1.1 BCA Steps

Monday, August 24, 2020 12:36 PM

CBA ↔ BCA

NB = B − C

- Clear about Aut Pose
- Alternatives?
- Who is impacted + how?
- Who matters? → STANDING

Technical Steps

- Predict, quantify, monetize, + discount impacts
- Sensitivity analysis
- Analyst recommendation

Cost effectiveness Analysis

Economic Impact analysis

↳ NOT A CBA/BCA

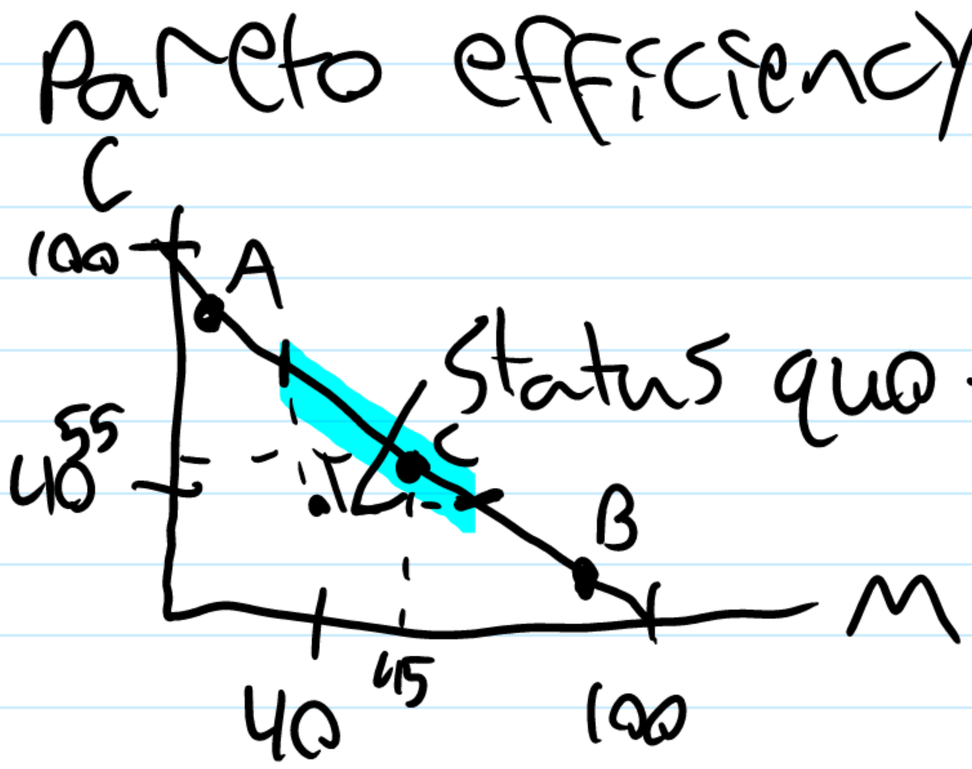
1.2 Measuring Efficiency

Monday, August 24, 2020 12:52 PM

More conceptual foundations

How to measure efficiency?

Pareto efficiency



Status quo → burn $20

Pareto efficient: Nobody loses

Kaldor-Hicks efficiency

↳ if something is potentially Pareto, do it

1.3 More Conceptual Foundations

Monday, August 24, 2020 1:06 PM

B+C?

WTP → Willingness to Pay

Opportunity Cost

NB = B − C

B : C = B/C

New users +10

Old users −5

Const cost 3

↳ NB : 10 − 5 + 3 = 2

↳ B : C = $\frac{10}{8}$ or $\frac{5}{3}$

1.2 1.67

1.4 BCA Limitations

Monday, August 24, 2020 1:16 PM

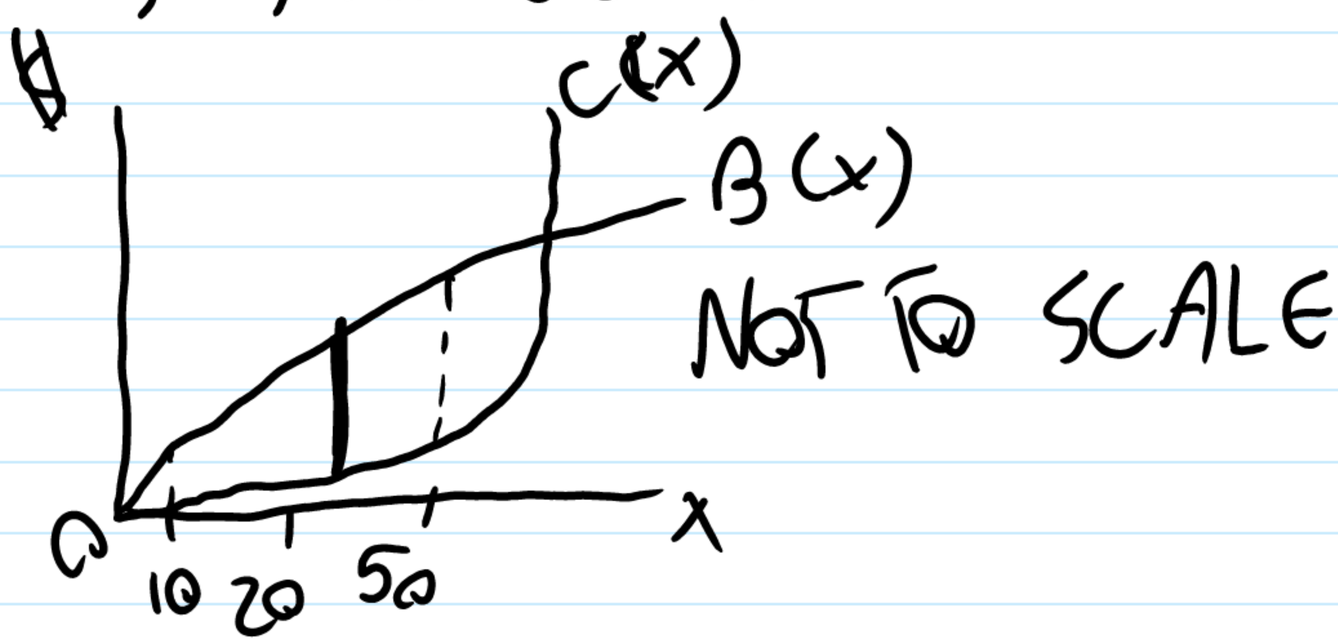
Potential Problems

Arrow's Impossibility theorem
- Depends on wealth distribution
- Standing

optimum may not be under consideration

$NB = B(x) - C(x)$

0, 10, 50 acres



HW 1.1

Tuesday, August 25, 2020 12:33 PM

Passed Solution review

city doesn't require helmets. I ride without a helmet

a. What are the benefits/costs of an ordinance to require helmets?

Costs	Benefits
Barrier to entry	Increased Safety
Enforcement	Stylishness
Pushback	
decreased Comforts	

b. Societies costs/benefits?

Costs	Benefits
Enforcement	Less medical debt
Pushback	

a) Personal...

Costs
- helmet cost
- reduced comfort
- helmet hair

benefits
- reduced risk of injury

b) Society...

costs
- enforcement
- increased pollution

benefits
- decreased healthcare costs

HW 1.2

Tuesday, August 25, 2020 12:47 PM

Tariffs on kumquats!

a. Growers are the focus! How is net benefit calculated as a spender?

Costs:
tariff revenues (8m)
production (6m)
reduced consumption (13m)

Benefits
profits (4m)

4 - 8 - 6 - 13 = $\boxed{-23m}$

b. Treasury behaves as a guardian. How would net benefit be calculated if profit taxes are 20%.

Costs:
Production (6m)
consumption (13m)

Benefits:
profits (4m)
revenues (8m)

4 + 8 - 6 - 13 = $\boxed{-7m}$

Passed Solution review

TEMPLATE	PV (million dollars)	
National government grant	2.2	
Construction and maintenance costs	12.5	
Personnel costs	8.2	
Revenue from municipal residents	8.6	
Revenue from non-residents	2.2	
Use value benefit to municipal residents	16.6	
Use value benefit to non-residents	3.1	
Scrap value	0.8	

3.a National standing	PV (million dollars)	C	
National government grant	2.2	-	0
Construction and maintenance costs	12.5	-	-
Personnel costs	8.2	B	-
Revenue from municipal residents	8.6	B	0
Revenue from non-residents	2.2	B	0
Use value benefit to municipal residents	16.6	B	+
Use value benefit to non-residents	3.1	B	+
Scrap value	0.8		+
NSB	29.1		-.2

3.d Municipal spender	PV (million dollars)		
National government grant	2.2	B	+
Construction and maintenance costs	12.5	C	-
Personnel costs	8.2	B	+
Revenue from municipal residents	8.6	B	-
Revenue from non-residents	2.2	B	+
Use value benefit to municipal residents	16.6	B	+
Use value benefit to non-residents	3.1	B	0
Scrap value	0.8	B	+
NSB	29.2		8.9

3.b Municipal standing	PV (million dollars)		
National government grant	2.2	B	+
Construction and maintenance costs	12.5	C	-
Personnel costs	8.2	C	-
Revenue from municipal residents	8.6	C	0
Revenue from non-residents	2.2	B	+
Use value benefit to municipal residents	16.6	B	+
Use value benefit to non-residents	3.1	-	0
Scrap value	0.8	B	+
NSB	-7.5		1.1

3.c Municipal guardian	PV (million dollars)		
National government grant	2.2	B	+
Construction and maintenance costs	12.5	C	-
Personnel costs	8.2	C	-
Revenue from municipal residents	8.6	B	+
Revenue from non-residents	2.2	B	+
Use value benefit to municipal residents	16.6	-	0
Use value benefit to non-residents	3.1	-	0
Scrap value	0.8	-	+
NSB	-7.7		-6.9

HW 2.4

Tuesday, September 1, 2020 8:51 PM

Worked w/ Austin
Passed Solution review

Project R has:
20m Benefits
16m Costs

W has:
10m Benefits
2m Costs

F has:
26m Benefits
20m costs

Road to improve Projects:
16m Benefits to R
10m Benefits to F
-2m Benefits to W
4m Benefits no Projects
8m costs

a)

Project	Benefits	Costs	B/C	NB
R w/ Road	36	24	1.5	12
R no Road	20	16	1.25	4
F w/ Road	36	28	1.29	8
F no Road	26	20	1.3	6
W w/ Road	16	10	1.6	6
W no Road	10	2	5	8
Road only	4	8	.5	-4

b) Project R with a road should be selected according to the CBA decision rule

HW 2.6

Tuesday, September 1, 2020 9:13 PM

Worked w/ Austin

Passed Solution review

Costs: 500k
600k

Benefits: 900k ← changed to 900k

900k − 500k − 600k = −200k

↑

The book says 900,000 million. I'm going to use 900k

There is a net social loss of 200,000

HW 2.7

Tuesday, September 1, 2020 9:22 PM

Worked w/ Austin
Passed solution review

Costs:	National or global?
40m	N
220m	N
180m	N

Benefits:	
350m	N
70 m	N
280m	G

NSB = -20m

required fraction = 20/280 = 1/14

The program has a negative NSB of -20m
The required fraction is 20/280

3 Book Notes

Tuesday, September 1, 2020 12:21 PM

3.5 Incorporating the social cost of raising revenue through taxation

Excise tax on a good results in deadweight loss

SS is reduced w/ taxes

leakage or excess tax burden = proportion of tax or subsidy that results in deadweight loss

Increase in DL from raising tax $1 = METB

METB = marginal excess tax burden

METB + 1 = MCPF

↳ marginal cost of public funds

SS = CS + PS + (MCPF)GS

3.6 Measuring Changes in Welfare

3.7 Conclusions

CBA aims to efficiently allocate resources

Appendix 3A CS and WTP

Compensating variation

Indifference Curves

Income + substitution effects

Demand Curves

Marshallian Demand uses Income + substitution effects

Utility Compensated

Hicksian compensated variation demand curve

Equivalence of CS + compensating variation

Equivalent variation as an alternative to compensating variation

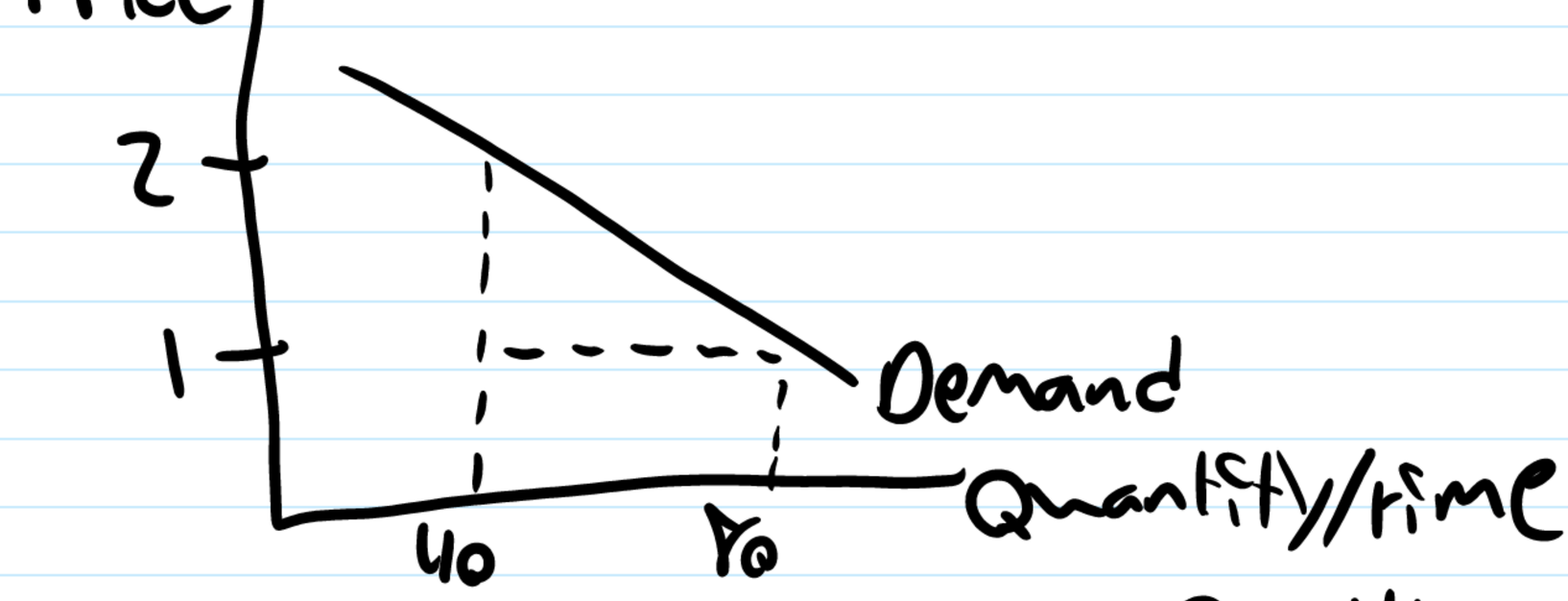
3.1 BCA Demand

Tuesday, August 25, 2020 7:55 PM

Microeconomic foundations:

Demand closely related to willingness to pay (W+P)

"Law of Demand"



Slope of demand is $\frac{\Delta Q}{\Delta P} = \frac{+40}{-1} = -40$

$Q = f(\text{Price}) \rightarrow$ Demand curve

$P = f(\text{Quantity}) \rightarrow$ inverse demand curve

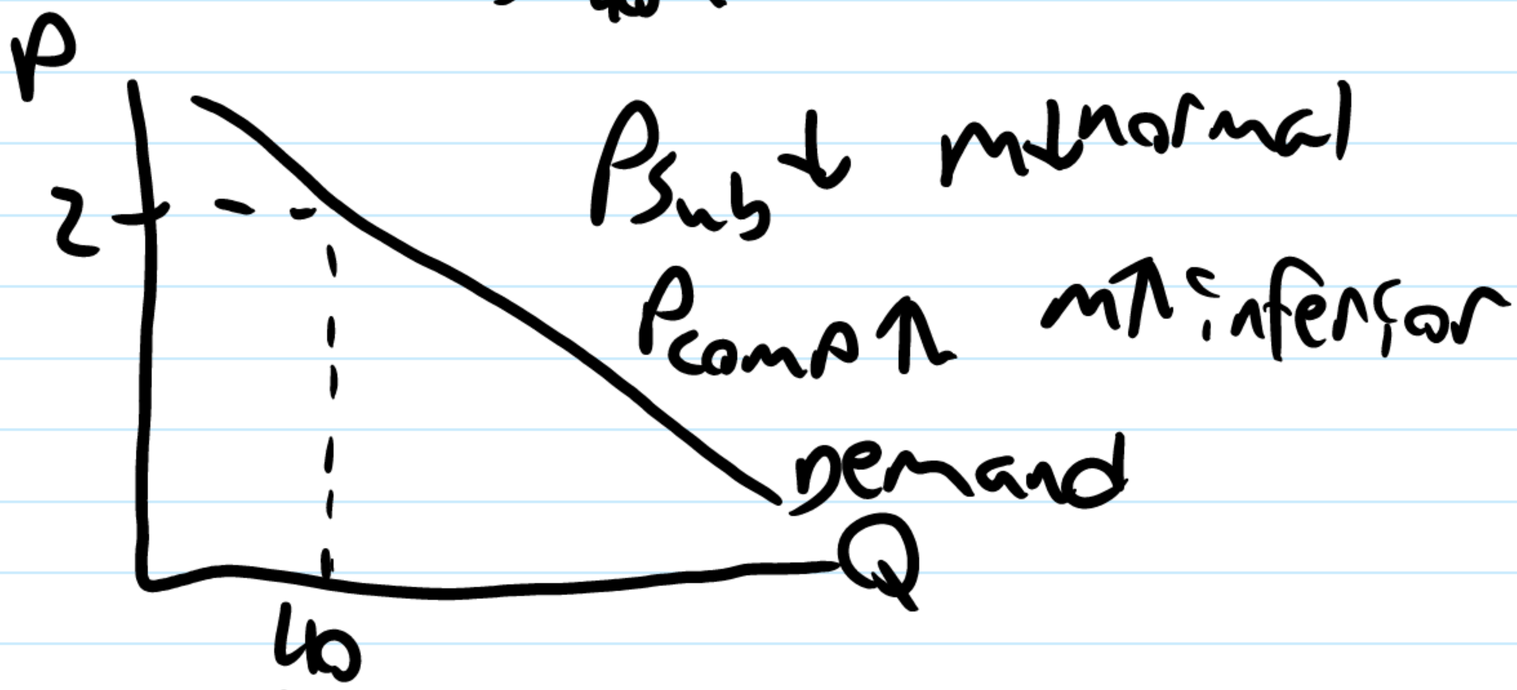
$$\frac{\Delta Q}{\Delta P} = \frac{Q_2 - Q_1}{P_2 - P_1} = \frac{80 - 40}{1 - 2} = \frac{40}{-1}$$

$$\frac{\Delta Q}{\Delta P} = -40 \rightarrow \Delta Q = -40 \Delta P$$

$$(Q - 40) = -40(P - 2)$$

$$Q = 120 - 40P$$

$$P = 3 - \frac{1}{40}Q$$



$P_{sub} \downarrow$ m↓normal

$P_{comp} \uparrow$ m↑inferior

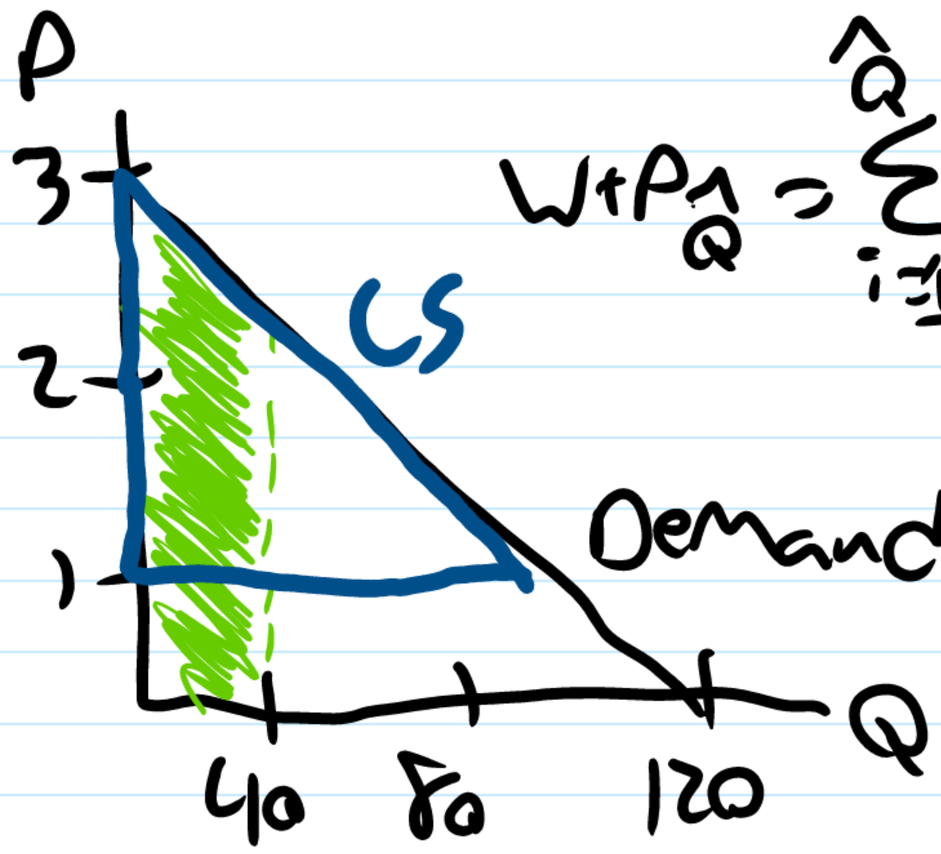
↳ Quantity demanded

$Q = f(P, P_{sub}, P_{comp}, M)$

↳ normal, inferior

3.2 Demand, WtP, and Consumer Surplus

Tuesday, August 25, 2020 8:16 PM



$$WtP_{\hat{Q}} = \sum_{i=1}^{\hat{Q}} P(1) + P(2) + \ldots P(\hat{Q})$$

$$WtP = \int_0^Q P(x)\,dx = (2-1)(40-0) + (3-2)\left(\tfrac{1}{2}(40-0)\right) = 80 + 20 = 100$$

$$CS = \tfrac{1}{2}(3-1)(80) = 80$$

$$CS = WtP - \text{Payments}$$

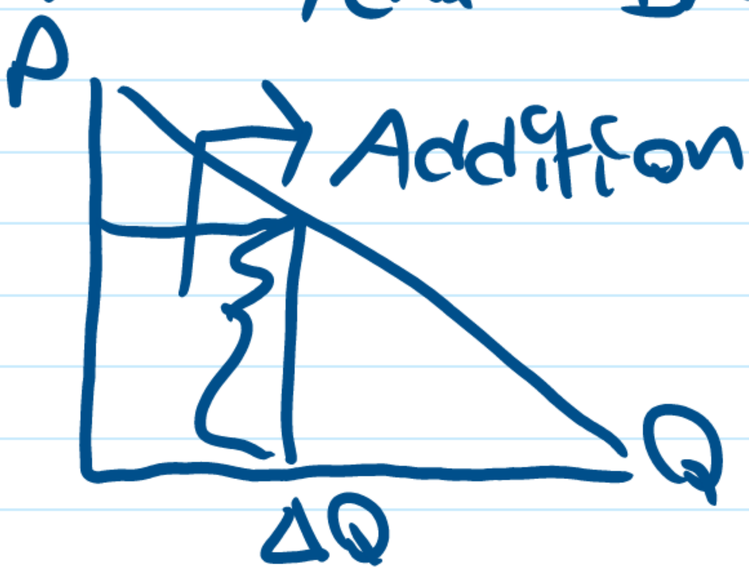
$$\Delta CS$$

$$CS = V(Q) - PQ$$

$V(Q)$ ↳ WtP, PQ ↳ Payment

$$\frac{dCS}{dQ} = \frac{dV}{dQ} - P = 0$$

$P = dV/dQ$ = Inverse demand function



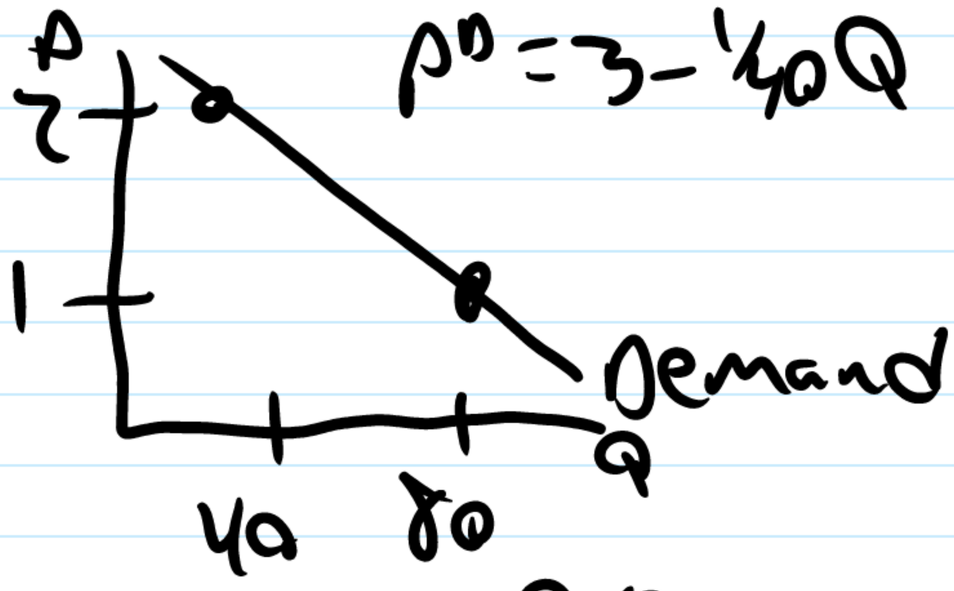
Addition to WtP for ΔQ

3.3 Elasticity

Tuesday, August 25, 2020 8:29 PM

$$\frac{\Delta Y}{\Delta X} \qquad \frac{\Delta Q^D}{\Delta P}$$

$$\frac{\Delta Q^D}{\Delta P} \qquad \frac{\%\Delta Q^D}{\%\Delta P} = \xi_P^D$$



$P^D = 3 - \frac{1}{40}Q$

$$\%\Delta Q = \frac{80-40}{40} = \frac{40}{40} = 100\%$$

$$\%\Delta P = \frac{2-1}{1} = \frac{-1}{1} = -100\%$$

$$\xi^D = -1$$

$$\%\Delta Q = \frac{40-80}{80} = -1/2$$

$$\%\Delta P = \frac{2-1}{1} = 1$$

$$\xi^D = \frac{-50\%}{100\%} = -1/2$$

$$\xi^P = \frac{\%\Delta Q}{\%\Delta P} = \frac{\Delta Q/Q}{\Delta P/P}$$

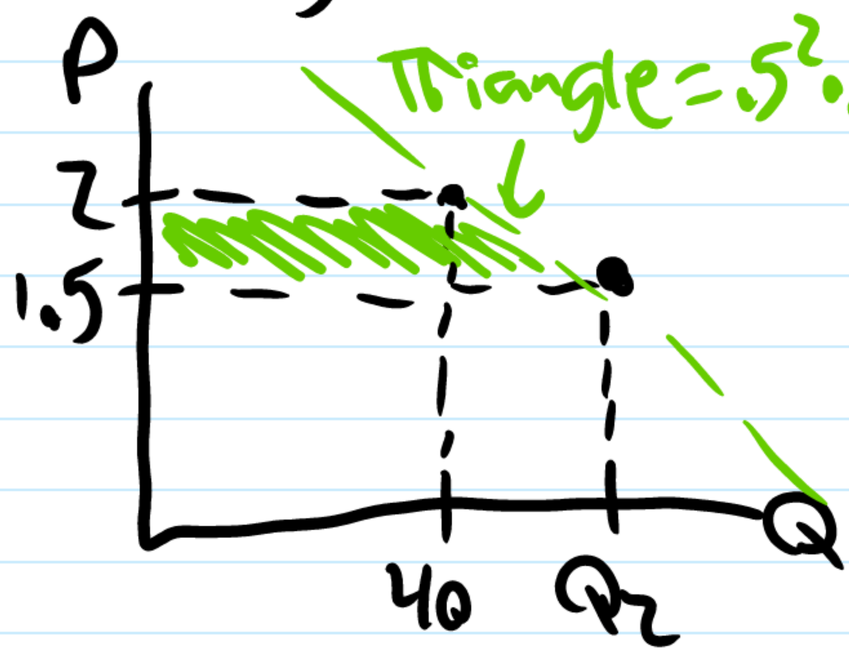
$$= \left(\frac{\Delta Q}{\Delta P}\right)\cdot\left(\frac{P}{Q}\right)$$

"Point elasticity"

3.4 Elasticity to monetize an impact

Tuesday, August 25, 2020 8:41 PM

Using Elasticity to Value impacts on Consumers



Triangle $= .5^2 \cdot .25$ \$2,4

$(2-1.5) \cdot 4 = 2$

$\frac{1}{2}(2-1.5)(Q_2-40)$

3rd is $-1/2$

$\frac{\Delta Q}{\Delta P} = \frac{Q_2-4}{1.5-2} = -1/2$

$Q_2 - 4 =$

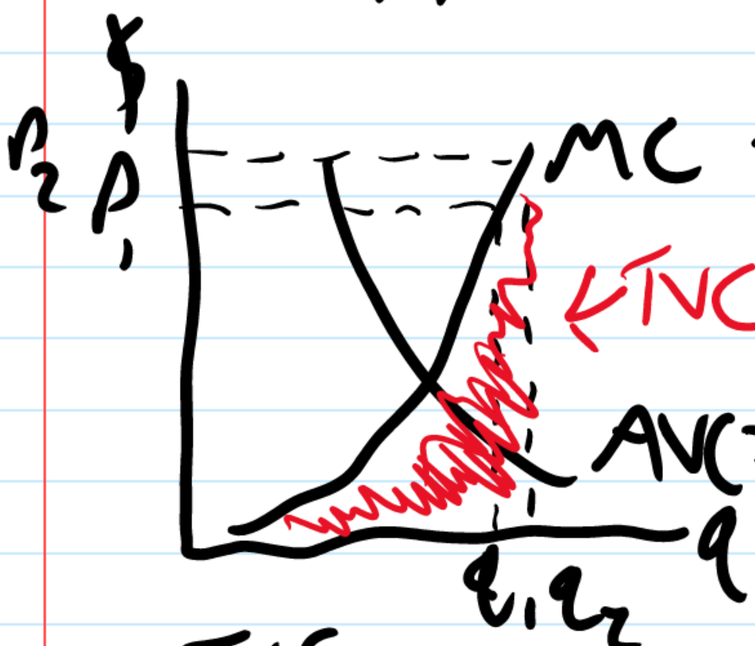
$\hookrightarrow 4.25$

$\Delta CS = 2\frac{1}{6}$

3.5 Supply and Producer Surplus

Saturday, August 29, 2020 3:00 PM

Supply, Producer Surplus, Factor Surplus



MC = marginal cost

"Diminishing returns to fixed factors"

$\leftarrow TVC = \int_0^q mc(x)\,dx$

AVC = Average Variable Cost

$\frac{TVC}{Q} = AVC$ TVC = total variable cost

$\pi = pq - C(q) \rightarrow \frac{d\pi}{dq} = p - \boxed{\frac{dC}{dq}} = 0$

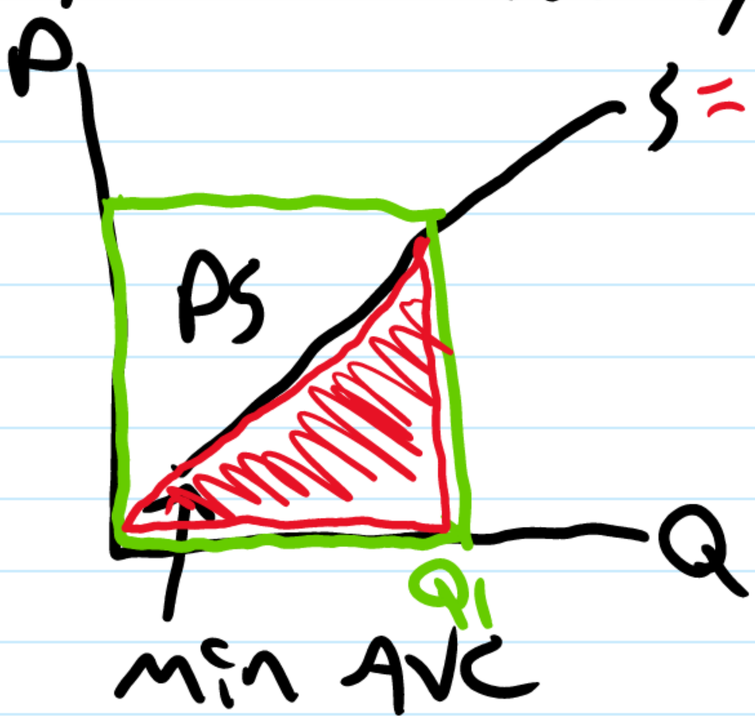
↳ profit ↳ cost ↳ MC

$p - MC = 0$

$p = MC \rightarrow$ see graph

$Q^s = \sum_{i=1}^{n} q_i(p)$

↳ market supply



TVC $\pi = pq - TVC - TFC$

↳ Total Fixed cost

$PS = pq - TVC$

↳ Producer surplus

$SS = CS + PS$

Social = Consumer + Producer

Long run ↔ All inputs are variable

3.6 Producer Surplus, Economic Profit, and Factor Surplus

Saturday, August 29, 2020 3:26 PM

Producer Surplus in the long run

π economic $> 0 \rightarrow$ enter or expand

$P\downarrow \rightarrow \pi^e\downarrow$

$\pi^e < 0 \rightarrow$ exit or contract

$\hookrightarrow P\downarrow, \pi^e\uparrow$

Factor Surplus

$PS = \pi + FS$

$PS = \pi^e +$ Ricardian rents

$\hookrightarrow FS$

$SS = CS + PS$

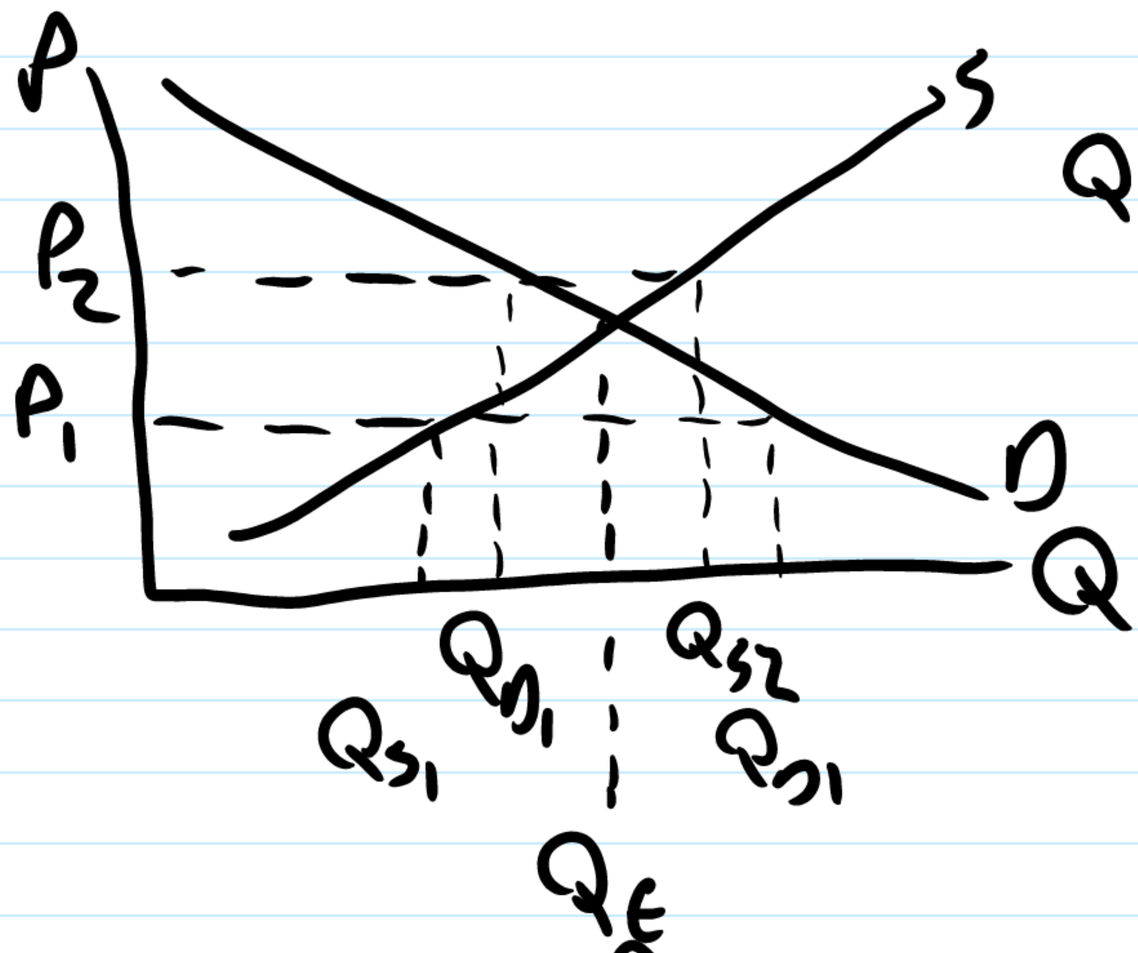
$= CS + \pi^e + FS$

3.7 Equilibrium, SS, and Allocative Efficiency

Saturday, August 29, 2020 3:46 PM

Social Surplus

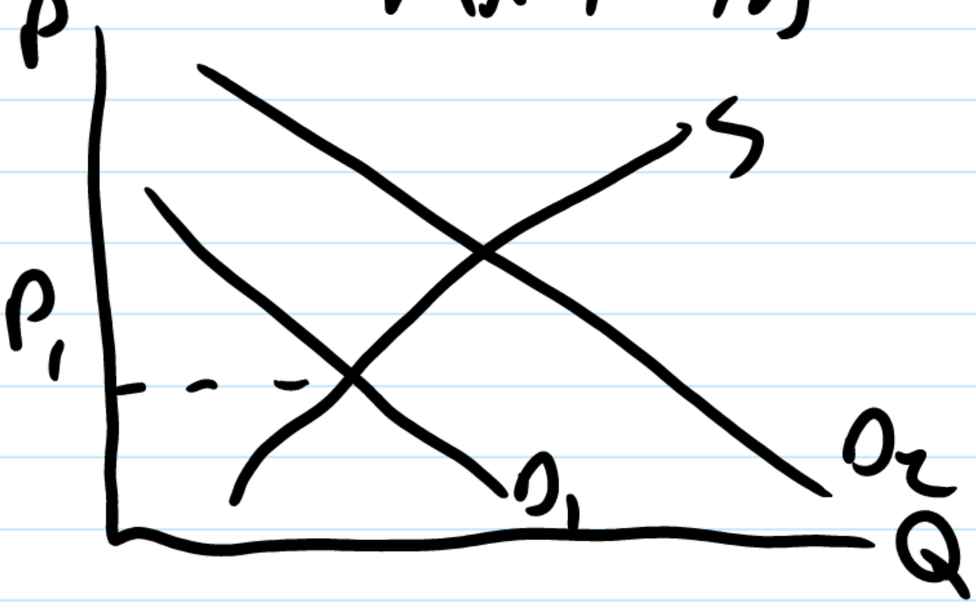
market equilibrium

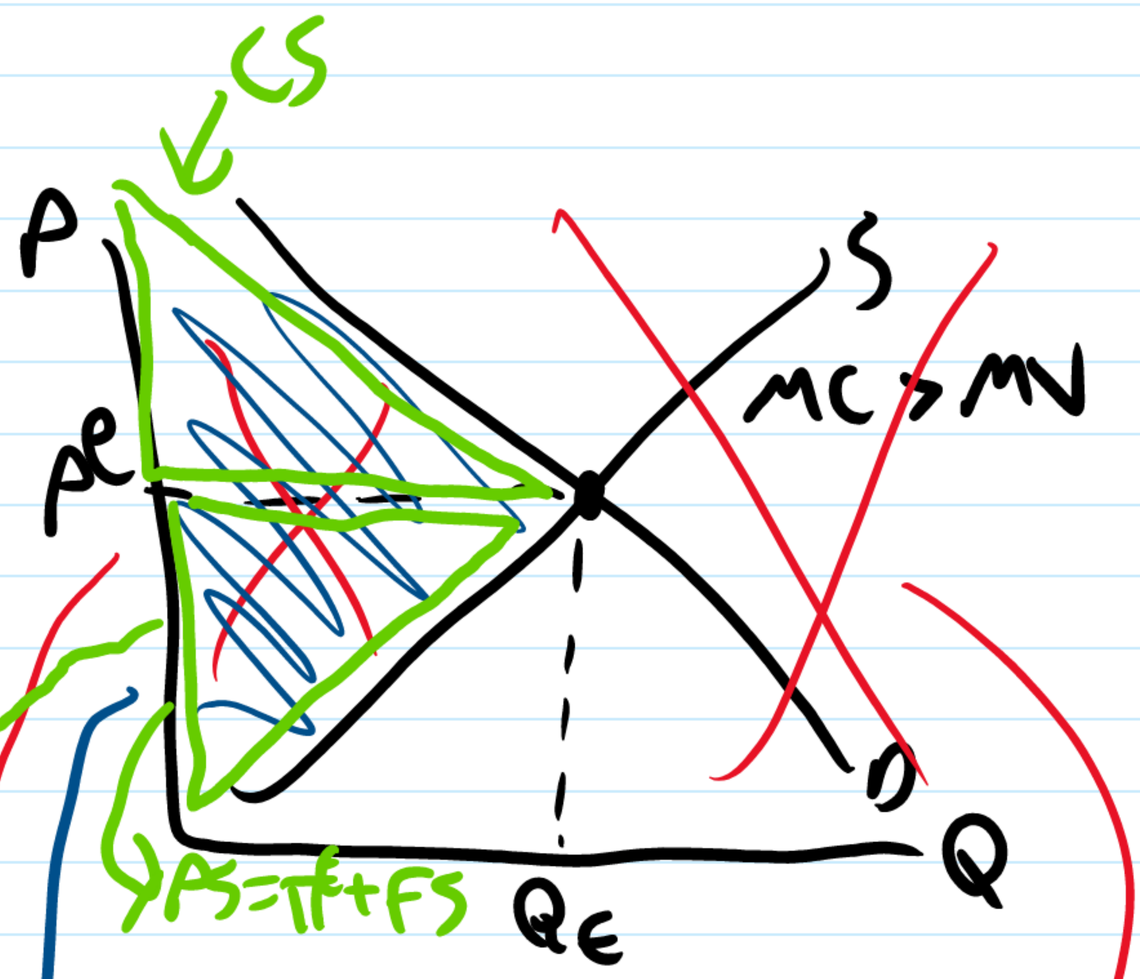


$Q_{S2} > QD_2$
↳ surplus

$Q_{D1} > Q_{S1}$
↳ shortage

MR → MD





PS = PF + FS

MV = marginal Value

Allocatively Efficient outcome

Too much production

↳ produced too little

max SS

3.8 Factors of Production

Tuesday, September 1, 2020 6:10 PM

Factors of Production:

- Labor
- Land (natural resources)
- Capital (roundaboutness of production)

Entrepreneurial Activity

↳ Paid w/ econ. profit

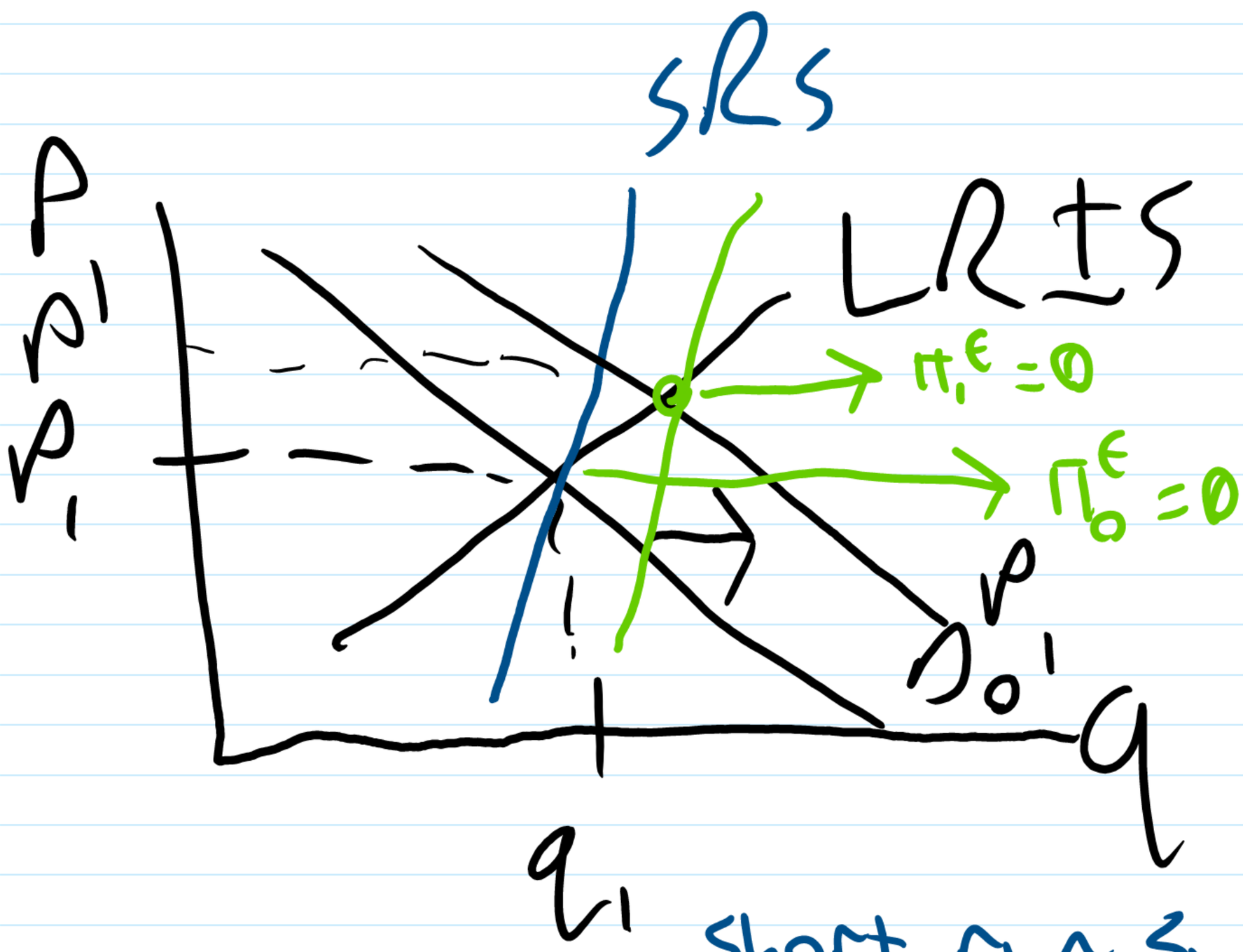
3.9 Long Run Equilibrium and Producer Surplus

