Electric Power Markets Spring 2023 ENV 717

Nicholas School of the Environment Duke University

Assignment #2

1. Download the file eGRID2020.xls from the eGRID website and use the information in the PLNT20 tab to fill out the following table:

a. (15%) Breakout of the U.S. into two regions: a) those with organized whole-sale electricity markets and b) those serve predominately by vertically-integrated utilities

	Number of states[1]	Capacity in 2020 (MW)	Generation in 2020 (MWh)
RTO/ISO	26	749,886.2	2.254 e9
Non-RTO/ISO	26	581,620.0	1.773 e9

2. (31%) Download data on state's average retail electricity prices for 2022 published by the Energy Information Administration EIA[2]. Then explore the average prices in the RTO/ISO and non RTO/ISO regions. Fill out the following table:

Sept Data	Number of States	Average retail electricity price in 2022 across states in the Eastern and Western Interconnects [3] (cents/kWh)	Minimum average retail electricity price in 2022 across states in the Eastern and Western Interconnects (cents/kWh)	Maximum average retail electricity price in 2022 across states in the Eastern and Western Interconnects (cents/kWh)
RTO/ISO	25	18.63	13.00	32.32
Non-RTO/ ISO	23	13.37	10.51	15.66

[1] For each of the 52 U.S. "states" determine whether they are a "ISO/RTO" or not by looking at their nameplate generation capacity. If 51% or more is associated to an ISO/RTO, then designate this state as a "restructured" state. Otherwise, designate it as state with vertically integrated utilities.

[2] "Rankings: Average Retail Price of Electricity to Residential Sector, September 2022 (cents/kWh)" Available at https://www.eia.gov/state/rankings/?sid=US#/series/31

[3] Same as above, for each of the states served mainly by the Eastern and Western Interconnects (i.e., excluding Alaska, Hawaii, Puerto Rico and Texas) determine whether they are a "ISO/RTO" or not by looking at their nameplate generation capacity in eGRID2020. This average is an unweighted average where the prices for all the states in the group are considered regardless of the magnitude of consumption/generation.

Oct Data	Number of States	Average retail electricity price in 2022 across states in the Eastern and Western Interconnects [4] (cents/kWh)	Minimum average retail electricity price in 2022 across states in the Eastern and Western Interconnects (cents/kWh)	Maximum average retail electricity price in 2022 across states in the Eastern and Western Interconnects (cents/kWh)
RTO/ISO	25	18.43	11.73	30.44
Non-RTO/ ISO	23	13.33	10.59	15.23

3. This part of the assignment provides you with the opportunity to refresh your knowledge on microeconomics in the context of markets for regular commodities.
a. (24%, each subproblem 3%) Problem 2.2. from Kirschen and Strbac.

> 2.2 The inverse demand function of a group of consumers for a given type of widgets is given by the following expression: $\pi = -10q + 2000[\$]$ where q is the demand and π is the unit price for this product.

[4] Same as above, for each of the states served mainly by the Eastern and Western Interconnects (i.e., excluding Alaska, Hawaii, Puerto Rico and Texas) determine whether they are a "ISO/RTO" or not by looking at their nameplate generation capacity in eGRID2020. This average is an unweighted average where the prices for all the states in the group are considered regardless of the magnitude of consumption/generation.

a. Determine the maximum consumption of these consumers.

Maximum consumption is when price is zero:

$0 = -10(q) + 2000$

$10q = 2000$

$q = 200$

The maximum consumption is 200 widgets.

b. Determine the price that no consumer is prepared to pay for this product.

The price that no consumer is willing to pay is when q is zero:

$\pi_{max} = -10(0) + 2000$

$\pi_{max} = 2000$

The price that no consumer is prepared to pay for this product is $2000/unit.

c. Determine the maximum consumers' surplus. Explain why the consumers will not be able to realize this surplus.

