-200	30	35	35	35	35	25	35	35	35	35	-20

5.6a Set up the formula for the NPV of this power plant? Let payments is X_i for i = 1, 11,

5.6b Most spread sheets have a net present value function. For example in Excel, you could enter the above income stream in cells A1 to A12. If you went to cell A12 and typed in the formula =A1 + NPV(0.15,a2:a12) it would compute the NPV for you. Note for NPV in this program you have to enter the current expenditure (-200) separately because Excel discounts the first number in the NPV function one year, the second value two years, etc. You can also get the NPV function in Excel with a menu to fill in if you go to Insert, Function, Financial, and scroll down to NPV. Compute the NPV using a spreadsheet. Note the 0 place holder for year 1 so that the years are discounted properly.

5.7 Suppose that a utility issues a stock that sells for $50, the future dividends are expected to be $30 for 2 years. Assume you buy the stock now and dividends are issued at the end of this year and at the end of next year.

5.7a What is the internal rate of return or the k for this stock.

5.7b Now suppose that a utility issues a stock that sells for $50, the future dividends are expected to be $10 for 10 years. Assume you buy the stock now and dividends are issued at the end of this year and at the end of each subsequent year. Use Equation 5.45 to write out the equation you would need to solve to get this stock's rate of return also called internal rate of return.

5.7c Since this is a difficult equation to solve it is easiest to turn to a spread sheet for its solution. For example, in Excel put –50 in A1 and 10 in each cell A2-A11. Go to cell A12 and type in =IRR(a1:a11,0.1), where the first expressions are the addresses for the cash flow and 0.1 is a starting guess. Note that the solutions are not necessarily unique. You can also use the IRR function from a menu if you go to Insert, Function, Financial and scroll down to IRR. What is the IRR for this stock?

5.7d Typically stocks last for more than 10 years. What is the IRR if the stock pays out $10 per year for 20 years? 30 years? 40 years?

5.7e What happens to the IRR as we add dividends further away in time? Why do you think that is?

5.7f What is the IRR for the power plant in 5.6?

5.7g What happens to the NPV and IRR if the electricity generator in 5.6 is building a nuclear plant and permitting problems delays starting up the plant for 3 years making the income stream -200 now and then no income until the end of year 5. Then the income stream commences as before for the next years 10 years.

5.8 The Bureau of Labor Statistics publishes a variety of useful data. Browse their homepage **www.bls.gov** to see what some of these statistics are. Read the information on how producer prices are constructed is given at **http://www.bls.gov/opub/hom/homch14_a.htm**.

For the following producer price indexes:

Year	Average Producer Price
1984	130.7
1985	130.2
1986	100.2
1987	102.8
1988	106.9
1989	112.2
1990	116.3
1991	116.5
1992	117.2
1993	118.9
1994	120.4
1995	126.7
1996	127.7
1997	127.6
1998	124.4
1999	125.5
2000	132.7

5.8a Construct and producer price index for 2000 in 1985 dollars

5.8b If you paid 190$ for a piece of machinery in 1985 what would it be worth in 2000 dollars?

5.8c If you paid $300 for a piece of machinery in 2000 dollars, what would it be worth in 1985 dollars?

5.8d Sometimes you may need to splice together two series in real dollars that are two different base years as in the example below.

1992: 37.34/36.81 = X/38.22 = 1.014*38.22 = 38.77

1993: (35.41/36.81) * 38.22 = 36.77$

Year	Pcoal 1996 dollars	Pcoal 2000 dollars
1992	37.34	
1993	35.41	
1994	38.29	
1995	40.77	
1996	36.81	38.22
1997		36.52
1998		45.77
1999		41.17
2000		41.74

In the above Table column 1 contains 1992 to 1996 coal prices in 1996 real dollars and column 2 contains 1996 to 2000 coal prices in 2000 dollars. Suppose we want them all in 2000 dollars. To do such a conversion you will need at least one year of overlap. To get 1995 in 2000 dollars we know that 1995 is 40.77/36.81 of 1996 dollars. Thus, the ratio in 1996 dollars must equal the ratio in 2000 dollars or (40.77/36.81) = X/38.22. Solve to get X = (40.77/36.81)$38.22 = $42.33. Therefore 1995 price in 2000 dollars equals $42.33. Similarly we can compute 1994 price in 2000 dollars as (38.29/40.77)*$42.33 = $ 39.75. Fill in the values for 1992-1995 in 2000 dollars.

5.9 If the rate of return in the market changed to 0.11, what would happen to the stock that equals to $100 and has no bonds if it were paying a dividend of $10 per year?

5.10 Suppose stand-alone costs in your market are

$C_x = 800 + 20X$

$C_y = 700 + 40Y$

If one utility provides services to both customers, combined costs are:

$C_{xy} = 1200 + 20X + 40Y$

Suppose you have marginal cost pricing and 75% of fixed costs are allocated to consumer class X and 25% to consumer class Y.

5.10a Are costs subbadditive for this example?

5.10b What amount of fixed costs would be charged to X and how much to Y?

5.10c What is the marginal cost of producing a unit for X? a unit for Y?

5.10d If you marginal cost price for X and Y and allocate fixed costs as in b, what are the new total cost curve for X? for Y?

5.10e If you were a customer in group X would you feel the prices were discriminatory, why or why not? If you were a customer in group Y would you feel the prices were discriminatory, why or why not?

5.10f If inverse demand for group X were P_x =380 - 3X and demand for group Y were P_y= 100-4Y, would the above fixed cost allocation be efficient? Why or why not.

5.10g If we split fixed costs equally between market X and Y, would the allocation be efficient?

5.10h If we allocate fixed cost in a 60/40 split and used average cost price, would the allocation be efficient. If not, what is the social loss compared to marginal cost pricing?

5.11 Let off-peak demand be $Q_{opk} = 10 - 2P_{opk}$, peak demand $Q_{pk} = 20 - P_{pk} = 4$, $c_k = 4$, and $c_{op} = 2$.

5.11a What are the socially optimal prices in this market?

5.11b How much electricity is consumed peak and off-peak.

5.11c How much is consumed in each market if a price of 5 is charged in each market.

5.11d What are the social losses if a price of 5 is charged.

5.11e Suppose you have been charging 5 and are considering charging optimal peak load prices for peak and off peak. The costs to implement peak load pricing are 10 would it be a good idea to implement peak load pricing or not? Why or why not?

5.11f Would your answers to a and b change if capital costs were 6 instead of 4.