Tuesday, September 1, 2020 6:20 PM

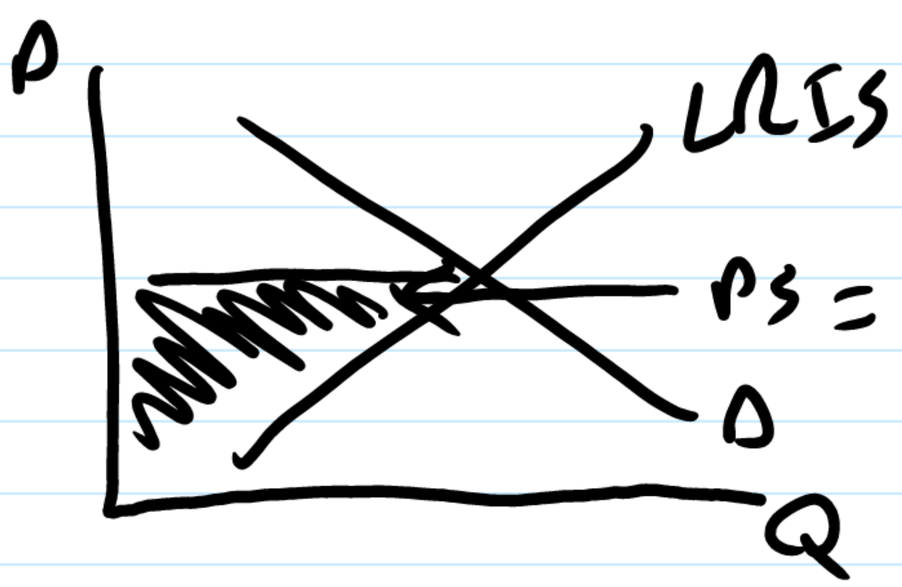
Long run equilibrium
Profit and factor surplus

firm supply curve

SR $\pi^E > 0$



Short run supply
Long run industry supply



factor payments wages, interest, rent

3.10 Social Surplus and Government Surplus

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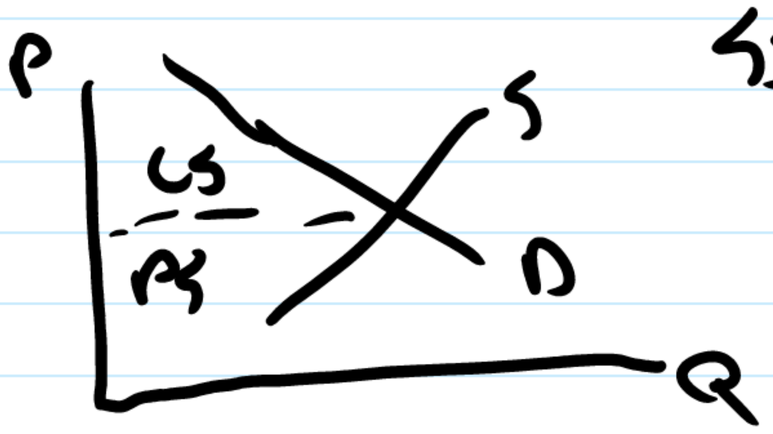
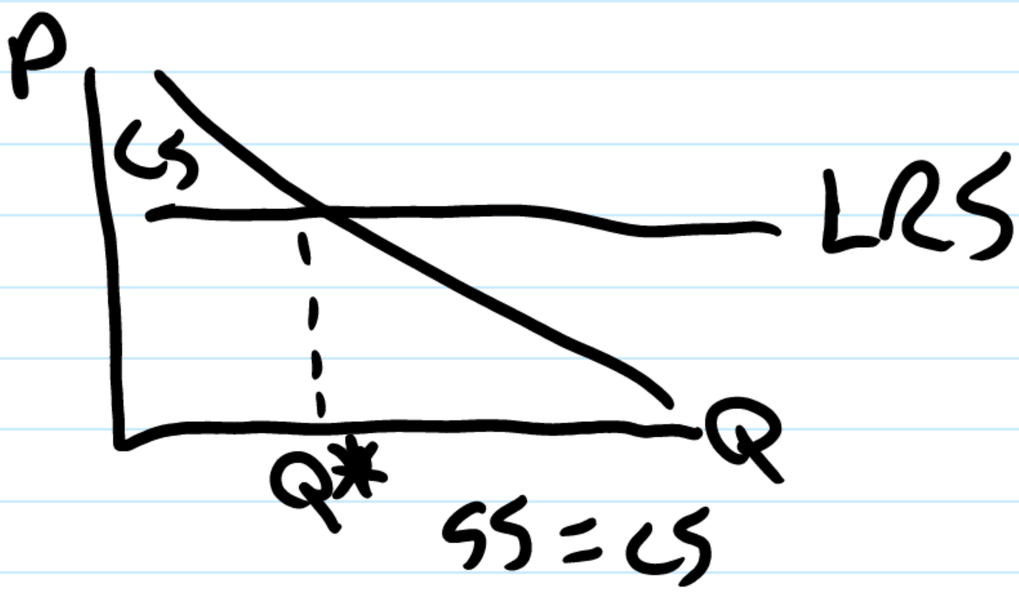
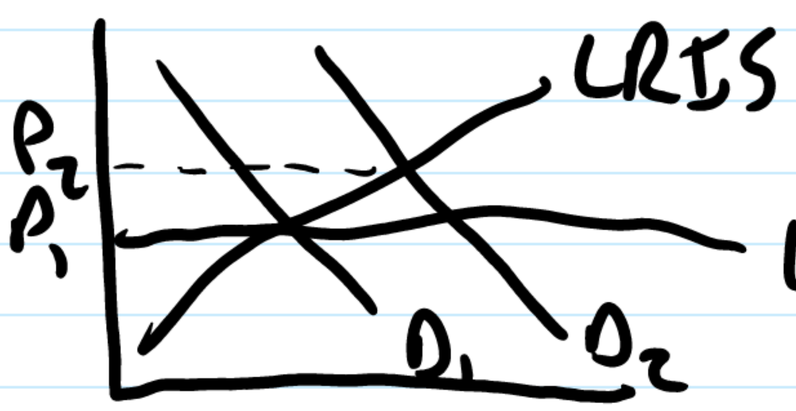
Social Surplus



$SS = CS + PS$



$SS = CS$



Increasing Cost Industry

LRIS constant cost industry

Government

$SS_1 = CS_1 + PS_1$ $\quad SS_2 = CS_2 + PS_2$

$\Delta SS = (CS_2 - CS_1) + (PS_2 - PS_1)$

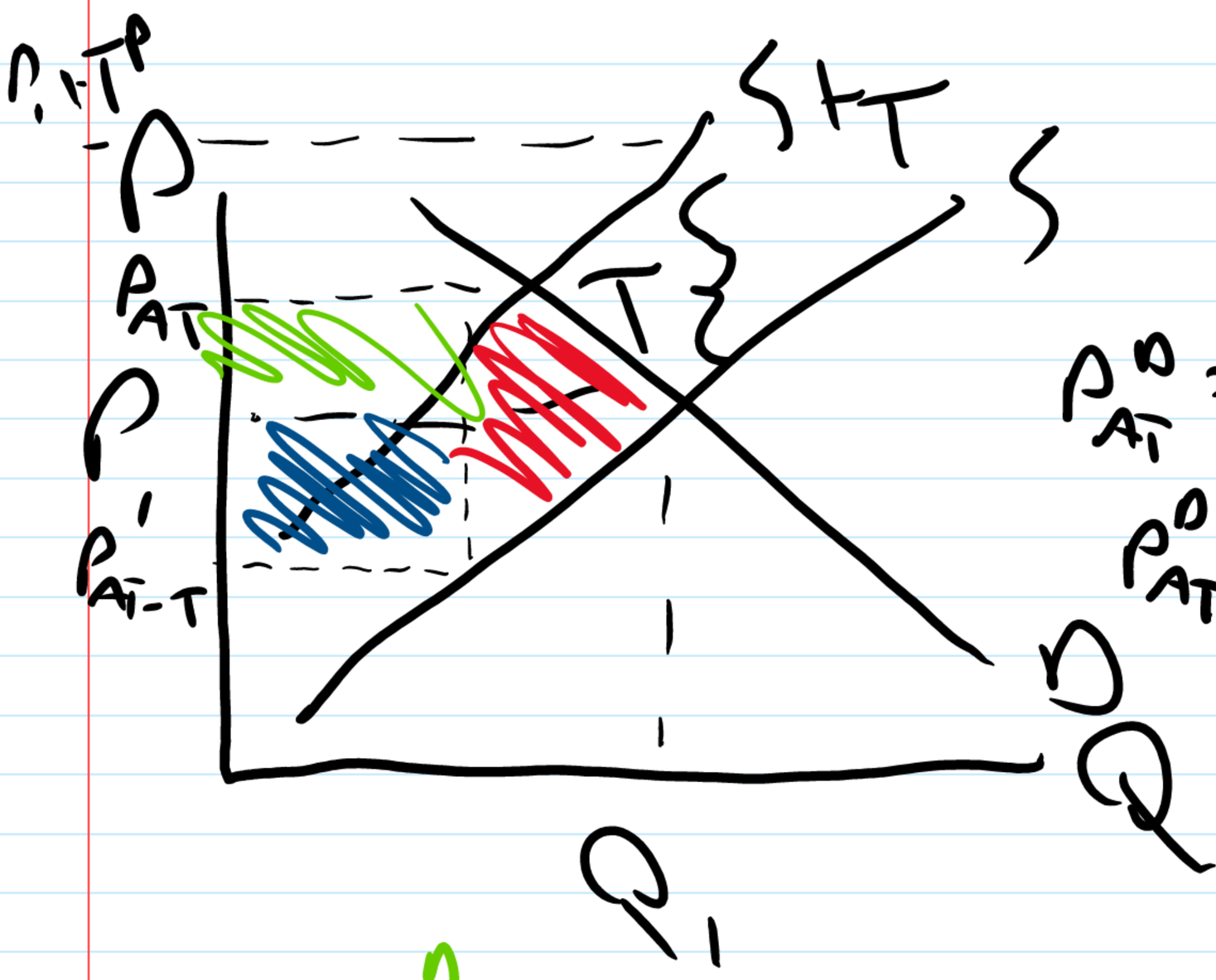
$\Delta SS = \Delta CS + \Delta PS$

$\Delta SS = \Delta CS + \Delta PS + (1 + \lambda)\Delta GS$ ← Budget Surplus

↳ marginal excess burden of taxation

3.11 Tax Burden

Tuesday, September 1, 2020 7:16 PM



$\$T/unit$

$P^D_{AT} = P^S_{AT} + t$

$P^D_{AT} - P^S_{AT} = t$

Consumer burden
Producer burden
Deadweight loss

$CB = (P^D_{AT} - P_1)\, Q_{AT}$

$PB = (P_1 - P^S_{AT})\, Q_{AT}$

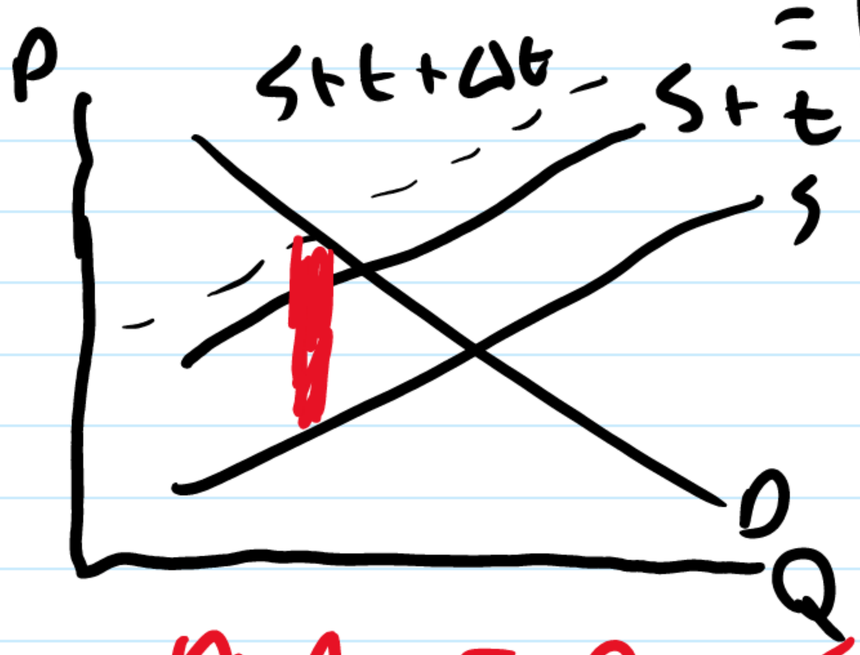
Tax rev $= (P^D_{AT} - P^S_{AT})\, Q_{AT}$

$= t \cdot Q_{AT}$

Taxes distort outcomes

$$\frac{CB + PB + DWL}{CB + PB} = \frac{\text{Tax revenue} + DWL}{\text{Tax rev}}$$

$$= 1 + \frac{DWL}{\text{Tax rev}}$$



DWL = excess burden

MEBT =

MEBT >> 0

↳ Why have taxes?

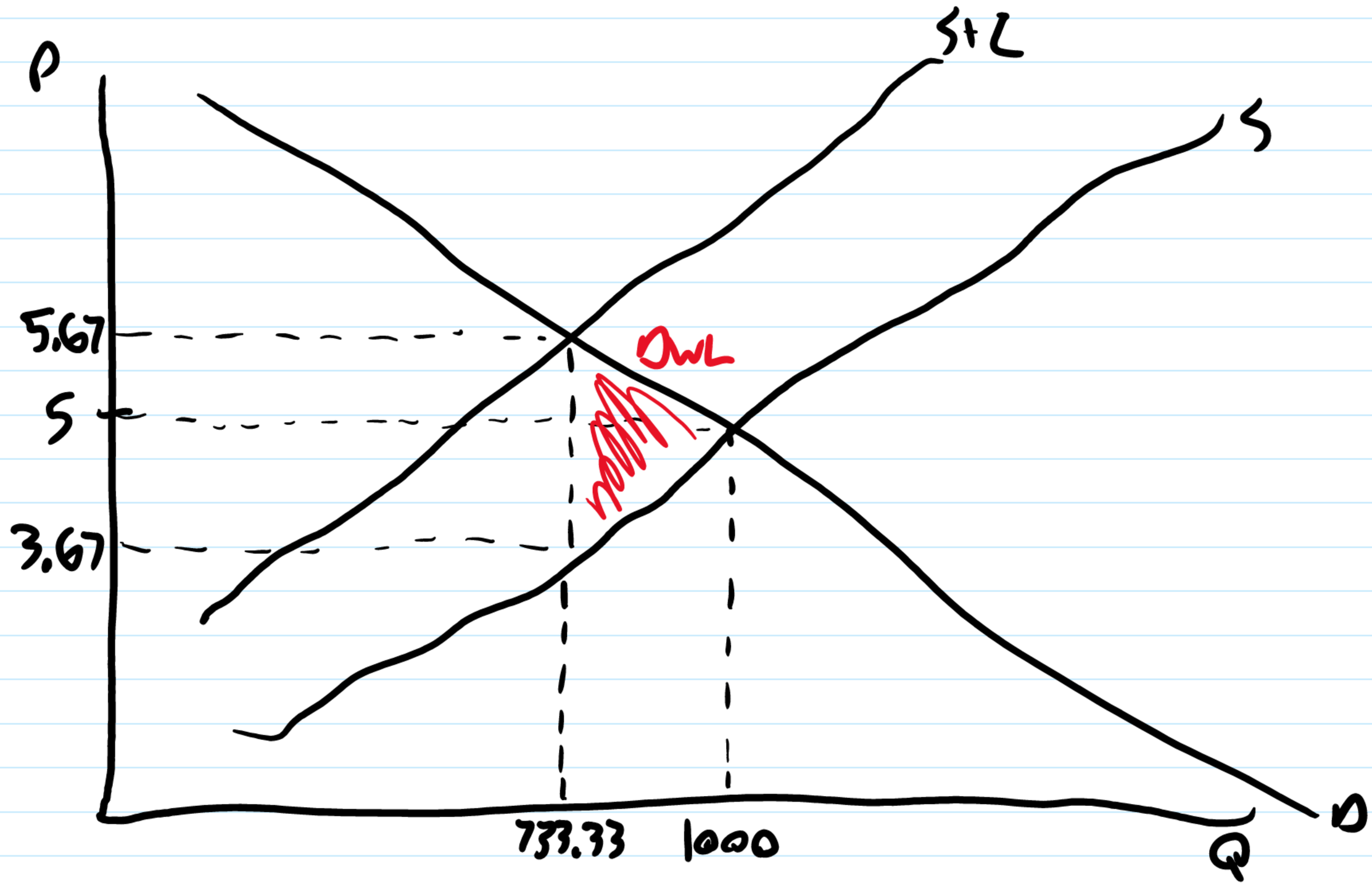
$\Delta SS = \Delta CS + \Delta PS + (1 + \lambda)\Delta GS$

Taxes destroy allocative efficiency

3.12 Tax Burden - Full Example

Saturday, September 5, 2020 5:51 PM

$t=2 \quad \varepsilon^d=-2 \quad \varepsilon^s=1 \quad P_0=5 \quad Q_0=1000$



$$-2=\frac{Q-1000}{P^D-5}\cdot\frac{5}{1000} \qquad 1=\frac{Q-1000}{P^D-7}$$

$P^D=P^S+t$

$$\frac{-2}{1}=\frac{1/P^D-5}{1/P^D-7}=\frac{P^D-7}{P^D-5}\rightarrow P^D=17/3=5.67$$

$$\frac{Q-1000}{5.67-7}\cdot\frac{5}{1000}=1\rightarrow Q=733.33$$

$\Delta CS=-(5.67-5)\cdot 733.33+\frac{1}{2}(733.33-1000)\cdot(5.67-5)$

$\Delta PS=(3.67-5)\cdot 733.33+\frac{1}{2}(733.33-1000)\cdot(3.67-5)$

$\Delta GS=2\cdot 733.33=1466.67$

$DWL=\frac{1}{2}(1000-733.33)\cdot 2=266.67\rightarrow 266.67/1466.67=.18$

↳ Excess Burden

Ad-Valorem

t: tax rate

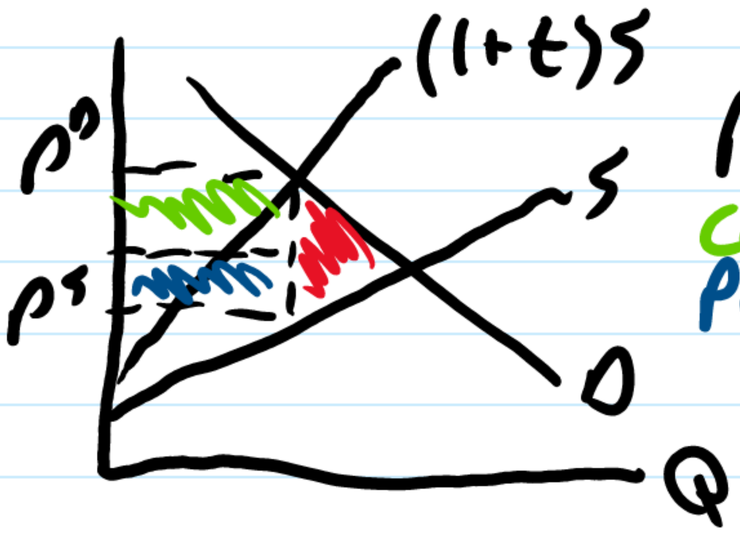
↳ $P^D=(1+t)\cdot P^S$

↑ tax rate

<u>constant tax</u>

$P^D=P^S+t$

↑ constant tax



$P^D=(1+t)P^S$

consumer burden

producer burden

3.13 Income and Substitution Effects and Willingness to Pay

Saturday, September 5, 2020 6:34 PM

Compensating Variation: Price goes up, consumers hurt
can supplement income to reduce
impact

Equivalent Variation: Price goes up, what income loss is
equivalent?

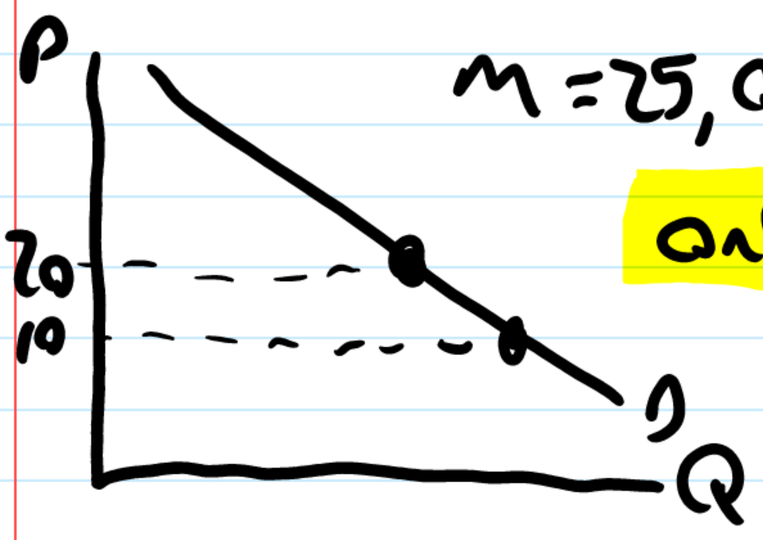
$|CV| < |CS| < |EV|$

Giffen good has upward demand curve
↳ inferior good. Potatoes in famine. P ↑. Poorer, buy
more potato.

3.14 A Few Words on Empirical Approximations

Saturday, September 5, 2020 6:49 PM

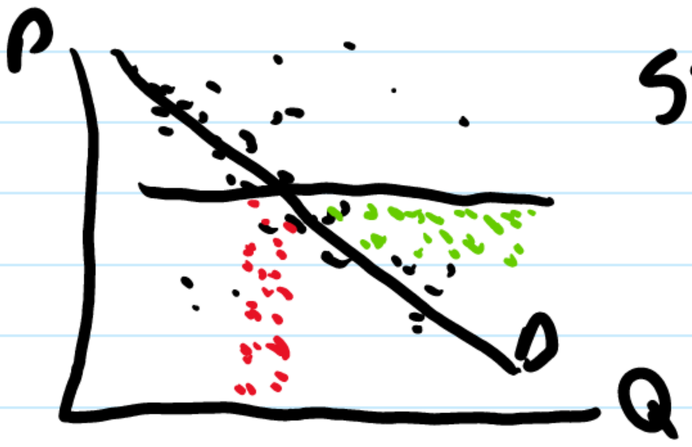
Extrapolation



$M = 25{,}000$ $M = [35k, 60k]$ $P = [16, 30]$

only use similar cases

Control Variables



Stay inside sample range

Linear Models

$Q = P^{B_1} M^{B_2} e^{B_0}$

Straight lines are good approximations

3.15 3.16 Gas Tax Full Example

Thursday, September 10, 2020 8:20 PM

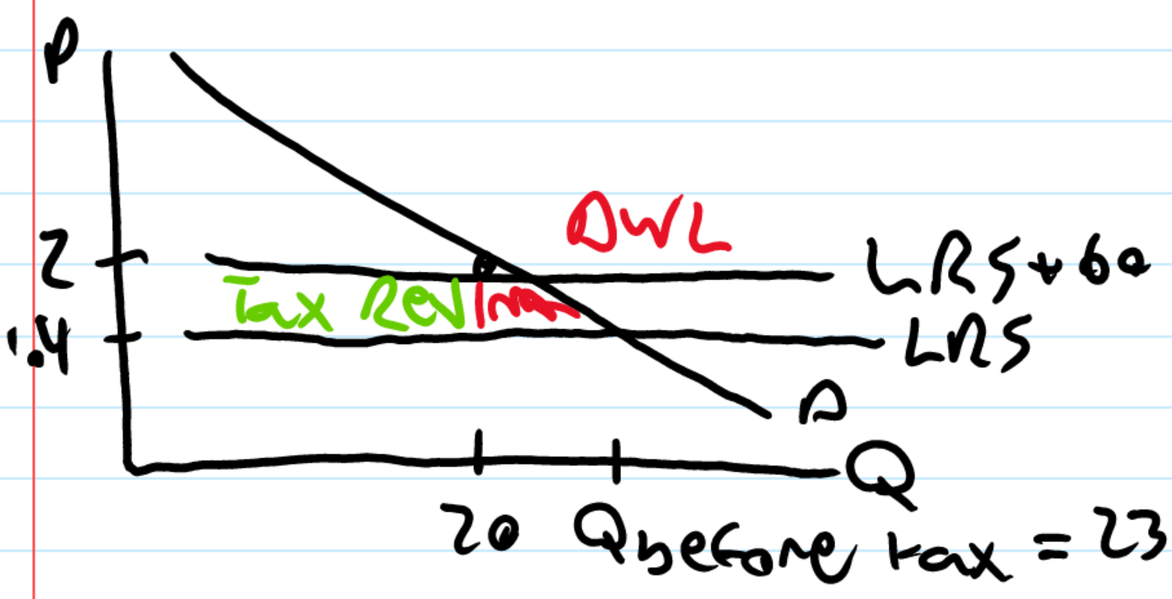
Floridians use about 20 million gallons of automotive gasoline per day. Including federal and state taxes, the tax rate is about $0.60 per gallon. The elasticity of demand for gasoline is approximately -0.5.

1) Illustrate the current equilibrium.
2) Calculate the quantity consumed daily if the price was lower by the amount of the gas tax. Add it to your illustration.
3) How much tax revenue is raised? Label it in your illustration.
4) Calculate the loss of consumer surplus due to the gas tax. Label it in your illustration.
5) How much consumer surplus was lost per unit of revenue raised by the tax?

Assume that the current gas tax is $0.50 per gallon too low to cover the cost of maintaining roadways in a safe condition for driving. If the tax were high enough to cover this cost…

6) What would consumption be? Add it to your illustration.
7) What would tax revenue be?
8) Calculate the loss of consumer surplus going from the original tax to the new tax. Show it in your illustration.
9) Going from the initial tax to the new tax, how much consumer surplus was lost per unit of additional tax revenue raised?
10) Compare your answer in (8) to your answer in (5). Can you explain the difference? What would happen to this ratio if the tax went from $1.1 to $1.15? Don't calculate anything. Just think it through and explain what would change and why.

11) Suppose elasticity of demand reasonably might be as high as 0.7 or as low as 0.3. How sensitive is your estimate of the consumer surplus loss form #4 to these possible differences?



$\xi^D = \frac{\%\Delta Q^D}{\%\Delta P}$

$\xi^D = \frac{\Delta Q}{\Delta P} \cdot \frac{P}{Q} = \frac{\Delta Q}{.6} \cdot \frac{2}{20} \rightarrow -.5 = \frac{\Delta Q}{.6} \rightarrow$

$\Delta Q = 3 \rightarrow Q_{AT} = 23$

$DWL = \frac{1}{2} \cdot .6 \cdot 3 = 0.9$

Tax rev = 12

6) $\%\Delta Q / 25\% = -1/2$ $\%\Delta Q = 12.5\%$

7) $\Delta CS = -.5 \cdot 17.5 - \frac{1}{2} \cdot .5 \cdot 2.5 = 9.375$

$\Delta CS / \Delta TR = -9.375 / 7.5 = -1.25$

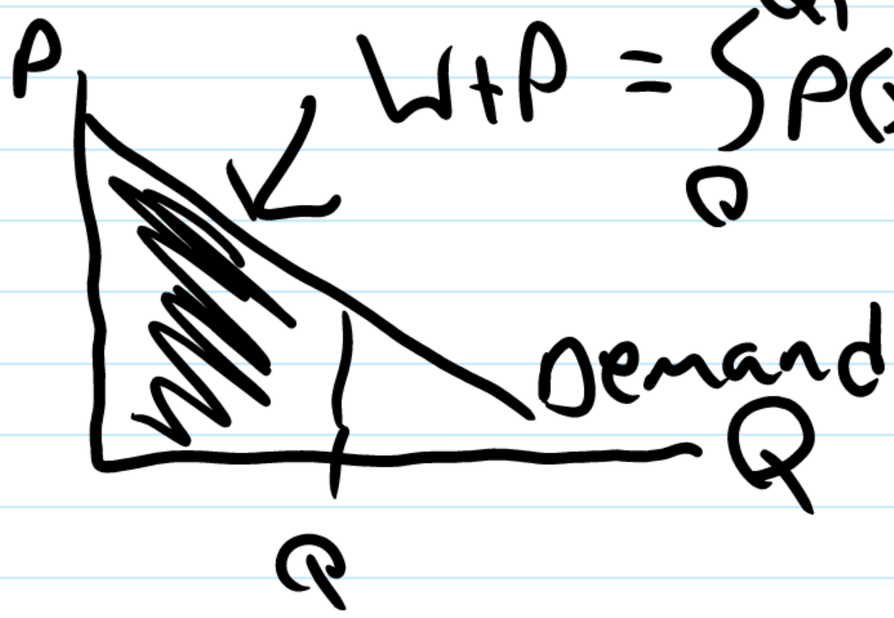
11) $\xi^d = -.7, -.3$

3 Extra Notes

Wednesday, August 26, 2020 2:20 PM

Why is $WTP = \frac{dV}{dQ}$

$WTP = \int_0^{Q_1} P(x)\,dx$



$V(Q) = aQ - \frac{1}{2}bQ^2$

Maximize $V(Q) - P \cdot Q$

optimal buy where derivative value = price

HW 3 Cigarette Taxation in Florida

Sunday, September 13, 2020 7:03 AM

Worked w/ Austin, River, + Alex
Passed Solution review

Suppose the elasticity of supply of cigarettes is 10.

1) Find estimates of the elasticity of demand for cigarettes, the current tax rate on cigarettes, average price, and annual quantity sold in Florida. Provide your sources.

Average price per pack: $5.50
https://www.salestaxhandbook.com/florida/tobacco
Current tax rate: $1.34/pack = 24.36%
https://www.salestaxhandbook.com/florida/tobacco
Elasticity of Demand: -.3
https://opentextbc.ca/principlesofeconomics/chapter/5-3-elasticity-and-pricing/
Quantity smoked: 14.6 cigarettes * .167 smokers/population * 21477737
population = 52,367,018.3534/year
https://www.sun-sentinel.com/health/fl-reg-florida-smokers-20180822-story.html
https://truthinitiative.org/research-resources/smoking-region/tobacco-use-florida-2019
https://www.census.gov/quickfacts/FL

2) How high would the price, including the tax, need to be to cut consumption by half?

$\frac{\%\Delta Q}{\%\Delta P} = -.3 \rightarrow \frac{-.5}{\%\Delta P} = -.3 \rightarrow \frac{-.5}{-.3} = \%\Delta P \rightarrow \%\Delta P = 1.667$

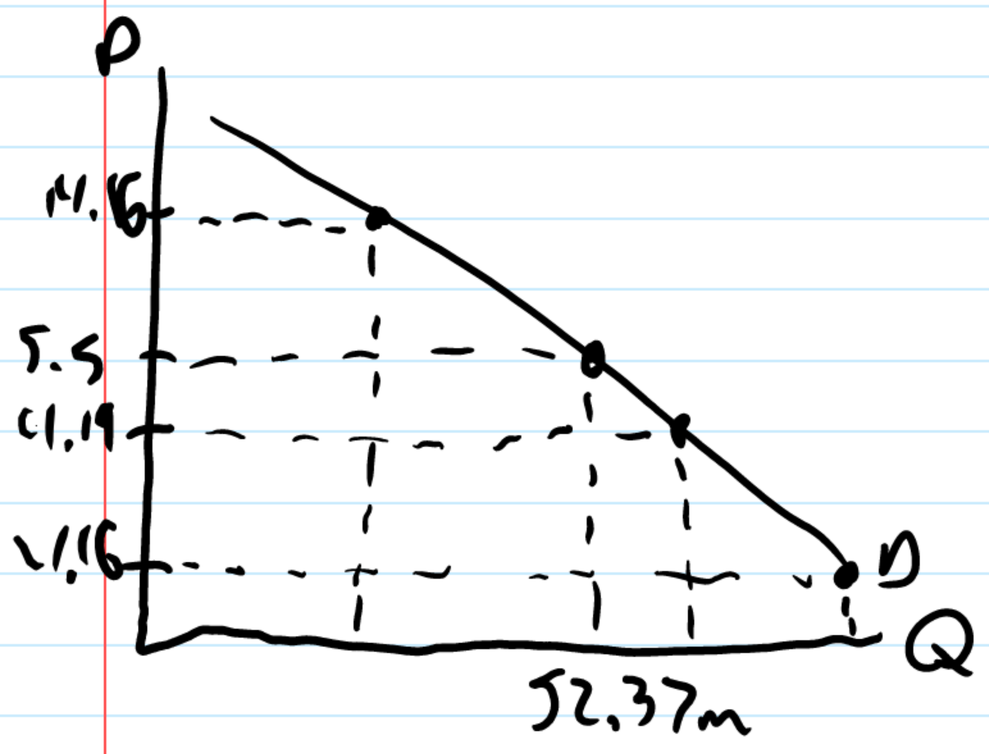
The new price would be $(1.667 \cdot 5.5) + 5.5 = 14.6675$

3) How high would the tax have to be to push the after tax price that high?

$14.1685 - 5.5 = 9.1685$
$9.1685 = (5.5 - 1.34) \cdot X$
$X = 9.1685 / (5.5 - 1.34)$
$X = 9.1685 / 4.16$
$X = 2.2039$

New tax is 220.39% = $9.1685

4) Estimate the consumer and producer burden of the current cigarette tax.



$-.3 = \frac{\Delta Q}{Q}\left(\frac{P}{5.5-P}\right)$ $10 = \frac{\Delta Q}{Q}\left(\frac{P}{4.16-P}\right)$

$-.03 = \frac{4.16-P}{5.5-P} \rightarrow -.165 + .03P = 4.16 - P$
$1.03P = 4.325$
$P = 4.199$

Tax = 1.34

$CB = (5.5 - 4.199)(52.36m) = 68.12m$
$PB = (4.199 - 4.16)(52.36m) = 2.04m$

5) How sensitive are your answers to modest errors in estimates of the elasticities of demand and supply?

The elasticity of demand is relatively small, so it is less sensitive to small changes while the elasticity of supply is a larger number and therefore more sensitive to small changes.

6) Do you think the tax creates a DWL or improves efficiency? Why?

I'm not really sure if it creates a DWL or improves efficiency. I can't imagine that raising the tax is very efficient. Most people who smoke are addicted and will continue to purchase cigarettes no matter the cost.

HW 3.1

Tuesday, September 1, 2020 9:32 PM

Worked w/ Austin
Passed solution review

Demand for gizmos: $q = 6 - .5p + .0002I$

I = income = 60k

a) $Q = 6 - .5P + .0002(60k)$
$Q = 6 - .5P + 12$
$Q = 18 - .5P$
$.5P = 18$
$P = 36$

b) $q = 6 - .5(10) + .0002(60k)$
$q = 6 - 5 + 12$
$q = 18 - 5$
$q = 13$

c) $PED = \%\Delta Q / \%\Delta P = (\Delta q / \Delta P)(P/q)$
$PED = -.5 \cdot (10/13) = -.38$

d) $\frac{1}{2} \cdot 13 \cdot (36 - 10) =$
$\frac{1}{2} \cdot 13 \cdot 26 =$
$13^2 = 169$

e) $q = 6 - .5(12) + .0002(60k)$
$q = 6 - 6 + 12$
$q = 12$
$\frac{1}{2} \cdot 12 \cdot (36 - 12) = 6 \cdot 24 = 144$
$169 - 144 = 25$
The loss in CS is 25

f) $Q = 6 - .5P + .0002(80k)$
$Q = 6 - .5P + 16$
$Q = 22 - .5P$
$.5P = 22$
$P = 44$

$q = 6 - .5(10) + .0002(80k)$
$q = 6 - 5 + 16$
$q = 17$

$q = 6 - .5(12) + 16$
$q = 6 - 6 + 16$
$q = 16$

$\frac{1}{2} \cdot 17 \cdot (44 - 10) = 8.5(34) = 289$
$\frac{1}{2} \cdot 16 \cdot (44 - 12) = 8 \cdot 32 = 256$

$289 - 256 = 33$

The loss in CS is 33

HW 3.2

Sunday, September 6, 2020 9:04 AM

Worked w/ River

Passed Solution review

2. At the current market equilibrium, the price of a good equals \$40 and the quantity equals 10 units. At this equilibrium, the price elasticity of supply is 2.0. Assume that the supply curve is linear.

   a. Use the price elasticity and market equilibrium to find the supply curve. (Hint: the supply curve has the following form: $q = a + (\Delta q/\Delta p)p$. First, find the value of $\Delta q/\Delta p$; then, find the value of a.)

   b. Calculate the producer surplus in the market.

   c. Imagine that a policy results in the price falling from \$40 to \$34. By how much does producer surplus fall?

   d. What fraction of the lost producer surplus is due to the reduction in the quantity supplied and what fraction is due to the fall in price received per unit sold?

a) $2 = \frac{\Delta q}{\Delta p} \cdot \frac{p}{q} \rightarrow 2 = \frac{\Delta q}{\Delta p} \cdot \frac{40}{10} \rightarrow 2 = \frac{\Delta q}{\Delta p} \cdot 4 \rightarrow \frac{\Delta q}{\Delta p} = .5$

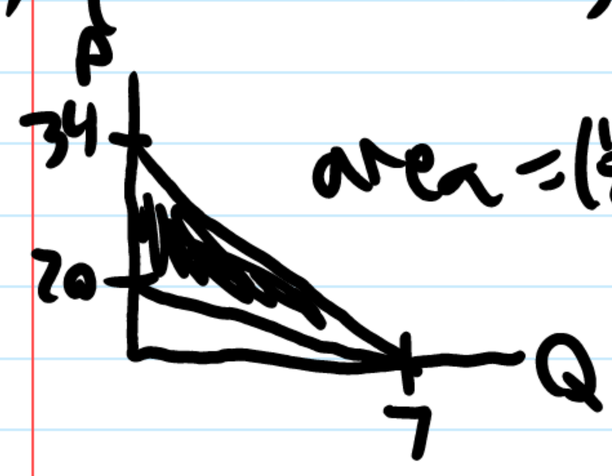
$q = a + .5p \rightarrow 10 = a + .5(40) \rightarrow 10 = a + 20 \rightarrow a = -10$

Supply schedule: $\boxed{q = -10 + .5p}$

b) $q = -10 + .5p \rightarrow .5p = 10 + q \rightarrow p = 20 + 2q$

area $= \frac{1}{2}bh \rightarrow (\frac{1}{2})(20)(10) = \boxed{100}$

c) $q = -10 + .5(34) \rightarrow q = -10 + 17 \rightarrow q = 7$



area $= (\frac{1}{2})bh \rightarrow (\frac{1}{2})(14)(7) = 49$

$100 - 49 = \boxed{51}$

d) $PS = (6 \cdot 7) + (\frac{1}{2})(6)(7)$

$PS = 42 + 21$

$PS = 63$

Price loss due to q: $21/63 = 1/3$

Price loss due to p: $42/63 = 2/3$

4 Book Notes

Saturday, August 29, 2020 1:46 PM

Change in SS are areas, usually triangles or trapezoids

4.1 Knowing the slope or price elasticity of demand

MPC - Marginal private cost
MSC - Marginal social cost

4.1.1 Linear demand curve

$q = \alpha_0 + \alpha_1 p$ where: q = quantity at price = p
α_0 quantity if $p = 0$
α_1 change in q if price increases by 1

$\epsilon_d = \alpha_1 \frac{p}{q} \rightarrow \alpha_1 = \epsilon_d \frac{q}{p}$

Construction of a linear demand curve to measure changes in SS requires an estimate of slope or ϵ_d and p and q of ϵ_d

4.1.2 Constant elasticity demand curve

$q = \beta_0 p^{\beta_1} \rightarrow \ln(q) = \ln(\beta_0) + \beta_1 \ln(p)$

$\text{Area} = \left(\frac{1}{\beta_0}\right)^{1/\beta_1} \left(\frac{q_1^{\rho} - q_0^{\rho}}{\rho}\right)$ where $\rho = 1 + \left(\frac{1}{\beta_1}\right)$

4.2 Extrapolating from a few observations

4.3 Econometric Estimation w/ many observations

linear regression is a good starting point

4.3.1 Model specification

$q = f(p, I, T)$
- T → temperature
- I → income
- p → price

OLS = ordinary least squares

4.3.2 Types of data

Cross-sectional vs time series
- cross-sectional → single or multiple units
- time series → repeated on same unit

GLS = generalized least squares

Can mix cross-sectional + time series

4.3.3 Identification

Endogenous variables: variables determined simultaneously
Exogenous variables: variables that are fixed or determined outside the model

4.3.4 Confidence intervals

4.3.5 Prediction vs Hypothesis testing

Appendix 4A Multiple regression

Independent = explanatory

β_0 = intercept parameter or constant

R^2 = square of correlation between actual + predicted value of dependent variable

Multicollinearity = explanatory var can be written as linear combo of others

5 Book Notes

Saturday, September 5, 2020 7:06 PM

Intro

change in allocative efficiency:

$\Delta SS = \Delta SS_O + \Delta SS_I + \Delta SS_S$

output input secondary markets

5.1 Shadow Pricing

When no market price exists or it is obscured, shadow pricing exists

5.2 Valuing impacts in Efficient markets

5.2.1 Direct increase in supply available to consumers

5.2.2 Direct reduction in costs to producers

5.3 Valuing impacts in distorted markets

if output market becomes distorted, hard to determine correct surplus changes

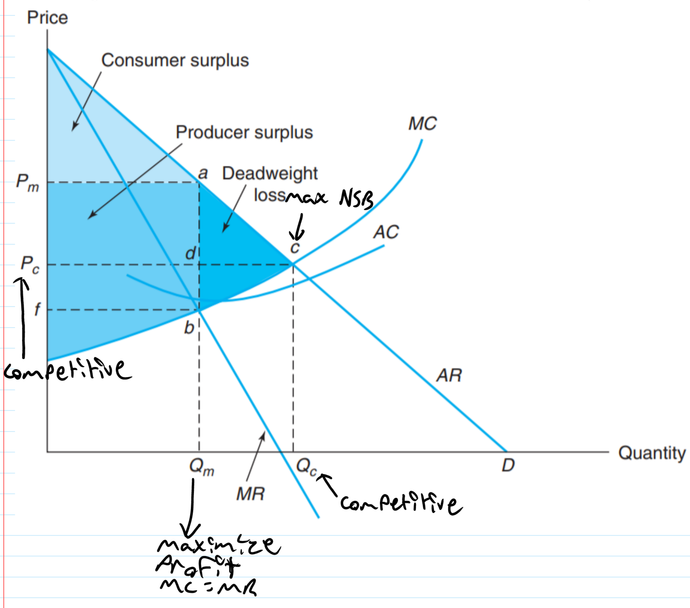
five types of failures:

- monopoly
- information asymmetry
- externalities
- public goods
- addictive goods

5.3.1 Monopoly

results in DWL and reduces SS

marginal revenue (MR) is below demand (AR)



SS = CS + PS

monopolist maximizes profits

5.3.2 Natural monopoly

Natural monopoly enjoys economies of scale over a wide range of outputs

Large fixed costs relative to variable costs

MC < AC over range

5.3.3 Information asymmetry

Government can intervene + provide missing info

1) Search goods: Products with researchable characteristics
2) Experience goods: consumers can only gain full knowledge after purchasing
3) Post-experience goods: consumption does not necessarily reveal information

5.3.4 Externalities

- an effect that production or consumption has on third parties
- by product for which there is no market
- problem of "missing markets"
- negative imposes social costs
- positive produces benefits
- to reduce DWL from negative externalities, increase taxes

5.3.5 Public goods

- non-excludable goods → everyone has access
- pure public goods are nonexcludable + non-rivalrous
- non-excludable = jointness in supply
- can cause free-rider problem
- non-rivalry → one's use does not exclude another's
- non-rivalry causes market failure
- toll goods are non-rivalrous + excludable
- open-access resources are non-excludable + rivalrous

5.3.6 Addictive goods

- rational addiction when consumers take consequences into account
- negative intrapersonal externalities - harm imposed on future self by current self

5.1 Valuing Impacts

Saturday, September 5, 2020 7:06 PM

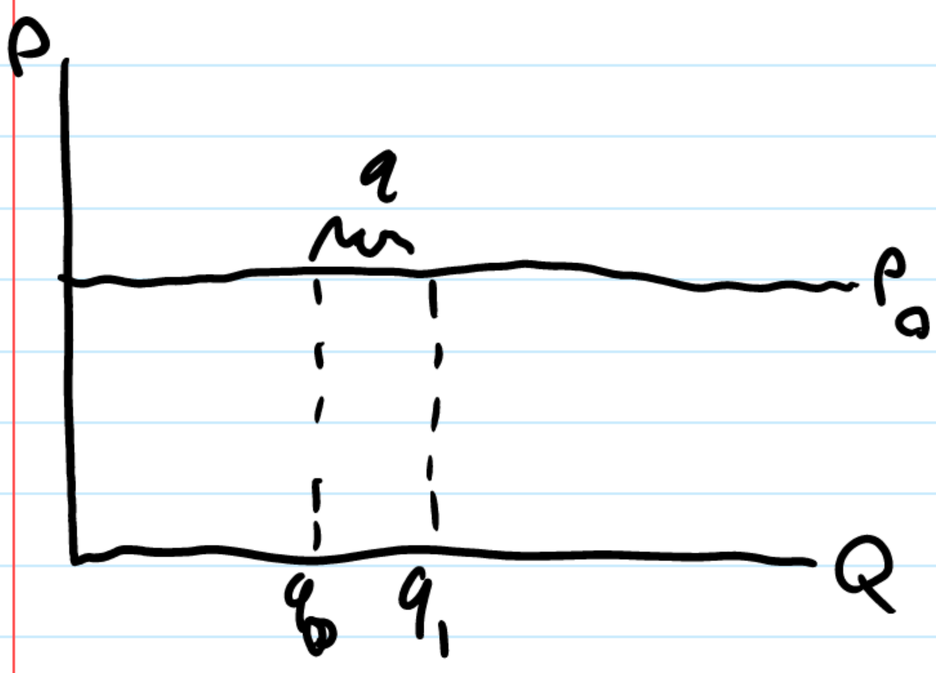
Output + Input markets

Efficient or distorted markets

Primary or Secondary markets

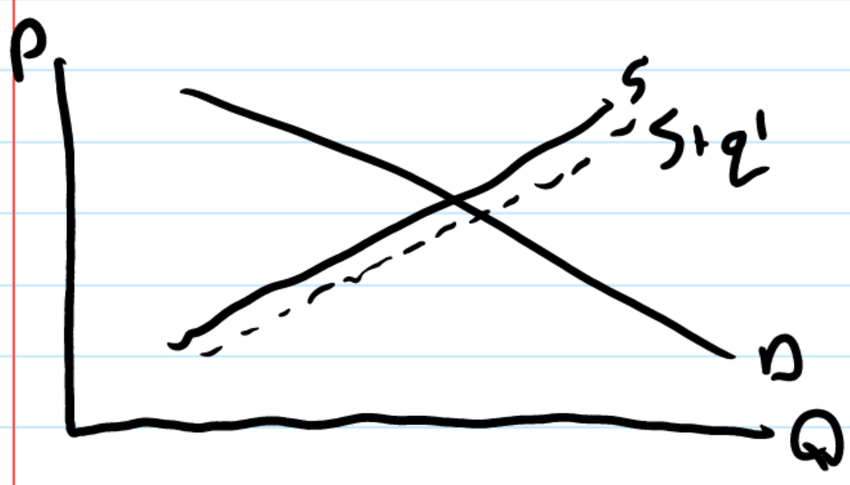
5.2 Efficient Output Markets - Introduction

Friday, September 11, 2020 11:57 AM



a) q' sold @ mkt price

$\Delta CS = P \cdot q'$



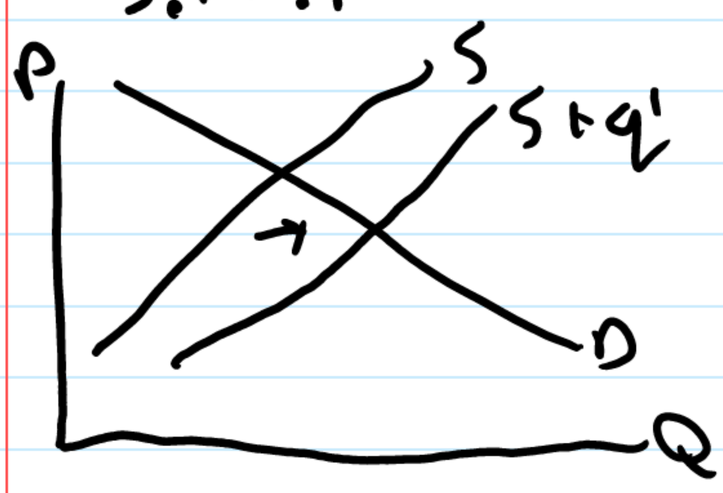
q/q' is tiny

b) gov't gives it away

- best case $\Delta CS = P \cdot q'$
- resale possible
- worst case $0 \leq \Delta CS \leq P \cdot q'$
  - Resale not possible

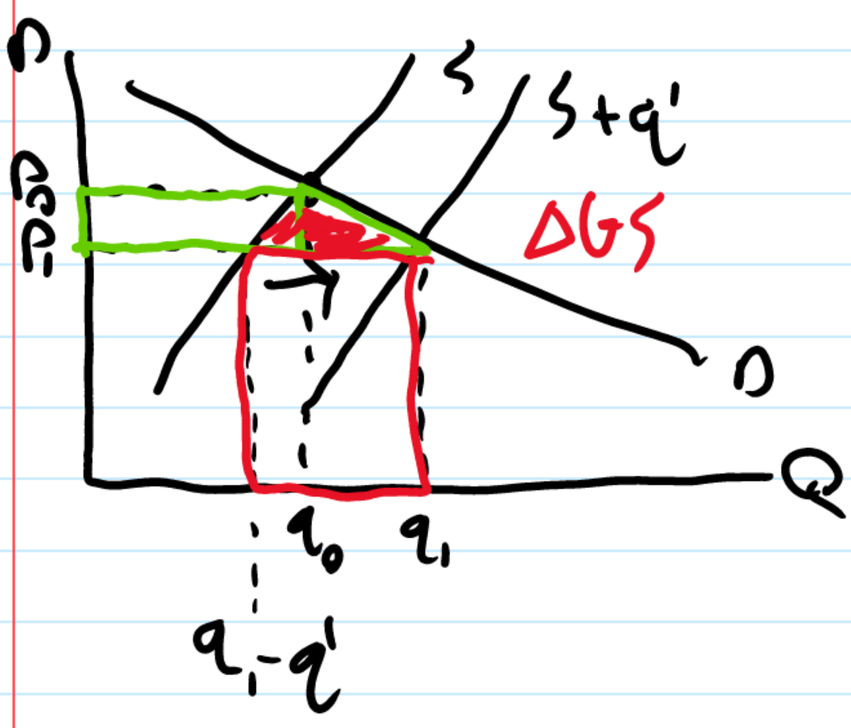
When things are free, they're hard to value

5.1 - ??