The maximum consumer surplus occurs when the price is zero and 200 units are consumed. Since consumers are willing to pay up to $2000 for this product, the consumer surplus is the area under the line given by -10(q) + 2000. This area is shown in the figure below:

The maximum consumer surplus is (200*$2000)/2 = $200,000. This will not be realized as producers will not make any profits by producing and selling widgets at $0.

d. For a price π of 1000 $/unit, calculate the consumption, the consumers' gross surplus, the revenue collected by the producers and the consumers' net surplus.

Consumption when price is $1000/unit:

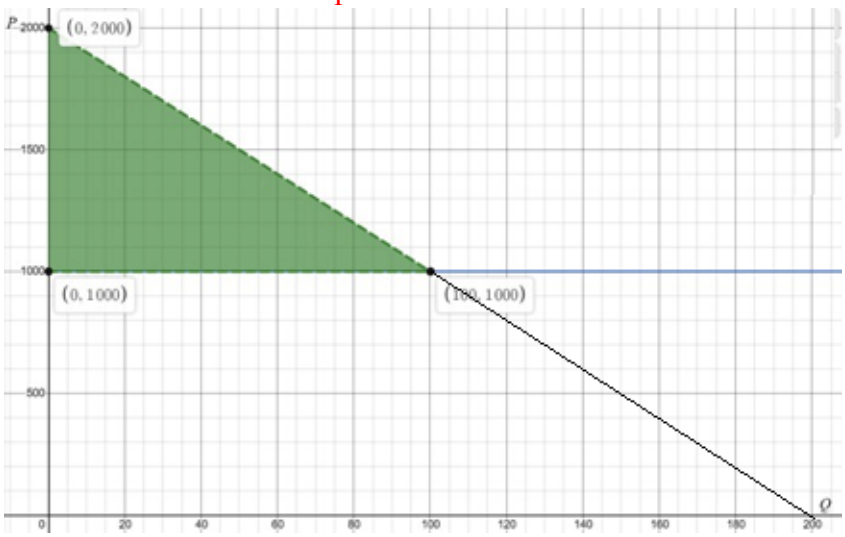
1000 = -10(q) + 2000

10q = 1000

q = 100

Consumers' net surplus when price is $1000/unit

Shadow area shown in the plot:



((2000-1000) * (100-0)) / 2

100,000/2 = 50,000

Consumers' net surplus = **$50,000**

Revenue collected by producers when price is $1000/unit:

$1000/unit * units sold

$1000 * 100

Producers' revenue = **$100,000**

Consumers' gross surplus = consumers' net surplus + producers' revenue:

$50,000 + $100,000 = $150,000

Consumers' gross surplus = **$150,000**

The Consumer Gross Surplus is shown in the following plot:

e. If the price π increases by 20%, calculate the change in consumption and the change in the revenue collected by the producers.

New price after increase: $1000*1.2 = $1200

Consumption when price is $1200/unit:

1200 = -10(q) + 2000
10q = 800
q = 80

Revenue collected by producers when price is $1200/unit:

$1200/unit * units sold
$1200 * 80
Producers' revenue = $96,000

With a 20% price increase, consumption decreases by 20 units (from 100 units to 80 units) and producers' revenue decrease by $4,000, or 4% (from $100,000 to $96,000).

f. What is the price elasticity of demand for this product and this group of consumers when the price π is 1000 $/unit?

Price Elasticity of Demand = percent change in quantity/percent change in price

We can estimate the marginal change in price and assess the marginal change in demand using previous example when a price of $1000 will yield a demand of 100 units. At a price of $1001, the demand would be:

1001 = -10Q2 + 2000
10Q2 = 999
Q2 = 99.9

dP = 1001 – 1000 = 1

$dQ = 99.9 - 100 = -0.1$

$\varepsilon = (P/Q) * (dQ/dP)$
$\varepsilon = (1000/100) * (-0.1/1)$
$\varepsilon = 10 * -0.1$
$\varepsilon = -1$

So, the **price elasticity of demand is -1.**

g. Derive an expression for the gross consumers' surplus and the net consumers' surplus as a function of the demand. Check these expressions using the results of part d.