5.3 Efficient Output Markets - Direct Supply

Friday, September 11, 2020 12:05 PM



$\Delta PS = -(P_0-P_1)\cdot(q_1-q') = -\frac{1}{2}(P_0-P_1)(q_0-q_1+q')$

$\Delta CS = (P_0-P_1)q_0 + \frac{1}{2}(P_0-P_1)(q_1-q_0)$

$\Delta PS + \Delta CS = q'\cdot(P_0-P_1)\cdot\frac{1}{2}$

$\Delta GS = P_1\cdot q_1$

- assuming Gov't sells at market price P_1

$\Delta SS = \alpha_C \Delta CS + \alpha_P \Delta PS + (1+MEBT)\cdot\Delta GS$

$\alpha_C = \alpha_P = 1$

$= q'\cdot(P_0-P_1)\cdot\frac{1}{2} + (1+MEBT)\cdot P_1\cdot q'$

assume given away, resale possible

$\Delta GS = 0$

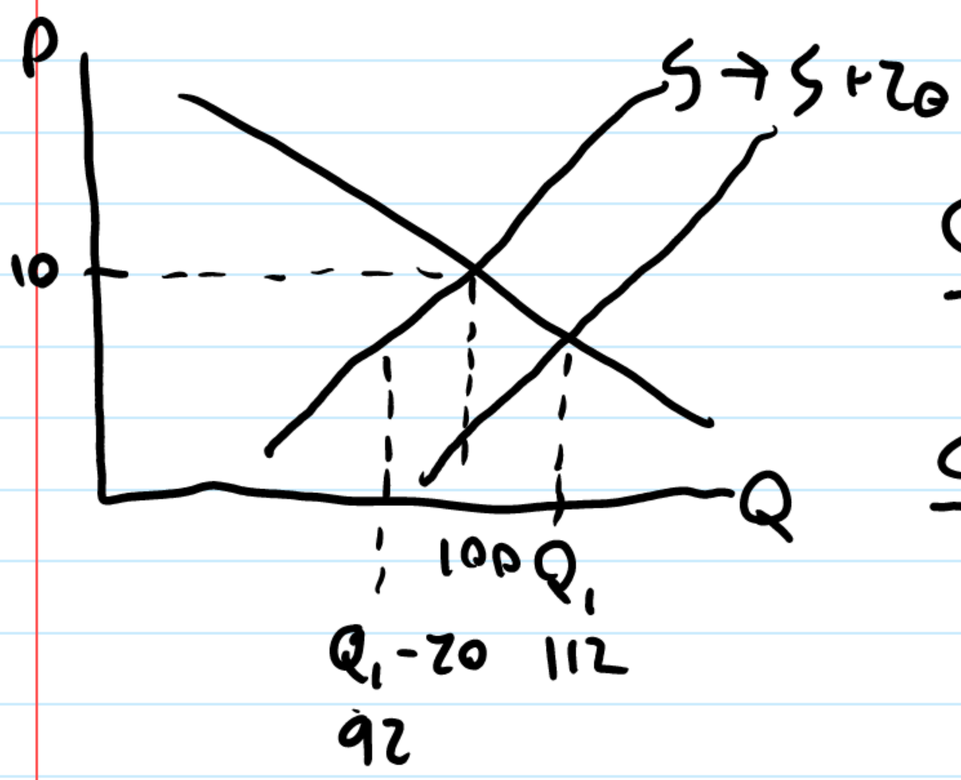
ΔCS is higher by $P_1\cdot q'$

- given away, no resale

5.4 Efficient Output Markets - Direct Supply - Example

Friday, September 11, 2020 12:35 PM

$\eta^S = 2,\ \eta^D = -3,\ P_0 = 10,\ Q_0 = 100,\ q' = 20$



$$\frac{Q_1 - 100}{P_1 - 10} \cdot \frac{10}{100} = -3 = \eta^D$$

$$\frac{Q_1 - 20 - 100}{P_1 - 10} \cdot \frac{10}{100} = 2 = \eta^S$$

$$\rightarrow \frac{Q_1 - 100}{Q - 120} = -1.5$$

$$\rightarrow Q_1 = 280/2.5 = 112$$

$$\frac{12}{P_1 - 10} \cdot \frac{10}{100} = -3 = \eta^D$$

$$(100 \cdot 3.6) + \frac{1}{2} \cdot 12(10 - 6.4)$$

$$360 + 6 \cdot 3.6$$

$$381.6 = \Delta CS$$

$$\Delta PS = -3.6 \cdot 92 =$$

$$\Delta GS = 6.4 \cdot 12 =$$

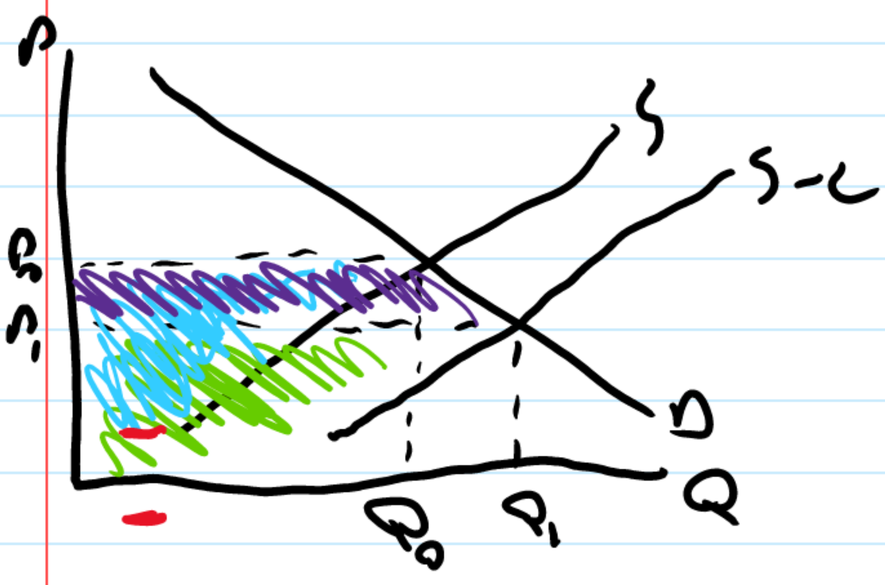
$$\Delta SS = 381.6 - 345.6 + (1 + MCFB) \cdot 76.8 = 132$$

$$.25$$

$$\Delta SS = \Delta CS - \Delta PS + (1 + MCFB) \cdot \Delta GS$$

5.5 Efficient Output Markets - Producer Cost Reductions

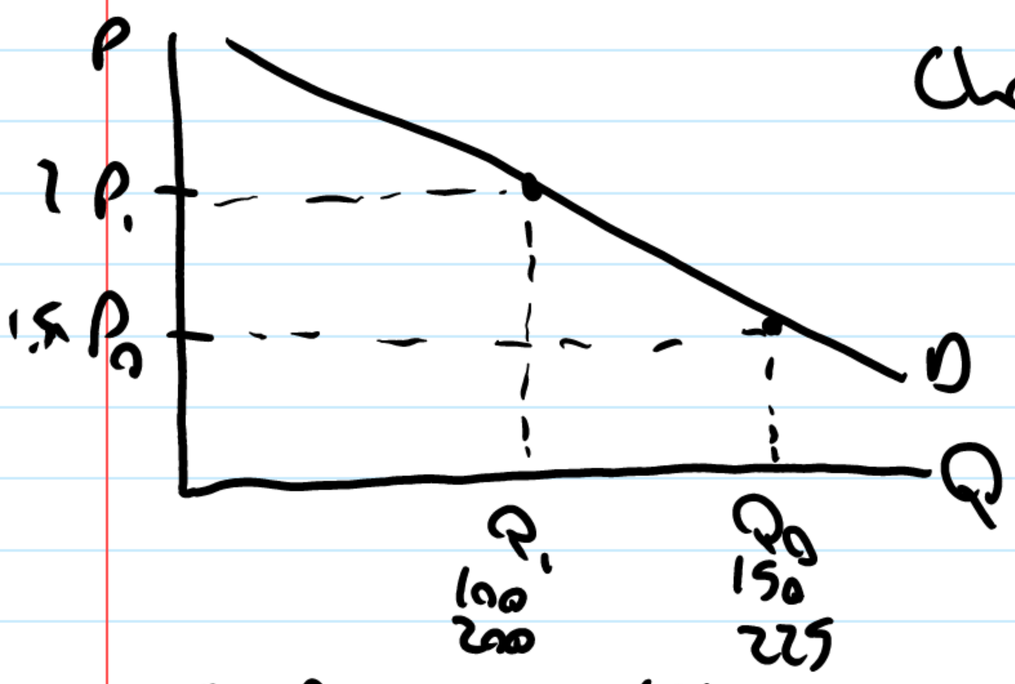
Friday, September 11, 2020 12:58 PM



$/unit lower cost is direct affect of program

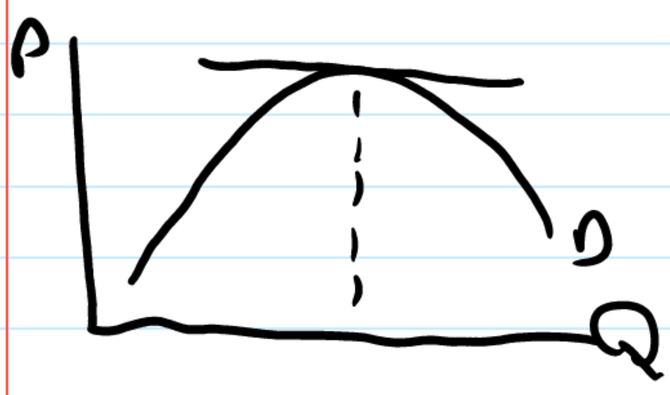
5.6 Monopoly Review - Demand and Revenue

Saturday, September 12, 2020 6:26 PM



Choose to sell at price or by quantity but not both

$\pi = P(Q) \cdot Q - C(Q)$



$R = P(Q) \cdot Q \rightarrow \frac{dR}{dQ} = \frac{dP}{dQ} \cdot Q + P(Q) \cdot 1$

$MR = P + \frac{dP}{dQ} \cdot Q = P\left(1 + \frac{dP}{dQ} \cdot \frac{Q}{P}\right)$

Inverse of η^d

$MR = P(1 + 1/\eta^d)$

5.7 Monopoly Review - Profit Maximization

Saturday, September 12, 2020 7:12 PM

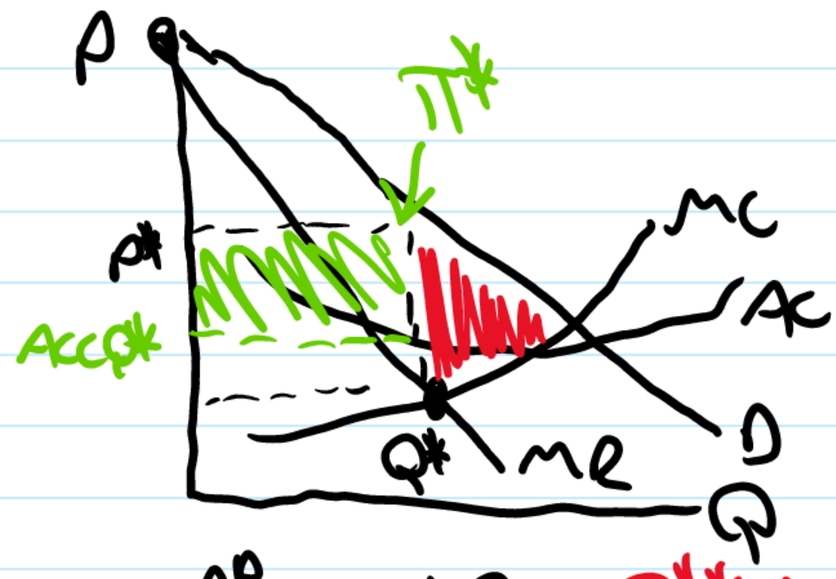
$$\pi = P(Q)\cdot Q - C(Q)$$

$$\frac{d\pi}{dQ} = \frac{dP}{dQ}\cdot Q + P - \frac{dC}{dQ} = 0$$

$MR = MC$

		Sell?
10	5	Yes
7	12	No

$MR > MC$? Sell!



$P^D = a - bQ$ $Q^{**} \rightarrow$ Loss

$MR = a - 2bQ$

$ACCQ^*$ = Average cost of Q^*

Profit/unit = $P^* - ACCQ^*$

$P^D = a - bQ$

$R = P\cdot Q = (a-bQ)Q$

$\frac{dR}{dQ} = -b\cdot Q + a - bQ = a - 2bQ$

MR is twice as steep as D

$MR = a - 2bQ = P[1 + 1/3^a]$

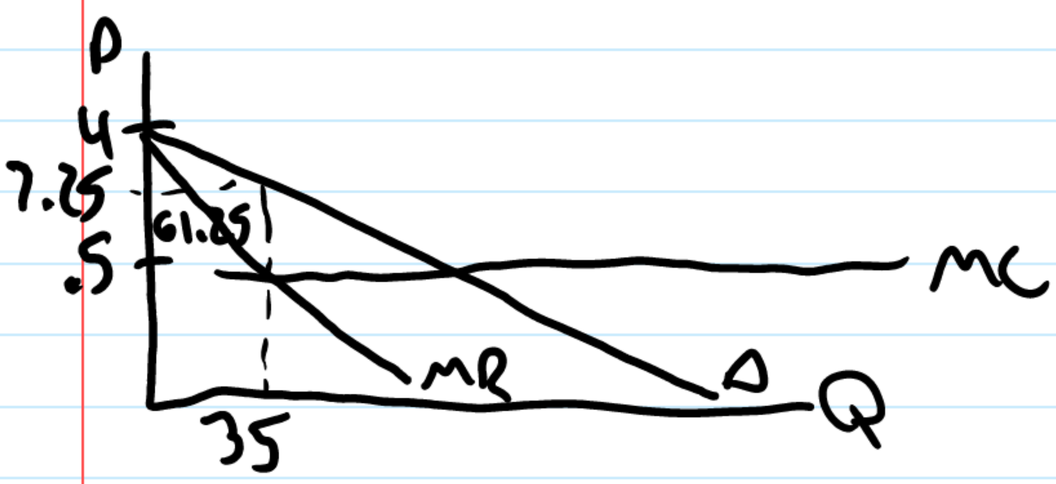
5.8 Monopoly Review - Numeric Example

Saturday, September 12, 2020 7:29 PM

$P = 4 - .05Q$

$C = 10 - .5Q$

$C(Q) = F + CQ$



$MR = 4 - .1Q$

$.5 = 4 - .1Q$

$3.5 = .1Q$

$Q = 35$

$P = 4 - .05 \cdot 35$

$P = 2.25$

$\pi = 1.75 \cdot 35 = 51.25$

5.9 Monopoly Review - Why do they persist

Saturday, September 12, 2020 7:35 PM

1) $\pi^E > 0$ → Should attract entry → Barrier to entry
2) DWL > 0 → Society wants to get rid of monopoly

Natural Monopoly → utilities

5.10 Valuing Direct Supply in Monopoly Markets

Thursday, September 17, 2020 4:08 PM

Valuing Impacts in Monopolized Markets

= DWL

Program provides q', sold at market price

$D - q'$ = residual demand

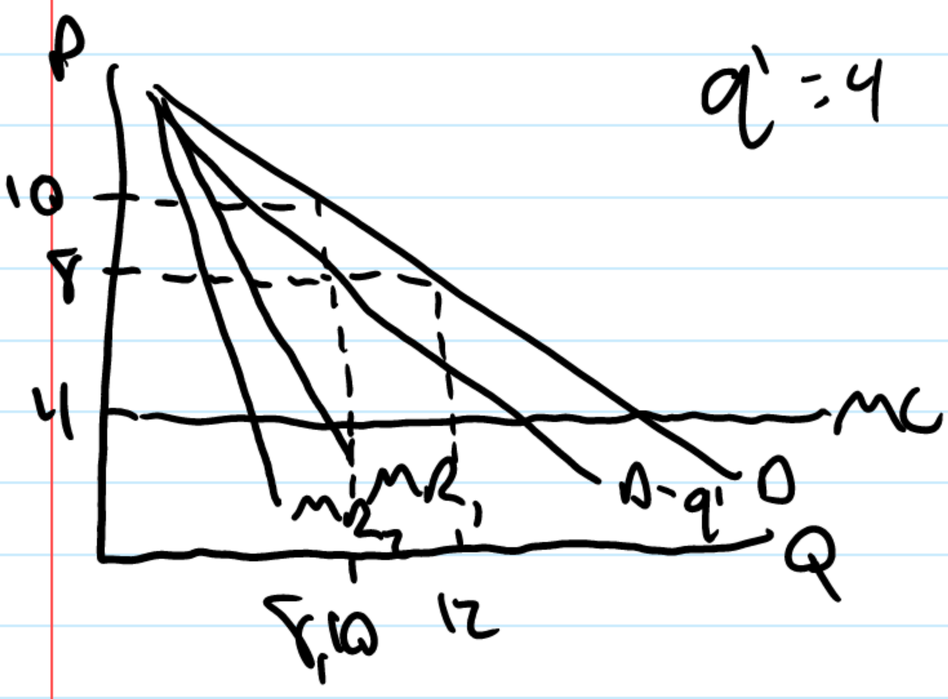
$\Delta GS = P_2^m \cdot q'$

$\Delta CS = (P_1^m - P_2^m) \cdot Q_1^m + \frac{1}{2}(P_1^m - P_2^m)(Q_2^m + q' - Q_1^m)$

$\Delta PS = (P_1^m - MC) \cdot Q_1^m - (P_2^m - MC) Q_2^m$

5.11 5.12 Valuing Direct Supply in Monopoly Markets - Examples

Thursday, September 17, 2020 4:28 PM



$\Delta CS = (10-8)\cdot 10 + \frac{1}{2}(10-8)(12-10) = 22$

$\Delta PS = (10-4)(10) - (8-4)(8) = -28$

$\Delta GS = (8)(4) = 32$

METB = .2

$\Delta SS = 22 - 28 + 1.2\cdot 32$

$P_0 = 10,\ Q_0 = 10,\ q' = 4,\ \eta^D = -2$

$-2 = \frac{\Delta Q}{\Delta P}\cdot\frac{P}{Q} \rightarrow -2 = \frac{Q-10}{P-10}\cdot\frac{10}{10} \rightarrow -2(P-10) = Q-10 \rightarrow 30 = Q-2P$

$Q = 30-2P$

$P = 15-.5Q$

Residual demand $\rightarrow Q - q' \rightarrow Q^{res} = 30-2P-4 = 26-2P$

$MR \rightarrow 2P = 26-Q \rightarrow P = 13-.5Q$

$MR = MC \rightarrow MR = P(1+1/\eta^D) = MC$

$10(1+1/-2) = MC$

$10(1/2) = MC$

$MC = 5$

$13 - Q = 5$

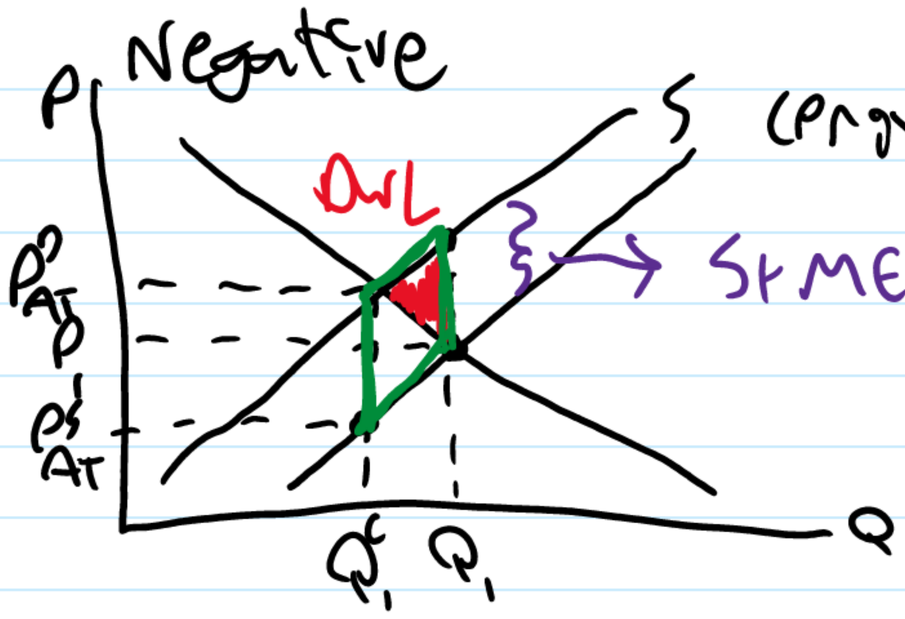
$Q = 8$

$P = 13 - \frac{1}{2}8 = 9$

Embodies Pareto efficiency

5.13 Externalities

Saturday, September 19, 2020 1:55 PM



S (private) → marginal external cost (MEC)

S + MEC = Social

tax = MEC → Q_{eff} → eliminate DWL

$P^D_{AT} - P^S_{AT} = t = MEC$

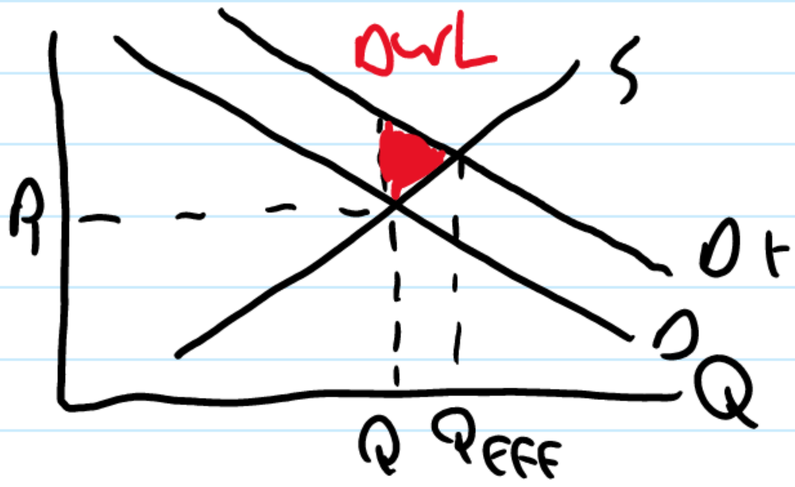
$\Delta CS = -(P^D_{AT} - P_1) \cdot Q_{EFF} - \frac{1}{2}(P^D_{AT} - P_D)(Q_1 - Q_{EFF})$

$\Delta PS = (P_1 - P^S_{AT}) \cdot Q_{EFF} - \frac{1}{2}(P_1 - P^S_{AT})(Q - Q_{EFF})$

$\Delta GS = t \cdot Q_{EFF} = MEC \cdot Q_{EFF}$

ΔExternal Value $= MEC \cdot (Q_1 - Q_{eff})$ External Gain

Positive externalities



fix subsidy?

D + MEB → marginal external benefit

5.14 Distorted Output Markets - Addiction

Saturday, September 19, 2020 2:16 PM

Person is resistant to treatment and adds value to drugs

Addicts are 2 people and play against themselves

Who has standing?

5.15 Distorted Output Markets - Asymmetric Information

Saturday, September 19, 2020 2:20 PM

All markets are uniquely distorted

- moral hazard
  "Peltzman effect" → people push limits
- adverse selection
  "market for lemons" → (used cars)
- Insider information

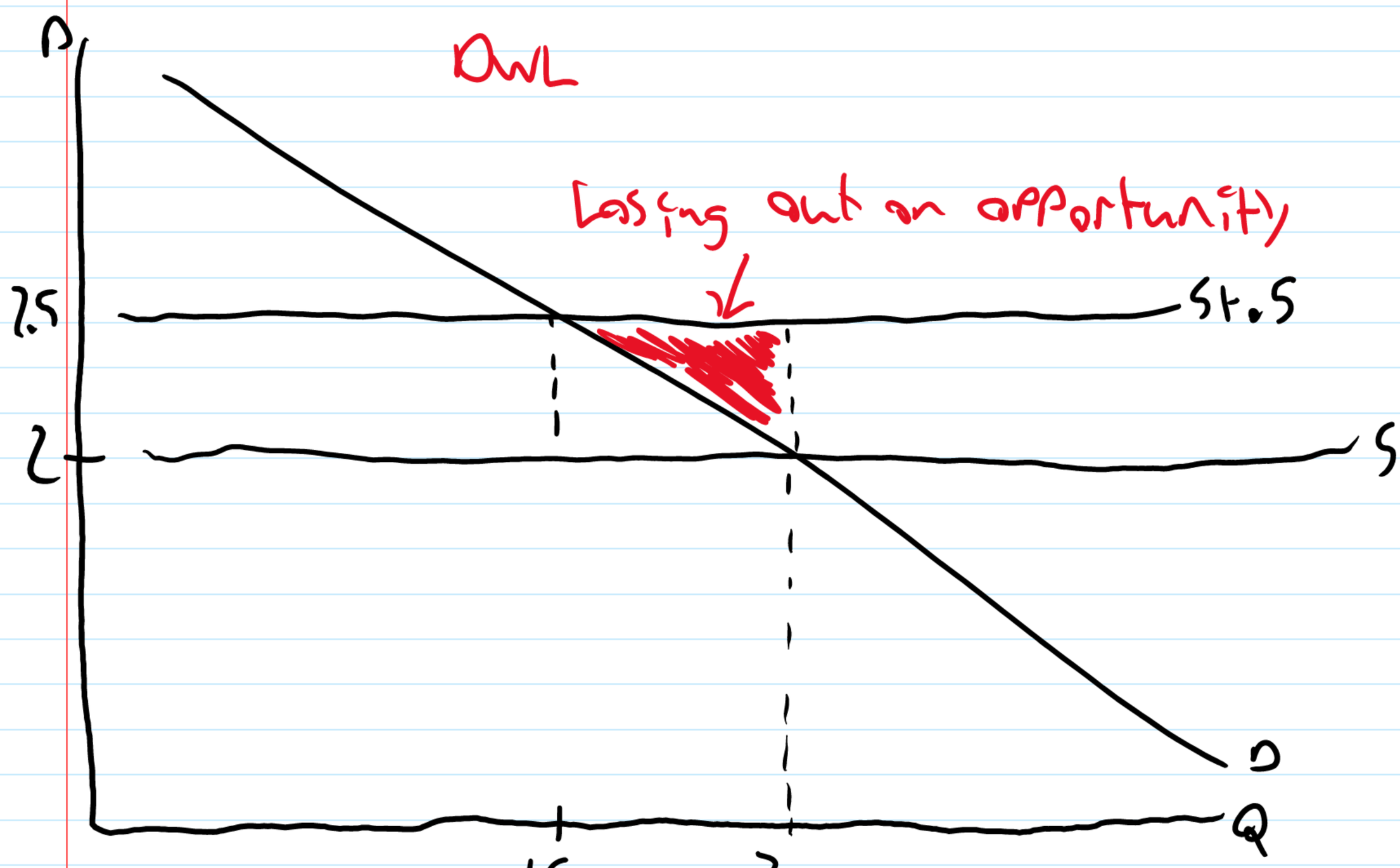
5 Extra Problems

Friday, September 11, 2020 2:02 PM

Suppose the current price of gasoline is $2 per gallon, at which price 20 million gallons are consumed daily. The elasticity of demand is -0.8. Suppose that in addition to the private costs of production and sales born by sellers, each gallon of gasoline consumed releases carbon and pollutants into the air imposing a burden on the rest of society equivalent to $0.50 per gallon. Assume this is a constant cost industry and that the METB is 0.2.

1) Over consumption of gasoline will lead to a DWL. How much overconsumption is there? Hint: You must first calculate the allocatively efficient quantity, which would balance the full costs against the benefits of consumption.
2) Illustrate.
3) How big is the DWL? Include it in the illustration.
4) How might the DWL be corrected?
5) All things considered, what would be the net benefit of that correction?

$\xi^d = -.8$ Q = 20m P = 2 METB = .2 $\xi^s =$



$-.8 = \frac{\Delta Q}{\Delta P} \cdot \frac{2}{20m}$

$-.8 = \frac{\Delta Q}{.5} \cdot \frac{2}{20m} \rightarrow -.8 = \Delta Q = -4m$

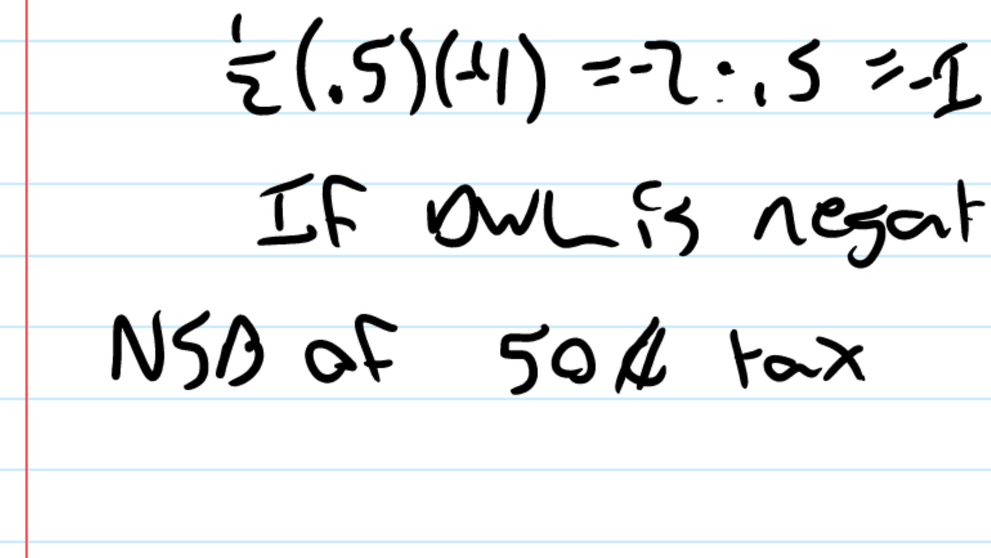
$\frac{1}{2}(.5)(4) = -2 \cdot .5 = -1 =$ DWL

If DWL is negative, flip triangle to above demand

NSB of 50¢ tax

1. Suppose a profit maximizing monopolist is charging a price of $12, and the best available estimate of the elasticity of demand is -4. If the monopolist's marginal cost is constant, estimate its value.

$\xi^D = -4$



$-4 = 12/Q \cdot$

MR = MC

$MR = \Delta R / \Delta Q$

$MR = P(1 + 1/\xi^D)$

HW 5 Cost and Demand Approximation

Tuesday, September 22, 2020 5:37 PM

Passed Solution review

A profit maximizing monopolist charges $20 and sells 100 units. Elasticity of demand is -2.5. The monopolist's cost function is C(Q)=F+cQ where F is a fixed cost and c is the constant per unit variable cost.

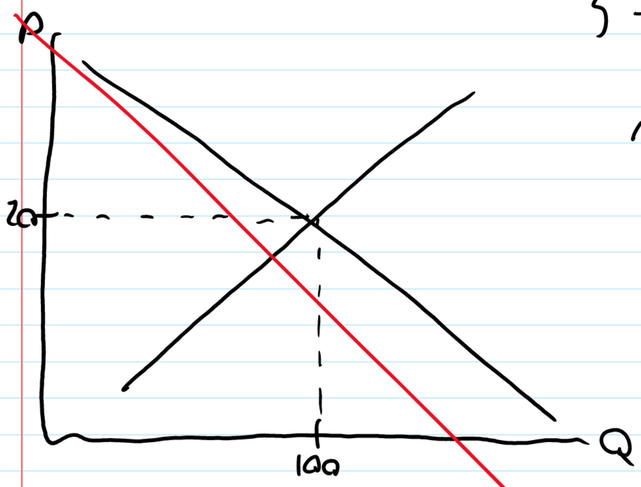
a) What is the per unit variable cost?

b) What is the highest fixed cost could be if the monopolist has not chosen to exit the industry?

c) Write a linear approximation of both demand and inverse demand around the current price. Hint, use the formula for point elasticity and the current price and quantity, then rearrange for Q to get demand and P to get inverse demand.

$$\zeta^D = \frac{\Delta Q}{\Delta P} \cdot \frac{P}{Q}$$

$$MR = P \cdot (1 + (1/\zeta^D))$$



a) $20/100 = .2$ dollars per unit

b) $\zeta^D = \frac{\Delta Q}{\Delta P} \cdot \frac{P}{Q} \rightarrow -2.5 = \frac{Q_1 - Q_0}{(F+cQ) - 20} \cdot \frac{20}{100} = \frac{Q_1 - 100}{F + (.2)(100) - 20} \cdot \frac{20}{100}$

If $F = 20$, then no profit can be made. But so long as $F < 20$, then at least some profit can be made

c) $\zeta^D = \frac{\Delta Q}{\Delta P} \cdot \frac{P}{Q}$

$-2.5 = \frac{Q_1 - Q_0}{P_1 - P_0} \cdot \frac{P_0}{Q_0} \rightarrow -2.5 = \frac{Q_1 - 100}{P_1 - 20} \cdot \frac{20}{100} \rightarrow -2.5 = \frac{Q - 100}{P - 20} \cdot .2$

$-12.5 = \frac{Q - 100}{P - 20} \rightarrow -12.5(P - 20) = Q - 100 \rightarrow -12.5P + 250 + 100 = Q$

$Q = -12.5P + 350$

$Q - 350 = -12.5P \rightarrow P = \frac{Q - 350}{-12.5} \rightarrow P = 28 - .08Q$

Restarted w/ Austin + River

a) $y = mx + b$

$P = \zeta^D Q + b$

$20P = -2.5Q + 100$

$P = -.125Q + 5$

$MR = P(1 + 1/\zeta^D) = MC$

$MR = 20(1 + 1/-2.5) = MC$

$MR = 20 + 20/-2.5 = MC$

$MR = 12 = MC$

Variable cost = $12

b) π = revenue - cost

$\pi = (20 \cdot 100) - (F + cQ)$

$\pi = 2000 - F + (12 \cdot 100)$

$\pi = 2000 - F + 1200$

$F = 800$

c) It turns out I got this right by myself!

$\zeta^D = \frac{\Delta Q}{\Delta P} \cdot \frac{P}{Q}$

$-2.5 = \frac{Q_1 - Q_0}{P_1 - P_0} \cdot \frac{P_0}{Q_0} \rightarrow -2.5 = \frac{Q_1 - 100}{P_1 - 20} \cdot \frac{20}{100} \rightarrow -2.5 = \frac{Q - 100}{P - 20} \cdot .2$

$-12.5 = \frac{Q - 100}{P - 20} \rightarrow -12.5(P - 20) = Q - 100 \rightarrow -12.5P + 250 + 100 = Q$

$Q = -12.5P + 350$

$Q - 350 = -12.5P \rightarrow P = \frac{Q - 350}{-12.5} \rightarrow P = 28 - .08Q$

HW 5 Taxation 1

Friday, September 11, 2020 4:41 PM

Worked w/ Alex, Austin, + River

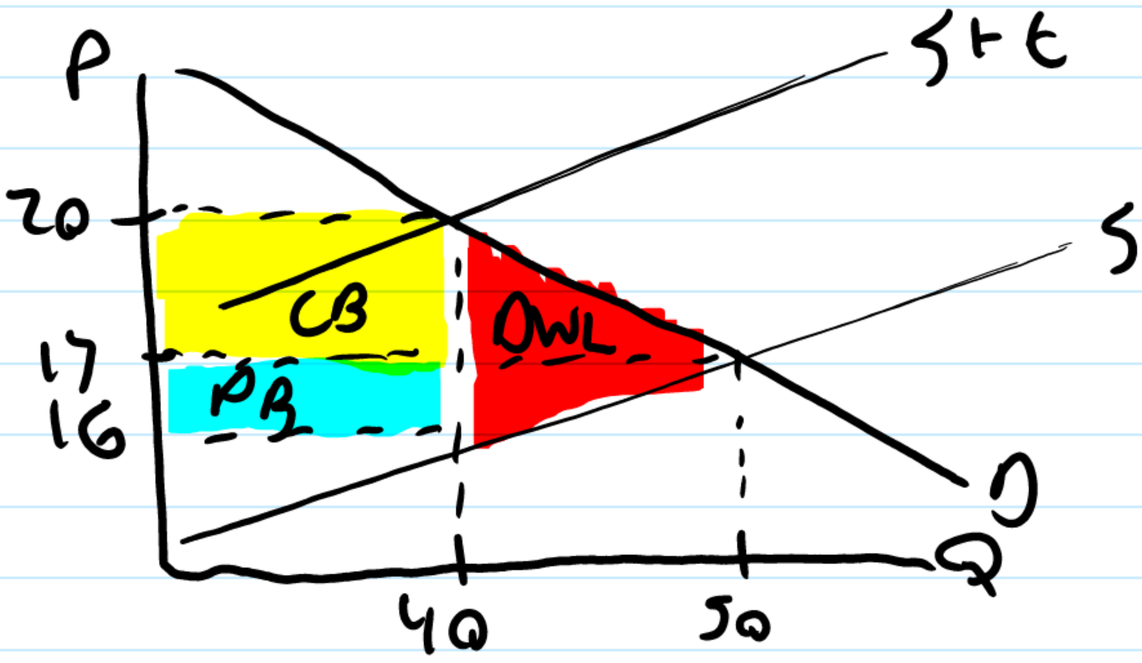
At the current market equilibrium, price is $17 and quantity is 50. A tax of 25% is imposed, after which the price paid by consumers including the tax is $20 and the new equilibrium quantity is 40. Sketch a figure illustrating the equilibrium before and after the tax. Calculate tax revenue, the producer burden, the consumer burden, and the excess burden. Label each.

Hint: If τ is the tax rate, the price paid by consumers is (1+τ) times the price received by suppliers once the tax is remitted to the government.

Passed Solution review

$P = 17 \quad Q = 50 \quad t = 25\%$

$P + t = 20 \quad Q + t = 40$



Tax revenue: $(20-16)\cdot 40 = 4\cdot 40 = \$160$

Producer burden: $(40-0)\cdot(17-16) = 40\cdot 1 = \$40$

$P_p = 15.25 \qquad Q_p = 40$

$P_e = 17 \qquad Q_e = 50$

$P_c = 20 \qquad Q_c = 40$

consumer burden: $(20-17)\cdot(40-0) = 3\cdot 40 = \$120$

DWL: $\frac{1}{2}(50-40)(17-16) + \frac{1}{2}(50-40)(20-17) = \frac{1}{2}(10)(1) + \frac{1}{2}(10)(3)$

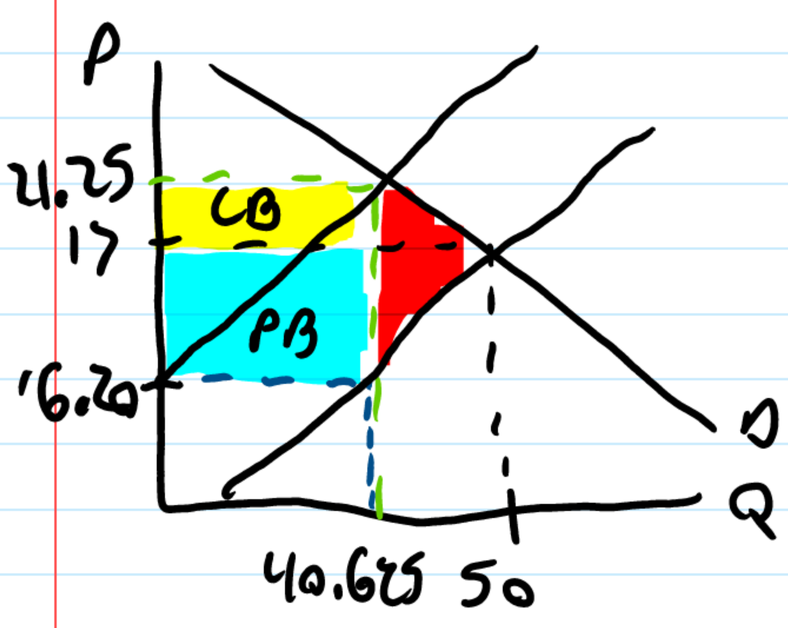
$= 5 + 15 = 20$

HW 5 Taxation 2

Tuesday, September 15, 2020 7:57 PM

Worked w/ Alex, Austin, + River

At the current market equilibrium, price is $17 and quantity is 50. A tax of 25% is imposed. The elasticity of demand is -0.75 and the elasticity of supply is 4. Find the new equilibrium quantity, the after tax price paid by consumers, the after tax price received by suppliers, tax revenue, the producer burden, the consumer burden, and the excess burden. Draw a figure to illustrate. Hint: It will help to sketch the figure noting what you know and what you need to figure out before starting the algebra!



$\xi^D = -.75$

Passed Solution review

Big Yikes

Demanded

Supplied

DWL

Equilibrium Quantity: $\Delta P = 17 \cdot .25 = 4.25$ $\quad \xi^D = \frac{\Delta Q}{\Delta P} \cdot \frac{P}{Q}$

Should've done $(Q_2-Q_1/Q_1)/(P_2-P_1/P_1) = \xi^d$

$-.75 = \frac{\Delta Q}{4.25} \cdot \frac{17}{50} \rightarrow -\frac{3}{4} \cdot \frac{50}{17} = \frac{\Delta Q}{4.25} \rightarrow -\frac{150}{68} = \frac{\Delta Q}{4.25} \rightarrow \Delta Q = -9.375$

$\boxed{Q_2 = 40.625}$

That mistake carries

After tax Prod: $4 = \frac{\%\Delta Q}{\%\Delta P} \rightarrow \%\Delta P = \frac{(-9.375/50)}{4} \rightarrow \%\Delta P = -.7969$

$\boxed{P_2 = 16.203}$

After tax consumer: $17 \cdot 1.25 = \boxed{21.25}$

CB: $(40.625)(21.25-17) = 40.625 \cdot 4.25 = \boxed{172.65625}$

PB: $(40.625)(17-16.203) = 40.625 \cdot .797 = \boxed{32.378125}$

Tax revenue: $172.65625 + 32.378125 = \boxed{205.03}$

DWL: $\frac{1}{2}(50-40.625)(17-16.2) + \frac{1}{2}(50-40.625)(21.25-17)$

$= \frac{1}{2}(9.375)(.8) + \frac{1}{2}(9.375)(4.25) = 3.75 + 19.92 = \boxed{23.67}$

Using ξ^D:

$\frac{Q-50}{50} \Big/ \frac{P_d-17}{17} = -.75 \rightarrow Q = 87.5 - 2.21P_d$

Using ξ^S

$\frac{Q-50}{50} \Big/ \frac{P_s-17}{17} = 4 \rightarrow Q = -150 + 11.76P_s$

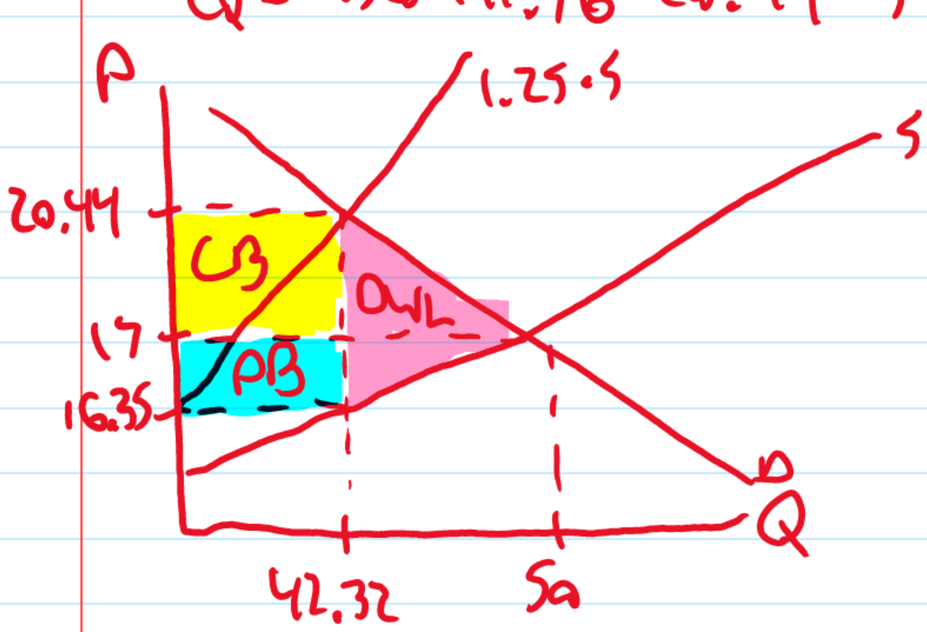
therefore... $1.25P_s = P_d$

Solving w/ substitution

$-150 + 11.76P_s = 87.5 - 2.21 \cdot 1.25P_s \rightarrow P_s = 16.35$

$P_d = 1.25P_s \rightarrow P_d = 1.25 \cdot 16.35 \rightarrow P_d = 20.44$

$Q = -150 + 11.76 \cdot 20.44 \rightarrow Q = 42.32$



Revenue $= .25 \cdot 16.35 \cdot 42.32 = 173.03$

CB $= (20.44-17) \cdot 42.32 = 145.69$

PB $= (17-16.35) \cdot 42.32 = 27.34$

DWL $=$ EB $= (20.44-16.35)(50-42.32)/2 = 15.69$

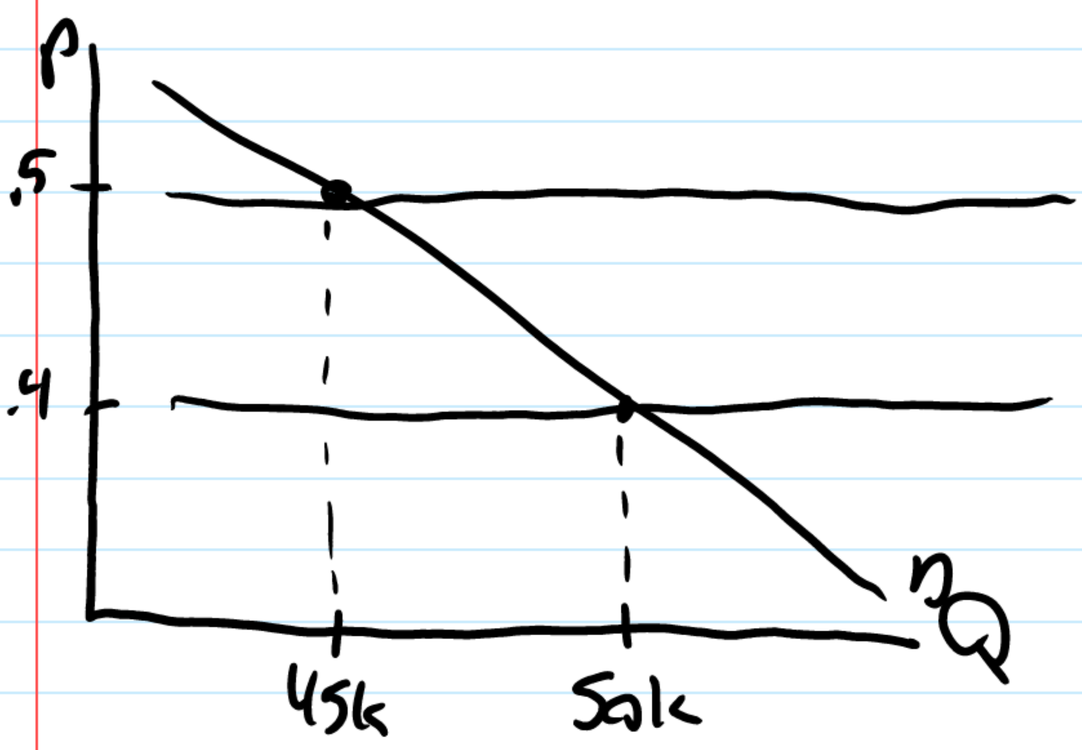
HW 5.1

Friday, September 11, 2020 3:40 PM

Passed Solution review

Suppose the government is considering an increase in the toll on a certain stretch of highway from \$.40 to \$.50. At present, 50,000 cars per week use that highway stretch; after the toll is imposed, it is projected that only 45,000 cars per week will use the highway stretch.

Assuming that the marginal cost of highway use is constant (i.e., the supply curve is horizontal) and equal to \$.40 per car, what is the social change in surplus attributable to the increase in the toll? (Hint: the toll increase will cause the supply curve, not the demand curve, to shift.)



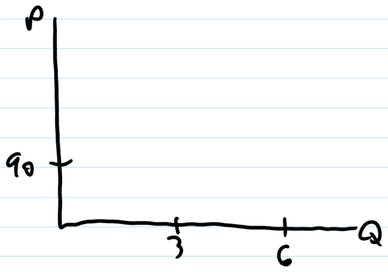
$$\Delta SS = \tfrac{1}{2}(.5-.4)(50-45)$$
$$= \tfrac{1}{2}(.1)(5)$$
$$= .05 \cdot 5$$
$$= .25k = \boxed{250 = \Delta SS}$$

HW 5.2

Friday, September 11, 2020 4:14 PM

Passed Solution review

A country imports 3 billion barrels of crude oil per year and domestically produces another 3 billion barrels of crude oil per year. The world price of crude oil is $90 per barrel. Assuming linear curves, economists estimate the price elasticity of domestic supply to be 0.25 and the price elasticity of domestic demand to be 0.1 at the current equilibrium.



a. Consider the changes in social surplus that would result from imposition of a $30 per barrel import fee on crude oil that would involve annual administrative costs of $250 million. Assume that the world price will not change as a result of the country imposing the import fee, but that the domestic price will increase by $30 per barrel. Also assume that only producers, consumers, and taxpayers within the country have standing. Determine the quantity consumed, the quantity produced domestically, and the quantity imported after the imposition of the import fee. Then estimate the annual social benefits of the import fee.

$\eta^D = \frac{\Delta Q}{\Delta P} \cdot \frac{P}{Q} = -.1$

$\Delta Q = 30\left(\frac{-.1}{15}\right)$

$\Delta Q = -.2$ Consumed

$\eta^S = \frac{\Delta Q}{\Delta P} \cdot \frac{P}{Q} = .25$

$\Delta Q = 30\left(\frac{.25}{30}\right) = .25$ Produced

$Q_D = 6 - .2 = 5.8$

$Q_S = 3 + .25 = 3.25$

$Q_D - Q_S = Q_I$

$5.8 - 3.25 = 2.55$

Forgot to do Parts B + C

b. Economists have estimated that the marginal excess burden of taxation in the country is 0.25 (see Chapter 3). Reestimate the net social benefits assuming that 20 percent of the increase in producer surplus is realized as tax revenue under the existing tax system. In answering this question, assume that increases in tax revenues less the cost of administrating the import fee are used to reduce domestic taxes.

CS = -177b

After tax P_S = 75b

Net tax gain = 95b

Net tax gain · MERB = 23.75b

Net benefits = 16.75b

c. The reduction in the country's demand for imports may affect the world price of crude oil. Assuming that the import fee reduces the world price from $90 to $80 per barrel, and thus, the after-tax domestic price is $80 + $30 = $110 per barrel, a net increase in domestic price of $20 per barrel, repeat the analysis done in parts a and b.

$-.1 = (\Delta Q/\Delta P)(P/Q)$ ← quantity consumed

$\Delta q = (-.1)(\Delta P)(q/P)$

$\Delta q = (-.1)(20)(6b)(90)$

$\Delta q = -.133$ b

Change in domestic supply

$\Delta q = (.25)\Delta P(q/P)$

$\Delta q = (.25)(20)(3b)(90)$

$\Delta q = .167$b

CS = 118.67 b

PS gain = 61.67 b

Net tax gain = 70.25b

Net social benefits = 47.016

6 Book Notes

Friday, September 25, 2020 11:44 AM

Valuing Impacts in Input Markets

opportunity cost of resources used = ass input markets

6.1 Valuing costs in efficient markets

6.1.1 perfectly elastic supply curves

Small purchases see horizontal supply curves

reasonable to assume that expenditures for project inputs equal their social costs

6.1.2 Perfect inelastic supply curves

6.1.3 efficient markets w/ noticeable price effects

big projects have upward sloping supply curves

6.2 Valuing costs in distorted markets

when efficient, $P = MC$

6.2.1 Purchases at below opportunity costs

Jury stipend/per diem

6.2.2 Purchases when inputs are in fixed supply

6.2.3 Hiring unemployed labor

unemployed workers are "in surplus"

five measures of social cost of hiring L unemployed workers

E < actual < B

6.2.4 Hiring labor when rural → urban migration within a developing country is important

rural → urban for higher wages

L = city workforce size E = employed (L − U)
U = # unemployed

migrate if $RW < UW(E/L)$

urban projects draw urban workers

6.2.5 Purchases from a monopoly

monopoly rents

budgetary expenditures > social costs

6.2.6 The general rule

opportunity cost = expenditures on inputs − gains in PS or CS

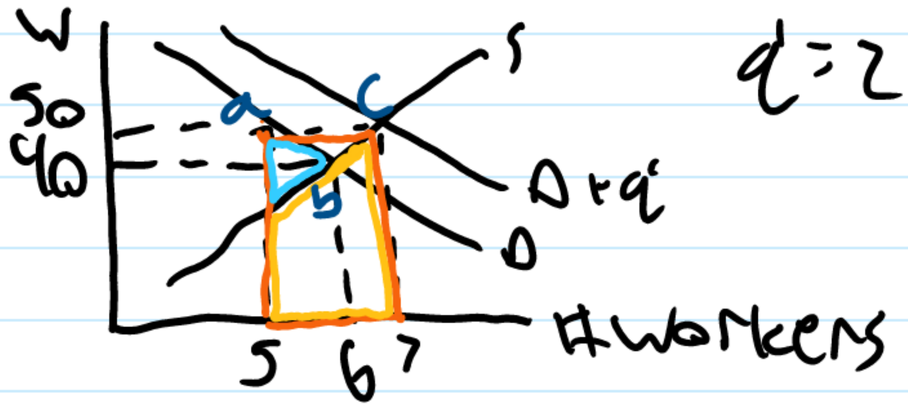
6.1 6.2 Opportunity Cost of Inputs in Efficient Markets

Saturday, September 26, 2020 3:59 PM

Impacts in efficient Input Markets

Land, labor, capital, materials → opportunity cost?

1) No impact on price → budgetary expenditure (1+METB)
2) Drive up price



$q = 2$

$Exp = 50 \cdot (7-5) = 50 \cdot 2 = 100$

How much is cost of something else?
Part of social cost
Net value in private market

$$\text{Social cost} = (7-5)(50) - abc + (METB)(7-5)(50)$$
$$= (1+METB)(7-5)(50) - abc$$

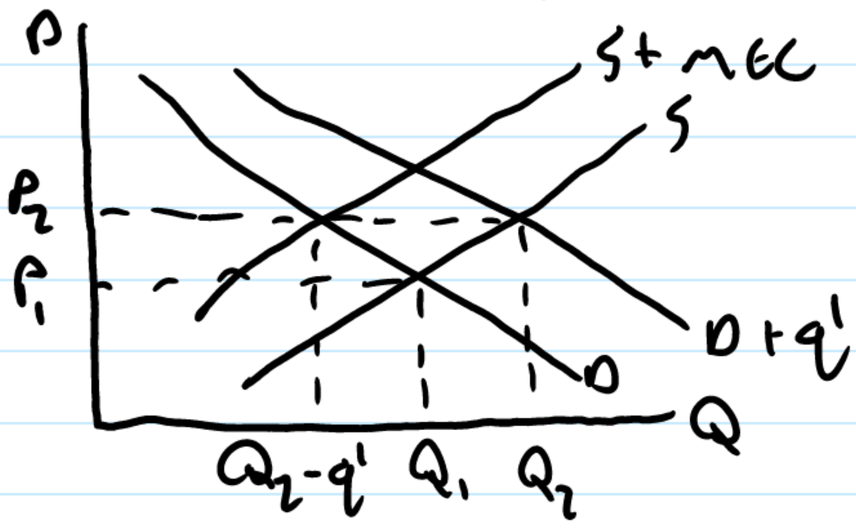
$\Delta CS = (50-40)(5) - \frac{1}{2}(50-40)(6-5) = -55$
$\Delta PS = (50-40)(6) + \frac{1}{2}(50-40)(7-6) = 65$
$Exp = (7-5)(50) = 100$
$METB = .25$
$\Delta SS = 65 - 55 - (1+.25)(100)$

$abc = \frac{1}{2}(50-40)(7-5) = 10 = \Delta PS - \Delta CS \rightarrow abc = \Delta PS - \Delta CS$

6.3 Opportunity Cost of Inputs Purchased in Distorted Markets

Saturday, September 26, 2020 4:27 PM

- Externalities
  - Price unchanged → $Q_2 - Q_1 = q'$
    - ↳ Cost $= (1 + METB)(Exp) + (MEC)(q')$
      $= (1 + METB)(P)(q') + (MEC)(q')$
  - Price changed



ΔExternal cost $= (Q_2 - Q_1)(MEC)$

$Q_p^o = Q_2 - q'$

- Tax to another jurisdiction?
  METB · Revenue Paid
- Legal restrictions on price?
  Juror compensation
  \$15/hr but wage = \$50/hr → not compensated
  Cost $= 50q' + (METB)(15)(q')$

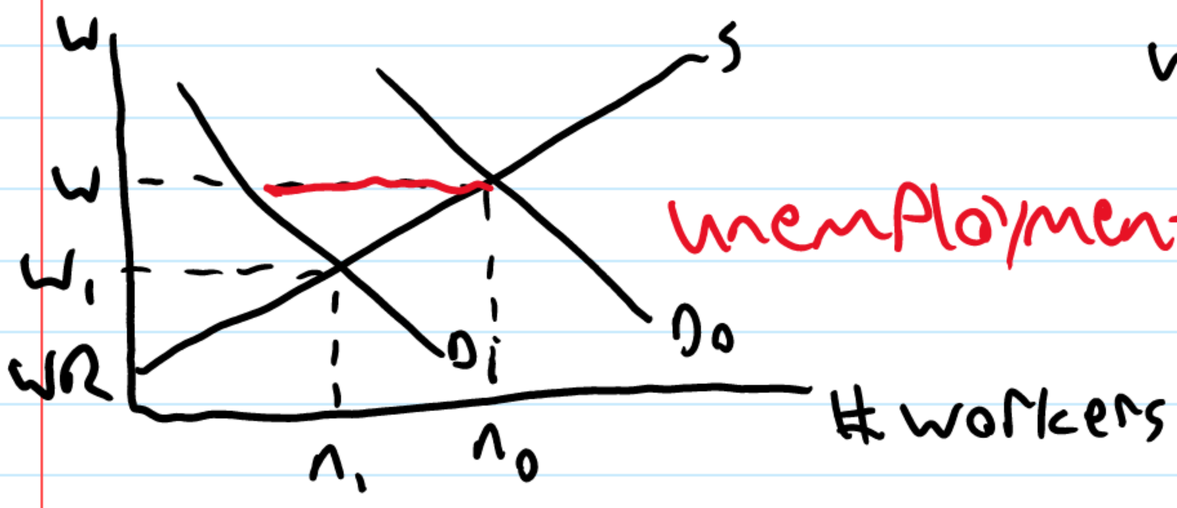
6.4 Opportunity Cost of Labor in Markets with High Unemployment

Saturday, September 26, 2020 4:40 PM

Natural rate of unemployment = 2.5-4 %

↳ Lowest unemployment before inflation

Wages are sticky on the way down



WR = lowest pay

unemployment → excess/surplus workers

SWAG

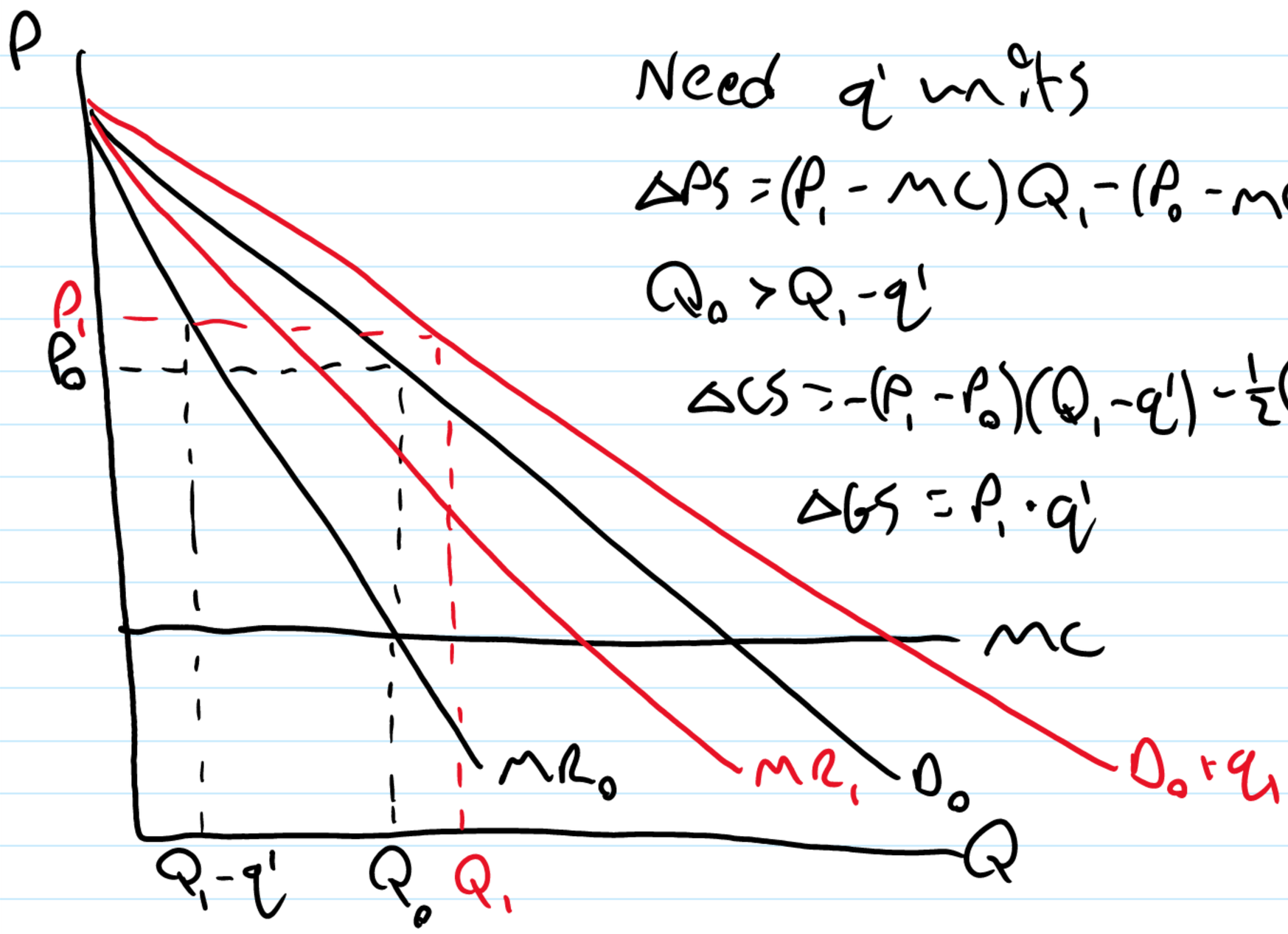
OC per worker = $(W + W_2)/2 = (50 + 20)/2 = 35$

Social cost = $35q' + 50(m \in rB)(q')$

WR = ? WR = 0 W/2 = OC/worker

6.5 Opportunity Cost of Inputs Purchased from a Monopolist

Wednesday, September 30, 2020 5:12 PM



Need q' units

$\Delta PS = (P_1 - MC)Q_1 - (P_0 - MC)Q_0$

$Q_0 > Q_1 - q'$

$\Delta CS = -(P_1 - P_0)(Q_1 - q') - \frac{1}{2}(P_1 - P_0)(Q_0 - Q_1 + q')$

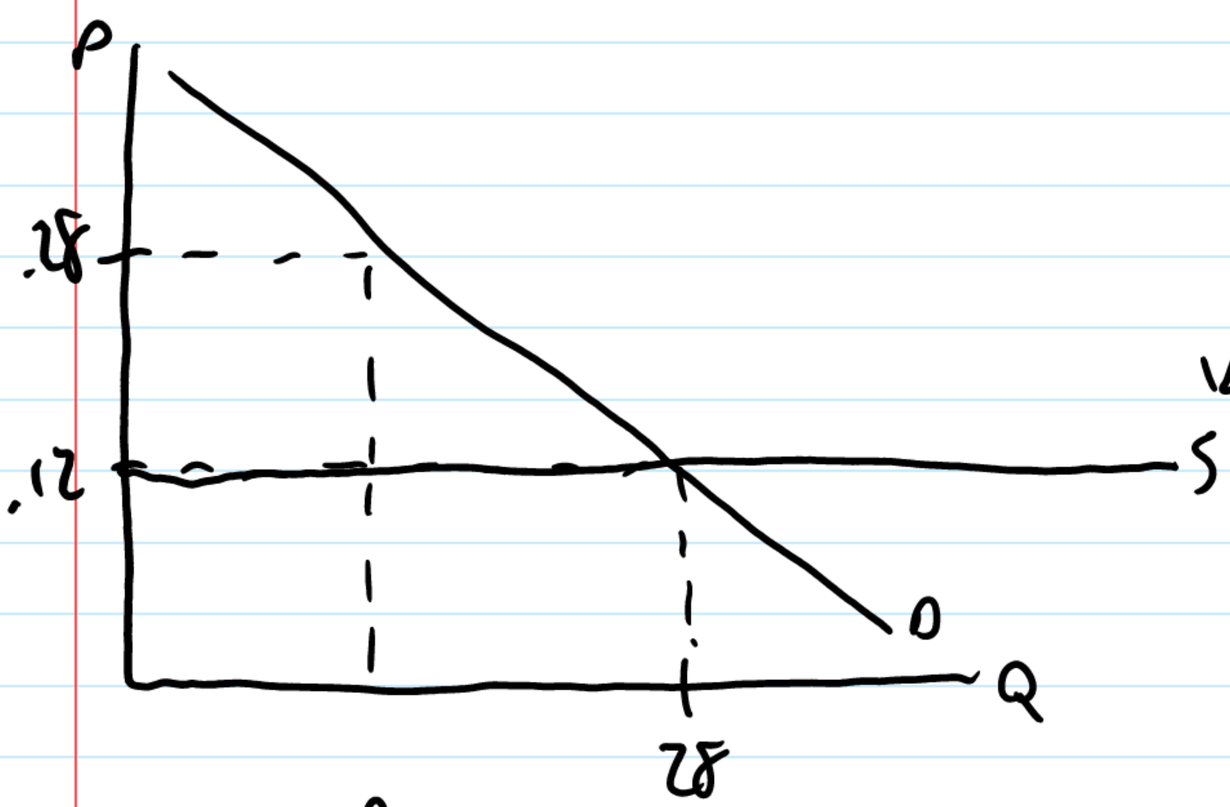
$\Delta GS = P_1 \cdot q'$

HW 6 BCA of Florida Carbon Emissions Tax

Sunday, September 27, 2020 4:59 PM

worked w/ Nick Lane
Passed Solution review

$\xi^d = -.75$ $P_0 = .12$ $MC = .12$ $Q_0 = 28$ $MEC = .05/1$ $MEB = .25$



Flat because electricity utility is a monopoly

$$-.75 = \frac{Q-28}{P-.12} \cdot \frac{.12}{28}$$

$$Q = \frac{Q-28}{P-.17} \cdot \frac{.12}{28}$$

ξ^D

$-.75 = (Q-28)/(P-.12) \cdot 3/700$
$-175 = Q-28 / P-.12$
$-175P + 21 = Q - 28$
$Q = -175P + 49$

ξ^S

$Q = (-175P + 49)/(P-.17) \cdot 3/700$
Numerator has to be Q
$Q = -175P + 49$
$175P = 49$
$P = .28$

Sorry! We got stuck here :(

We're going to use P and Q instead of real numbers

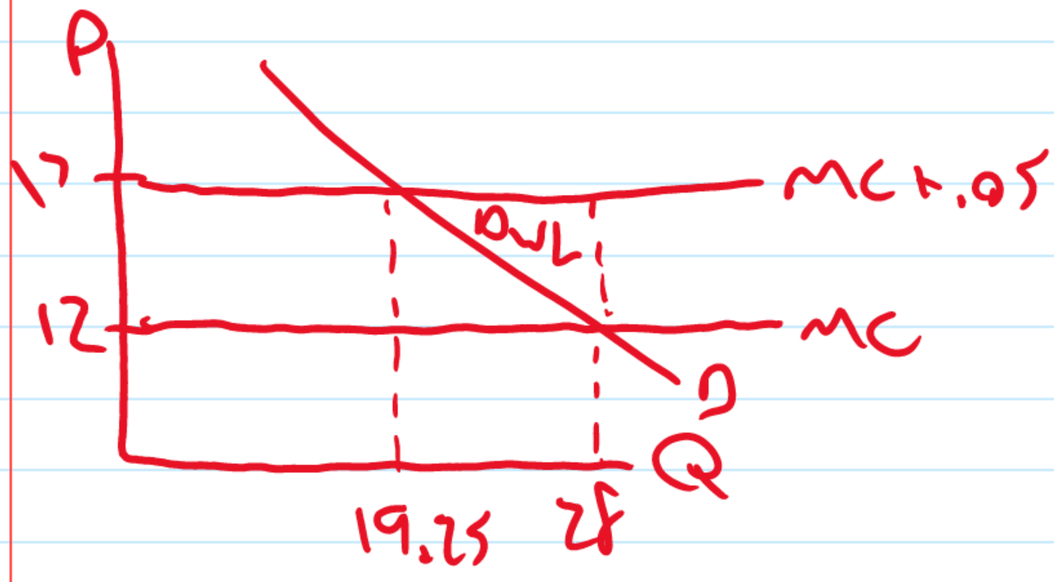
$Q = (-175P + 49 - 28)/(P-.17) \cdot 3/700$
$Q = -175P + 21$
$175P = 21$
$P = .12$

2) Cost = 21 500,000 P
benefit to taxpayers = .05Q
decreased emissions $\xi(Q - Q_0) \cdot 21{,}500{,}000$

3) $\frac{(Q-Q_0) \cdot 21500000}{7600000000} = 43(Q-Q_0)/15200$

4) Emissions could be effectively regulated in cities and other areas with high smog such as LA or cities in India and China. This is because smog is usually very local to the city and has a large negative impact.

1)



$\Delta CS = -.05 \cdot 19.25 - .05 \cdot \frac{8.75}{2} = -1.18$
$\Delta PS = 0$
$\Delta GS = .05 \cdot 19.25 = .9625$
$\Delta SS = -1.18 + 1.25 \cdot .9625 = .021875$

2) $\frac{1.18 \text{ Person}}{\text{day}} \cdot \frac{365 \text{ day}}{\text{Year}} \cdot 21.5\text{m People} = 9.44\text{B/year gain}$

$\frac{.9625 \text{ Person}}{\text{day}} \cdot \frac{365 \text{ day}}{\text{Year}} \cdot 21.5\text{m People} \cdot 1.25 = 9.27\text{B/year cost}$

$\frac{7.75 \text{ kwh}}{\text{Person day}} \cdot 21.5\text{m People} \cdot \frac{365 \text{ day}}{\text{Year}} \cdot \frac{.05}{\text{kwh}} = 3.43\text{B/year benefit}$

Floridian benefits = 21.5m/7.6B = .283% or 9.7m/year

HW 6 Elasticity Given

Sunday, September 27, 2020 6:47 PM

Worked w/ Austin

Passed Solution review

Initially, a profit maximizing local monopolist charges $15 and sells 500 units per week. Elasticity of demand is -3. The monopolist's cost function is C(Q)=F+cQ where F is a fixed cost and c is the constant per unit variable cost.

a) What is the per unit cost of the product?

b) What are the demand and inverse demand functions?

Now assume the local government begins to provide 100 units per week at the market price.

c) What is the residual demand left for the monopolist?

d) Find the new price and the monopolist's quantity and the total market quantity.

e) Assume the METB is 0.25. Find the changes in CS, PS, GS, and SS.

f) Depict all of this in a diagram. You probably want to sketch the diagram right at the start of the problem for reference as you work, and then to redraw a neat version to submit.

a) per unit $= 15/500 = .03/\text{unit}$

b) $\varepsilon = \frac{\Delta Q}{\Delta P} \cdot \frac{P}{Q}$

$-3 = (Q-500)/(P-15) \cdot 15/500$

$-100 = (Q-500)/(P-15)$

$-100P + 1500 = Q - 500$

$Q = 2000 - 100P$

$Q - 2000 = -100P$

$P = 20 - Q/100$

c) $res = Q - q'$

$res = (2000 - 100P) - 100$

$res = 1900 - 100P$

$P = 19 - .01Q^R$

d) $P = 19 - .01Q^R$

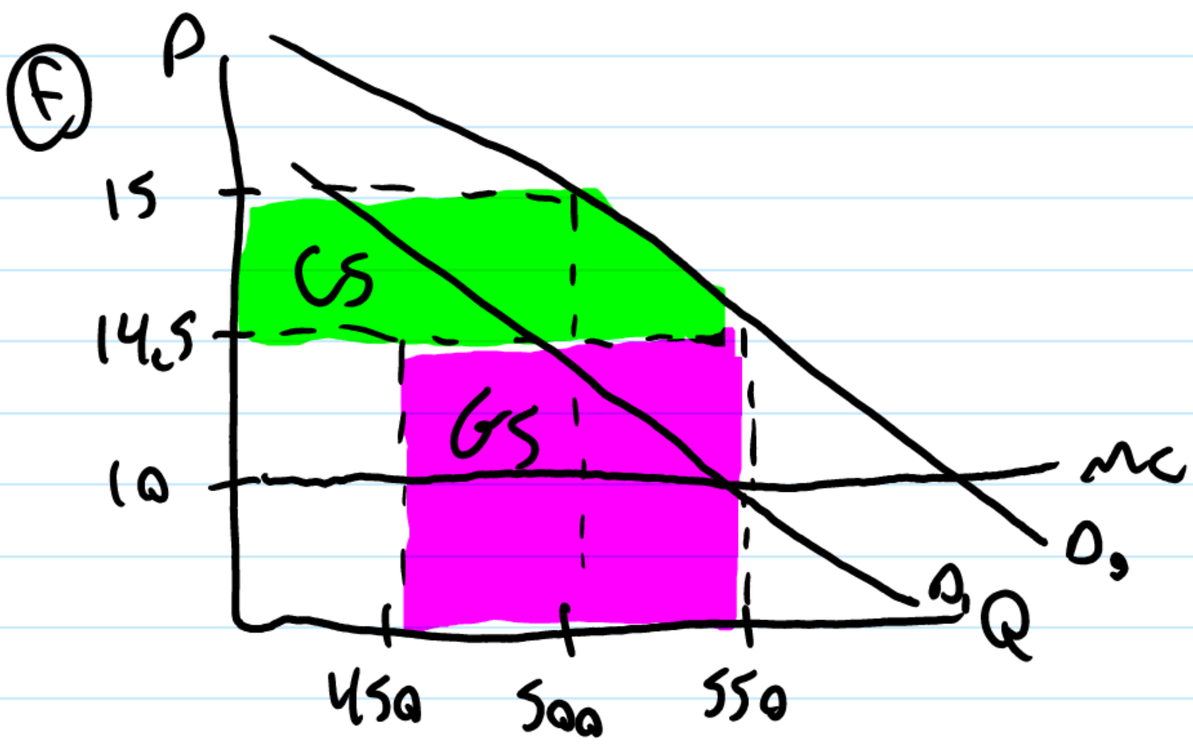
$P = 19 - (.01 \cdot 450)$

$P = 14.5$

$Q = 1900 - (100 \cdot 14.5)$

$Q = 450$

f)



e) $\Delta CS = (.5 \cdot 500) + (\frac{1}{2} \cdot 50 \cdot .5)$

$\Delta CS = 262.5$

$\Delta PS = (-1 \cdot .5 \cdot 500) - (50 \cdot 4.5)$

$\Delta PS = -475$

$\Delta GS = (100 \cdot 14.5)$

$\Delta GS = 1450$

$\Delta SS = 262.5 - 475 + (1.25 \cdot 1450)$

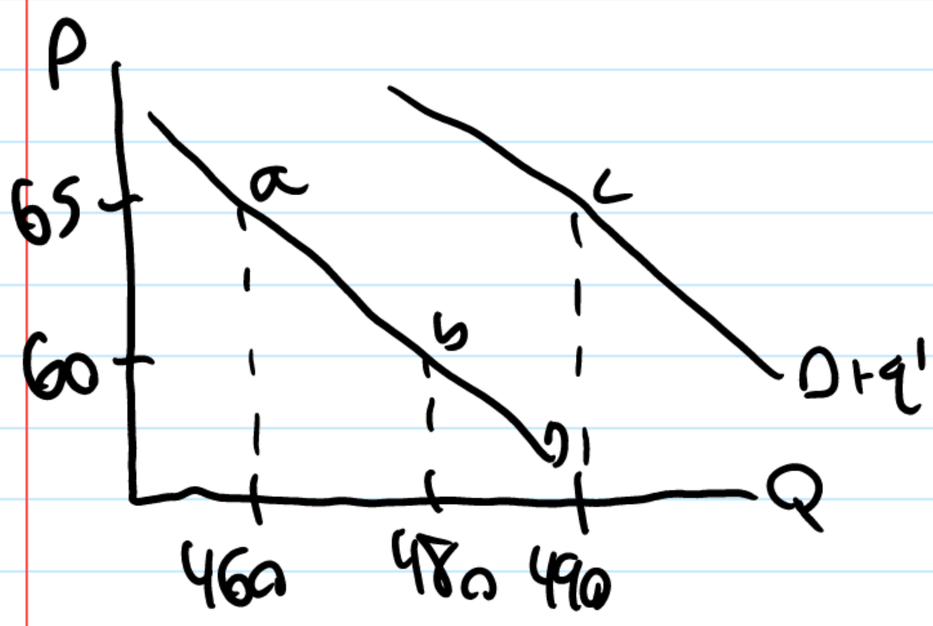
$\Delta SS = 1600$

HW 6 Opportunity Cost of Inputs 1

Sunday, October 4, 2020 5:04 PM

Passed solution review

Suppose a project needs to hire 10 electricians. At the initial wage of 60K/year (including benefits) 480 are currently employed in the local area and 20 are estimated to be unemployed. The MEBT is 0.2. Estimate the opportunity cost of hiring the workers. Explain, and defend any assumptions you make.



Assuming new wage is 65k as it does in problem 2

$q' = 10$

$abc = \frac{1}{2}(65-60)(.49-.46) = 75{,}000$

$SC = (490-460)\cdot 65000 - abc + MEBT(490-460)(65000)$

$SC = 30\cdot 65000 - 75000 + (.2\cdot 30\cdot 65000)$

$SC = 2{,}265{,}000$

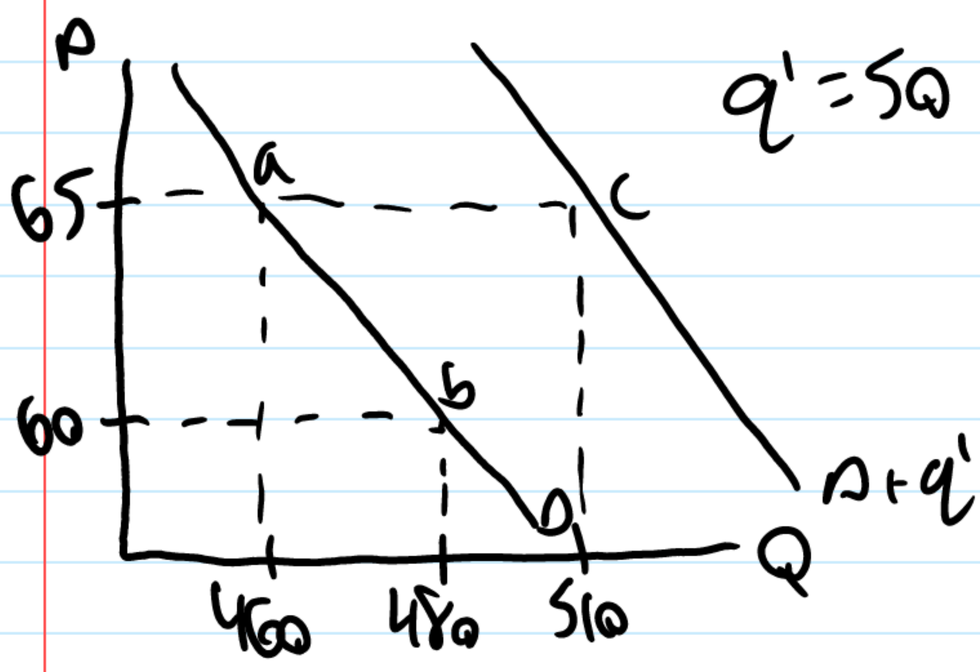
Since there is low unemployment, worker time is valued at market rate. Since the number hired is a small amount compared to total workforce, hiring does not affect the wage. Thus, $SC = 1.02\cdot 60\cdot 10 = 720$

HW 6 Opportunity Cost of Inputs 2

Sunday, October 4, 2020 5:20 PM

Passed solution review

Suppose a project needs to hire 50 electricians. At the initial wage of 60K/year (including benefits) 480 are currently employed in the local area and 20 are estimated to be unemployed. The MEBT is 0.2. After electricians are hired for the project, the local wage increases to 65K/year and the number employed locally increases to 510. Estimate the opportunity cost of hiring the workers. Draw a diagram to illustrate. Explain, and defend any assumptions you make.



$q' = 50$

$abc = \frac{1}{2}(65-60)(.51-.46) = 125k$

$SC = (510-460) \cdot 65k - abc + (MEBT)(510-460)(65000)$

$SC = (50) \cdot 65k - 125k + (.2 \cdot 50 \cdot 65000)$

$SC = 3{,}175{,}000$

We're assuming opportunity cost = social cost

HW 6 Opportunity Cost of Inputs 3

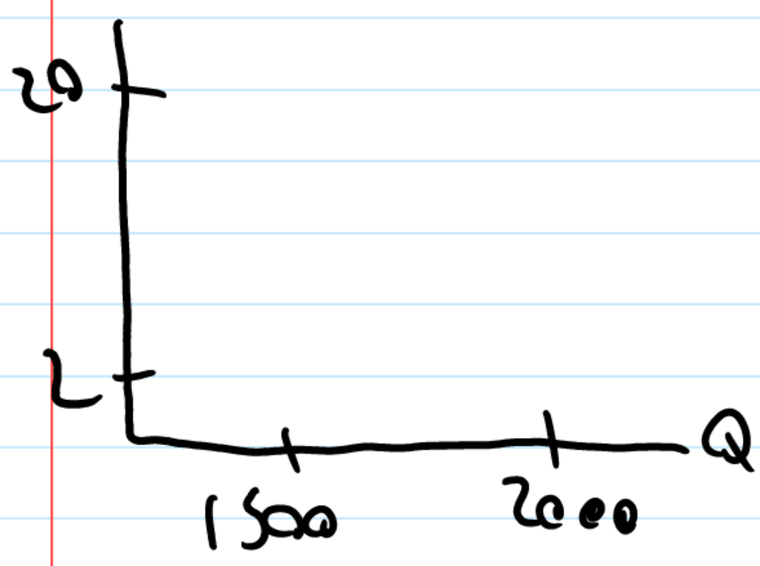
Sunday, October 4, 2020 5:55 PM

Passed Solution review

Worked w/ Nick L + Austin

Imagine a rural area with a current wage rate of $20 at which 1500 workers are employed and 500 are unemployed. A government project will hire 50 workers at the going wage rate. Assume reservation wages for those hired are more or less uniformly distributed between $2 and $20. The METB is 0.2. Estimate the expected opportunity cost of project labor.