The gross consumer surplus is determined by calculating the area under the demand curve from zero units to the number of units consumed (Q). Therefore, I can replace Q in my previous calculations. We can still split the equation into two pieces. The first is a calculation of the area of the rectangle from price = 0 to price = equilibrium price (P).

$A = l * w$
$l = Q - 0 = Q$
$w = P - 0 = P$
$A = P * Q$

The second part is the area of the triangle that represents the area under the demand curve but above the equilibrium price.

$A = 0.5 * b * h$
$b = Q$
$h = 2000 - P$
$A = 0.5 * Q * (2000 - P)$
$A = 1000Q - 0.5QP$

Adding these two areas together:

$CGS = QP + 1000Q - 0.5QP$
$CGS = 1000Q + 0.5QP$

We can substitute $P = -10Q + 2000$ into this equation, so that it depends only on demand.

$CGS = 1000Q + 0.5Q(-10Q + 2000)$
$CGS = 1000Q - 5Q^2 + 1000Q$
Consumer Gross Surplus = $-5Q^2 + 2000Q$

The net consumer surplus is represented by just the area of the triangle calculated above.

$CNS = 1000Q - 0.5QP$

Substituting $P = -10Q + 2000$

$CNS = 1000Q - 0.5Q(-10Q + 2000)$

$CNS = 1000Q + 5Q^2 - 1000Q$

Consumer Net Surplus = $5Q^2$

These equations make sense based on calculations in question d. When Q = 100,

$CGS = -5(100^2) + 2000(100)$

$CGS = -50{,}000 + 200{,}000 = 150{,}000$

$CNS = 5(100^2) = 50{,}000$

h. Derive an expression for the net consumers' surplus and the gross consumers' surplus as a function of the price. Check these expressions using the results of part d.

To change both equations above into functions with base price rather than quantity, I will substitute the demand curve solve for Q.

$P = -10Q + 2000$

$10Q = 2000 - P$

$Q = (2000 - P)/10 = 200 - P/10$

$CGS = -5Q^2 + 2000Q$

$CGS = -5(200 - P/10)^2 + 2000(200 - P/10)$

$CGS = -5(40000 - 40P + P^2/100) + 400000 - 200P$

$CGS = -200000 + 200P - P^2/20 + 400000 - 200P$

$CGS = 200000 - P^2/20$

Consumer Gross Surplus = $200{,}000 - 0.05P^2$

A similar substitution into the consumer net surplus equation derived in part g can be done to derive the consumer net surplus (CNS):

$CNS = 5Q^2$

$CNS = 5(200 - P/10)^2$

$CNS = 5(40000 - 40P + P^2/100)$

$CNS = 200000 - 200P + P^2/20$

Consumer Net Surplus = $200{,}000 - 200P + 0.05P^2$

b. (15%, a;6%, b; 9%) Problem 2.3. from Kirschen and Strbac.

2.3 Economists estimate that the supply function for the widget market is given by the following expression: $q = 0.2 \cdot \pi - 40$

a. Calculate the demand and price at the market equilibrium if the demand is as defined in Problem 2.2.

Market equilibrium is when supply equals demand:

$q = 0.2p - 40$

$p = 5q + 200$ = supply

$p = 5q + 200 = -10q + 2000$

$15q = 1800$

$q = 120$

$p = 5(120) + 200$

$p = 600 + 200$

$p = 800$

The demand is equal to 120 units and the price is **$800/unit.**

b. For this equilibrium, calculate the consumers' gross surplus, the consumers' net surplus, the producers' revenue, the producers' profit, and the global welfare.