OC/worker $(20+2)/2 = 11$ → reservation wage



worker $oc = 11 \cdot 50 = 550$

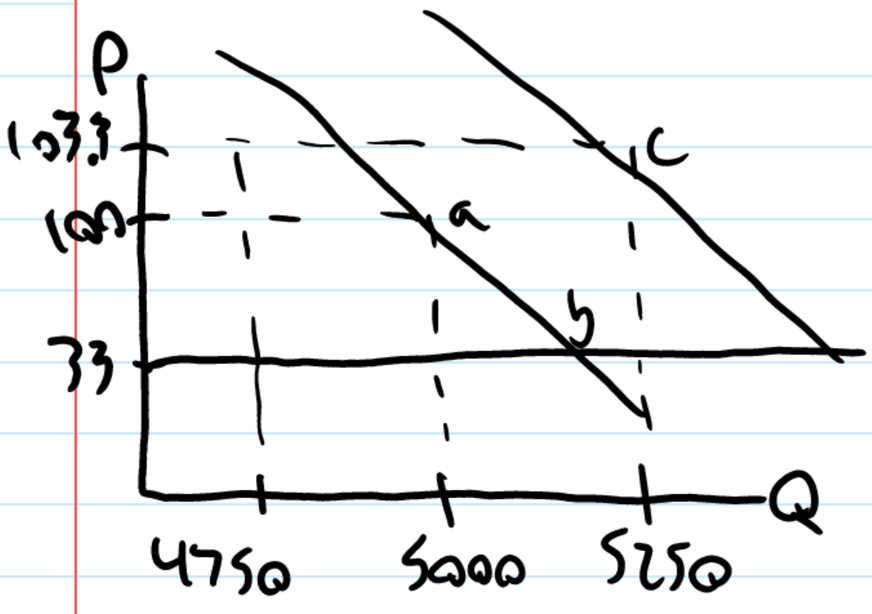
overall $oc = (11 \cdot 50) + (20 \cdot .2 \cdot 50) = 750$

HW 6 Opportunity Cost of Inputs 4

Monday, October 5, 2020 2:41 PM

Passed Solution review

A project requires signing buying 500 cubic yards of concrete per week for the next year from the only local provider. The currently price is $100 per yard and the provider sells 5,000 yards per week. Assuming marginal cost is constant, elasticity of demand at the current price is -1.5, and using a linear demand approximation, estimate the opportunity cost of the weekly government purchase. The METB is 0.2. Note you will need to find the original demand, the new demand, the new price, and the new quantity purchased by those other than the government in the process.



$$-1.5 = \frac{Q-5000}{P-100} \cdot \frac{100}{5000}$$

$$MC\,q' = 500$$

$$MC = P(1+1/\varepsilon^d) = 100(1+1/-1.5) = 33\tfrac{1}{3}$$ ✓ $P = MC(\eta/(1+\eta))$

$$(-1.5)(50)(P-100)+5000 = Q = 12500-75P$$ ✓

$$Q^m = Q + q' - 75P = 13000 - 75P$$
$$75P = 13000 - Q^m$$
$$P = \frac{13000-Q^m}{75}$$

~~$MR = 173.\overline{3} - .026 = 33.3$~~ $MR \to P = 166.67 - 1/75q \to MR = 166.67 - 2/75q$

$$-.026Q^2 = -140$$
$$Q^2 = 5250 = Q^2$$

$$5250 = 13000 - 75P$$ $q = 13000 - 75P$
$$75P = 7750$$
$$P = 103.\overline{3}$$

625

$$SC = (5250-4750)\cdot 103\tfrac{1}{3} - \left(\tfrac{1}{2}\cdot(103\tfrac{1}{3}-100)(5250-4750)\right) + (.2(5250-4750)(103.\overline{3}))$$
$$SC = 500\cdot 103\tfrac{1}{3} - 625 + 10333\tfrac{1}{3}$$
$$SC = 51666.\overline{66} - 625 + 10333\tfrac{1}{3}$$
$$SC = 61{,}175$$

New MR:

$Q = 13000 - 75A \to A = 173.33 \to MR = 173.33 - 2/75q$

New q: $MR = MC \to 173.33 - 2/75q = 33.33 \to q = 5250$

Private $q = 5250 - 500 = 4750$

New P: $5250 = 13000 - 75P \to P = 103.33$

New Surplus:

$\Delta CS = -3.33\cdot 4750 - 3.33\cdot 250/2 = -1633.75$
$\Delta PS = 70\cdot 5250 - 66.67\cdot 5000 = 34150$
$\Delta GS = -103.33\cdot 500 = -51665$
$\Delta SS = -4700 + 4950 - (1.2\cdot 51665) = -61748$

HW 6 P & Q Given

Sunday, September 27, 2020 6:20 PM

Worked w/ Austin

Passed solution review

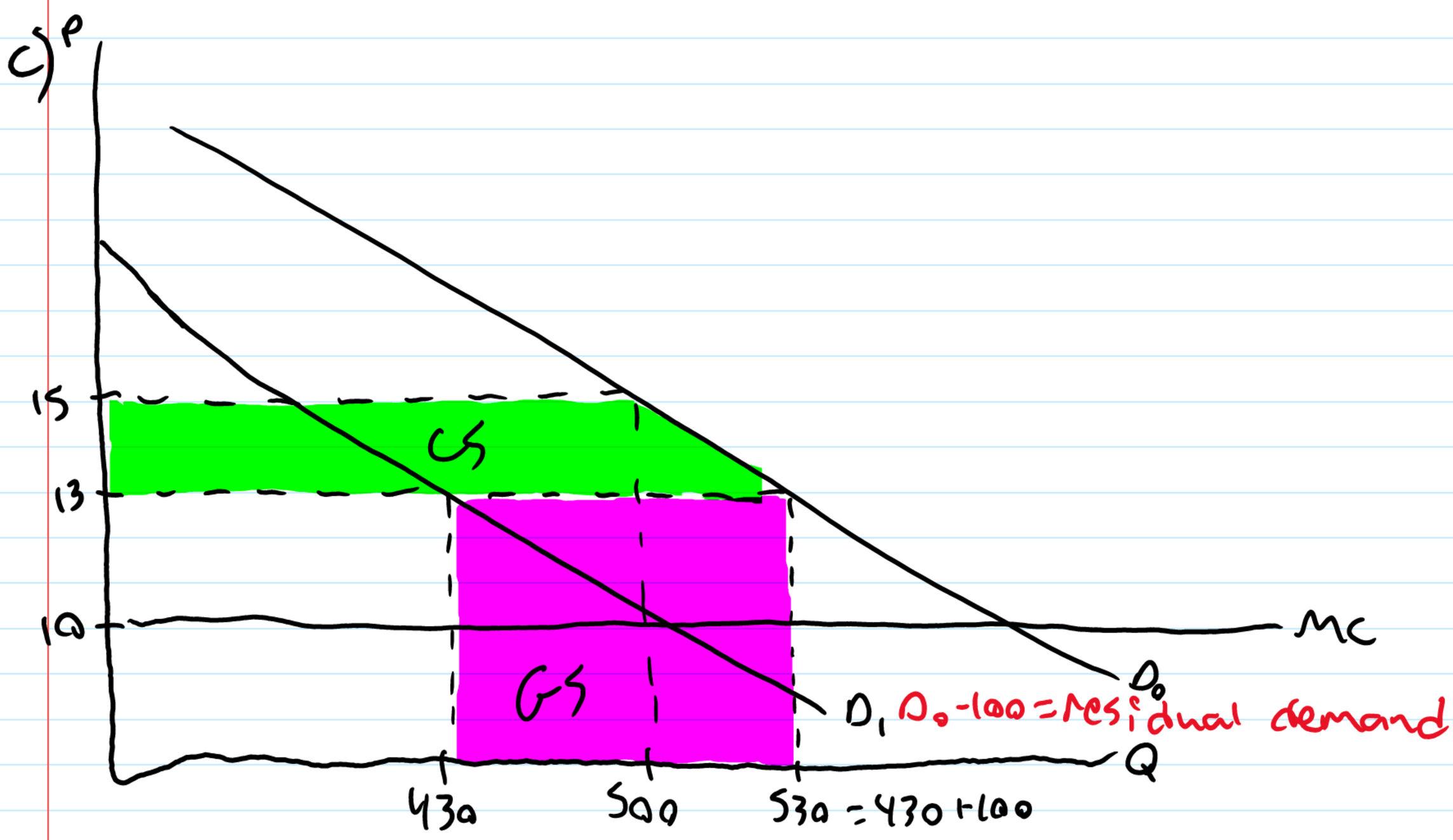
Initially, a profit maximizing local monopolist charges $15 and sells 500 units per week. Per unit variable cost is $10. Now assume the local government begins to provide 100 units per week at the market price. As a result, the market price falls to $13 and the quantity sold by the monopolist falls to 430.

a) Find the changes in CS, PS, and GS created by the monopoly.

b) Assume the METB is 0.25. Find the changes in SS.

c) Depict all of this in a diagram. You probably want to sketch the diagram right at the start of the problem for reference as you work, and then to redraw a neat version to submit.

c)



a) $\Delta CS = (2 \cdot 500) + (\frac{1}{2} \cdot 2 \cdot 30)$
$= 1000 + 30$
$\Delta CS = \$1030$

$\Delta PS = (-1)(15-13)(500) - (500-430)(13-10)$
$= (-1 \cdot 2 \cdot 500) - (70 \cdot 3)$
$= -1000 - 210$
$\Delta PS = -1210$

$\Delta GS = (530 - 430)(13)$
$\Delta GS = 1300$

b) $\Delta SS = \Delta CS + \Delta PS + (1 + METB)(\Delta GS)$
$= 1030 - 1210 + (1.25 \cdot 1300)$
$= -180 + 1625$
$\Delta SS = 1445$

Midterm - Gus Lipkin

Friday, October 9, 2020 1:56 PM

5·6 are switched

Passed solution review

1) What is the difference between Pareto efficiency and Hicks-Kaldor efficiency, and why is it relevant to benefit cost analysis? It helps some + hurts none. Hicks-Kaldor if total benefits exceed total costs. BCAs use Hicks-Kaldor or nothing would ever happen to change the status quo.

In Pareto efficiency, so long as one person is better and no one is worse off, it is Pareto efficient. In Hicks-Kaldor efficiency, it is efficient so long as people benefit more than those who are worse off so long as the people worse off could be compensated by the benefits. It is relevant because when doing a BCA of a project, especially a public project, it is important to consider how the community will be affected and to consider how a project can be made Pareto efficient so that no one is worse off after the project is finished.

2) Why are benefit cost ratios inappropriate for evaluating alternative projects? 1) can be manipulated by counting effects as benefits or costs

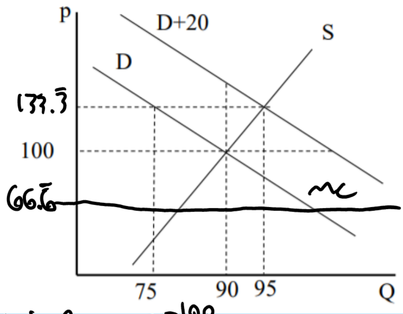
Benefit-cost ratios are inappropriate for evaluating alternative projects because the ratio is not indicative of total value added. It would be better to gauge projects by the net benefits. A project that has a benefit value of 15 and a cost value of 14 will have a much lower ratio than a project with 5 benefits and 1 cost.

2) a project w/ a low ratio may have large net benefits

3) Suppose your company is preparing a benefit-cost analysis to use to lobby the local government for a policy you want passed. Why would you want to know if the relevant decision makers are guardians or spenders? Spenders would focus on benefits while guardians would focus on revenues to the local government

The distinction between guardians and spenders is important because that largely controls their decisions on how to spend money. Guardians will be less likely to pass a new policy if it involves spending money while a Spender will be more likely to pass a policy if the money spent benefits the greater good.

4) A government project directly purchase 20 units in a local market. The METB is 0.2. The elasticity of demand is -2/3. Other pertinent information is summarized in the figure provided. Calculate the changes in PS, CS, GS, and SS associated with the purchase.



$MC = 133.\bar{3}(1 - 1/(-2/3)) = 200/3$

Calculate new price

$\%\Delta Q = -15/90 \cdot 100 = -16.7\%$

$-50/3 = \%\Delta P \cdot (-2/3) \rightarrow \%\Delta P = 25\%$

$\eta = \frac{\Delta Q}{\Delta P} \cdot \frac{P}{Q} \rightarrow -\frac{2}{3} = \frac{95-75}{P-100} \cdot \frac{100}{90} \rightarrow -\frac{3}{5} = \frac{20}{P-100} \rightarrow P - 100 = -\frac{100}{3}$

$P = 200/3$

or $100 - P$

$-\frac{2}{3} = 20/(100-P) \cdot 100/90 \rightarrow 100 - P = -100/3 \rightarrow P = 100 + 100/3 = 400/3$

$\Delta CS = (100/3 \cdot 90) + (100/3 \cdot 5 \cdot \frac{1}{2}) = 3083.\bar{3}$ $(-25 \cdot 75) - (\frac{1}{2} \cdot 25 \cdot 15) = -2062.5$

$\Delta PS = (100/3 \cdot 75) - (200/3 \cdot 90) = -3500$ $(25 \cdot 90) + (\frac{1}{2} \cdot 25 \cdot 5) = 2312.5$

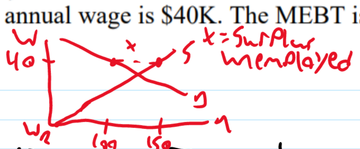
$\Delta GS = (90 \cdot 20 = 2000$ $(-125 \cdot 20) = -2500$

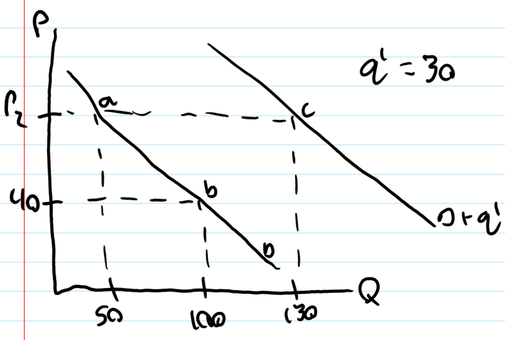
$\Delta SS = 3083.3 - 3500 + (1.2 \cdot 2000) = 1983.\bar{3}$ $(-2062.5 + 2312.5) - (\frac{1}{2} \cdot 2500) = -2250$

6) A local government project requires 30 workers for a year from a market in which currently 100 workers are employed, 50 are unemployed, and the annual wage is $40K. The MEBT is 0.2.

a) Draw a figure illustrating the state of the market.

b) Calculate the opportunity cost of hiring the workers.





$q' = 30$

According to official solution for opportunity cost I, since unemployment is small, wage doesn't change. I don't believe it applies here, but I did it that way so I would have an answer. Unemployment is high so wage overestimates OC of labor

$abc = \frac{1}{2}(P_2 - 40k)(130 - 50) = 40(P_2 - 40k)$ OC of hire is ½ way between W^2 and wage, don't know W^2 so use Q. High SC of unemployment so

$SC = 1.2 \cdot 40{,}000 \cdot 30 = 1{,}440{,}000$ OC is $20

Net $SC = (30 \cdot 20) + (.2 \cdot 30 \cdot 40) = 840{,}000$

5) Suppose:

i) the price of gasoline is $2 per gallon

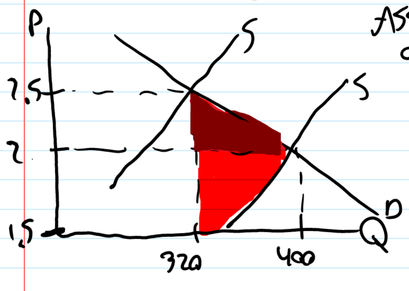
ii) current consumption is 400 (million) gallons per day

iii) the elasticity of demand is -0.8

iv) retail provision of gasoline may be approximated as a constant cost industry

v) there is an external cost of $0.5 per gallon of gas ← tax!

Calculate deadweight loss associated with the externality. Draw a figure to illustrate.



Assuming tax is what changed (is added)

$-.8 = \frac{Q - 400m}{2.5 - 2} \cdot \frac{2}{400m} \rightarrow Q = 320m$

= DWL

$-.8 = \frac{320 - 400}{2 - P} \cdot \frac{2}{400} \rightarrow P = 1.5$

$DWL = (2.5 - 1.5)(\frac{1}{2})(80m) = 40{,}000{,}000$

$DWL = (\frac{1}{2})(2.5 - 2)(80m) = 20{,}000{,}000$

7 Book Notes

Saturday, October 10, 2020 12:49 PM

Valuing impacts in secondary markets

Primary markets: directly affected by policy
Secondary markets: indirectly affected by policy

7.1 Valuing benefits and costs in efficient secondary markets

7.1.1 Complements and substitutes

7.1.2 Efficient secondary market effects without price changes

We should ignore impacts in secondary markets as long as ΔCS in the primary market is measured and prices in the secondary market don't change

7.1.3 Efficient secondary markets w/ price changes

demand schedule = equilibrium/observed demand schedule

7.2 Valuing benefits and costs in distorted secondary markets

all ΔCS is in primary market but increase in tax revenue happens in both

7.3 Indirect effects of infrastructure projects

7.4 Secondary market effects from the perspective of local communities

multiplier effects = money recirculated into the economy

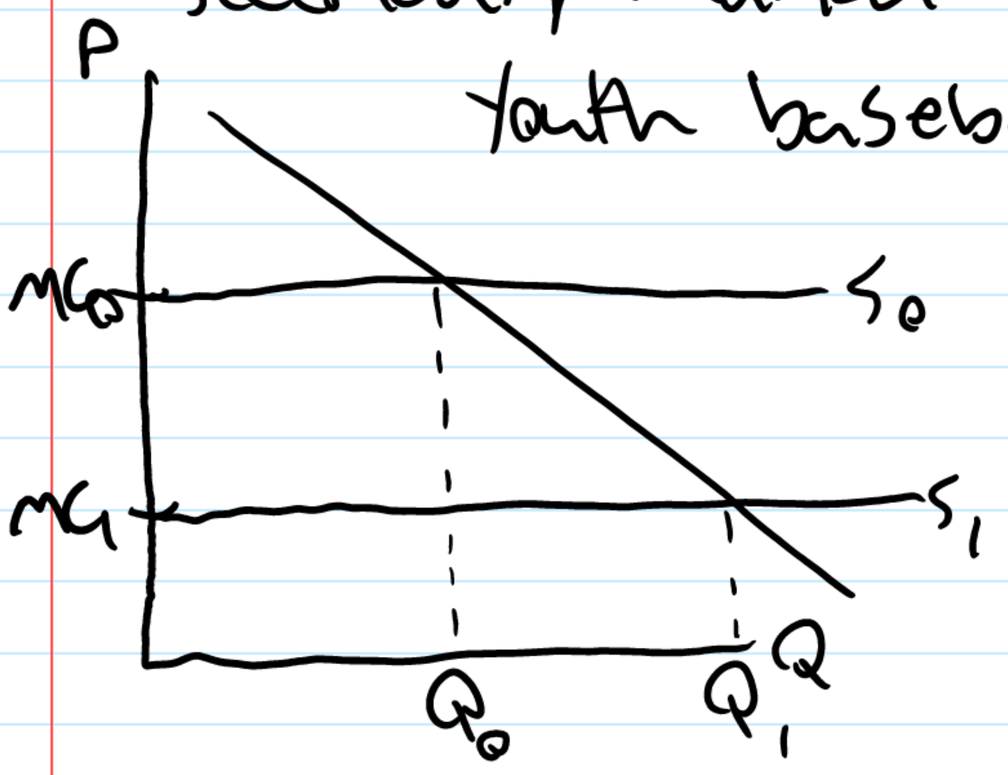
only relevant to specific communities

7.1 Secondary Market Impacts 1

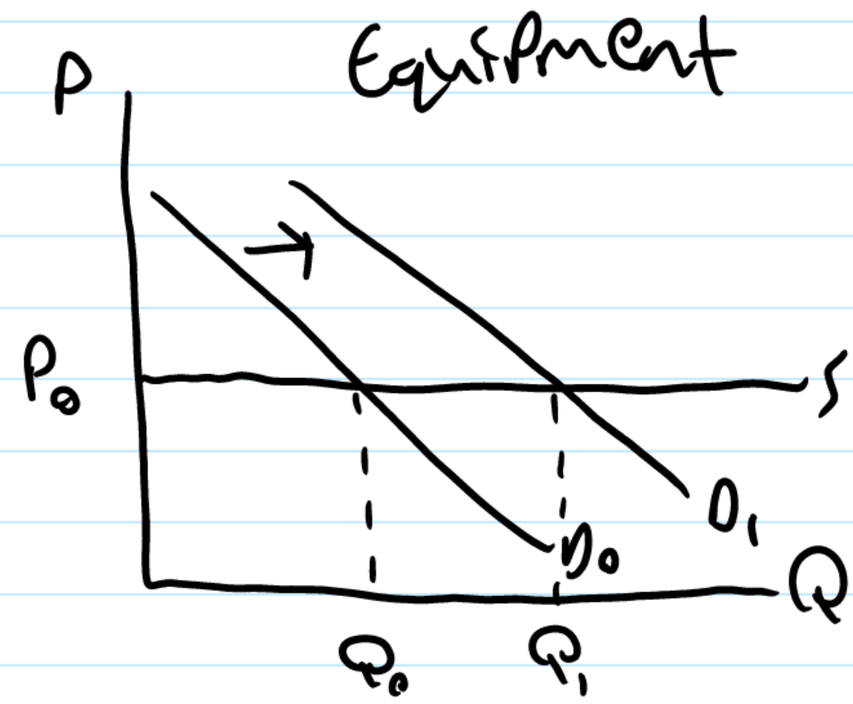
Saturday, October 10, 2020 1:24 PM

Valuing impacts in secondary markets

Efficient (not distorted) negligible price change in secondary market



Players



Gloves

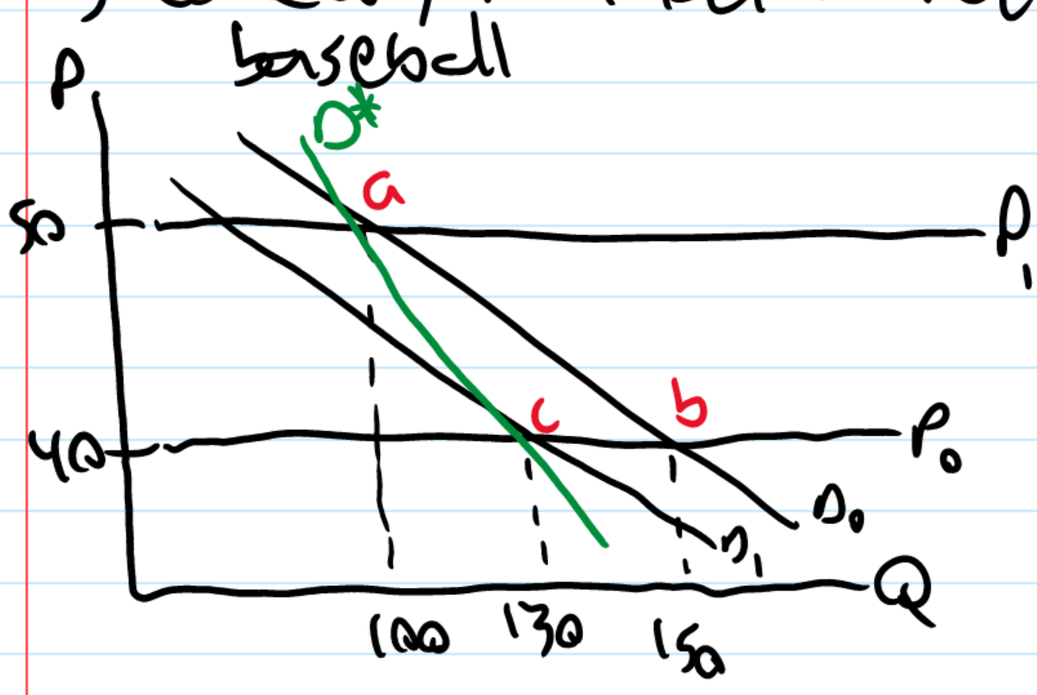
BCA ≠ Economic impact analysis

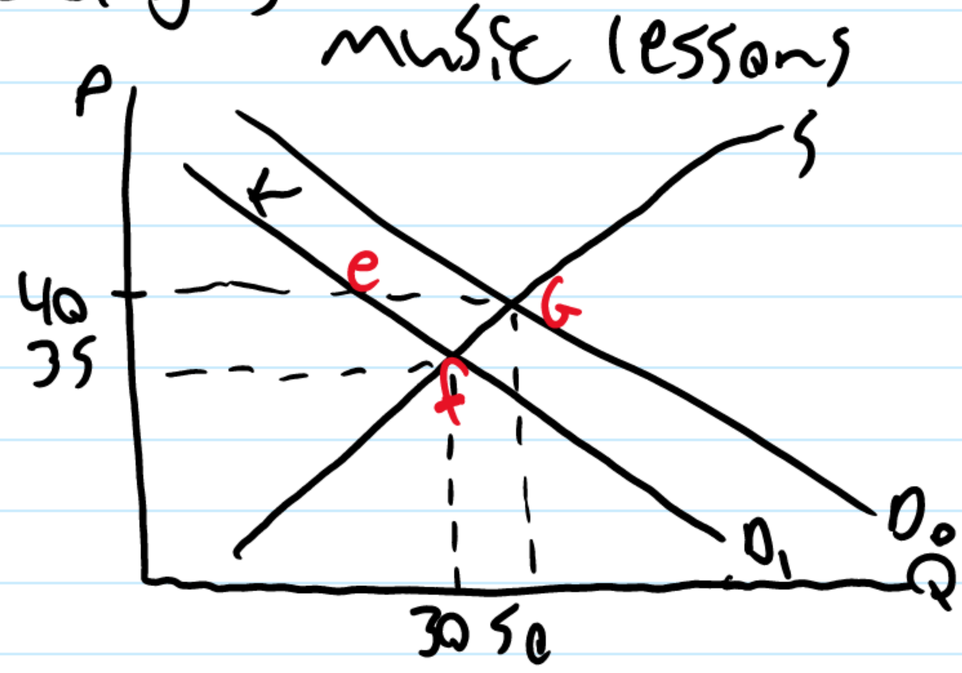
does consider secondary markets

7.2 Secondary Market Impacts 2

Saturday, October 10, 2020 1:36 PM

Secondary market price changes





Players Students

Initially $P = 50$, $Q = 100$ given } new $P = 40$
estimate → estimate new $Q = 150$

$\Delta CS = 10 \cdot 100 + (\frac{1}{2} \cdot 50 \cdot 10) = 1250$

$\Delta CS + \Delta PS = e \cdot f \cdot g = 50$

$\Delta SS = 1250 - 50 = 1250$

Initially $P = 50$, $Q = 100$
est new point $P = 40$, $Q = 130$

"equilibrium demand"

$\Delta CS = 10 \cdot 100 + \frac{1}{2} \cdot 100 \cdot 30 = 1150$

abc ≈ efg

→ ignore the secondary market

7.3 Secondary Market Impacts 3

Saturday, October 10, 2020 3:27 PM

Impacts in distorted secondary markets

<u>Example 1</u>

\$X/gallon

Reg. → q' decrease in gas consumption

To ΔSS add Xq'

<u>Example 2</u>

Good A is taxed, B is not

- Add tax in A
  A + B are complements

Consumption of B ↓ (price unchanged)

add to ΔGS loss of tax rev in B

7.4 Secondary Market Impacts 4

Saturday, October 10, 2020 3:35 PM

Secondary impacts of infrastructure projects

Ex Bridge

ex port improvement

7.5 7.6 Local Perspective on Secondary Markets and Impact Analysis

Saturday, October 17, 2020 8:11 PM

Local perspectives on secondary market impacts

- economic impact studies

s spent up front
δ fraction of that that local residents spend locally
always less than 1

Total after T rounds of spending
total $= x(T) = s + \delta s + \delta^2 s + \delta^3 s + \ldots \delta^T s$

$\delta x(T) = \delta s + \delta^2 s + \ldots \delta^{T+1} s$

$x(T) - \delta x(T) = s - s\delta^{T+1} \rightarrow x(T) = (s \cdot (1 - \delta^{T+1}))/1 - \delta$

Let $T \rightarrow \infty$ $\delta < 1 \rightarrow \delta^{\infty} = 0$

$x(T) \rightarrow s/1-\delta \rightarrow$ multiplier

Supply?

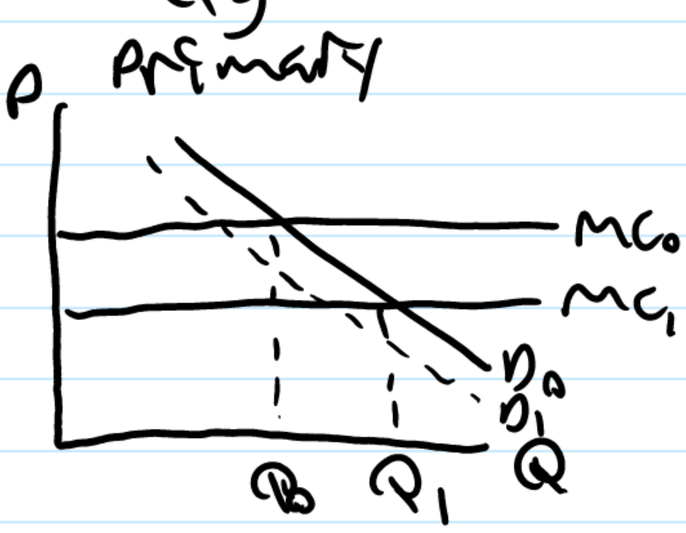
Crowding out
↳ spending displaces other spending

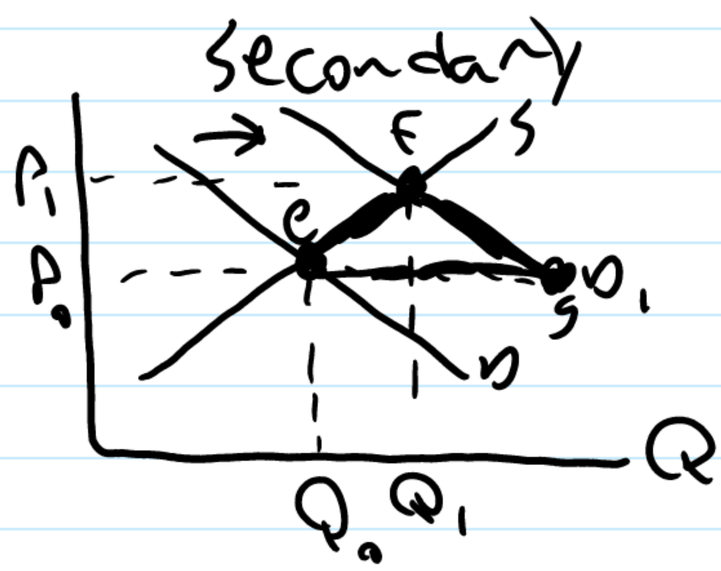
What else could have been done w/ those resources?

Not a BCA

Absent distortions?
Prices change negligibly
only local standing?

If prices in secondary markets ↑?
Always Negative
- efg





loss CS gain PS

Different if there are major local distortions

7 Extra Problems

Monday, October 19, 2020 2:02 PM

Consider an analysis of changes in safety regulations for US automobiles.

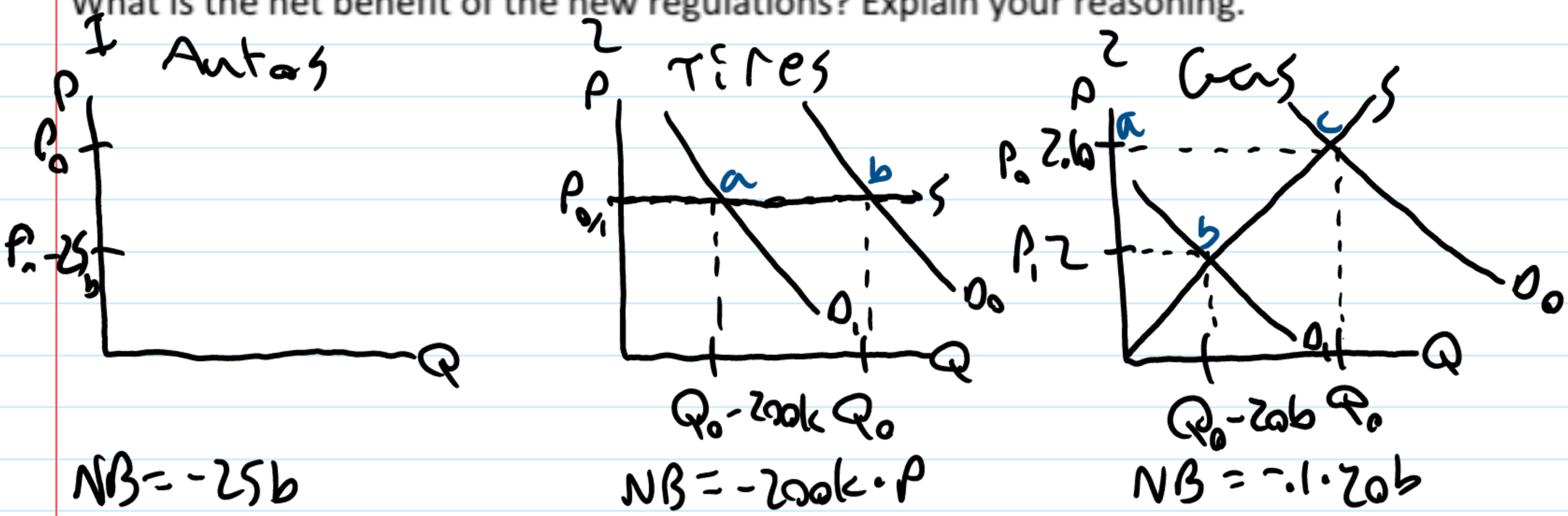
The net impact in the primary market is a loss of $25 billion per year, measured using actual prices and quantities before and after the change (i.e. not holding other prices constant).

The change in regulations effected the US tire market, reducing consumption by 200K, but price did not change appreciably.

The change in regulations effected the US gasoline market. The price of gasoline fell from $2.10 per gallon to $2.00, with both prices including a $0.5 per gallon tax. Annual gasoline consumption fell 20 billion gallons.

There is an external cost of $1 per gallon of gasoline.

What is the net benefit of the new regulations? Explain your reasoning.

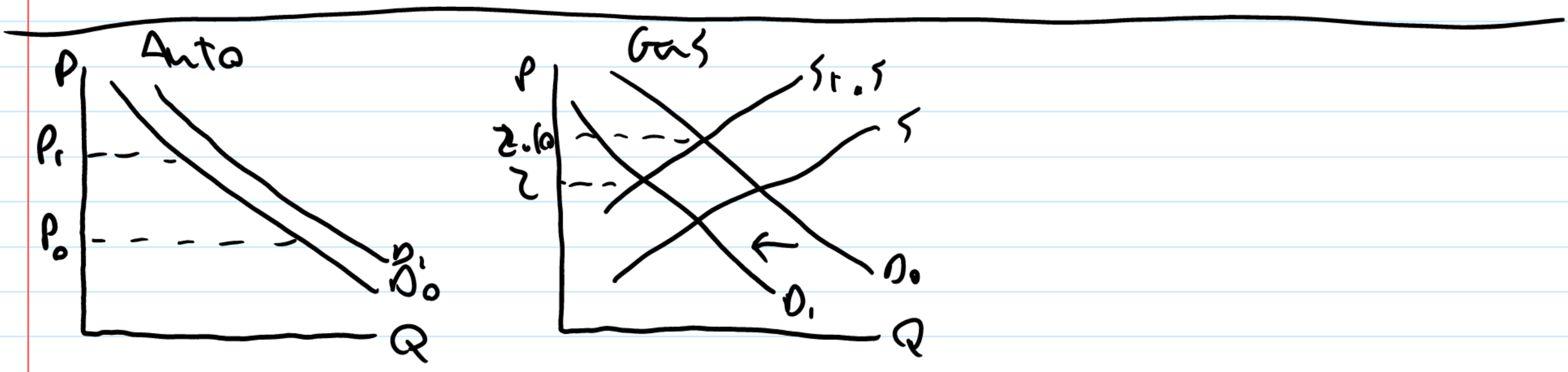


$NB = -25b$

$NB = -200k \cdot P$

$NB = -.1 \cdot 20b$

Total $NB = -25b - (200k \cdot P) - (.1 \cdot 20b) - (.5 \cdot 20b)$



$-25b + (1 \cdot 20b) - (.5 \cdot 20m \cdot (1 + MEFB))$

↳ Loss of tax rev

↳ savings on external costs

Ignore tires because P constant

gas price change

HW 7.1

Friday, October 23, 2020 7:58 PM

Passed Solution review

1. Recall exercise 1 from Chapter 5 in which an increase in the toll on a highway from \$.40 to \$.50 would reduce use of the highway by 5,000 cars per week.

1. Suppose the government is considering an increase in the toll on a certain stretch of highway from \$.40 to \$.50. At present, 50,000 cars per week use that highway stretch; after the toll is imposed, it is projected that only 45,000 cars per week will use the highway stretch.

   Assuming that the marginal cost of highway use is constant (i.e., the supply curve is horizontal) and equal to \$.40 per car, what is the social change in surplus attributable to the increase in the toll? (Hint: the toll increase will cause the supply curve, not the demand curve, to shift.)

a. Because of the reduced use of the highway, demand in the secondary market for subway rides increases. Assuming that the price of subway rides is set equal to the marginal cost of operating the subway and marginal costs are constant (i.e., the supply schedule is horizontal), and no externalities result from the reduced use of the highway and the increased use of the subway, are there additional costs or benefits due to the increased demand for subway rides? Why or why not?

Because the subway costs are constant and do not change with increased ridership, the cannot be counted as a benefit or a cost.

b. Because of the reduced use of the highway, demand in the secondary market for gasoline falls by 20,000 gallons per year. There is a stiff tax on gasoline, one that existed prior to the new toll. Assuming that the marginal cost of producing gasoline is \$1 per gallon, that these marginal costs are constant (i.e., the supply schedule is horizontal), that no externalities result from the consumption of gasoline, and that the gasoline tax adds 30 percent to the supply price, are there any additional costs or benefits due to this shift? If so, how large are they?

There are a lot of words here trying to confuse me but I'm not falling for it (famous last words). There are no changes to CS or PS because it's a constant cost industry. But as demand falls, the government loses tax revenue of $(.3 \cdot 20000) = \$6000$ which would affect the total

HW 7.2

Friday, October 23, 2020 8:23 PM

Passed Solution review

2. Recall exercise 2 from Chapter 5 in which a country imposes an import fee on the crude oil it imports. Assume that prior to the imposition of the import fee, the country annually consumed 900 million short tons of coal, all domestically mined, at a price of $66 per short ton. How would the CBA of the import fee change if, after imposition of the import fee, the following circumstances are assumed to result from energy consumers switching from crude oil to coal?

2. A country imports 3 billion barrels of crude oil per year and domestically produces another 3 billion barrels of crude oil per year. The world price of crude oil is $90 per barrel. Assuming linear curves, economists estimate the price elasticity of domestic supply to be 0.25 and the price elasticity of domestic demand to be 0.1 at the current equilibrium.

a. Annual consumption of coal rises by 40 million short tons, but the price of coal remains unchanged.

So long as price remains the same, this doesn't matter in a BCA for ΔSS in the primary market

b. Annual consumption of coal rises by 40 million short tons and the price of coal rises to $69 per short ton. In answering this question, assume that the prices of other goods, including coal, were not held constant in estimating the demand schedule for crude oil.

Because they're not constant, they find a new equilibrium when coal shifts and therefore don't need to be counted.

c. Annual consumption of coal rises by 40 million short tons and the price of coal rises to $69 per short ton. In answering this question, assume that the prices of other goods, including coal, were held constant in estimating the demand schedule for crude oil. Also assume that the demand schedule for coal is completely inelastic.

If coal rises and others are constant, then not everything is considered in SS and you must subtract coal SS from OIL SS.

$\Delta PS = (.5 \cdot 40m \cdot 3) + (900m \cdot 3) = 2.76b$

$\Delta CS = (940m \cdot 3) = 2.82b$

$Net = 2.82b - 2.76b = 60m$

d. The market price of coal underestimates its marginal social cost by $7 per short ton because the coal mined in the country has a high sulphur content that produces smog when burned. In answering this question, assume that the annual consumption of coal rises by 40 million short tons, but the price of coal remains unchanged.

If there is an externality, SS changes even if price is constant.

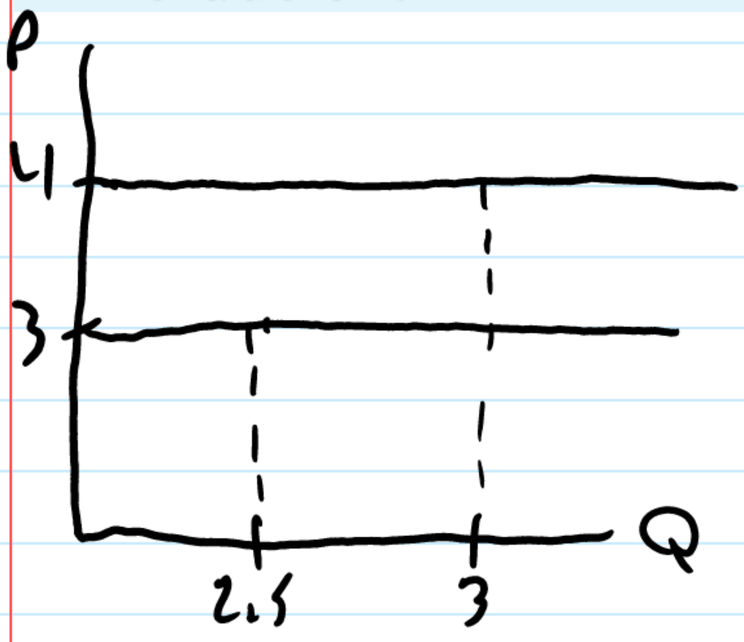
$\Delta SS = 40m \cdot 7 = 280m$

HW 7.3

Friday, October 23, 2020 8:51 PM

Passed solution review

3. Recall exercise 2 from Chapter 5 in which a country imposes an import fee on the crude oil it imports. Imagine that all the crude oil imports to the country are made by ships owned by its nationals. The Association of Petroleum Shippers argues that the reduction in imports resulting from the import fee will drive down the price of shipping services and thereby inflict a loss on them. The Committee for Energy Independence, which favors the import fee, argues that the reduction in shipping prices will benefit consumers of shipping services. Which argument is correct? In preparing an answer, make the following assumptions: the import fee will reduce the quantity of imported crude oil from 3 billion to 2.5 billion barrels per year; the reduction in barrels shipped will drive per-barrel shipping costs down from \$4 per barrel to \$3 per barrel; and the elasticity of demand in the shipping market at the new equilibrium (\$3, 2.5 billion barrels) is −0.3. Also assume that the shipping market is undistorted and that the prices of other goods, including shipping services, were held constant in estimating the demand schedule for crude oil.



The Committee is wrong because net SS will be negative even though ΔCS is positive.

$\Delta PS = (.5 \cdot 1 \cdot .5b) + (1 \cdot 2.5b) = 2.75b$

$-.3 = dq/dp \cdot p/q$

$dq = (-.3)(dp)(q/p)$

$dq = (-.3)(-1)(2.5b)(3) = .25b$

$\Delta CS = (.5 \cdot 1 \cdot .25b) + (1 \cdot 2.25b) = 2.38b$

$\Delta SS = 2.75b - 2.38b = .37b$

8 Book Notes

Friday, October 23, 2020 9:11 PM

Predicting and monetizing impacts

- Assume ex ante analysis
- Pure CBA

8.1 Predicting impacts

Three major errors during application of a CBA:
1) omission errors
2) forecasting errors
3) valuation errors

8.1.1 Simplify by predicting incremental impacts relative to the status quo

↳ only measure changes

8.1.2 Predict using data from an ongoing policy

8.1.3 Predict based on single evaluation of a similar policy

optimism bias

8.1.4 Predictions based on meta-analyses of similar policies

meta-analysis
effect size

8.1.5 Predict using generic elasticities

8.1.6 Guesstimate

8.2 Monetizing impacts

8.2.1 Monetizing when impacts change quantities consumed in markets

shadow prices

8.1 Predicting and Monetizing Impacts 1

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What have we done so far?

1) Alternative decisions, impacts, standing, efficiency
2) Benefits + costs, willingness to pay, ΔCS, ΔPS, opportunity cost
3) Distortions
4) secondary market impacts
5) when market impacts observable, use them
6) If only observe initial P, Q
   - elasticity estimates
7) make reasonable assumptions
   - constant cost
   - pure monopoly, use ζ^D, P_0 → get MC
8) focus on ΔPS, ΔCS, ΔSS, and ΔGS

8.2 Predicting and Monetizing Impacts 2

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Where to get data if market outcomes not observed?

- study a similar program, policy, or change
- meta analysis of similar changes
- guesstimate
  - ↳ closely related elasticity
  - ↳ price elasticity AVE $\xi^p = -1$
  - ↳ lots of sensitivity analysis

"predicting vs monetizing impacts"

No market??

$\boxed{\text{Shadow prices}}$

9 Book Notes

Saturday, October 24, 2020 6:20 PM

Discounting future impacts and handling inflation

9.1 The Basics of Discounting

9.1.1 Projects w/ lives of 1 year

9.1.2 Future Value analysis

Compare project or investment benefits

Future Value (FV) = $X(1+i)$
↳ interest rate
↳ initial investment

9.1.3 Present Value analysis

$PV = Y/(1+i)$
↳ Y = amount received in one year

9.1.4 Net Present Value analysis

$NPV = PV(\text{Benefits}) - PV(\text{costs})$

9.2 Compounding and Discounting over Multiple Years

9.2.1 Future Value over Multiple years

Simple vs Compounded interest

$FV = X(1+i)^n$ → n = years

9.2.2 Present Value over Multiple years

$PV = Y/(1+i)^n$

$1/(1+i)^n$ = present value factor or discount factor

$PV = FV/(1+i)^n$ and $FV = PV(1+i)^n$

if B = benefits received in time t
↳ $PV(B) = \sum_{t=0}^{n} B_t/(1+i)^t$

Can also use C instead for costs

9.2.3 Net Present Value of a Project

$NPV = PV(B) - PV(C)$

$NSB_t = B_t - C_t$

$NPV = \sum_{t=0}^{n} NSB_t/(1+i)^t$

9.2.4 Annuities and Perpetuities

Annuity is an equal, fixed amount received or paid every period

Perpetuity is an indefinite annuity

A = annuity

$PV = \sum_{t=1}^{n} A/(1+i)^t = A\sum_{t=1}^{n} 1/(1+i)^t = A a_{\overline{n}|i}$

$a_{\overline{n}|i}$ = **annuity factor** = PV of A of \$1 for n years at interest rate i

in perpetuity, $PV = A/i$ if $i > 0$

9.2.5 Continuous Compounding

9.3 Timing of Benefits and Costs

ordinary annuity = **regular annuity** → paid at year's end

deferred annuity = **annuity due** → paid at year's start

With continuous annuity, $NPV = -C_0 + \sum_{t=1}^{n} NSB_t/(1+i)^{t-.5}$

Appendix 9A
Formulas for Calculating the Present Value of annuities and perpetuities

Present Value of an annuity

$PV = \sum_{t=1}^{n} A/(1+i)^t$

$PV = A a_{\overline{n}|i}$

$a_{\overline{n}|i} = \frac{1-(1+i)^{-n}}{i}$

PV of A that grows or declines at a constant rate

$B_t = B_1(1+g)^{t-1}$ g = rate at which benefits grow

$PV(B) = \frac{B_1}{(1+g)} \cdot a^{*}_{\overline{n}|i^*}$ → $i^* = \frac{i-g}{1+g}$ for $i > g$

PV of perpetuity that grows or declines at a constant rate

$NPV = NSB_1/(i-g)$ if $i > g$

9.4 Comparing Projects w/ different time frames

rollover method
repeat short project X times so total time matches long project

Equivalent annual net benefit method (EANB)

$EANB = NPV/a_{\overline{n}|i}$

9.5 Inflation and Real vs Nominal Dollars

Nominal dollars = current dollars

Real dollars = Constant dollars

deflator

9.5.1 Problems w/ indices based on consumer prices

9.5.2 Discounting using real or nominal dollars

$r = \frac{i-\pi}{1+\pi}$ ← inflation
real nominal

9.5.6 Estimates of future inflation

9.6 Relative price changes

9.7 Terminal Values and Fixed-Length Projects

$NPV = -C_0 + \sum_{t=1}^{n} NSB_t/(1+i)^{t-.5} + T_n/(1+i)^n$

C_0 = initial cost
NSB_t = regular annual net social benefits
T_n = terminal value at end of year n
i = discount rate

9.8 Terminal (or horizon) Values and Long-Lived Projects

If benefits or costs are indefinite $NPV = \sum_{t=0}^{\infty} NSB_t/(1+i)^t$

discounting horizon **horizon value** = terminal value

at horizon value ... $NPV = \sum_{t=0}^{k} NSB_t/(1+i)^t + H_k/(1+i)^k$

where ... $H_k = \sum_{t=k+1}^{\infty} NSB_t/(1+i)^t$

9.8.1 Horizon value estimated directly

9.8.2 Horizon value based on depreciated value of the asset(s)

Economic value **economic depreciation**

decline at geometric rate

accounting depreciation is not a cost in BCA

9.8.3 Replace of horizon value

Sensitivity analysis w/ different horizon values

9.9 Time-decline Discounting

9.10 Sensitivity analysis in Discounting

Internal Rate of Return (breakeven discount rate)
↳ IRR
↳ yields NPV of 0

9.10.1 The Internal Rate of Return as a decision Rule

9.1 Discounting

Saturday, October 24, 2020 7:29 PM

Discounting and Net Present Value

<u>Time</u>

Present Value

i = interest rate

$FV = (1+i)PV \rightarrow 1(1+.1) = 1.10$

$FV_2 = (1+i)(1+i)PV$

$V_t = (1+i)^t V_0 \qquad V_0 = V_t/(1+i)^t$

9.2 Net Present Value

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i = discount rate Start at time $t=0$

T = end point

Payments are beginning of period

$$\sum_{t=0}^{T} B_t/(1+i)^t - \sum C_t/(1+i)^t = NPV = \sum_{t=0}^{T} B_t - C_t/(1+i)^t = \sum_{t=0}^{T} NB_t/(1+i)^t$$

δ = discount factor = $1/1+i$

$0 < \delta < 1$

T	B	C	NPV
0	0	20	-20
1	0	10	-10
2	10	5	5
3	40	5	35

Timing of Payments

$\delta = 1/(1+i/12)$

9.3 Annuity Formulae 1

Sunday, October 25, 2020 11:33 AM

$\delta = 1/(1+i)$

A, Paid at $t = 1, 2, 3, \ldots, T$

$S(A, T, \delta) = A\delta^1 + A\delta^2 + \ldots + A\delta^T$

$\hookrightarrow \delta S(\,) = A\delta^2 + A\delta^3 + \ldots + A\delta^{T+1}$

$\hookrightarrow S - \delta S = A\delta - A\delta^{T+1}$

$\hookrightarrow (1-\delta)S(\,) = A(\delta - \delta^{T+1}) = A\delta(1-\delta)^T$

$\hookrightarrow S(A, T, \delta) = A\delta(1-\delta)(1-\delta^T)$

$\hookrightarrow S(\,) = Aa(A, T, \delta)$

$\hookrightarrow a(A, T, \delta) = \delta/(1-\delta)(1-\delta^T)$

$i = 4\%$ $A = 8$ $T = 11$

$\delta = 1/1.04$ $a = (1/1.04)/(1 - 1/1.04) \cdot (1 - (1/1.04)^{11}) = 8.76$

$S = 8 \cdot 8.76 = 70.08$

9.4 Annuity Formulae 2

Sunday, October 25, 2020 12:11 PM

Things δ can represent:

1) Interest i $\delta = 1/(1+i)$
2) Time value of money
3) real interest rate r $\delta = 1/(1+r)$
4) inflation m $\delta = 1/(1+m)$
5) depreciation d $\delta = 1-d$
6) obsolescence f $\delta = 1-f$
7) growth g $\delta = 1+g$ $\rightarrow A?$

Combinations:

- obsolescence + discounting $\delta = 1-f/1+r$
- obs, tvm, depr $\delta = [(1-f)(1-d)]/(1+r)$

$S = A\delta + A\delta^2 + \dots A\delta^T$

$\hookrightarrow A_1 + A_1(1+g)^1 + A_1(1+g)^2$

$\hookrightarrow A_0(1+g) = A_1 \rightarrow A_0 = A_1/(1+g)$

$\hookrightarrow S = A_0(1+g) + A_0(1+g)^2 + \dots A_0(1+g)^T$

$\hookrightarrow S = [\delta(1-\delta)(1-\delta^T)] \cdot A_0$

9.5 Annuity Formulae 3

Sunday, October 25, 2020 12:25 PM

Four useful things of Annuity formulae

1) If Payments start at $t=0$?

$S(1, A, T, \delta) = aA$

$S(0, A, T, \delta) = A + aA = (1+a)A$

2) $T \to \infty$

$a = (\delta/(1-\delta))(1-\delta^T)$

if $0 < \delta < 1$ $\delta^T \to 0$ as $T \to \infty$

$a \to \delta/(1-\delta) \to$ Perpetuity

3) $\delta = 1/(1+y)$, $T \to \infty$

$1/y$

$i = 3\%$ 1k $\to a = 1/.03 = 33.33 \to a = 1/.03(1-(1/.03)^{50}) = 25.72$

100 years $= 31.6$

9.6 Differing Project Time Frames

Sunday, November 1, 2020 2:13 PM

Projects

t	X	Y
0	-10	-20
1	5	15
2	5	10
3	5	NA

$i = 5\%$ NPV = 3.62 and 3.36

↑ x ↑ y

Rollover method

Equivalent annual net benefit (EANB)

$NPV = a(i,T) \cdot V$

$= a(i,T) \cdot EANB$

$EANB = NPV / a(i,T)$ $a(i,T) = (1-\delta^T)\delta/(1-\delta)$

$EANB_x = 3.62/3.56 = 1.02$

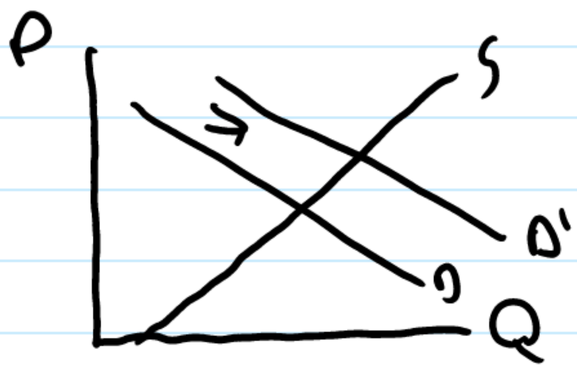
$EANB_Y = 3.36/2.72 = 1.23$

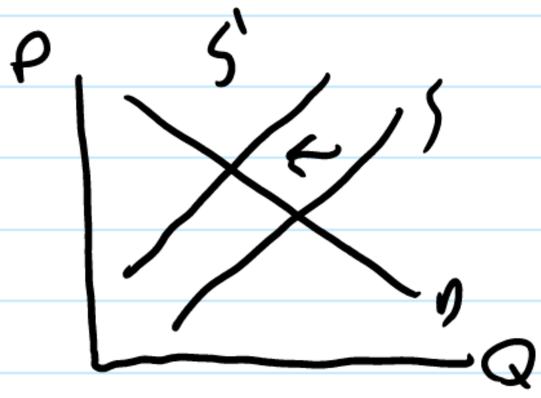
9.7 Inflation 1

Sunday, November 1, 2020 2:27 PM

m = annual rate of inflation

Not about relative prices! Is about price level increases over time





$1·(1+m)

Nominal value$_t$ = real $(1+m)^t$

12 m = 2% → $12(1.02)^5$

Inflation changes from year to year

Real = nom$_t$ / ($\prod_{i=1}^{t}(1+m_i)$)

9.8 Inflation 2

Sunday, November 1, 2020 2:38 PM

See excel stuff

Just applications of Inflation 1 in excel

9.9 The Real Interest Rate

Monday, November 2, 2020 3:28 PM

Inflation and the time value of money

Invest \$1 at $i\%$, inflation is $m\%$

$1+i$ at year 1 $\rightarrow$ $1+i/1+m$ = Purchasing Power

$1+r = 1+i/1+m \rightarrow r$ = real interest rate

$r = 1+i/1+m - 1 = i-m/1+m$ if m is small, $r \approx i-m$

$m = 1.8$ $i = 3.4 \rightarrow r \approx .6$ or $r = 1.034/1.018 - 1 = 1.57$

9.10 Long Lived Projects

Sunday, November 8, 2020 12:45 PM

1) Infinite horizon → if believe indefinite benefit flow

2) Horizon values → T relatively confident in B+C estimates
↳ T = discounting period
→ NPV through T
→ estimate NPV of H_T
→ do sensitivity analysis with respect to H_T

choose T before expect major unpredictable events/repairs

9.10 Real or Nominal Discounting

Monday, November 2, 2020 3:40 PM

real or nominal interest rate for discounting

recall: $1+r = \frac{1+i}{1+m} \rightarrow r = \frac{i-m}{1+m}$

If BCA in nominal dollars, use the nominal rate
If in real dollars, use the real rate (r)

Use real values
- easier to interpret
- you do not know future prices

Inflation and Price indices?

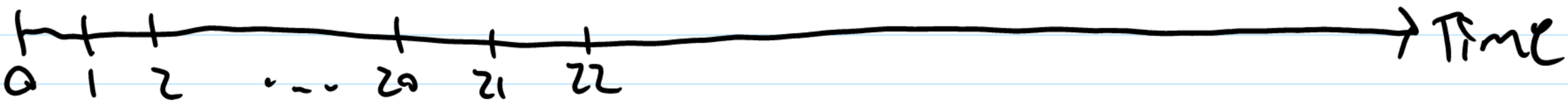
T	B	C
2000	200	400
2001	300	600
2002	400	100
2003	50	200

1) adjust past prices to today
2) forecast future budget exp
3) $r = i - m$

9.11 9.12 Estimating Horizon Values

Sunday, November 8, 2020 12:56 PM

1) Infinite horizon with probability of obsolescence



NPV

f = prob end after each year from 20 onwards

↳ $1-f$ reach $T+1$
$(1-f)^2$ reach $T+2$
$(1-f)^3$ reach $T+3$
$(1-f)^n$ reach $T+n$

$$\frac{(1-f)}{(1+r)} NB_{21} + \frac{(1-f)^2}{(1-r)^2} NB_{22} + \dots \text{ OR } \left[NB \sum_{t=1}^{\infty} \left(\frac{1-f}{1+r}\right)^t \right] \Big/ (1+r)^T$$

2) Scrap or Liquidation Value
- can be negative
- how to estimate

3) Depreciated Value
- accounting rules ≠ market value
- market depreciation value
- Liquidation Value = $V_0(1-d)^T$

4) Fraction of initial cost
- if $(1-d)^T$ is the fraction, same as 3. If not, what?

NPV throug $T + H_T/(1+r)^T$

Sensitivity analysis on T, H_T, breakeven values

9.11 Interest Rates and Expected Inflation Data

Monday, November 2, 2020 3:55 PM

Video walkthrough of researching rates and data

9 Extra Problems

Wednesday, October 28, 2020 2:09 PM

$V_0 = V(1-\delta^T)(\delta/(1-\delta)) = V_1\delta + V_2\delta^2 + \dots V_T\delta^T$

$b_1 = V_1 + V_1(1+g) + V_1(1+g)^2 + \dots V_1(1+g)^{T-1}$

$V_0 = PV$

$a = (1-\delta^T)(\delta/(1-\delta))$

$T = 1, \dots, 20 \quad V = 100 \quad i = .04 \rightarrow \delta = 1/1.04$

$Va = (1-(1/1.04)^{20})(1/1.04)\cdot 100 = 1339$

$V = 1000 \quad r = 5\% \quad T = \text{very big}$

$P_0 = 200 \quad m = 1.5\% \quad P_{10} = 200\cdot 1.015^{10} = 232.10$

depr rate $= 2\%$

$t = 1 \dots 10 \quad i = 3\% \quad V_0 = 1000 \quad \delta = (1-.02)/(1+.03)$

$PV =$

PROBLEM

Megan has two investment options.

Option one involves an upfront cost of 100. At the end of one year it returns $12. Thereafter the annual payment increases by 10% per year, with the last payment in 10 years.

Option two involves an upfront cost of $200 to purchase an asset. At the end of each of the next four years, the asset returns $40. After year 4, she will have no further use for the asset and will sell it, taking payment for the asset at the end of year 5 at its market value of that time. The market value depreciates at 10% per year. Assume Megan's discount rate (safe interest rate) is 5%. Which, if either, should she choose?

$1 = (12/1.05) + 12(1.1)/1.05^2 + \dots$

I thought I had it before but now I'm super lost

$1 \rightarrow \delta = 1.1/1.05 \quad V = (12/1.1)(1-(1.1/1.05)^{10})(\delta/(1-\delta)) - 100$

$2 \rightarrow 40(1-(1/1.05)^4)(1/1.05/(1-1/1.05)) - 200 + \frac{200(.9)^5}{1.05^5}$

---

m = inflation rate

$P_{today}\cdot(1+m_1)\cdot(1+m_2)\cdot(1+m_3) = P_{3\text{ years}}$

t	A	B
0	-10	-10
1	15	-5
2	NA	10
3	NA	15
NPV	4.56	8.30
EANB	2.38	2.23

$r = 3\% \qquad \delta = 1/1.03$

$NPV_A = -10/1.03^0 + 15/1.03^1$

$NPV_B = -10/1.03^0 + -5/1.03^1 + 10/1.03^2 + 15/1.03^3$

$a_A = 1-(1/1.03)^2\cdot(1/1.03)/(1-1/1.03) \rightarrow EANB = 4.56/1.91 = 2.38$

$a_B = 3.717$

Cost in 2011 was $246,000

Cost in Jan 2020?

Problem for 11-16-2020

Suppose that the forecast period for a project is from year 0 thru year 15. You think there is a 10% chance each year from 15 on will be the last. The real net benefit in year 15 was 225 and grows at 2% per year. The discount rate is 3%.

a) What is the horizon value?

$NB_{15} = 225 \quad g = 2\% \quad r = 3\% \quad$ 10% chance of ending each year

$\underset{15}{225} + \underset{16}{([1.02\cdot.9]/1.03)(225)} + \underset{17}{\left(\frac{1.02\cdot.9}{1.03}\right)^2(225)}$

$\delta = 1.02\cdot.9/1.03 \rightarrow 225\cdot\sum_0^{\infty}\delta^T\left(\frac{1}{1.03}\right)^{15} = \left(\frac{1}{1.03}\right)^{15}(225)(\delta/1-\delta)$

$a(\delta, T) = [1-\delta^T](\delta/1-\delta)$

b) Suppose that when the program ends, there will be a clean-up cost of $1000 that must be subtracted to calculate the horizon value. What is the horizon value now?

At end, $C = 1000$

$t \quad 15 \quad 16 \quad 17 \quad 18 \dots$

P_t

$\sum_{t=0}^{\infty} P_t \frac{1000}{1.03^t} \qquad \sum P_t = 1$

$.1 + .1\sum_1^{\infty}(.9/1.03)^t \qquad \delta = .9/1.03$

$\frac{1000}{1.03^{15}}\left[.1 + .1\left(\frac{\delta}{1-\delta}\right)\right] = \frac{100}{1.03^{15}}\left[1 + \frac{\delta}{1-\delta}\right] = \frac{100}{1.03^{15}}\left[\frac{1}{1-\delta}\right] = 508.55$

T	V	i = .1				
0	-10	PV = ??				
1	2					
2	26	PV = 13.31 = (-10/1.1^0) + (2/1.1^1) + (26/1.1^2)				
	PV =	13.30578512	(B2/(1.1^A2) + (B3/1.1^A3) + (B4/1.1^A4))			
T	V					
0.5	-10					
1.5	2					
2.5	26					
	PV =	12.68656834	(B9/1.1^A9) + (B10/1.1^A10) + (B11/1.1^A11)			
T	V					
0.5	12.69					
	PV =	12.09944026	((B16)/1.1^A16)			
All the same project but starting at different time periods						
T	V					
0	-100					
5	-50					
10	100					
15	50					
20	30					
	PV =	-20.02				
If i = .01	PV =	10.61				

T	Year	SUM((A2*(1.1^(B2 - 1))/(1.05^B2)))
12	1	11.42857143
12	2	11.97278912
12	3	12.54292193
12	4	13.14020393
12	5	13.76592792
12	6	14.4214483
12	7	15.10818393
12	8	15.82762126
12	9	16.58131752
12	10	17.37090406
		-100

HW 9 Annuity Formulae

Wednesday, November 4, 2020 3:45 PM

Passed Solution review

You may want to use a spreadsheet to actually find the solutions to some of these problems. But make sure to write out the equations you need to solve in your answers.

a. What is the present value of 15 annual payments of $100, with the first payment one year from now, if the discount rate is 0.05?

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	t	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
2		95.24	90.70	86.38	82.27	78.35	74.62	71.07	67.68	64.46	61.39	58.47	55.68	53.03	50.51	48.10	1,037.97

b. What is the present value of 15 annual payments of $100, with the first payment right now, if the discount rate is 0.05?

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	t	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
2		95.24	90.70	86.38	82.27	78.35	74.62	71.07	67.68	64.46	61.39	58.47	55.68	53.03	50.51	48.10	1,037.97
3																	
4												Add 100 for first payment					1,137.97

$NPV = 100\sum_{0}^{14} 1.05^{-t} = 100 + 100(1-1.05^{-14})/[(1/1.05)/(1-1/1.05)] = 1090$

c. What is the present value of 15 annual payments of $100, with the first payment five years from now, if the discount rate is 0.05?

A	B	C	D	E	F	G	H	I	J	K	L
t	0	1	2	3	4	5	6	7	8	9	
	0.00	0.00	0.00	0.00	0.00	78.35	74.62	71.07	67.68	64.46	
	10	11	12	13	14	15	16	17	18	19	Total
	61.39	58.47	55.68	53.03	50.51	48.10	45.81	43.63	41.55	39.57	853.94

d. At what discount rate would the present value of 15 annual payments of $100, with the first payment right now, be 0?

There's no way that the NPV can be 0 if it's paying out 100 and never charging anything. This will always be positive.

e. How many annual payments of $100, with the first payment right now, would it take to be worth more than $1,000, if the discount rate is 0.05?

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	t	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
2		100.00	95.24	90.70	86.38	82.27	78.35	74.62	71.07	67.68	64.46	61.39	58.47	55.68	53.03	50.51	48.10	1,137.97
3		100.00	195.24	285.94	372.32	454.60	532.95	607.57	678.64	746.32	810.78	872.17	930.64	986.33	1,039.36	1,089.86	1,137.97	
4		i	0.05															1,237.97

It would take 14 annual payments.

f. What is the value of 15 annual payments which begin at $100 one year from now and increase at 2% per year thereafter, if the discount rate is 0.05?

	A	B
1	d	0.97
2	a	11.99
3	PV	1,198.89

t	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
	95.24	90.70	86.38	82.27	78.35	74.62	71.07	67.68	64.46	61.39	58.47	55.68	53.03	50.51	48.10	1,037.97
	100 / (1.05 ^B2)	100 / (1.05 ^C2)	100 / (1.05 ^D2)	100 / (1.05 ^E2)	100 / (1.05 ^F2)	100 / (1.05 ^G2)	100 / (1.05 ^H2)	100 / (1.05 ^I2)	100 / (1.05 ^J2)	100 / (1.05 ^K2)	100 / (1.05 ^L2)	100 / (1.05 ^M2)	100 / (1.05 ^N2)	100 / (1.05 ^O2)	100 / (1.05 ^P2)	SUM(B3:P3)
											Add 100 for first payment					1,137.97
																Q2 + 100

t	0	1	2	3	4	5	6	7	8	9			
	0.00	0.00	0.00	0.00	0.00	78.35	74.62	71.07	67.68	64.46			
	0 / (1.05^B2)	0.00	0.00	0.00	0.00	100 / (1.05^G2)	100 / (1.05^H2)	100 / (1.05^I2)	100 / (1.05^J2)	100 / (1.05^K2)			
	10	11	12	13	14	15	16	17	18	19	Total		
	61.39	58.47	55.68	53.03	50.51	48.10	45.81	43.63	41.55	39.57	853.94		
	100 / (1.05^B5)	100 / (1.05^C5)	100 / (1.05^D5)	100 / (1.05^E5)	100 / (1.05^F5)	100 / (1.05^G5)	100 / (1.05^H5)	100 / (1.05^I5)	100 / (1.05^J5)	100 / (1.05^K5)	SUM(B2:K2) + SUM(B6:K6)		

t	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
	100 / ((1 + $C$4)^B1)				And so on												
	i	536870															

t	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total	
	100.00	95.24	90.70	86.38	82.27	78.35	74.62	71.07	67.68	64.46	61.39	58.47	55.68	53.03	50.51	48.10	1,137.97	SUM(B2:Q2)
	100 / ((1 + $C$5)^B1)			And so on														
	100.00	195.24	285.94	372.32	454.60	532.95	607.57	678.64	746.32	810.78	872.17	930.64	986.33	1,039.36	1,089.86	1,137.97		
	SUM ($B$2:B2)	SUM ($B$2:C2)	And so on															
	i	0.05															1,237.97	R2 + 100

d	0.97	1.02/1.05			
a	11.99	B1 / (1-B1) * (1-B1 ^ 15)			
PV	1,198.89	100 * B2			

	Time	1	2	3	4	5	6	7	8
Project A	NB	-20	-10	5	10	10	10	10	5
Project B	NB	-30	10	15	15	5			
	Total								
Value A	11.89	-19.23	-9.25	4.44	8.55	8.22	7.90	7.60	3.65
Value B	10.67	-28.85	9.25	13.33	12.82	4.11	0	0	0
delta	96.15%								
aa	7.00205467								
ab	4.629895224								
EANB A	1.70								
EANB B	2.30								
Project B has the higher EANB at an interest rate of 4%									

Passed Solution review

	Time	1	2	3	4	5	6	7	8
Project A	NB	-20	-10	5	10	10	10	10	5
Project B	NB	-30	10	15	15	5			
	Total								
Value A	11.89	-19.23	-9.25	4.44	8.55	8.22	7.90	7.60	3.65
Value B	10.67	-28.85	9.25	13.33	12.82	4.11	0	0	0
delta	96.15%								
aa	7.00205467								
ab	4.629895224								
EANB A	1.70								
EANB B	2.30								
Project B has the higher EANB at an interest rate of 4%									

HW 9 Horizon Value 1

Monday, November 9, 2020 2:07 PM

Passed Solution review

A project involved initial construction costs of $2.5 million. The annual rate of economic depreciation for that construction class is 0.008. The project is expected to terminate in 25 years. The expected annual rate of inflation is 0.025.

a. Estimate the horizon value at time t=25 owing to the remaining value of this asset.

$V_0 = 2.5$ million $d = .8\%$ $T = 25$ $m = 2.5$

$2.5(1-(.008))^{25} = 2.05$ million

b. If the real discount rate is 0.035, what is the present value of the horizon value from (a)?

$(2.05/(1.035)^{25}) = .8675$ million

HW 9 Horizon Value 2

Monday, November 9, 2020 2:18 PM

Passed Solution review

A project involved initial construction costs of $1.75 million. After 15 years, the useful life of that construction will be over and the facility will be demolished, involving sensitive environmental protections and cleanup. You estimate that 25% of the cost of the facility represents items that could be sold for scrap at 30% of their initial construction cost. You estimate the proper demolition cost of such a facility to be $0.9M.

assuming initial costs are not recouped

a. What is the NPV of the horizon value if the real discount rate is 0.035?

$V_0 = 1.75$ million $T = 15$ $SV = .25 \cdot .3 \cdot 1.75m = .13125$ million $C = .9$

$-1.75 + .13125/1.035^{15} - .9/1.035^{15} = -2.2$ million

$H_{15} = -(.9 - .3 \cdot 1.75/4) \cdot 1m = -768.8k$ discount $= .035$

$NPV = -768.8k/1.035^{15} = -458.9k$

b. If the expected annual rate of inflation is 0.02, what is the nominal horizon value in 15 years?

$-2.2(1.02)^{15} = -2.96$ million

$-768.8k \cdot 1.02^{15} = -1.034m$

HW 9 Horizon Value 3

Monday, November 9, 2020 2:35 PM

Passed solution review

A program, if implemented, will operate for 10 years for certain. Your best guess is that after year 10 and following each year thereafter there will be a 0.02 probability the program will end. Real net benefits are $25/year currently, and are expected to grow 1% per year as long as the program is in operation. The real discount rate is 3.5%. What is the NPV of the horizon value of net benefits following year 10?

$T=10 \quad f=.02 \quad NB=25 \quad g=.01 \quad r=.035$

$$NB \sum_{t=1}^{\infty} \left(\frac{1-f}{1+r}\right)^t$$

$\delta = (1.01 \cdot .98)/1.035 = .956 \rightarrow \delta/1-\delta = 21.898 = a$

$25(1.01)^{10}(1) = 27.615$

$(25 \cdot 1.01^{10} \cdot \underset{\substack{\uparrow \\ 21.898}}{a})/1.035^{10} = 428.7957$

HW 9 Inflation 1

Friday, November 6, 2020 2:02 PM

Passed solution review

a. What is the value in today's dollars of $300 in 2024 if average annual compound rate of inflation is 0.015 between now and then?

$300(1.015)^4 = 318.409$ $300/1.025^4 = 271.79$

b. What is the value of $200 today expressed in 2030 dollars if the average annual compound rate of inflation is 0.025 between now and then?

$200(1.025)^{10} = 256.0169$ $200 \cdot 1.05^{10} = 325.78$

HW 9 Inflation 2

Friday, November 6, 2020 2:11 PM

Passed Solution review

a. Go to the Federal Reserve Economic Database (FRED) maintained by the St. Louis Fed at https://fred.stlouisfed.org/ and calculate/estimate/retrieve the 2006 average of the *10-Year Treasury Constant Maturity Rate* and the *10-Year Treasury Inflation-Indexed Security, Constant Maturity*, both series maintained in FRED. Based on these, what was the expected annual rate of inflation from 2006 to 2016?

4.8 2.31 ← Filter data to 2006 and take the average

$r = i - m / 1+m \rightarrow 1.0231 = 1.048 / 1+m \rightarrow 1+m = 1.024 \rightarrow m = 2.4\%$

b. Obtain the Consumer Price Index for 2006 and 2016 (FRED has it, or you can get it from the Bureau of Labor Statistics) and calculate the average annual rate of inflation for those 10 years. (Remember, it gets compounded each year to produce the full difference between the 2016 and 2006 price levels.) What do your calculations suggest about the ability to forecast inflation?

2006 = 201.558 = 199.3
2016 = 239.989 = 242.8

$\rightarrow 242.8 = 199.3(1+\pi)^{16} \rightarrow \pi = .012 = 1.2\%$

$239.989 / 201.558 = 1.1906^{1/10} = 1.0176 \rightarrow 1.76\%$

forecasting inflation is less than an exact science. The rate found in Part A is less than Part B.

In the last decade, inflation was half the expected value

$1+i = 1.048$
$1+r = 1.0231 \rightarrow = (1+m)(1+$

HW 9 More Discounting

Wednesday, November 4, 2020 3:30 PM

Passed Solution review

A project has benefits and costs as shown in the table below. You will probably want to do these calculations in a spreadsheet. Assuming you do, include a copy of the relevant portion of the spreadsheet, neatly formatted, labeled, and explained, with your answers.

Time	0	1	2	3	4	5	6	7
Cost	25	40	10	5	5	5	5	20
Benefit	0	0	10	25	45	35	25	5

a. Assuming time 0 is right now and every benefit and cost is received at exactly the time indicated, calculate the NPV if i=0.06.

Time	0	1	2	3	4	5	6	7	Total
Cost	25	40	10	5	5	5	5	20	
Benefit	0	0	10	25	45	35	25	5	
	-25.00	-37.74	0.00	16.79	31.68	22.42	14.10	-9.98	12.28

b. Continuing from (a), what discount rate makes the NPV 0?

Time	0	1	2	3	4	5	6	7	Total
Cost	25	40	10	5	5	5	5	20	
Benefit	0	0	10	25	45	35	25	5	
Test Value									
0.1163	-25.00	-35.83	0.00	14.38	25.76	17.31	10.34	-6.94	0.00

c. Assume time 0 is right now and that benefits and costs benefits and costs are spread more or less evenly over the period following where they are listed. For example the cost of 25 at time 0 represents expenditures spread out evenly between t=0 and t=1. Estimate the NPV if i=0.06.

	A	B	C	D	E	F	G	H	I	J
1	Time	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	Total
2	Cost	25	40	10	5	5	5	5	20	
3	Benefit	0	0	10	25	45	35	25	5	
4										
5	Test Value									
6	0.06	-24.28	-36.65	0.00	16.31	30.77	21.77	13.69	-9.69	11.93

d. Continuing from (c), at what discount rate would the NPV be 0?

	A	B	C	D	E	F	G	H	I	J
1	Time	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	Total
2	Cost	25	40	10	5	5	5	5	20	
3	Benefit	0	0	10	25	45	35	25	5	
4										
5	Test Value									
6	0.1163118023	-23.66	-33.91	0.00	13.61	24.38	16.38	9.78	-6.57	0.00

Time	0	1	2	3	4	5	6
Cost	25	40	10	5	5	5	5
Benefit	0	0	10	25	45	35	25
Test Value							
0.1163	-25.00	-35.83	0.00	14.38	25.76	17.31	10.34
	(B3 - B2)/((1 + $A$6)^B1)		And so on				
	-25.00	-37.74	0.00	16.79	31.68	22.42	14.10
	(B3 - B2)/(1.06^B1)		And so on				

Time	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	Total
Cost	25	40	10	5	5	5	5	20	
Benefit	0	0	10	25	45	35	25	5	
Test Value									
0.06	-24.28	-36.65	0.00	16.31	30.77	21.77	13.69	-9.69	11.93
	(B3 - B2)/((1 + $A$6)^B1)			And so on					SUM(B6:I6)

Time	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	Total
Cost	25	40	10	5	5	5	5	20	
Benefit	0	0	10	25	45	35	25	5	
Test Value									
0.1163118023	-23.66	-33.91	0.00	13.61	24.38	16.38	9.78	-6.57	0.00
	(B3 - B2)/((1 + $A$6)^B1)			And so on					SUM(B6:I6)

HW 9 Simple Discounting

Wednesday, November 4, 2020 12:50 PM

Passed solution review

a. A project costs $10 up front and has net benefits of -$1 at the end of the first year and $15 at the end of the second year. The discount rate is 0.05. What is the NPV?

$NPV = B - C$ $PV = Y/1+i$

$PV = 9/(1.05) + 16/1.05^2 + -10/1.05^0 = -.95 + 13.6 - 10 = 2.65$

$NPV = 2.65$

b. At what discount rate would the NPV be 0? (You may just want to use a spreadsheet, trying different rates until you find the right one, to solve this. But, write out the equation that defines what you are solving for in your answer.)

$0 = -1/(1+i) + 15/(1+i)^2 - 10$

$i = 17.577\%$

10 Book Notes

Sunday, November 8, 2020 1:34 PM

The Social Discount Rate

W_t = weights → $NPV = \sum_{t=0}^{\infty} W_t NSB_t$

↳ social discount factors

$W_t = 1/(1+SDR)^t$

↳ SDR = real social discount rate

Weights generally decline over time

$W_t = W_{t-1}/(1+SDR)$ where $t > 0$ and $W_t = 1$

To determine SDR:
1) social opportunity cost of capital (SOC) → descriptive
2) social time preference (STP) → prescriptive

10.1 Does the choice of Discount Rate Matter?

yes!

10.2 When there's no doubt about the value of the social discount rate

time preference

Marginal rate of time preference (MRTP)

10.2.1 Individual marginal rate of time preference

money now or later?

10.2.2 Equality of MRTPs and market rates in perfect markets

C = consumption i = interest rate T = PV of $

$\max U(C_1, C_2) = s.t. C_1 + C_2/(1+i) = T$

Marginal rate of substitution (MRS)

10.2.3 Equality of social rate of time preference and the return on investment in imperfect markets

Social indifference curves

10.2.4 Complications in real economics

Consumption rate of interest (CRI)

10.3 The social opportunity of cost of capital (SOC) method

$SOC = (a \cdot CRI) + (b \cdot ROI)$

10.3.1 Special cases of the SOC

10.3.2 Estimation of, and numerical values for, the SOC

10.4 The social time preference (STP) method

10.4.1 The Ramsey formula

W = social welfare

$W = \int_0^{\infty} e^{-\rho t} U(C_t) dt$

$U(C_t)$ = utility from per capita consumption during period t

$e^{-\rho t}$ = discount factor

ρ = future utility discount rate

$STP = \rho + g\epsilon$

g = % Δ in per-capita consumption
ε = elasticity of marginal utility

10.4.2 Estimation of, and numerical values for, the STP

10.4.3 Special case for STP: Shadow Price of Capital (SPC)

Consumption equivalents

$SPC = ROI/STP$

10.4.4 Numerical values of the SPC

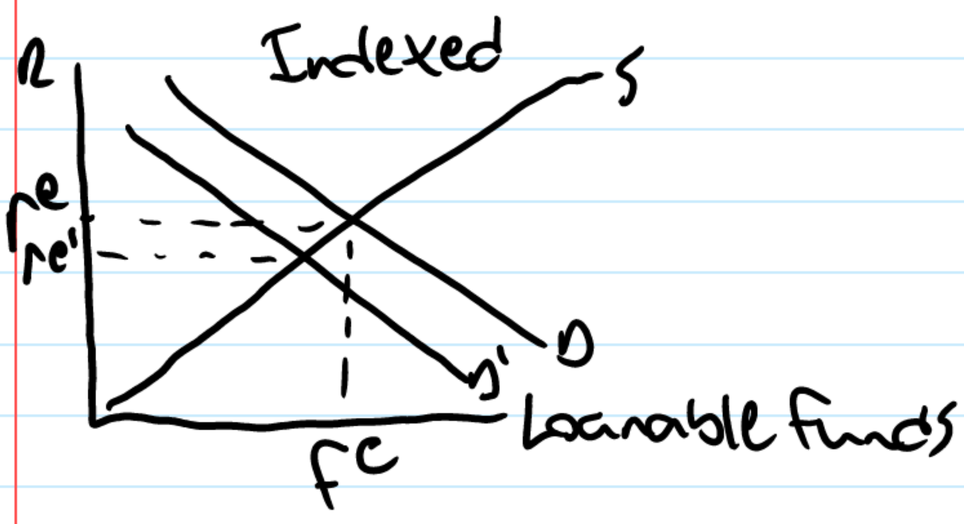
10.5 Discounting intergenerational projects

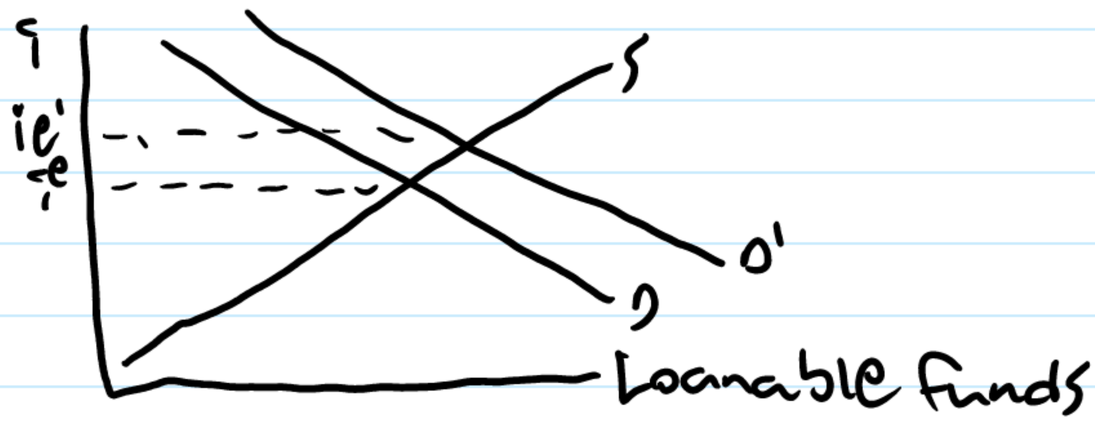
hyperbolic discounting

10.6 The social discount rate in practice

10.1 The Social Discount Rate 1

Sunday, November 8, 2020 7:04 PM





$i \approx r + m$

$i^e = r^e + \hat{m}$ (estimated

IF perfect financial markets
- transaction costs
- Liquidity constraints
- Asymmetric information → moral hazard

10.2 Social Discount Rate 2

Sunday, November 8, 2020 7:22 PM

Ad hoc estimates of the social discount rate

1) real before tax return on AAA corporate bonds ≈ 4.5%
2) real After tax return on savings (10 year indexed t-bill)
3) Govt long term borrowing cost? ≈ 2.5%

4) Avg 1-3 ≈ 2.5-3%

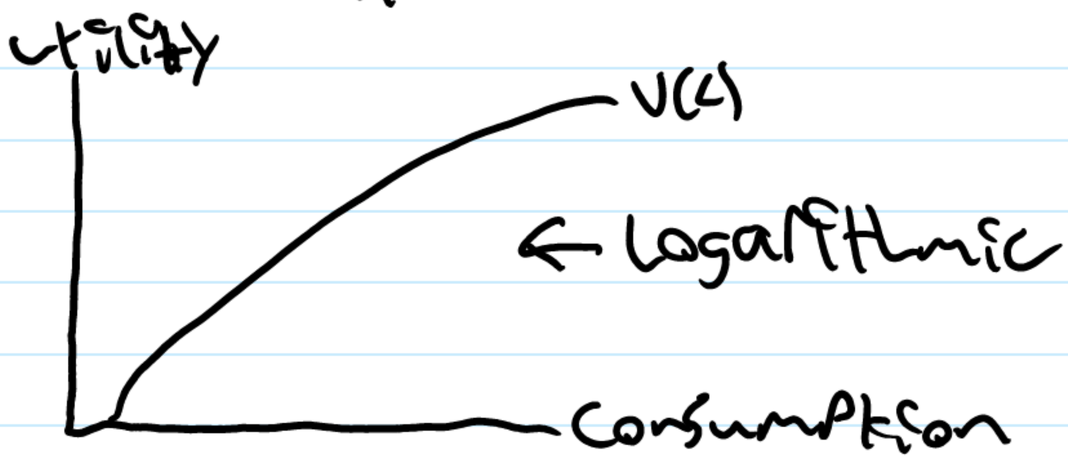
10.3 Social Discount Rate 3

Sunday, November 8, 2020 7:31 PM

Optimal growth approach to the social discount rate
- current vs future individuals
- future individuals richer (econ growth)
- more productive later if invest today (econ growth)
- impatience

Golden rule ⇒ veil of ignorance

g = real econ growth rate ≈ 2%
d = pure rate of time preference ≈ 1%
e = relative marginal utility of consumption ≈ 1.5%



r = d + ge ≈ 3.5%

11 Book Notes

Tuesday, November 10, 2020 8:35 AM

Dealing w/ uncertainty: expected values, sensitivity analysis, and the value of information

Expected value: measure to take account of risks

Sensitivity analysis: investigate the robustness of NB estimates to different resolutions of uncertainty

Value of information: benefit category for CBA and guide for allocating analytical effort

11.1 Expected Value Analysis

11.1.1 Contingencies and their Probabilities

Contingencies must be exhaustive and mutually exclusive

11.1.2 Calculating the expected value of Net Benefits

Sum NB for all contingencies

Risk neutral: indifferent between amounts and lotteries w/ equal payoffs

Risk averse: prefers a certain amount

Risk seeking: prefers the lottery

expected values = certain amounts if averaging out over large populations/quantities

11.1.3 Decision Trees and Expected Net Benefits

Decision analysis → sequential or extended form game against nature

logical structure into a **decision tree**

11.2 Sensitivity analysis

base case

approaches:
- **Partial sensitivity analysis** → one variable
- **Worst and best case analysis** → range of values
- **Monte Carlo** → distribution of net benefits

11.3 Information and Quasi Option Value

11.3.1 Introduction to the value of information

11.3.2 Quasi-option value

Quasi-option value: expected value of information gained by delaying an irreversible decision

↳ If this can be quantified, ENB can and should be calculated directly

exogenous learning: information is revealed regardless of action taken

endogenous learning: information is generated only from development itself

11.4 Conclusion

11.1 Uncertainty and Expected Value

Tuesday, November 10, 2020 6:17 PM

risk neutral decision makers
Expected Value

Coin Flip:
$H=10$, $T=-10$ $\rightarrow EV = \frac{1}{2}(10) + \frac{1}{2}(-10) = 0$

Probability distribution function = PDF

Contingencies: V_i: $-5, -1, 2, 10$
Probability: f_i: $.1, .1, .5, .3$ $\rightarrow EV = \sum_{i=1}^{4} f_i \cdot V_i = 34/10 = 3.4$

$EV = \sum f_i \cdot V_i = \int_{-\infty}^{\infty} f(x)\,dx$

$ENB = \sum (B_i - C_i) \cdot f_i$

Contingencies exhaustive + mutually exclusive

$\sum f_i = 1$

Scenarios, enough to be representative of underlying contingencies

Risk averse

Probabilities? Objective vs subjective

11.2 Decisions Under Uncertainty - Normal Form Games Against Nature

Tuesday, November 10, 2020 6:35 PM

	Growth			
Scenario	Rapid	Medium	Slow	EV
Probability	.2	.4	.4	
Actions	Net Benefits			
Start Now	9	4	-2	(.2 * 9) + (.4 * 4) - (.4 * 2) = 2.6
Start in 4 Years	4	6	3	(.2 * 4) + (.4 * 6) + (.4 * 3) = 4.4
Start in 8 Years	-2	2	6	- (.2 * 2) + (.4 * 2) + (.4 * 6) = 2.8

11.3 Uncertainty and Decisions Over Time - Expected Net Present Value

Tuesday, November 10, 2020 8:21 PM

$$ENPV = \sum_t \sum_i F_{it}(B_{it} - C_{it})/(1+r_i)^t = \sum_t 1/(1+r_i)^t \Big(\underbrace{\sum_i F_{it}(B_{it} - C_{it})}_{ENB_t}\Big)$$

Decisions at different points in time?

Model decision as extensive form game against nature

11.4 11.5 11.6 Uncertainty and Decisions Over Time - Extensive Form Games Against Nature

Tuesday, November 10, 2020 8:28 PM

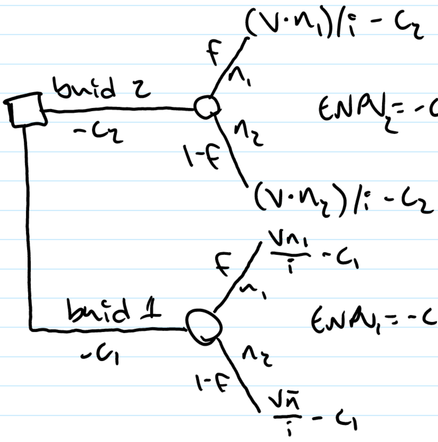
Example → Sports facility
unsure about level of demand
1 or 2 fields

Actions:
Build 1 → maybe another later
Build 2

C_1 = cost to build 1
C_2 = cost to build 2 → $C_2 \leq 2 \cdot C_1$

$\bar{n}$ = field capacity
V = benefit per user, up to capacity
n = # of users → $0 \leq n_1 \leq \bar{n} \leq n_2 \leq 2 \cdot \bar{n}$
f = Prob $n = n_1$

Payoff if build 2 or 1 now



$$ENPV_2 = -C_2 + \frac{fVn_1}{i} + \frac{(1-f)Vn_2}{i}$$

$$ENPV_1 = -C_1 + \frac{fn_1V}{i} + \frac{(1-f)\bar{n}V}{i}$$

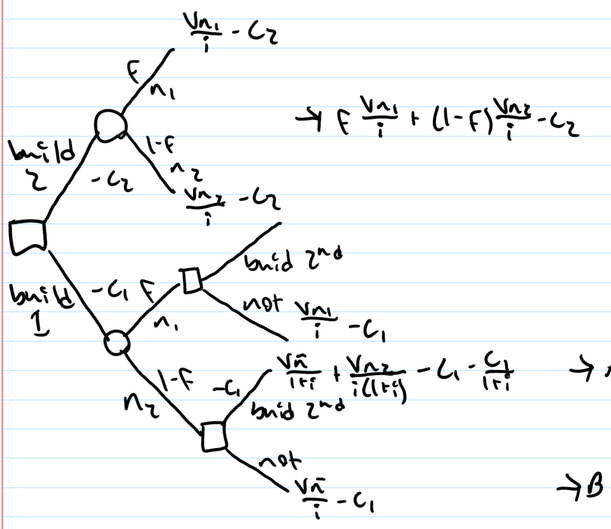
$$ENPV_2 - ENPV_1 = \frac{(1-f)V}{i}(n_2 - \bar{n}) - (C_2 - C_1)$$

↑ high ↑ serve more ↑ always cost more

Build 2 or 1 now. MAYBE another later

Real option value or Quasi-option value

Put vs Call



→ $f\frac{Vn_1}{i} + (1-f)\frac{Vn_2}{i} - C_2$

→ A

→ B

→ max(A, B)

Backwards Induction!

$$\frac{V}{(1+i)} \cdot \left(\bar{n} + \frac{n_2 - n_1}{i}\right) - \frac{C_1}{1+i}$$

Build 1 + wait → $ENPV = f\frac{Vn_1}{i} - C_1 + (1-f)\max(A, B)$

build 2 @ start → $ENPV = f\frac{Vn_1}{i} + (1-f)\frac{Vn_2}{i} - C_2$

Assume $A > B$

Build 1 + wait → $ENPV = f\frac{Vn_1}{i} + (1-f)\left[\frac{V\bar{n}}{1+i} + \frac{Vn_2}{i(1+i)}\right] - C_1 - (1-f)C_1$

2: $ENPV = f\frac{Vn_1}{i} + \left(\frac{1-f}{i}\right)Vn_2 - C_2$

Sensitivity Analysis

11 Extra Problems

Wednesday, November 18, 2020 2:13 PM

Normal Form Game Against Nature

A business needs a production facility. Four scenarios in the table below capture demand possibilities.

Scenario	A	B	C	D
Probability	0.05	0.5	0.35	0.1
Quantity	0	100	150	250

Assume product price is $5 and assume all sales will take place immediately. (This is too simplistic, but ignore choosing price and the flow of sales over time to let us focus on the other important parts of the problem).

The business can choose from three types of production facilities with different up front cost, per unit costs, and capacities, as shown in the table below.

Type	Low	High	Flex
Up Front Cost	300	500	600
Capacity	125	200	Unlimited
Cost per unit	2	1	1 up to 125, 2 above 125

a) With no further information, what facility should be chosen?

Net Benefits

		A	B	C	D	Exp Value
	Probability	0.05	0.5	0.35	0.1	
	Quantity	0	100	150	250	
Facility	Low	-300	0	75	75	18.75
	High	-500	-100	100	300	-10
	Flex	-600	-200	-25	275	-111.25

b) Suppose they can contract for a study that will tell them with certainty whether demand will be over 100 or not before the facility is chosen, but sheds no more information on other states. What is it worth?

HW 11 A More Complex Normal Form Game Against Nature

Thursday, November 26, 2020 12:39 PM

Passed solution review

A project faces uncertainty about the number of users of the service to be provided. It might be 10, 20, or 40 with probabilities 0.3, 0.5, and 0.2, respectively. There are two options, A and B. Under option A, the value per user is $10. Under option B, the value per user is $5 with probability 0.4 and otherwise $20. Assume the number of users and the value per user under option A are independent. Option A costs $100 and option B costs $250.

a. Set up the normal form representation.

	1	2	3	Exp Value
Probability	.3	.5	.2	
Quantity	10	20	40	
A: B=$10/ C=$100	=(10*10)-100=0	=(10*20)-100=100	=(10*40)-100=300	=(.3*0)+(.5*100)+(.2*300)=110
.4B: B=$5/ C=$250	=(5*10)-250=-200	=(5*20)-250=-150	=(5*40)-250=-50	=(.3*-200)+(.5*-150)+(.2*-50)=-145
.6B: B=$20/ C=$250	=(20*10)-250=-50	=(20*20)-250=150	=(20*40)-250=550	=(.3*-50)+(.5*150)+(.2*550)=170

b. What are the expected values for each option?

See values in above table

c. What is the value of perfect information before the decision is made?

170 - (-145) = 170 + 145 = 315

If n=10, A or nothing else if n=20 or 40, A if B_v=5, else B

$E(V|Info) = (0 \cdot .3) + (.5)[(.4 \cdot 100) + (.6 \cdot 150)] + (.2)[(.4 \cdot 300) + (.6 \cdot 550)] = 155$

Value = 155 - 110 = 45

d. Suppose the decision maker could, for a price, determine whether value per user would be 5 or 20 under option B, tough you would learn nothing about the number of users. What is the value of that information?