Consumers' gross surplus:

(1200*120) / 2 = 72,000 + 120*800 = 72,000 + 96,000 = **$168,000**

Consumers' net surplus:

(1200*120) / 2 = **$72,000**

Producers' revenue:

P*Q = 800*120 = **$96,000**

Producer's profits:

When Q = 0, P(Supply) = 5(0) + 200 = 200

((800-200) * 120) / 2 = (600 * 120) /2 = 72,000 / 2 = $36,000

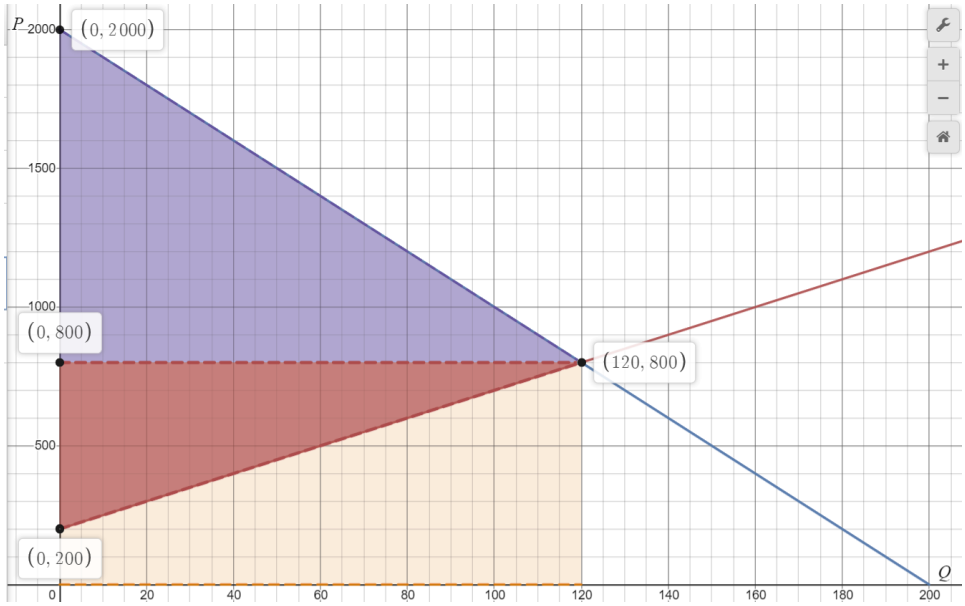
Producers' profits = $36,000

Global welfare:

Consumers' net surplus + Producers' profits

$72,000 + $36,000 = $108,000

Global welfare = $108,000



Consumers' net surplus = purple area
Producers' profit = red area
Producers' revenue = orange area + red area = (quantity * price)
Global welfare = consumers' net surplus + producers' profit

c. (15%) Problem 2.4. from Kirschen and Strbac.

Calculate the effect on the market equilibrium of Problem 2.3 of the following interventions:
a. A minimum price of $900 per widget
b. A maximum price of $600 per widget
c. A sales tax of $450 per widget.
In each case, calculate the market price, the quantity transacted, the consumers' net surplus, the producers' profit, and the global welfare. Illustrate your calculations using diagrams.

2.4a: A minimum price of $900 per widget

The market price is $900/unit, so the quantity transacted is equal to the point where $900 intersects with the demand curve. As the price of $900 is greater than the equilibrium price of $800 found in Problem 2.3:

Quantity transacted could be obtained as:

$p = -10q + 2000$
$900 = -10q + 2000$
$q = 110$

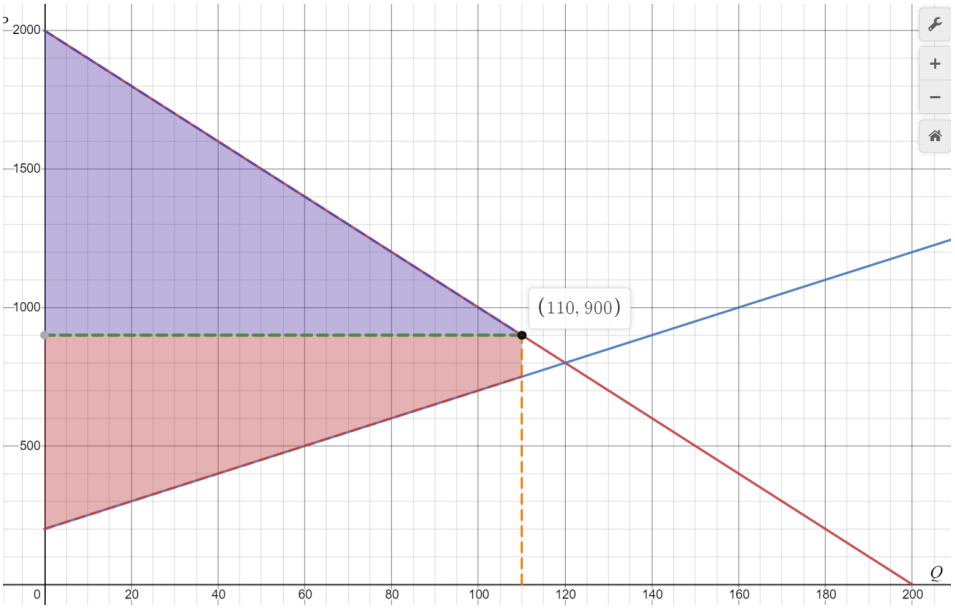
Consumers' net surplus:

$1100 * 110 / 2 =$ **$60,500**

Producers' profits:

$(140*700) / 2 – (30*150) / 2$
$49000 – 2,250 =$ **$46,750**

Global welfare (consumer net surplus + producers' profits):
$60,500 + $46,750 = **$107,250**



Consumer surplus = purple area; Producers' profit = red area
Global welfare = consumer surplus + producers' profit

2.4b A maximum price of $600 per widget

With a maximum price of $600 per widget, market price = $600/unit.

The quantity transacted therefore equals the point where $600 intersects with the supply curve, since the price of $600 is less than the equilibrium price of $800 solved for in Problem 2.3 from Kirschen and Strbac.

Quantity transacted:

$p = 5q + 200$
$600 = 5q + 200$
$q = 80$

Consumers net surplus:

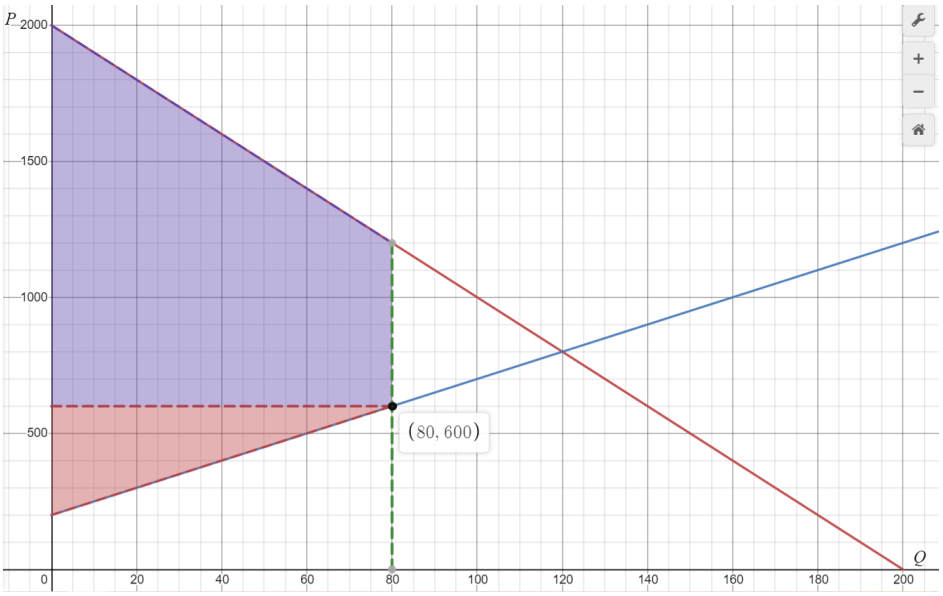
$((2000-1200) * (80-0)) / 2 + ((1200-600) * 80)) = \$80,000$