$.4(110 - (-145)) + .6(170 - 110) = .4(255) + .6(60) = 102 + 36 = 138$

If B_v=5, A else $E(V|B) = (.3 \cdot 0) + (.5 \cdot 150) + (.2 \cdot 550) = 185$

Value = 185 - 110 = 75

HW 11 A Simple Normal Form Game Against Nature

Wednesday, November 25, 2020 6:11 PM

Passed Solution review

A project faces three potential states of the world with a varying number of users (n): 10, 20, or 80, with probabilities 0.3, 0.5, and 0.2. Three options are available with values per user, v, of $2, $5, and $10, with total costs of 10, 50, and 200, respectively.

a. Set up the normal form representation.

	A	B	C	Exp Value
Probability	.3	.5	.2	
Quantity	10	20	80	
B=$2/ C=$10 1	=(2*10)-10=10	=(2*20)-10=30	=(2*80)-10=150	=(.3*10)+(.5*30)+(.2*150)=48
B=$5/ C=$50 2	=(5*10)-50=0	=(5*20)-50=50	=(5*80)-50=350	=(.3*0)+(.5*50)+(.2*350)=95
B=$10/ C=$200 3	=(10*10)-200=-100	=(10*20)-200=0	=(10*80)-200=600	=(.3*-100)+(.5*0)+(.2*600)=90

b. Find the expected value of each option. Without additional information, which option is best?

See above table for Exp value, option 2 (B=$5/ and C=$50) is the best

B

c. What would be the value of perfect information about the state of the world before the decision is made?

95-48=47

P(c| A, B, or C)?

I'm definitely missing something but can't figure out what

Tough choices: A, B, and C if n=10, 20, or 80

E(v) = (.3·10)+(.5·50)+(.2·600) =148

value =148-95=53 → did this in d, apparently

d. Suppose the decision maker could purchase information that would reveal, prior to making the decision, whether the number of users will be more than 10 but provide no other insight. What is this information worth?

E(v|A, 1) =10 P(A|A)=1

E(v| B or C,

E(v| Buy) =(.3·10)+(.5·50)+(.2·600)=148

Info Value =148-95=$53

If n=10, A otherwise

E(v|B, N>10) =(.5/.7)(50) +(.2/.7)(350) =136
E(v|C, N>10) =(.5/.7)(0) +(.2/.7)(600) =171

Thus C is chosen

E(v|info) =(.3·10)+(.7·171) =123

Value =123-95=28

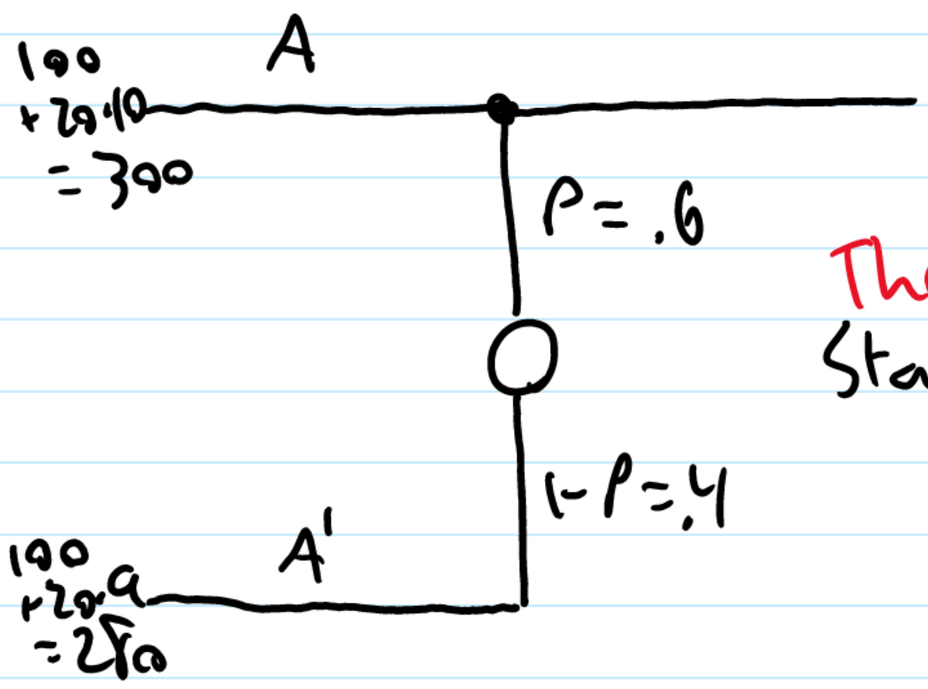
HW 11 An Extensive Form Game Against Nature

Wednesday, November 25, 2020 4:51 PM

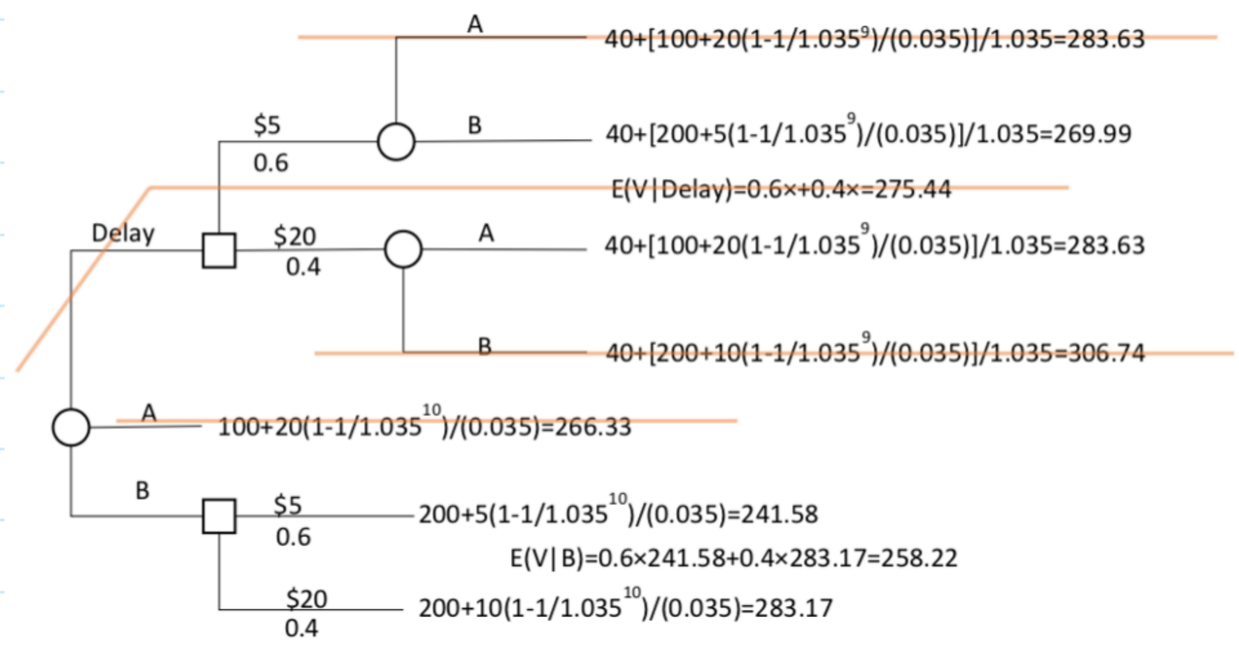
Passed solution review

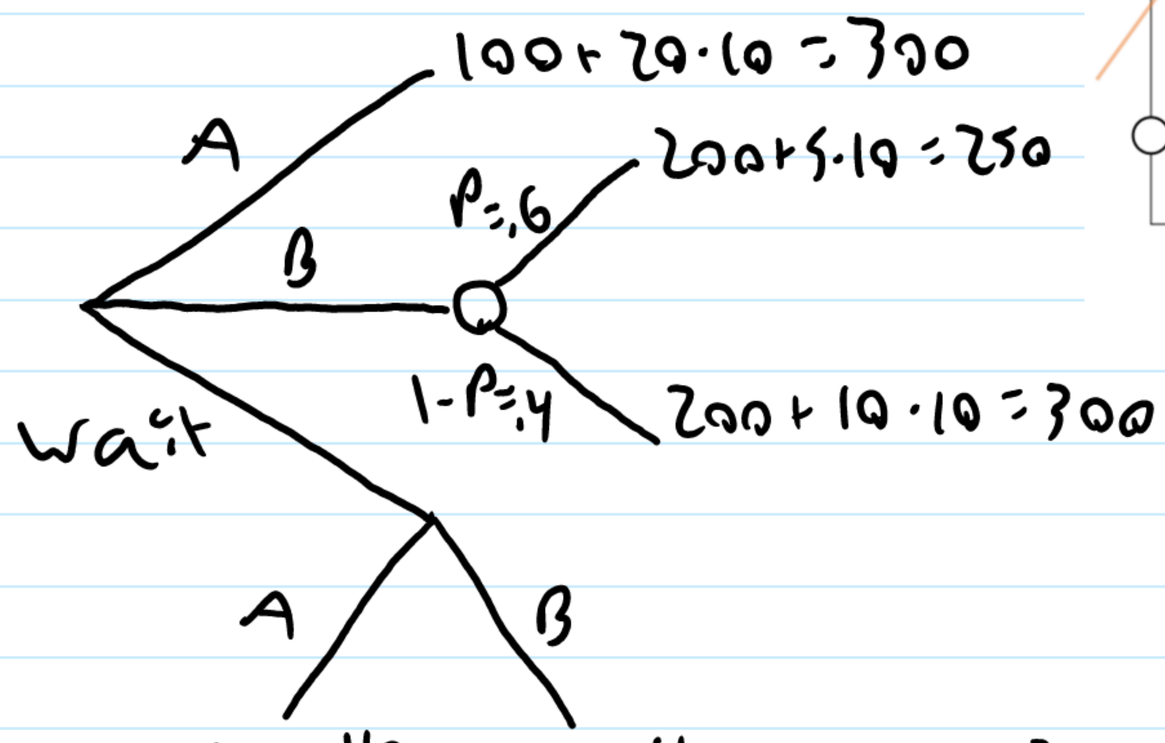
The sheriff's department is upgrading its information management system. They have a choice between system A and system B. System A will cost them $100 up front and $20 per year over 10 years. System B will cost $200 up front and then each year for 10 years will cost $5 with probability 0.6 or else $10. Alternatively, they could pay $40 to keep their current system working one more year, at which time it would be known whether the annual cost of system B is $5 or $10. If they delay one year, the up front cost would still be the same, but they would only get 9 years of service from the new system.

a) Draw the extensive form game against nature.



Did this all wrong
Put nature in the wrong spot
Then didn't do math for nature
Started doing game theory but it's not





100+40
+20·9
=320

200+40
+5·9·.6
+10·9·.4
=303

200+40
OR +9q where q = 10 or 5 depending

assume the worst
200+40
+10·9
=330

assume the best
200+40
+5·9
=285

b) What should they do at what time?

They should buy now as their maximum cost is less than the expected later costs. Max B = A so there's no reason not to get B and hope it's $5/year

HW 11 Another Extensive Form Game Against Nature

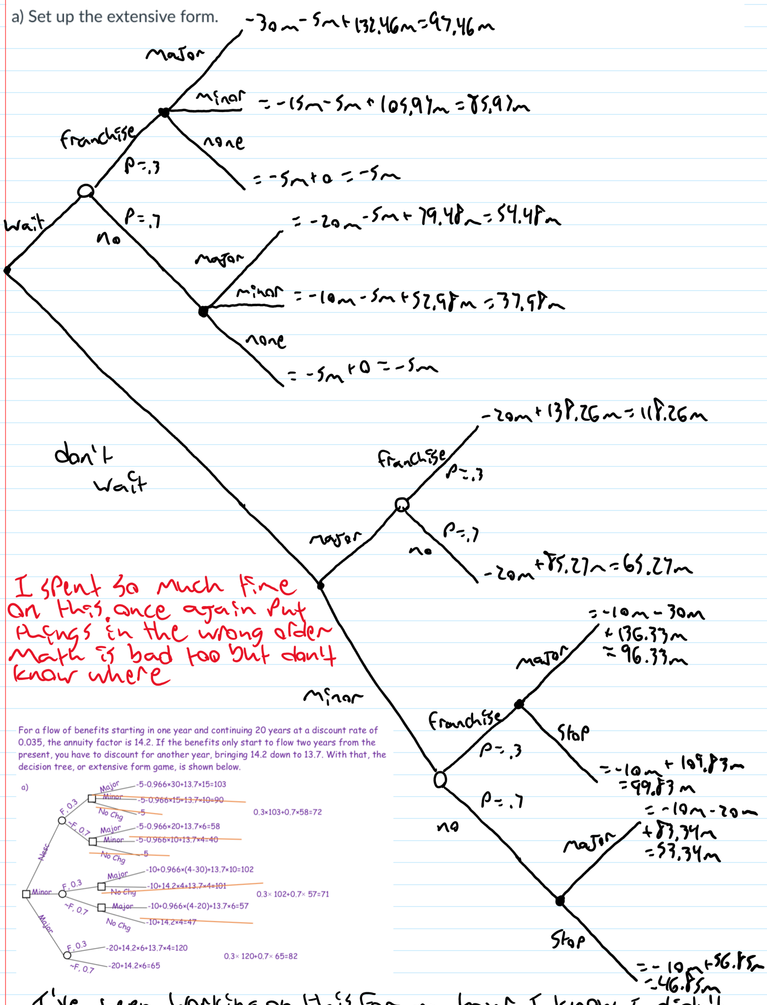
Thursday, November 26, 2020 1:05 PM

Passed Solution review

A city is in the running for a major sports franchise, with a 30% chance (officials think) of being selected. They will not know for 1 year. A road not far from the stadium cite is in need of repair following flooding from ruptured water pipelines. The road was in need of upgrades anyway, and will need improvement more urgently if the franchise is awarded.

- Benefits accrue for 20 years beginning one year from incurring the cost of improvements.
- The horizon value is 0.
- The real discount rate is 0.035.
- The cost of a minor upgrade is $10M and benefits are $4M/year if the franchise has not been awarded. If and after the franchise is awarded, the cost is $15M (more traffic disruption) and benefits are $8M/year.
- The cost of a major upgrade is $20M and benefits are $6M/year if the franchise has not yet been awarded. If and after the franchise is awarded, the cost is $30M (more traffic disruption) and benefits are $10M/year.
- The city could implement minimum necessary repairs for $5M now and delay deciding on improvements. Benefits are $0/year. (This restores the status quo level of service.)
- The city could undertake the minor improvement now and the major improvement later.

a) Set up the extensive form.



I spent so much time on this, once again put things in the wrong order. Math is bad too but don't know where

For a flow of benefits starting in one year and continuing 20 years at a discount rate of 0.035, the annuity factor is 14.2. If the benefits only start to flow two years from the present, you have to discount for another year, bringing 14.2 down to 13.7. With that, the decision tree, or extensive form game, is shown below.

a)

I've been working on this for an hour. I know I didn't calculate benefits, but I'm moving on.

b) Find the solution with the highest ENPV.

Assuming time to build improvements is ≤1 year
Assume doing major after minor as soon as they find out about the franchise
Assume major after minor incurs full costs
Assume benefits end at year 20 even if they waited or upgraded

Not waiting, doing the major upgrade, then getting the franchise has the highest ENPV

c) What are the best and worst case scenarios for the option with the highest ENPV?

Ugh. I did this wrong and I'm in too deep.

Worst case = no franchise = 65.27m =65m
Best case = 118.26m =120m
E(U) = 82m

Wait. This is right!

d) What is the value of perfect information on whether the franchise will be awarded?

118.26m - (-5m) = 123.26m

Even perfect information has no impact because BR is always build no matter what

(definitely wrong)

Year	Wait, Franchise, Major	Wait, Franchise, Minor	Wait, Franchise, None	Wait, No Franchise, Major	Wait, No Franchise, Minor	Wait, No Franchise, None	No Wait, Major, Franchise	No Wait, Major, No Franchise	No Wait, Minor, Franchise, Major	No Wait, Minor, Franchise, Stop	No Wait, Minor, No Franchise, Major	No Wait, Minor, No Franchise, Stop
1	0	0	0	0	0	0	5.80	5.80	3.86	3.86	3.86	3.86
2	9.34	7.47	0	5.60	3.73	0	9.34	5.60	9.34	7.47	5.60	3.73
3	9.02	7.22	0	5.41	3.61	0	9.02	5.41	9.02	7.22	5.41	3.61
4	8.71	6.97	0	5.23	3.49	0	8.71	5.23	8.71	6.97	5.23	3.49
5	8.42	6.74	0	5.05	3.37	0	8.42	5.05	8.42	6.74	5.05	3.37
6	8.14	6.51	0	4.88	3.25	0	8.14	4.88	8.14	6.51	4.88	3.25
7	7.86	6.29	0	4.72	3.14	0	7.86	4.72	7.86	6.29	4.72	3.14
8	7.59	6.08	0	4.56	3.04	0	7.59	4.56	7.59	6.08	4.56	3.04
9	7.34	5.87	0	4.40	2.93	0	7.34	4.40	7.34	5.87	4.40	2.93
10	7.09	5.67	0	4.25	2.84	0	7.09	4.25	7.09	5.67	4.25	2.84
11	6.85	5.48	0	4.11	2.74	0	6.85	4.11	6.85	5.48	4.11	2.74
12	6.62	5.29	0	3.97	2.65	0	6.62	3.97	6.62	5.29	3.97	2.65
13	6.39	5.12	0	3.84	2.56	0	6.39	3.84	6.39	5.12	3.84	2.56
14	6.18	4.94	0	3.71	2.47	0	6.18	3.71	6.18	4.94	3.71	2.47
15	5.97	4.78	0	3.58	2.39	0	5.97	3.58	5.97	4.78	3.58	2.39
16	5.77	4.61	0	3.46	2.31	0	5.77	3.46	5.77	4.61	3.46	2.31
17	5.57	4.46	0	3.34	2.23	0	5.57	3.34	5.57	4.46	3.34	2.23
18	5.38	4.31	0	3.23	2.15	0	5.38	3.23	5.38	4.31	3.23	2.15
19	5.20	4.16	0	3.12	2.08	0	5.20	3.12	5.20	4.16	3.12	2.08
20	5.03	4.02	0	3.02	2.01	0	5.03	3.02	5.03	4.02	3.02	2.01
Total B	132.46	105.97	0	79.48	52.98	0	138.26	85.27	136.33	109.83	83.34	56.85
NB	97.46	85.97	-5	54.48	37.98	-5	118.26	65.27	96.33	99.83	53.34	46.85
NB with Bad P	29.24	25.79	-1.50	38.13	26.59	-3.50	35.48	45.69	28.90	29.95	37.34	32.79

HW 11 Simple ENPV

Wednesday, November 25, 2020 5:30 PM

Passed Solution review

a. A project costs $10 up front and has net benefits of $15 with probability 0.8 at the end of the second year and otherwise returns nothing. The discount rate is 0.035. What is the NPV?

$-10 + (0/1.035^1) + (15/1.035^2 \cdot .8) = -10 + 0 + 11.202 = 1.202$

b. At what probability of returning $15 after year 2 would the ENPV be 0?

$-10 + (15/1.035^2 \cdot p) = 0$

$15/1.035^2 \cdot p = 10$

$14.002p = 10$

$p = .71415$

12 Book Notes

Monday, November 16, 2020 10:25 PM

Risk, option Price, and option Value

option Price - amount WTP for Policies before realization of contingencies

Option Value - difference between option Price and expected surplus

12.1 Ex-Ante WTP: option Price and certainty Equivalents

maximum WTP for a Policy in any contingency → option Price

↳ **certainty equivalent**

12.1.1 Illustrations of option Price

expected surplus can under or over-estimate option Price

Contingent contract

certainty line - Payments are the same along the line

fair bet line - average Payoff based on Probability

WTP Locus - All combos of contingent Payments for same expected Utility

12.1.2 Is option Price the best measure of benefits

Moral hazard - insurance encourages risk by insurees

Adverse selection - insurees know more about risks than insurers

If complete and actuarilly fair insurance is available, then the larger of option price or expected surplus is the appropiate measure of benefits

12.2 Determining the bias in expected surplus: signing option value

$OV = OP - E(S) \rightarrow OP = E(S) + OV$

risk Premium (RP) $= E(S) - OP \rightarrow RP = -OV$

12.2.1 Determining the sign of option value

12.3 Rationales for Expected Surplus as a Practical Net Benefit measure

12.3.1 Small changes in individual risks

systematic vs **non-systematic risk**

for broadly spread impacts, use NB

12.3.2 Risk reduction through Policy Portfolios

if systematic risk is small, Projects can be discounted by expected NB at risk free social discount rate

12.3.4 Pooling risks across individuals: collective and individual risk

individual risk: larger of OP or E(S) is better

12.1 Option Price and Option Value

Monday, November 16, 2020 11:02 PM

Expected Social Surplus → E(SS)

Risk averse

Ask WTP policy/program/decision → "option price"

OV = OP - E(SS)

13 Book Notes

Thursday, November 26, 2020 3:30 PM

Existence Value

additional category of benefit

non-use or passive use benefits

13.1 Active and Passive Value

non-use value

Existence value is non-rivalrous and non-excludable

↳ passive use

total economic value = total WTP

individualistic vs alternative altruism

direct vs indirect consumption

4 kinds of existence value
- option value
- pure existence value
- altruistic existence value
- bequest value

13.2 The measurement of Existence Value

13.2.1 Directly Eliciting Total Economic Value

Structured conversation

13.2.2 Behavioral Traces of existence value?

13.2.3 Should Existence value be included in CBA?

yes and no to give clear sense of happenings

13.3 Conclusion

13.1 Existence Value

Thursday, November 26, 2020 6:16 PM

Active use vs Passive use

- rivalrous or not
- Pure existence value
- Altruism

Option to use in future

Austin Adams
Gus Lipkin
River Anderson
Alex Pierstroff

Topic Choice:

- Benefit Cost Analysis of implementing Tesla charging stations in ***Lakeland/Florida Polytechnic within existing parking structures.
    - ** - *could become more generic and would need info/the goods from FPU*

- Tesla is still holding about 80% of the US electric vehicle market despite buyers not having access to the federal tax credit anymore unlike they do for some of the competition...but TSLA has a much larger head start than any other automobile company with EV's
    - https://electrek.co/2020/08/21/tesla-holds-us-ev-market-losing-federal-tax-credit/

- http://www.swenergy.org/pubs/azevstudy
    - [Full CBA was conducted for EV's in AZ]

Potential Social Costs:

- Installing a charger at home can be expensive after the costs of the electrician and components. Using a regular wall plug will charge but can be very slow.
    - https://www.marketwatch.com/story/youll-save-money-on-gas-with-a-tesla-but-also-consider-these-unique-expenses-2017-07-06,

- The Impact of Charging Plug-In Hybrid Electric Vehicles on a Residential Distribution Grid
    - https://ieeexplore.ieee.org/abstract/document/5356176

- This article goes into the potential cost of having unregulated or controlled charging stations in a residential distribution grid. The purpose of the article would be to clarify what costs EV implementation would have, by using the data provided here.
    - The economics of using plug-in hybrid electric vehicle battery packs for grid storages
        - https://www.sciencedirect.com/science/article/abs/pii/S0378775309017303

- This article goes through implications of plug in stations for EV vehicles and may help in daily pricing for EV vehicles.
    - https://www.investopedia.com/articles/active-trading/041515/economics-owning-tesla-car.asp
        - Using a TSLA Model S as the basis for the individual consumer:
            - Costs: $69,490 basic model

- Model 3:
    - Costs: $33,690 for basic model

Examples to lean on for BCA:

Willingness to pay for electric vehicles and their attributes

- We can use this article for considering what attributes or variables to consider in our analysis based on their survey results
    - https://www.sciencedirect.com/science/article/abs/pii/S0928765511000200

- California is mandating only the sale of electric vehicles by the year 2035. Dealerships/companies can only sell electric vehicles – pushing this issue into the forefront and forcing consumers to choose EV's in the near future.
    - https://www.wsj.com/articles/california-to-ban-sales-of-new-gas-powered-cars-starting-in-2035-11600882738

"Tesla's Supercharger network solves the range anxiety issue in three ways. First, the Supercharger network is designed to be large enough to cover key routes so that consumers can have confidence that they can access them when needed. In the United States, we have placed Superchargers across major transcontinental routes, as well as along key routes on the East and West Coasts. In Europe, Superchargers enable long distance travel along key routes in numerous countries, including Norway, the Netherlands, Germany, Switzerland and Austria. And in Asia, we began in 2014 to establish Supercharger stations along key routes in China, Japan and Hong Kong. Second, charging a Tesla vehicle using the Supercharger network is fast enough to comfortably enable long-distance travel. It is designed to replenish up to 50% of the vehicle's battery pack in as little as 20 minutes. Third, access to the Supercharger network is free for every Tesla vehicle that is enabled with Supercharging capability."

- As of December 31, 2013, the net book value of our Supercharger network assets, including those in-service and under construction, was $25.6 million. This amount represented approximately 3.5% on total property, plant and equipment, net of $738 million and approximately 1% on total assets of $2,417 million. Thus, notwithstanding the importance of the Supercharger network to the Tesla brand, the cost to build this network has remained small compared with our other capital expenditures, including throughout 2014.

- https://www.sec.gov/Archives/edgar/data/1318605/000119312515017866/filename1.htm

- Growing supercharger networks across the world.
    - The Supercharger network currently consists of 1,533 stations with 13,344 Superchargers. [at the time the article was written]
    - Tesla has been talking about more than doubling the network over the next year. [at the time the article was written]
        - https://electrek.co/2019/07/19/tesla-updates-map-supercharger-stations/

- 1,971 Supercharger stations with 17,467 Superchargers
    - Superchargers are now being implemented into Urban Areas and where out of town visitors can easily charge

- Placed at convenient locations like grocery stores, downtown districts, and shopping centers so charging fits seamlessly into the life
- Less than the cost of gas – for a baseline of 2,000 miles, gasoline $271 and supercharger cost is roughly $155
- ********Charging cost estimate assumes Supercharger cost of $0.26 per kilowatt hour. Gasoline cost assumes 21 MPG for Model X and Model S and 28 MPG for Model 3 at $2.85 per gallon. Cost may vary depending on the vehicle location, configuration, battery age and condition, driving style and operation, and environmental and climate conditions.**********
    - https://www.tesla.com/supercharger

- Discusses the costs of installing electric vehicle chargers based on costs of installing past chargers and how implementations in different places will cost different amounts.
    - https://afdc.energy.gov/files/u/publication/evse_cost_report_2015.pdf#:~:text=The%20cost%20of%20a%20single,51%2C000%20for%20DC%20fast%20charging.

- A business model for financially sustainable EV charging networks. Three phases: assess the state of EV charging in Washington, identify and evaluate "innovative business models for EV charging," and made recommendations for how the public sector can support the business models to maximize private sector investment.
    - https://www.c2es.org/site/assets/uploads/2015/03/business-models-ev-charging-infrastructure-03-15.pdf

Austin Adams, Gus Lipkin, Alex Pierstorff, River Anderson

Benefit - Cost Analysis -

The Implementation of a Tesla Supercharger in Lakeland, Florida.

Abstract:

The purpose of this Benefit-Cost Analysis is to assess the feasibility of implementing Tesla charging stations and access the alternative options for local, city and state residents in Florida. In North America, most electric vehicles follow the same universal plug in style. These are more accurately put into three levels: Level 1 (120 volts AC), Level 2 (208-220 volts AC), and Level 3 DCFC (480 volts AC) charging.

Decision to be Analyzed & Literature Review:

Most EV manufacturers include a Level 1 EVC cord set so that no additional charging equipment is required. As a general rule, Level 1 recharging will add approximately four miles of travel per hour. Level 1 charging is the most common form of battery recharging and can typically recharge a EV's batteries overnight; however, a completely depleted EV battery could take up to 20 hours to completely recharge (Groover Combs et al, 2020).

Level 2 recharging will supply up to approximately 15 miles of travel for one hour of charging to vehicles with a 3.3 kW onboard charger, or 30 miles of travel for one hour of charging for vehicles with a 6.6kWh on-board charger. Level 2 EVC utilizes equipment specifically designed to provide accelerated recharging and requires professional electrical installation using a dedicated electrical circuit. Level 2 equipment is available for purchase online or from retailers that sell other residential

appliances. A completely depleted EV battery could be recharged in approximately seven hours using a Level 2 charger (Groover Combs et al, 2020).

DCFC recharging will add approximately 80-100 miles of travel with 20-30 minutes of charging. The DCFC EVC converts AC to DC within the EVC equipment, bypassing the car's charger to provide high-power DC directly to the EV's traction batteries through the charging inlet on the vehicle .While the power supplied to EVs by all DCFCs is standardized, there is not uniform agreement on the connector that is used to connect the charger to the vehicle (Groover Combs et al, 2020).

One of the most revolutionary changes is that of Tesla's very own supercharging network, which represents a large market for both Electric Vehicles and a high demand for charging stations (US Department of Energy, November 2015). The increase in charging stations directly reflects consumer demand for Electric Vehicles.

An increase in the purchasement of Electric Vehicles, the demand for open charging stalls at the stations will also increase. Electric Vehicles and Charging Networks are complementary products. Therefore, as we see the gradual movement away from fossil fuels, electricity as a renewable energy source is increasing in usage and demand. This is furthered by states', like California, decision to move towards solely electric-based vehicles by the year 2035. Level 2 and DCFC chargers are going to see an exponential rise in demand due to more electric vehicles being in the market. More consumers are going to want their cars to be charged from these stations, and

they will want it to be done incredibly fast. As a result, we will likely see an increase in DCFC chargers and their charging capabilities across the state.

One of the common reasons for choosing EV's is due to the price of gas versus the power consumption. Looking at the willingness to pay for an Electric vehicle, it would be in the range of $35 to $75 for a mile of added driving range and would pay more a decrease in charging time as well (*Willingness to pay…)*.

This factors into the demand for Tesla's charging stations and the ability to have a plugin that works at home for cars, as consumers are treated to more Electric vehicles in the market.

Alternatives to Public Charging Stations

The alternatives to having public charging stations involve having residential private charging stations, at home charging stations and renewable energy power charging stations, at home. The direction for public charging stations is to pay a per kilowatt charge and with Tesla, paying for the charge varies on the package and model year of purchase. For at home charging stations, the costs vary based on the age of the house and community and electrical wiring of the house, which can cost up to an additional $1,000 (Albrecht 2019).

In addition, the Governor of Florida, awarded 27 contracts to build charging stations along the I-95, I-4, I75 and I-295 highways (Calvan 2020). The state will use about $25 million of that settlement to build EV chargers at Florida's Turnpike service

plazas. Based on another state level direction, California has instead imposed a mandate that the entire automotive industry in California transition to selling only EVs by 2035, effectively forcing the consumer market into a direction.

The other alternative is to do nothing but build out more charging networks regardless of demand.

(https://afdc.energy.gov/files/u/publication/evse_cost_report_2015.pdf#:~:text=The%20cost%20of%20a%20single,51%2C000%20for%20DC%20fast%20charging)

https://www.bizjournals.com/jacksonville/news/2020/03/27/florida-a-top-market-for-growth-in-electric.html - stats on chargers

Technical Plan:

Our technical plan will follow the steps from chapter 1:

1. Decide whose benefits and costs count, specifically standing.
2. Identify the impact categories, catalogue them and select metrics.
3. Predict the impacts quantitatively, we will say over 5 years.
4. Monetize these impacts over 5 years.
5. Discount benefits and costs to obtain present values.
6. Compute the net present value of each alternate.
7. Perform sensitivity analysis.
8. Make our Lakeland, Polytech Recommendation.

We plan to obtain our data from a group of sources attached in our references, and from States California, New York and Florida, and finally from universities that have done economic impact studies on EV charging stations.

Draft Analysis

Topic: The purpose of this Benefit-Cost Analysis is to assess the feasibility of implementing Tesla charging stations and access the alternative options for local, city and state residents in Florida.

Impacted Parties:

State	Lakeland County	Residents

Social Costs	**State**	**Lakeland County**	**Residents**
Construction Costs For Charging Stations			
Cost of conversion from gas v power			
Cost of a new work force for maintenance on EV			

Social Benefits	**State**	**Lakeland County**	**Residents**
Reduction in Carbon emissions			
EV sales			
Eliminating purchase of gasoline			

We defined Q = # of cars

P = # of gas stations

Our first assumption is for P = we used the elasticity for gas gallons / station.

Elasticity for gas = -.26

P= 9.2 million barrels nationally per day

Q = 13,358,246 cars in the State of Florida

Number of gas stations in FL: 7,043

Number of gas stations in Lakeland: 93

Number of existing electric charging stations in FL, this will be our equilibrium:

Number of electric charging stations in Lakeland: 22

Number of charging stations in FL: 5182

Number of gas stations with charging stations: 7

Cost for using charging stations: .10 KwH, kilowatts per hour

Cost to install a charging level 3 charging stations at home: $50,000

One of Gus' famous Author's Notes: I know that some of these numbers are wrong or mis-applied. I'm working on correcting them but need help from someone smarter than myself. Preferably someone who has taught or does teach QMB 3200 ~ Advanced Quantitative Methods. In addition, many of these assumptions are made under the guidance of Fermi Estimates.

The first two lines are currently the equilibrium 72,296 gas pumps (assuming each station has 8 pumps) and 14.442 million registered vehicles in the state of FL. Through pure conversion, and stating that 80% of those cars exclusively use in home-charging Level 1 capabilities, we have an equilibrium of 14,460 charging outlets required for Level 2/DCFC charging needs. At current point, there are 28,535 registered EV vehicles in the state by the total number of sales from 2011-2019, and 5,182

charging outlets in the state of FL. If we change the number of EV vehicles to the total number of vehicles registered, we can conclude that we are under-utilizing our current number of charging outlets because it projects more charging stations than our current equilibrium number of gas pumps. Thus a guardian-perspective could conclude that at this time it does not make sense to install new electric vehicle chargers. However, with the market shifting towards electric-vehicle utilization, a spender would find that it would be forward-thinking and in the best interest of Lakeland to place an EV Charging stall understanding that in the future there will be a greater need of charging ports available to the every-day EV consumer. Some may note that more electric vehicles would be sold if there were more chargers to reduce so-called “range anxiety”.

The costs of Level 1 chargers are incredibly minimal for installation. The average residential electricity rate in Lakeland is 10.58¢/kWh [https://www.electricitylocal.com/states/florida/lakeland/#:~:text=Residential%20electricity%20rates%20in%20Lakeland&text=The%20average%20residential%20electricity%20rate%20in%20Lakeland%20is%2010.58%C2%A2,rate%20of%2011.42%C2%A2%2FkWh.]

Our second assumption is related to the demand for public charging stations: Currently the estimated use of at home charging stations among hybrid or electric vehicles is 80%, meaning that 20% of all drivers can’t charge at home. But, in relation to time, we can use all drivers of vehicles if our time to charge is proportional to drivers needing a quick charge vs a full charge for their vehicles.

Our first objective is to prove that cost to install chargers + cost to change <= cost of gas in X time period.

Equation for objective 1:

(14.4m *.8 *$50) + (14460 chargers installed) + (average charging cost: $.1/ hour * 14.4m) <= (14.4m *$2.00/hr)

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"Define the impacts and impacted parties, calculate the net benefits, and analyze which decision will make the most sense. Explain your work so someone unfamiliar with the topic can follow your calculation. Write this up as if it will be a section of your project report—because the final version of it will be."

- Impacts and impacted parties
- Net benefits
- Pick something and explain it

Austin Adams, Gus Lipkin, Alex Pierstorff, River Anderson

Benefit - Cost Analysis -

The Implementation of a Tesla Supercharger in Lakeland, Florida.

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Abstract:

The purpose of this Benefit-Cost Analysis is to assess the feasibility of implementing Tesla charging stations and access the alternative options for local, city, and state residents in Florida. In North America, most electric vehicles follow the same universal plug in style. These are more accurately put into three levels: Level 1 (120 volts AC), Level 2 (208-220 volts AC), and Level 3 DCFC (480 volts AC) charging.

Decision to be Analyzed & Literature Review:

Tesla Batteries:

Battery capacity degradation over time or distance traveled is one of the several main concerns in terms of electric cars. About 10 years ago, no one really knew how those new EVs would cope and some models were clearly underperforming (for various reasons). Taking a look at the official data from Tesla, which is extremely valuable because the company already has the most experience in terms of the number of all-electric cars sold globally.

Tesla says that its battery packs were designed to outlast the cars. The average usage of private passenger cars (ICE) in the U.S. is 17 years and roughly 200,000 miles (322,000 km). The mileage in Europe is lower - about 130,000 miles (209,000 km). So, we have the first indication that the batteries should last longer than that. Battery capacity is above 85% (on average) after 150,000-200,000 mile After selling more than 1 million electric cars, Tesla's battery degradation data shows that vehicles with

mileage between 150,000-200,000 miles (241,000-322,000 km), on average, still have more than 85% of initial battery capacity the battery degradation is below 15%.

A group of Tesla owners on the Dutch-Belgian Tesla Forum are gathering data from over 350 Tesla vehicles across the world and frequently updating it in a public Google file located here: (https://docs.google.com/spreadsheets/d/t024bMoRiDPIDialGnuKPsg/edit#gid=0).

There is previously reported data, but they have since added many more vehicles and those vehicles have been driving a lot more – completing more battery cycles. The data clearly shows that for the first 50,000 miles (100,000 km), most Tesla battery packs will lose about 5% of their capacity, but after the 50,000-mile mark, the capacity levels off and it looks like it could be difficult to make a pack degrade by another 5%. The trend line currently suggests that the average battery pack could cycle through over 300,000 km (186,000) before coming close to 90% capacity.

When it relates to electric vehicles, battery degradation means the loss of battery capacity and range over time. It's one of the main concerns of new electric car buyers and it can vary greatly based on several factors like cell chemistry, battery management system, and usage. Tesla has historically been able to limit degradation to reasonable levels thanks to its robust battery management system. Real-world data showed that Tesla battery degradation was less than 10% after over 160,000 miles (257,500 km). Tesla interestingly used to not clearly cover battery capacity degradation in its warranty until it launched Model 3. With an update to its warranty earlier this year,

Tesla now covers all battery capacity degradation in all its vehicles with a limit of 70% capacity for up to 8 years or 100,000 to 150,000 miles depending on the model. Based on the previously mentioned data, it looks like Tesla won't have to do too many battery replacements due to accelerated battery capacity degradation. However, some of Tesla's battery packs are known to perform better than others and the 90D, which is the one I have in this car, is known to be Tesla's worst battery pack for battery degradation. Tesla forums are full of Tesla Model S and Model X 90D owners reporting quicker battery capacity degradation compared to the average Tesla vehicle.

Public and Private Charging:

You can consider Level 1 charging as the default EV charging option. It works on all electric vehicles and at all places with a standard power outlet. Level 1 charging equipment is included with every EV. With Level 1 charging, all you do is plug your EV into a standard 120 volt AC wall outlet. This is the same kind of outlet you plug your laptop or phone charger into. Easy. The problem with Level 1 EV charging is that it's slow – very slow. They are typically powered at a measly 12 or 16 amps and provide just 2-6 miles of range per hour. Level 1 is the lowest charging option available and is often referred to as "trickle charging".

For faster charging, homeowners can upgrade to Level 2 chargers. These use a 240-volt power outlet, the same as those used by air conditioners or clothes dryers. Level 2 charging is a lot faster than Level 1 charging, providing 14 to 35 miles of range per hour by taking advantage of the circuit's higher amperage. These charging cords

are traditionally sold as a separate add-on for your EV. Some homes might not have a 240-volt outlet, so you may need to work with an electrician to get one installed. You'll want to ensure that the circuit supports a high enough amperage to allow your charge to operate at its peak output to charge your car as fast as possible. For pretty much every EV brand except Tesla, Level 2 chargers use a J1772 port. Tesla has their own Level 2 charging port, however, all Tesla's come with a J1772 adaptor for charging. So, all EVs should be able to take advantage of most public Level 2 charging stations.

Unlike the first two options which use residential AC current, DC fast chargers (often called Level 3 chargers) use DC current. Because Level 3 chargers provide DC current, they bypass the on-board charger and directly charge the EV's battery. This allows for very fast charging speeds: they can provide 100 miles of range per hour or more. While Level 3 chargers are fast, manufacturers warn that you should not rely on them as your main charging source. The large amount of power that fast charging stations use can damage your EV battery's health, and potentially shorten its lifespan. It's recommended to only use fast-charging if you need it for long-distance travel or if you are pressed for time. Level 3 chargers are not feasible for home use, as they require special utility connections, hardware, wiring, and permits. They also have extremely high setup and energy costs. You'll only find Level 3 DC charging stations along highways or in other public areas.

In addition to the aforementioned Level 2 stations, the DOE says there are now 3,653 DC fast-charging stations in the U.S., 813 of which are for Teslas. But those

numbers don't tell the whole story. First, knowing there's a station doesn't mean you know how many plugs are available; some may have a dozen plugs while others have just one or two. Second, vehicle connectivity is simply one aspect of public charging. After all, gas pumps will work with any car, but you still need to pay for the fuel. And that's where charging networks come in. The three biggest non-Tesla networks in the U.S. are operated by EVgo, ChargePoint, and Electrify America.

Most EV manufacturers include a Level 1 EVC cord set so that no additional charging equipment is required. As a general rule, Level 1 recharging will add approximately four miles of travel per hour. Level 1 charging is the most common form of battery recharging and can typically recharge a EV's batteries overnight; however, a completely depleted EV battery could take up to 20 hours to completely recharge (Groover Combs et al, 2020).

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DCFC recharging will add approximately 80-100 miles of travel with 20-30 minutes of charging. The DCFC EVC converts AC to DC within the EVC equipment, bypassing the car's charger to provide high-power DC directly to the EV's traction batteries through the charging inlet on the vehicle .While the power supplied to EVs by all DCFCs is standardized, there is not uniform agreement on the connector that is used to connect the charger to the vehicle (Groover Combs et al, 2020).

One of the most revolutionary changes is that of Tesla's very own supercharging network, which represents a large market for both Electric Vehicles and a high demand for charging stations (US Department of Energy, November 2015). The increase in charging stations directly reflects consumer demand for Electric Vehicles.

An increase in the purchasement of Electric Vehicles, the demand for open charging stalls at the stations will also increase. Electric Vehicles and Charging Networks are complementary products. Therefore, as we see the gradual movement away from fossil fuels, electricity as a renewable energy source is increasing in usage and demand. This is furthered by states', like California, decision to move towards solely electric-based vehicles by the year 2035. Level 2 and DCFC chargers are going to see an exponential rise in demand due to more electric vehicles being in the market. More consumers are going to want their cars to be charged from these stations, and they will want it to be done incredibly fast. As a result, we will likely see an increase in DCFC chargers and their charging capabilities across the state.

One of the common reasons for choosing EV's is due to the price of gas versus the power consumption. A consumer's willingness to pay for the Electric Vehicle and the costs to charge factors into the demand for Tesla's charging stations and the ability to have a plugin that works at home for cars, as consumers are treated to more Electric vehicles in the market.

Alternatives to Public Charging Stations

The alternatives to having public charging stations involve having residential private charging stations, at home charging stations and renewable energy power charging stations, at home. The direction for public charging stations is to pay a per kilowatt charge and with Tesla, paying for the charge varies on the package and model year of purchase. For at home charging stations, the costs vary based on the age of the house and community and electrical wiring of the house, which can cost up to an additional $1,000 (Albrecht 2019).

In addition, the Governor of Florida awarded 27 contracts to build charging stations along the I-95, I-4, I75 and I-295 highways (Calvan 2020). The state will use about $25 million of that settlement to build EV chargers at Florida's Turnpike service plazas. Based on another state level direction, California has instead imposed a mandate that the entire automotive industry in California transition to selling only EVs by 2035, effectively forcing the consumer market into action. The other alternative is to do nothing but build out more charging networks regardless of demand.

Elasticity of Demand:

Measuring the elasticity of demand for any good is a difficult process, with cars, however, this task becomes incredibly difficult. Cars typically only change prices with the release of the next year's model which can have anywhere from minor comfort and trim updates every year to major body and technology overhauls every three to five years. Because the price of a specific new vehicle only changes when a new model is released, it is difficult to track the change in price needed to calculate the elasticity. Even though we know the different quantities sold each year and the price, since each year is technically a different product, we are not able to compare across model years. It is also not practical to compare a vehicle of one model year to other versions of itself (e.g. base vs sport vs luxury) because each trim level is competing in slightly separate markets. A consumer looking to buy a base model vehicle of one brand is most likely compared to other brands' base models and not a sport or luxury model. Although it may be the case that one vehicle's luxury trim level is compared to a higher end vehicle's base model. Nevertheless, this has not stopped people from finding the elasticity of demand for both specific vehicles and vehicles by class.

Using standard and nested logit models, Qin (2014) estimates the elasticity of a compact internal combustion vehicle, such as the Jaguar XF, to be .022 within group and .0015 across group. The Jaguar XF itself has an own-elasticity of .0004 and a cross-elasticity of -6.22. Continuing with examining entry level luxury vehicle brands, we see within group elasticities as low as .429 for Audi and as high as 1.260 for Jaguar

and as low as .0002 for Jaguar and high as .0017 for Mercedes-Benz and BMW across group (Qin, 2014). In 2019, (Xing et al., 2019) estimated the own-price elasticity for gasoline vehicles to be -2.761 and -2.751 for battery electric vehicles. When analysing just the Tesla Model S, they found an own-price elasticity of -2.37 and a cross-price elasticity average of .005 (Xing et al., 2019).

Willingness to Pay

Calculating willingness to pay, the maximum price at which a consumer will buy a product, like calculating elasticities, is a science. As when calculating elasticities, it is important to take into account the vehicle trim level, but also now associated costs such as fuel or electricity, fueling or charging station availability, and climate impact sensitivity. Tanaka et al. found that American consumers were willing to spend $49.8 for each percent decrease in fuel costs and $21.5 for every 10 miles added to the total range of the vehicle (Tanaka et al., 2014). For those consumers for whom carbon emissions were a concern, they were willing to pay $29.0 for each percent decrease in emissions. Because charging an electric vehicle takes considerably more time than fueling an internal combustion vehicle, the charge time must also be considered when calculating willingness to pay. Hidrue et al. found that consumers were willing to pay between $425 and $3250 per hour reduction in charging time and that to reduce a 50 mile recharge from 10 hours to one hour, consumers were willing to pay $5646. They suggest that range anxiety, long charging times, and higher entry prices were consumers' main concerns (Hidrue et al., 2011).