The producers' profit:

$((600-200) * (80-0)) / 2 = \$16,000$

Global welfare (consumer net surplus + producers' profit):

$80,000 + $16,000 = $96,000



Consumer surplus = purple area; Producers' profit = red area
Global welfare = consumer surplus + producers' profit

3c: A sales tax of $450 per widget

With a sales tax of $450 per widget, this becomes a $450 tax on producers. Therefore, this needs to be added to the supply curve to solve for the market price and quantity with the sales tax imposed.

Original supply: $p = 5q + 200$
New supply with tax: $p = 5q + 650$
Setting demand = supply:

$-10q + 2000 = 5q + 650$
$15q = 1350$
$q = 90$

Solving for p with q = 90:

$p = 5(90) + 650$
$p = 450 + 650$
$p = 1100$

The market price is $1100/unit.

Price producers receive is from pre-tax supply equation:

$p = 5(90) + 200 = 450 + 200$
$\pi_{producers} = 650$

Price consumers pay is from demand equation:

$\pi = -10q + 2000 = -10(90) + 2000$
$\pi = 1100$

Government revenue (tax * quantity):

450 * 90 = **$40,500**

Consumers' net surplus:

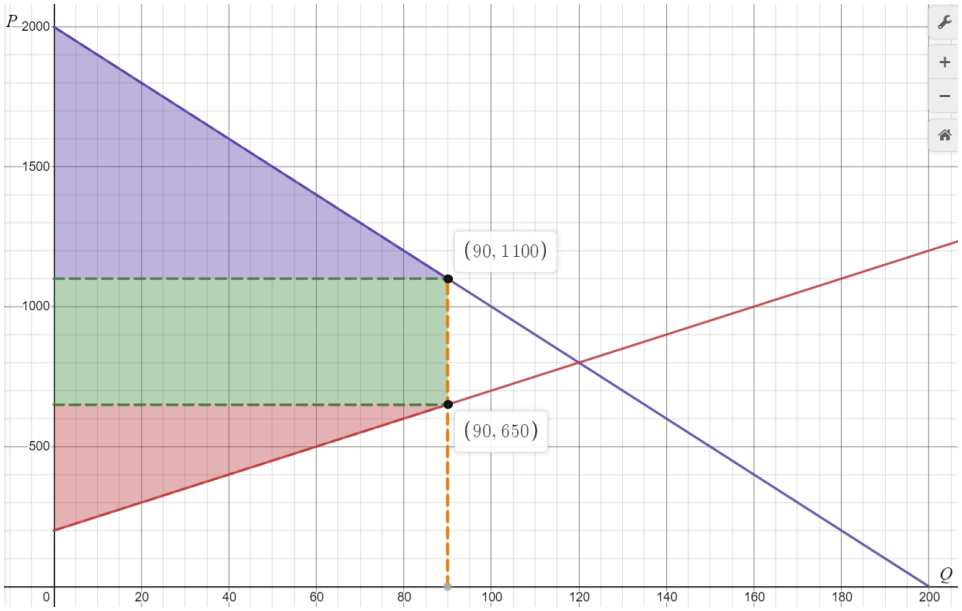
((2000-1100) * (90-0)) / 2 = **$40,500**

Producers' profit:

((650-200) * (90-0)) / 2 = **$20,250**

Global welfare (consumer net surplus + producers' profit + government revenue):

$40,500 + $20,250 + 40,500 = **$101,250**



Consumer surplus = purple area

Producers' profit = red area

Government revenue = green area

Global welfare = Consumer surplus + Producers' profit + Government revenue