Asides on Willingness to Pay: Ownership Cost and Fuel Savings

As cemented in American culture as cars are, every car owner has a rough idea of how much maintenance and ownership costs will be before purchasing a new internal combustion engine vehicle. In late February of 2020, Investopedia did a brief overview of the least expensive way to own a Tesla Model S 85D, a middle of the line Model S. They found that at the end of five years, the cost of ownership is just over $100k (Page, 2020). Taking advantage of all available offers and calculating fuel and maintenance savings and selling the vehicle back to Tesla brought the five year cost to just under $44k which is about $730 per month (Page, 2020) The cost of purchasing a new Jaguar Xf is $72,950 on the sticker for a model most similar to a Tesla Model S 85D. According to Kelley Blue Book, the equivalent five year old Jaguar XF in good condition could be sold for between $30k and $35k. Assuming the best, the five year cost would be brought down to $38k for five years which is about $583 per month before gas and maintenance costs. A 2019 article on CleanTechnica compared Tesla Model 3 and Honda Civic costs over five years. Each vehicle was compared at three different equivalent trim levels. With as many as possible variables constant, the deciding factor was the cost of fuel vs electricity (Shahan, 2019). Across the five different comparisons of low, moderate, and high gas and electricity prices, they found that the five year ownership costs were roughly equivalent between the two vehicles (Shahan, 2019).

Asides on Willingness to Pay: Road Trip Time Comparisons (Trip time and distance measured with Google Maps)

For many people across the country, the ability to drive long distances to visit relatives for holidays, drive to school out of state, or simply like to vacation in far away places is of the utmost importance. For example, Gus drives back and forth between his home in Framingham, MA and his apartment near Florida Polytechnic University several times each year. Like an electric vehicle owner would, he meticulously plans out his route. Rather than optimizing charging times, Gus optimizes distance between gas stations and has a heavy bias towards BJ's, Costco, and Sam's Club gas stations. Because fueling time is negligible, he tries to get as far as possible between stops without running out of gas. Gus knows that he starts to get fuel anxiety at 315 miles, when his fuel needle is well below empty. His planned route from Lakeland to Framingham has five essential gas stops, with a sixth just before arriving home so that he has a full tank the next day. The average distance between gas stations is 221 miles with a maximum of 261 miles.

Using Tesla's trip builder, we can compare trips from Lakeland to Framingham with a Model 3 Performance which has a range of 315 miles, similar to Gus' maximum willing travel distance. The Tesla trip has 10 essential supercharger stops with an eleventh close to home, so that the two trips are as similar as possible. The average

distance between superchargers is 130 miles with a maximum of 180 miles. Even though the Tesla stops more frequently to charge, Gus' trip is still 13 miles longer due to suboptimal routing towards his preferred gas stations. The Tesla's driving time is also shorter by roughly 18 minutes. The differences between the Tesla and gas trips constitute less than 1% of the total trips. This seems wrong, and it is because it does not take into account fueling or charging times. The Tesla trip builder estimates a total of 4.8 hours will be spent charging. Assuming a total time of five minutes per gas station that Gus stops at, that means that Gus' trip will take more than four hours less than the Tesla's trip.

The Tesla trip builder also estimates gas savings at $32. However, on closer inspection, we find that Gus has a lower dollar per mile driven and the gas savings are less than the $32 estimated. Assuming that the gas costs saved are directly related to charging times, we find that for each dollar saved we are spending nine minutes at a supercharger which comes out to $7.87 per hour. This is significantly less than the $425 per hour charging time found by Hidrue et al (2011). Until the cost savings per hour can meet the consumer's willingness to pay per hour charging, it does not make sense for consumers to choose a Tesla over a traditional gas vehicle for long trips.

Quantitative Analysis on Data from Users and Contextual Meaning:

To obtain more data on the numbers themselves, the team looked at some data provided by current Model 3 owners. For continuity purposes, the owners of the Model 3 have Long-Range Dual Motors, with 19" Sport Wheels, and have Autopilot (Tesla

Motors, 2020), all of which have factors on driving and utility for the driver. However, do note that the total value of the car is nearly $60,500 (Tesla Motors, 2020) and Tesla requires a down-payment of $1,000. In comparison, the average new vehicle in 2019 was roughly $40,000. More on these comparisons later.

The first set of data below was calculated and taken from John Kraus, one of the current Model 3 LR Dual Motor owners we spoke with. John's old data provides an interesting insight into the home charging prices in comparison to supercharger prices.

To completely fill-up the vehicle at home, he spends roughly $9.00. This charge has quite the contrast to what owners of combustion vehicles face per fill-up. Assuming that the average tank size of a car is 14 gallons (average between 12 and 16 gallon tanks) [RocketHQ, 2020), and that gas costs are currently anywhere between $2.00 a gallon to $3.50 (AAA Insurance, 2020), it could take a consumer between $28-$49 to completely fill their vehicle. This is nearly 3 - 5.4 times the amount an electric vehicle driver, who charges strictly at home, faces. The data is further broken down into subdivisions to see more insights.

Home charging

Miles per dollar	34.91
Dollars per mile	$0.0286
Average cost to add full rated miles (322)	$8.8887
Percent per hour	6.52
Miles per hour	20.24

However, these values significantly increase with the supercharging capability. Do note that a better value of the average cost to add full rated miles (322) should truly lie within the $16-$20 range. John's numbers are currently skewed as he calculated these values including the "free miles of charging" he earned from the use of Tesla's referral code program. Even using the maximum end of this range, an owner of the vehicle is not paying as much as they would if they have stayed with their electric vehicle. This data is also further broken down into subdivisions to see more insights.

Supercharging before reimbursement

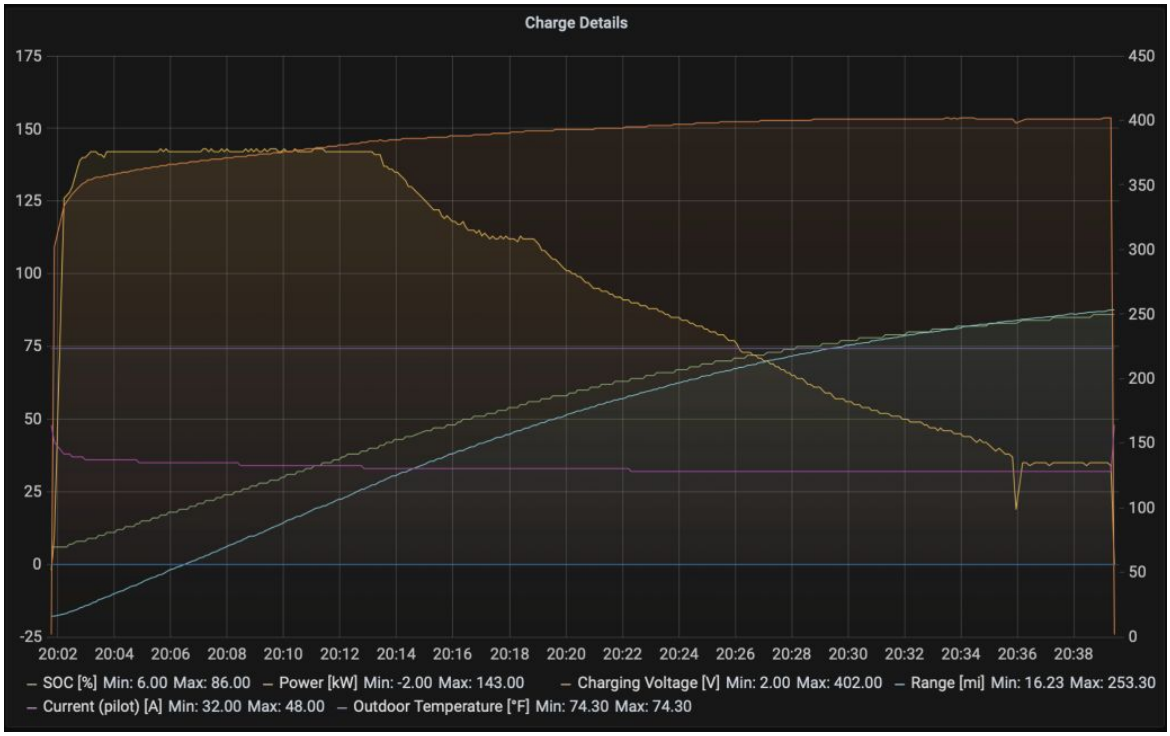
Miles per dollar	25.59
Dollars per mile	$0.0391
Average cost to add full rated miles (322)	$12.0259
Dollars per minute	$0.2455
Miles per minute	6.28

With this in mind, Trevor Mahlmann also shared his data in regards to his Tesla Model 3, named Cobalt. For Trevor, on average he is able to obtain a charge from 0-80% in roughly 6-6.5 hours at home. However, as mentioned in the Level 1 charging literature review, this amount of time is highly dependent on what kind of charger you buy. Average percentage gained per hour is roughly 10%. A different method in determining costs, in comparison to John, Trevor's costs per KwH $0.055/kWh as he bases it off of his value of time of use.

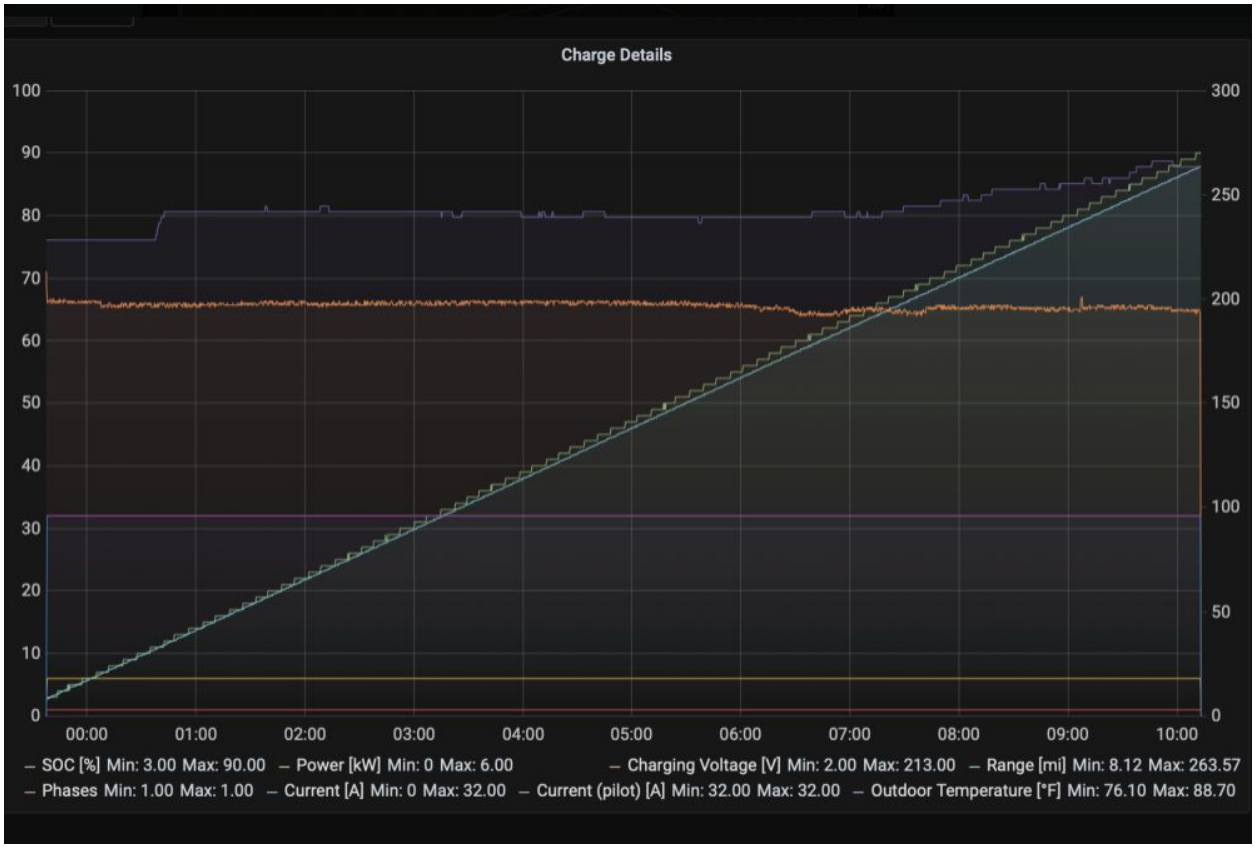
At home charging costs is roughly $4 for a full charge off-peak and roughly $20 for an on-peak charge. DCFC chargers are anywhere ~2-3 and 5-6 times the price of normal electricity. However, similar to John Kraus and Andrew Kaylor, these costs are justified due to the acknowledgement of the required infrastructure and that it is still cheaper than to fill-up a tank of gas.

There is a ~10% difference between the Level 2 charging network / KwH than at home, off peak. These prices become exponentially higher when comparing off-peak to DCFC, as it is roughly five to six times the cost. Off-peak is ~$0.05 / kWh and Supercharging is $0.25-0.30. The main reason for the increase in price? Speed.

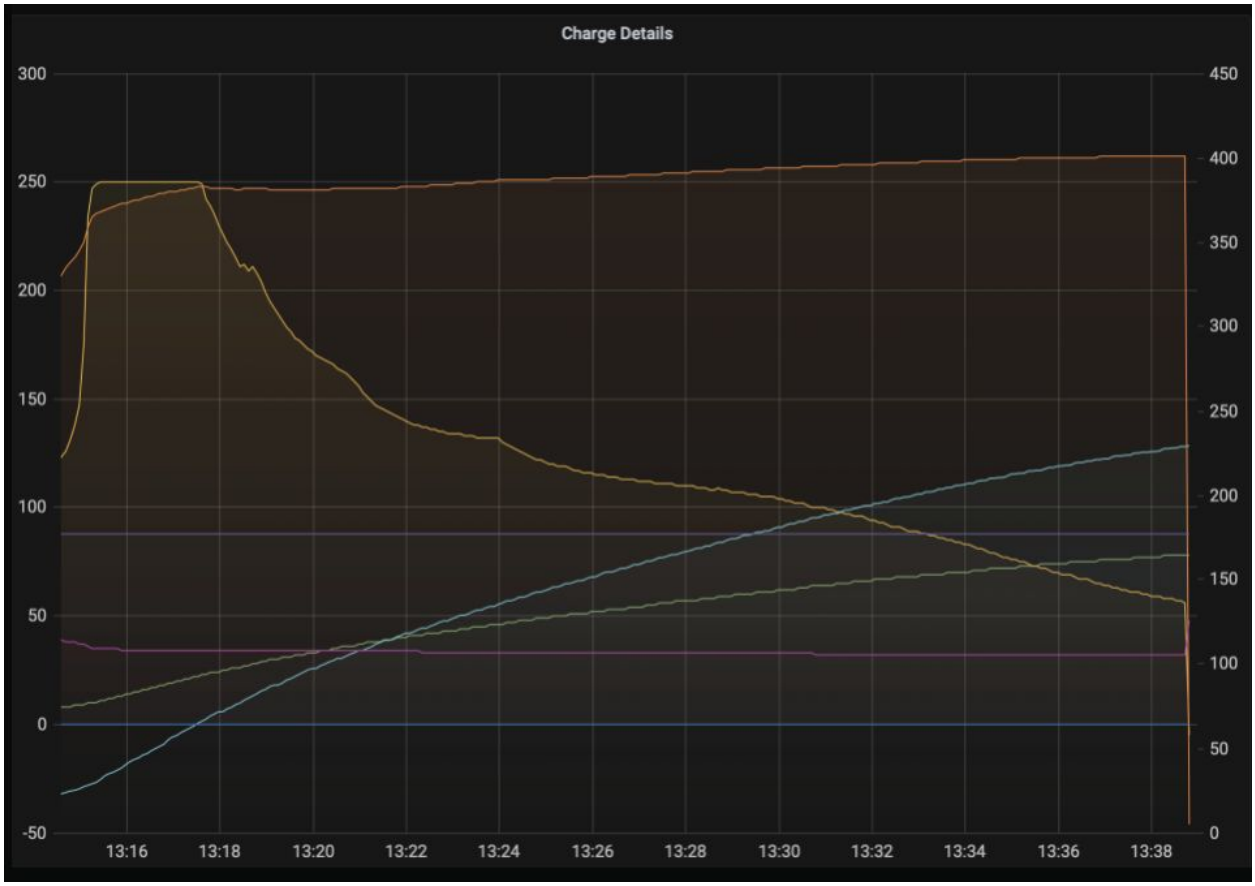
Supercharger networks are incredibly effective at providing consumers a very fast ability to recharge their vehicle. Tesla's Version 3 Supercharger network can provide a vehicle 250 miles of range within nearly 20 minutes; Version 2 Supercharger Networks take just over 30 minutes of charging time. At home charging takes at least twelve times longer.



This graph depicts what is occurring to Trevor's vehicle under DCFC - Supercharging, V2 150kW during peak time at a charger. This is most likely equivalent to what we refer to as Level 2 charging. 250 miles are added within 36 minutes of plug-in. This means roughly seven miles of driving capability is added every minute of charge time. This is quite a decent rate of charge, but certainly takes a decent amount of time.



This graph depicts what is occurring to the vehicle under AC charging over roughly 10 hours at 6kWh. This is most equivalent to what we refer to as Level 1 charging, which often occurs overnight while the consumer is sleeping. 250 miles are added within 10 hours of plug-in. This means roughly 0.4167 miles of driving capability is added every minute of charge time. This is incredibly slow, however is the cheapest option for a consumer due to electricity rates being lower than supercharging rates.



This graph depicts what is occurring to the vehicle under DCFC Supercharging - V3 at 250kW. This is most equivalent to what we refer to as Level 3 charging, and is the fastest rate at which EV's can be charged today. 250 miles are added within minutes of plug-in. This means roughly 11.363 miles of driving capability is added every minute of charge time. DCFC Supercharging at the V3 stations, charging at 250kWh is significantly more expensive however is lightning fast compared to AC Level 1 charging.

Overall, the DCFC Supercharging - V3 at 250kW provides an incredible ability for the vehicle to recharge in a very faster manner. However, as mentioned, the rate at which the consumer must pay for this convenience is roughly five to six times higher

than the cost of charging at home, at a very slow 6 KwH off-peak. For the consumer, the best way to charge, strictly monetarily speaking, is to solely charge at home, which is why nearly 80% of all EV owners do so. However, to minimize the amount of money spent and time charging, it is best to combine a mixture of at home charging and supercharger usage.

For the sake of argument, let us assume that the new Tesla is bought for $60,500, the charging costs for *charging only by the supercharger network* are $16 to obtain a fully charged vehicle, and has maintenance costs of $200 per year. In comparison, a new gas-powered vehicle is purchased for $40,000, has maintenance and repair costs of $600 per year (AAA Insurance, 2020) an average tank size of 12.5 gallons, has an average estimated miles per gallon of 20 mpg (enabling 250 miles per gallon), and gas costs $2.60 per gallon. Both scenarios have the consumer filling up their vehicle, with electricity and gas respectively, traveling 250 miles, and filling up once a week. It would take nearly 17 years for the price of the gas car to exceed the cost of the electric vehicle, should the consumer solely use the supercharger network at that rate, holding everything else constant. This was calculated by taking the initial cost of the vehicle plus the sum of maintenance costs and fill up costs each year. Excluding factors such as the Autopilot, Full-Service Driving Capabilities, and other perks of owning a Tesla, unless the consumer is wanting to keep the vehicle far past the average period a car is held for and about six years after the average lifespan of a

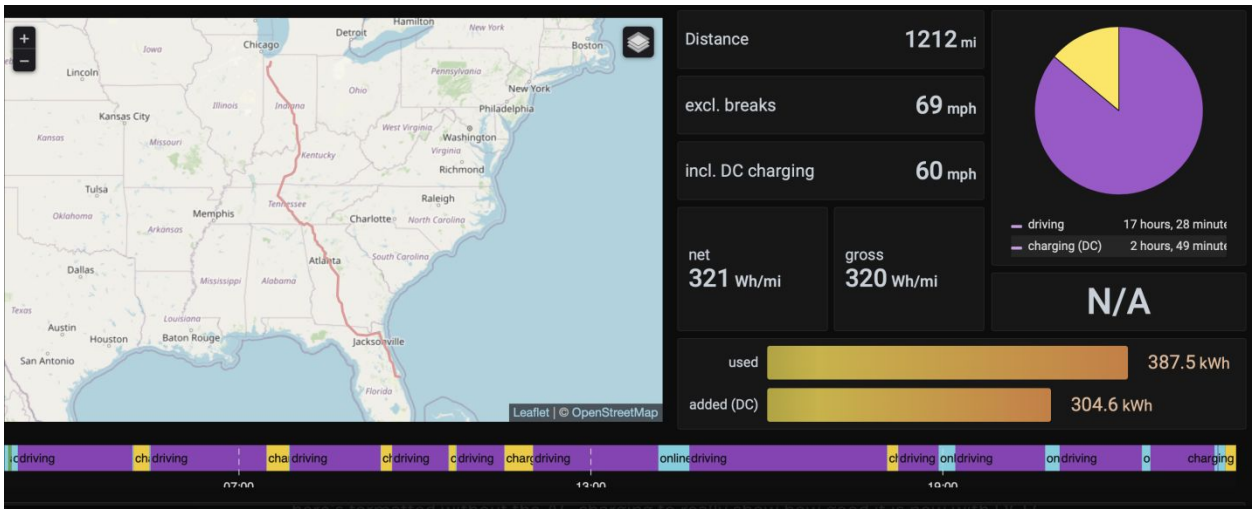
vehicle, simply the costs of owning an electric vehicle do not make sense and cannot be justified by the money alone.

Initial Cost	Maintence Costs	Fillup Costs			20 mpg vehicle	250 miles	per week									
60500	200	832		1032	12.5 gallons per week											
40000	600	1690		2290	gas price of $2.60											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
61532	62564	63596	64628	65660	66692	67724	68756	69788	70820	71852	72884	73916	74948	75980	77012	78044
42290	44580	46870	49160	51450	53740	56030	58320	60610	62900	65190	67480	69770	72060	74350	76640	78930

The Myth of Range Anxiety - (hint: it's a lie):

According to John, Andrew, and Trevor, there is no thought of range anxiety or worry when comparing their Tesla's to their gas-powered vehicles. Being a Tesla customer means you have access to 3rd party charging plus the 20,000 stalls. Natively, Tesla's on screen display (OSD) will provide info on the quantity of public supervision chargers available real time. While the data reported on availability is highly accurate, some chargers do have issues and that's entirely understandable. However, Andrew mentioned that the speed and availability were very reasonably accurate enough to feel comfortable with planning his route. There is full-confidence in Tesla Superchargers being available for charging, but other networks much less so. A supercharger stall stands tall and Tesla signs the spots well to prevent people from parking there. Additionally, the charging network is almost seen as superior to a gas station because they put them frequently near good food options versus gas stations, so consumers can get bathrooms and also good food options /amenities, instead of nasty bathrooms and poorer food options in and near typical gas stations.

The only pitfall is that it can be challenging to determine wait times when charging was at full capacity, but this was not a frequent occurrence fortunately. Most stops are within 20 minutes, which is confirmed by the data above, just enough to make it to the next charging location. Charging while low is “better bang for the buck” as far as return on investment (ROI) on time investment goes; therefore the vehicle typically runs between 5-10% and 70% charge.



For instance, this is a track of Trevor’s most recent road trip from Indiana. Out of the twenty hours it took to arrive, only roughly three hours were spent driving. This means about 85% of the entire drive was spent solely on the road - this is excellent! Trevor mentioned that when he made his stops, he was not solely just sitting there doing nothing; only roughly thirty minutes of that was true waiting time. The other time was time spent doing road trip activities like stretching his legs, using the restroom, eating, etc. Factoring in everything except thirty minutes, it is mentioned that only 0.025% of the trip was “wasted” due to having to stop and use a Supercharger.

Fundamentally, the concept of range anxiety for an electric vehicle is no different than that of a combustion engine. Those who claim otherwise have falsely made preconceived ideas, and if anything, more supercharger stations available should help reduce that anxiety.

Impacted Parties:

State	Lakeland County	Residents

Social Costs	**State**	**Lakeland County**	**Residents**
Costs For Charging Stations	50,000* 5,182 = 259,100,000	1000*1,628,000= 1,628,000 50,000* 22= 1,100,000 2,728,000 total	1,000
Cost to wait for charging	383,468 * 25.19= 9,659,558.92	41,009.32	25.19/per hour
Cost for an EV	0	0	60,000 +
Total	268,759,558	2,769,000	61,025.19-one time costs

Social Benefits	**State**	**Lakeland County**	**Resident**
Reduction in Carbon emissions	212 * 383,468= 81,295,216	212 *1628= 345,136	212
EV	60,000* 383,468 = 23 billion/5 years	60,000 * 1628 = 97,680,000	0
Eliminating purchase of gasoline	498*383,468 =190,967,064	1628*498= 810,744	498
Total	272,262,303	98,835,880	710/per year

We defined Q = # of cars

P = # of gas stations

Our first assumption is for P = we used the elasticity for gas gallons / station, which is -2.37. In determining the Number of gas stations in FL: 7,043, this gives us a total supply, as charging stations would be used in gas station lots. So with a ratio of 1:74 to users we we can determine the total amount of EV users in FL using the market ratio, which is 74 * 7,043 = 521,182 users in FL. With the average of 80% charge at home, we know that the total amount of users at home in FL will be , .8 * 521,182 = 416,945. Meaning that, for public stations, 104,236 users need the availability of public

stations in FL. Looking at the lakeland county level, with 93 gas stations * 74 EV users, we can get an estimate of 6,882 total EV users possible in Lakeland. 6,882 * .8 = 5,505 users charge at home with 1,376 needing public charging stations.

Elasticity for gas = -2.37

Cost for using charging stations: .030 cents per mile

Sensitivity Analysis

Assumptions	State	Lakeland				Users charging in public stations						
					11,008	20	40	80	93	120	140	160
charging stations public	104,236	1,376		Price	$20	160	320	640	744	960	1120	1280
Price/station	168	20			$17	100	200	400	465	600	700	800
Cost/station	136	12			$16	80	160	320	372	480	560	640
					$14	40	80	160	186	240	280	320
					$13	20	40	80	93	120	140	160
					$8	-80	-160	-320	-372	-480	-560	-640
					$6	-118	-236	-472	-548.7	-708	-826	-944

Conclusion:

Overall, there are varying options that the state and county can undertake. The demand for electric vehicles is taking the world and automobile market by storm as climate change becomes more prevalent. Tesla is incredibly exclusive due to the capability of the supercharger network and the requirements to charge at one of their stations. Consumers who are buying an Electric Vehicle, specifically a Tesla, at some point will be using the network. To aid in distilling range anxiety and reduce the amount of charging time, more superchargers must be built. Lakeland, and Florida Polytechnic in particular, is in a great location due to their geographical proximity to I-4, a route with lots of demand for vehicle usage. As the future evolves, Florida Polytechnic and Lakeland have the ability to become leaders at the forefront of this change and fight against climate change, as well as have their own Tesla Supercharger on campus. The

costs for the county and state will increase, but these are offset what it benefits the consumer and the planet. Adding more superchargers enables the ability to grow the electric vehicle market and therefore meet future demand. It is best to invest now for the future's sake, rather than investing in the future.

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Benefit - Cost Analysis -
The Implementation of a Tesla Supercharger in Lakeland, Florida.

Austin Adams, Gus Lipkin, Alex Pierstorff, River Anderson

30 November 2020

Image Source: https://www.pinterest.com/pin/821695894486058631/

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Abstract

In North America, most electric vehicles follow the same universal plug in style. These are more accurately put into three levels: Level 1 (120 volts AC), Level 2 (208-220 volts AC), and Level 3 DCFC (480 volts AC) charging. The alternative to at home charging is public chargers that charge at a significantly higher rate. The purpose of this Benefit-Cost Analysis is to assess the desirability of implementing Tesla charging stations and access the alternative options for City of Lakeland, and Polk County, and state residents in Florida.

Decision to be Analyzed & Literature Review

Tesla Batteries

Tesla states that its battery packs were designed to outlast the cars. The average usage of private passenger cars in the U.S. is 17 years and roughly 200,000 miles (322,000 km). The mileage in Europe is lower - about 130,000 miles (209,000 km). So, we have the first indication that the batteries should last longer than that. Battery capacity is above 85% (on average) after 150,000-200,000 mile After selling more than 1 million electric cars, Tesla's battery degradation data shows that vehicles with mileage between 150,000-200,000 miles (241,000-322,000 km), on average, still have more than 85% of initial battery capacity the battery degradation is below 15%. This is pertinent to the owners of Tesla vehicles because the rate at which their batteries degrade over time is minimal compared to the mileage of the lifetime usage of the vehicle.

A group of Tesla owners on the Dutch-Belgian Tesla Forum are gathering data from over 350 Tesla vehicles across the world and frequently updating it in a public Google file located here: (https://docs.google.com/spreadsheets/d/t024bMoRiDPIDialGnuKPsg/edit#gid=0).

There is previously reported data, but Tesla has since added many more vehicles and those vehicles have been driving a lot more and therefore completing more battery cycles. The data clearly shows that for the first 50,000 miles (100,000 km), most Tesla battery packs will lose about 5% of their capacity, but after the 50,000-mile mark, the capacity loss levels off and it looks like it could take a long time for a pack to degrade by another 5%. This trend suggests that the average battery pack could cycle through over 186k miles (300k km) before coming close to 90% capacity.

When it relates to electric vehicles, battery degradation means not only the loss of battery capacity but also the loss of range over time. This is one of the main concerns of new electric car buyers and can vary greatly based on several factors like battery cell chemistry, battery management system, and usage. Tesla has historically been able to limit degradation to industry-low levels due to its robust battery management system. Real-world data showed that Tesla battery degradation was less than 10% after over 160,000 miles (257,500 km). Interestingly, Tesla used to not clearly cover battery capacity degradation in its warranty until it launched Model 3. With an update to its warranty earlier this year, Tesla now covers all battery capacity degradation in all of its vehicles with a limit of 70% capacity for up to 8 years or 100,000 to 150,000 miles depending on the model. Based on the previously mentioned data, it looks like Tesla won’t have to honor too many warranty battery replacements due to accelerated battery capacity degradation.

Public and Private Charging

Level 1 charging is the default EV charging option. It is accessible to all electric vehicles and all locations that have a standard power outlet. The issue with Level 1 charging is that it is relatively slow. Typically they are 12-16 amps which translates into 2-6 miles of range per hour, and it is commonly referred to as trickle charging.

For faster charging, homeowners can upgrade to Level 2 chargers. These use a 240-volt power outlet, the same as those used by some air conditioners or clothes dryers. Level 2 charging is a lot faster than Level 1 charging, providing 14 to 35 miles of range per hour by taking advantage of the circuit's higher amperage. These charging cords are traditionally sold as a separate add-on for your EV. Because some homes might not have a 240-volt outlet, homeowners may need to work with an electrician to get one installed. You'll want to ensure that the circuit supports a high enough amperage to allow your charge to operate at its peak output to charge your car as fast as possible. For pretty much every EV brand except Tesla, Level 2 chargers use a J1772 port. Tesla has their own Level 2 charging port, however, all Tesla's come with a J1772 adaptor for charging. So, all EVs should be able to take advantage of most public Level 2 charging stations.

Unlike the first two options which use residential AC current, DC fast chargers ,often called Level 3 chargers, use DC current. Because Level 3 chargers provide DC current, they bypass the on-board charger and directly charge the EV's battery meaning that it charges faster providing current to the battery itself rather than going through secondary systems.This allows for very fast charging speeds: they can provide 100 miles of range per hour or more. While Level 3 chargers are fast, manufacturers warn that you should not rely on them as your main charging source. The large amount of power that fast charging stations use can damage your EV battery's health, and potentially shorten its lifespan. It's recommended to only use fast-charging if you need it for long-distance travel or if you are pressed for time. Level 3 chargers are not feasible for home use, as they require special utility connections, hardware, wiring, and permits. They also have extremely high setup and energy costs. You'll only find Level 3 DC charging stations along highways or in other public areas.

In addition to the aforementioned Level 2 stations, the DOE says there are now 3,653 DC fast-charging stations in the U.S., 813 of which are for Teslas. But those numbers don't tell the whole story. First, knowing there's a station doesn't mean you know how many plugs are available; some may have a dozen plugs while others have just one or two. Second, vehicle connectivity is simply one aspect of public charging. After all, gas pumps will work with any car, but you still need to pay for the fuel. And that's where charging networks come in.

Most EV manufacturers include a Level 1 EVC cord set so that no additional charging equipment is required. As a general rule, Level 1 recharging will add approximately four miles of travel per hour. Level 1 charging is the most common form of battery recharging and can typically recharge a EV's batteries overnight; however, a completely depleted EV battery could take up to 20 hours to completely recharge (Groover Combs et al, 2020).

Level 2 recharging will supply up to approximately 15 miles of travel for one hour of charging to vehicles with a 3.3 kW onboard charger, or 30 miles of travel for one hour of charging for vehicles with a 6.6kWh on-board charger. Level 2 EVC utilizes equipment specifically designed to provide accelerated recharging and requires professional electrical installation using a dedicated electrical circuit. Level 2 equipment is available for purchase online or from retailers that sell other residential appliances. A completely depleted EV battery

could be recharged in approximately seven hours using a Level 2 charger (Groover Combs et al, 2020).

DCFC recharging will add approximately 80-100 miles of travel with 20-30 minutes of charging. The DCFC EVC converts AC to DC within the EVC equipment, bypassing the car's charger to provide high-power DC directly to the EV's traction batteries through the charging inlet on the vehicle .While the power supplied to EVs by all DCFCs is standardized, there is not uniform agreement on the connector that is used to connect the charger to the vehicle (Groover Combs et al, 2020).

One of the most revolutionary changes is that of Tesla's very own supercharging network, which represents a large market for both Electric Vehicles and a high demand for charging stations (US Department of Energy, November 2015). The increase in charging stations directly reflects consumer demand for Electric Vehicles. As there is an increase in electric vehicles purchased, there is going to also be an increase in demand for chargers as there needs to be more means for consumers to charge their vehicles outside of '"in-home" charging.

An increase in purchases of Electric Vehicles, the demand for open charging stalls at the stations will also increase. Electric Vehicles and Charging Networks are complementary products. Therefore, as we see the gradual movement away from fossil fuels, electricity as a renewable energy source is increasing in usage and demand. Level 2 and DCFC chargers are going to see an exponential rise in demand due to more electric vehicles being in the market. More consumers are going to want their cars to be charged from these stations, and they will want it to be done incredibly fast. As a result, we will likely see an increase in DCFC chargers and their charging capabilities across the state.

One of the common reasons for choosing EVs is due to the price of gas versus the power consumption. A consumer's willingness to pay for the Electric Vehicle and the costs to charge factors into the demand for Tesla's charging stations and the ability to have a plugin that works at home for cars, as consumers are treated to more Electric vehicles in the market. This will be discussed more in depth later on.

Alternatives to Public Charging Stations

The alternatives to having public charging stations involve having residential private charging stations, at home charging stations and renewable energy power charging stations, at home. The direction for public charging stations is to pay a per kilowatt charge and with Tesla, paying for the charge varies on the package and model year of purchase. For at home charging stations, the costs vary based on the age of the house and community and electrical wiring of the house, which can cost up to an additional $1,000 (Albrecht 2019).

In addition, the Governor of Florida awarded 27 contracts to build charging stations along the I-95, I-4, I75 and I-295 highways (Calvan 2020). Florida will implement EV chargers at Florida's Turnpike service plazas. Based on another state level direction, California has instead imposed a mandate that the entire automotive industry in California transition to selling only EVs by 2035, effectively forcing the consumer market into action.

Demand and Elasticity of Demand for Cars

The analysis for which this paper was created does not actually need elasticity of demand for cars, electric vehicles, or fueling or charging stations. By briefly discussing the elasticity of demand for automobiles, we are able to paint a better picture of the market that creates demand for electric vehicle charging stations and Tesla Superchargers in particular.

Measuring the elasticity of demand for any good is a difficult process, with cars, however, this task becomes incredibly difficult. Cars typically only change prices with the release of the next year's model which can have anywhere from minor comfort and trim updates every year to major body and technology overhauls every three to five years. Because the price of a specific new vehicle only changes when a new model is released, it is difficult to track the change in price needed to calculate the elasticity. Even though we know the different quantities sold each year and the price, since each year is technically a different product, we are not able to compare across model years. It is also not practical to compare a vehicle of one model year to other versions of itself (e.g. base vs sport vs luxury) because each trim level is competing in slightly separate markets. A consumer looking to buy a base model vehicle of one brand is most likely compared to other brands' base models and not a sport or luxury model. Although it may be the case that one vehicle's luxury trim level is compared to a higher end vehicle's base model. Nevertheless, this has not stopped people from finding the elasticity of demand for both specific vehicles and vehicles by class.

Using standard and nested logit models, Qin (2014) estimates the elasticity of a compact internal combustion vehicle, such as the Jaguar XF, to be .022 within group and .0015 across group. As a luxury vehicle, the XF's elasticity will be relatively low and changing the quantity available would not affect the price as much and may in fact increase it if that means that sourcing the appropriate number of materials is more difficult. The Jaguar XF itself has an own-elasticity of .0004 and a cross-elasticity of -6.22 with consideration to other vehicles in the group. Continuing with examining entry level luxury vehicle brands, we see within group elasticities as low as .429 for Audi and as high as 1.260 for Jaguar and as low as .0002 for Jaguar and high as .0017 for Mercedes-Benz and BMW across group (Qin, 2014). In 2019, (Xing et al., 2019) estimated the own-price elasticity for gasoline vehicles to be -2.761 and -2.751 for battery electric vehicles. When analysing just the Tesla Model S, they found an own-price elasticity of -2.37 and a cross-price elasticity average of .005 with other vehicles in the group (Xing et al., 2019).

Willingness to Pay

Calculating willingness to pay, the maximum price at which a consumer will buy a product, like calculating elasticities, is a science. As when calculating elasticities, it is important to take into account the vehicle trim level, but also now associated costs such as fuel or electricity, fueling or charging station availability, and climate impact sensitivity. Tanaka et al. found that American consumers were willing to spend $49.84 for each percent decrease in fuel costs and $21.5 for every 10 miles added to the total range of the vehicle (Tanaka et al., 2014). While these may seem low, it is important to note that the willingness to pay is an upfront cost while the potential savings are over the lifetime of the vehicle. For those consumers for whom carbon emissions were a concern, they were willing to pay $29.00 for each percent decrease in emissions. Because charging an electric vehicle takes considerably more time than fueling an internal combustion vehicle, the charge time must also be considered when calculating willingness to pay. Hidrue et al. found that consumers were willing to pay between $425 and $3250 per hour reduction in charging time and that to reduce a 50 mile recharge from 10 hours to one hour, consumers were willing to pay $5646. They suggest that range anxiety, long charging times, and higher entry prices were consumers' main concerns (Hidrue et al., 2011).

Asides on Willingness to Pay: Ownership Cost and Fuel Savings

As cemented in American culture as cars are, every car owner has a rough idea of how much maintenance and ownership costs will be before purchasing a new internal combustion engine vehicle. In late February of 2020, Investopedia did a brief overview of the least expensive way to own a Tesla Model S 85D, a middle of the line Model S. They found that at the end of five years, the cost of ownership is just over $100k (Page, 2020). Taking advantage of all available offers and calculating fuel and maintenance savings and selling the vehicle back to Tesla brought the five year cost to just under $44k which is about $730 per month (Page, 2020) The cost of purchasing a new Jaguar Xf is $72,950 on the sticker for a model most similar to a Tesla Model S 85D. According to Kelley Blue Book, the equivalent five year old Jaguar XF in good condition could be sold for between $30k and $35k. Assuming the best, the five year cost would be brought down to $38k for five years which is about $583 per month before gas and maintenance costs. A 2019 article on CleanTechnica compared Tesla Model 3 and Honda Civic costs over five years. Each vehicle was compared at three different equivalent trim levels. With as many as possible variables constant, the deciding factor was the cost of fuel vs electricity (Shahan, 2019). Across the five different comparisons of low, moderate, and high gas and electricity prices, they found that the five year ownership costs were roughly equivalent between the two vehicles (Shahan, 2019).

Asides on Willingness to Pay: Road Trip Time Comparisons (Trip time and distance measured with Google Maps)

For many people across the country, the ability to drive long distances to visit relatives for holidays, drive to school out of state, or simply like to vacation in far away places is of the utmost importance. For example, Gus drives back and forth between his home in Framingham, MA and his apartment near Florida Polytechnic University several times each year. Like an electric vehicle owner would, he meticulously plans out his route. Rather than optimizing charging times, Gus optimizes distance between gas stations and has a heavy bias towards BJ's, Costco, and Sam's Club gas stations. Because fueling time is negligible, he tries to get as far as possible between stops without running out of gas. Gus knows that he starts to get fuel anxiety at 315 miles, when his fuel needle is well below empty. His planned route from Lakeland to Framingham has five essential gas stops, with a sixth just before arriving home so that he has a full tank the next day. The average distance between gas stations is 221 miles with a maximum of 261 miles.

Using Tesla's trip builder, we can compare trips from Lakeland to Framingham with a Model 3 Performance which has a range of 315 miles, similar to Gus' maximum willing travel distance. The Tesla trip has 10 essential supercharger stops with an eleventh close to home, so that the two trips are as similar as possible. Even if Gus did own an electric vehicle, it is unrealistic for him to install even a Level 1 charger at home that would have access to the charging port on a car, thus the need for the charging stop close to home. The average distance between superchargers is 130 miles with a maximum of 180 miles. Even though the Tesla stops more frequently to charge, Gus' trip is still 13 miles longer due to suboptimal routing towards his preferred gas stations. The Tesla's driving time is also shorter by roughly 18 minutes. The differences between the Tesla and gas trips constitute less than 1% of the total trips. This seems wrong, and it is because it does not take into account fueling or charging times. The Tesla trip builder estimates a total of 4.8 hours will be spent charging. Assuming a total time of five

minutes per gas station that Gus stops at, that means that Gus' trip will take more than four hours less than the Tesla's trip.

The Tesla trip builder also estimates gas savings at $32. However, on closer inspection, we find that Gus has a lower dollar per mile driven and the gas savings are less than the $32 estimated. Assuming that the gas costs saved are directly related to charging times, we find that for each dollar saved we are spending nine minutes at a supercharger which comes out to $7.87 per hour after adjusting for time Gus would have otherwise spent at a gas station. In 2011, Hidrue et al found that consumers were willing to pay $425 to $3250 up front for each hour decrease in charging time to full. Just after fifty-four total hours of charging and roughly 17,600 miles of driving, Gus would have saved enough money to break even with his initial investment of $425. Over the lifetime of the vehicle, until the cost savings per hour can meet the consumer's willingness to pay per hour charging, it does not make sense for consumers to choose a Tesla over a traditional gas vehicle for long trips.

Quantitative Analysis on Data from Users and Contextual Meaning

To obtain more data, the team looked at some data provided by current Model 3 owners. For continuity purposes, the owners of the Blue Model 3 have Long-Range Dual Motors, with 19" Sport Wheels, and have Autopilot (Tesla Motors, 2020), all of which have factors on driving and utility for the driver. However, do note that the total value of the car is nearly $60,500 (Tesla Motors, 2020) and Tesla requires a down-payment of $1,000. In comparison, the average new vehicle in 2019 was roughly $40,000. More on these comparisons later.

The first set of data below was calculated and taken from John Kraus, one of the current Model 3 LR Dual Motor owners we spoke with. John's old data provides an interesting insight into the home charging prices in comparison to supercharger prices.

To completely fill-up the vehicle at home, he spends roughly $9.00. "At-home costs" are based strictly off the cost per kilowatt hour that the given utility company charges for. This is different from the Supercharging network (and potential referral program promotion), which users directly pay Tesla for their charging. This charge has quite the contrast to what owners of combustion vehicles face per fill-up. Assuming that the average tank size of a car is 14 gallons (average between 12 and 16 gallon tanks) (RocketHQ, 2020), and that gas costs are currently anywhere between $2.00 a gallon to $3.50 (AAA Insurance, 2020), it could take a consumer between $28-$49 to completely fill their vehicle(which is comparable in size of the vehicle, EPA estimates on range, and fuel economy). This is nearly 3 - 5.4 times the amount an electric vehicle driver, who charges strictly at home, faces. The data is further broken down into subdivisions to see more insights.

Home charging	
Miles per dollar	34.91
Dollars per mile	$0.0286
Average cost to add full rated miles (322)	$8.8887
Percent per hour	6.52
Miles per hour	20.24

Table 1: Home Charging Data from John Kraus for his Tesla Model 3 LR Dual Motor

However, these values significantly increase with the supercharging capability. Do note that a better value of the average cost to add full rated miles (322) should truly lie within the $16-$20 range. John's numbers are currently skewed as he calculated these values including the "free miles of charging" he earned from the use of Tesla's referral code program. This referral code program is used strictly at the supercharging networks. Even using the maximum end of this range, an owner of the vehicle is not paying as much as they would if they have stayed with their electric vehicle. This data is also further broken down into subdivisions to see more insights.

Supercharging before reimbursement	
Miles per dollar	25.59
Dollars per mile	$0.0391
Average cost to add full rated miles (322)	$12.0259
Dollars per minute	$0.2455
Miles per minute	6.28

Table 2: Supercharging Data from John Kraus for his Tesla Model 3 LR Dual Motor

With this in mind, Trevor Mahlmann also shared his data in regards to his Tesla Model 3, named Cobalt. For Trevor, on average he is able to obtain a charge from 0-80% in roughly 6-6.5 hours at home. However, as mentioned in the Level 1 charging literature review, this amount of time is highly dependent on what kind of charger you buy. Average percentage gained per hour is roughly 10%. A different method in determining costs, in comparison to John, Trevor's costs per KwH is roughly $0.055/kWh.

At home charging costs is roughly $4 for a full charge off-peak and roughly $20 for an on-peak charge. DCFC chargers are anywhere ~2-3 and 5-6 times the price of normal electricity. However, similar to John Kraus and Andrew Kaylor, these costs are justified due to the

acknowledgement of the required infrastructure and that it is still cheaper than to fill-up a tank of gas.

There is a ~10% difference between the Level 2 charging network / KwH than at home, off peak. These prices become exponentially higher when comparing off-peak to DCFC, as it is roughly five to six times the cost. Off-peak is ~$0.05 / kWh and Supercharging is $0.25-0.30. The main reason for the increase in price? Speed.

Supercharger networks are incredibly effective at providing consumers a very fast ability to recharge their vehicle. Tesla's Version 3 Supercharger network can provide a vehicle 250 miles of range within nearly 20 minutes; Version 2 Supercharger Networks take just over 30 minutes of charging time. At home charging takes at least twelve times longer.

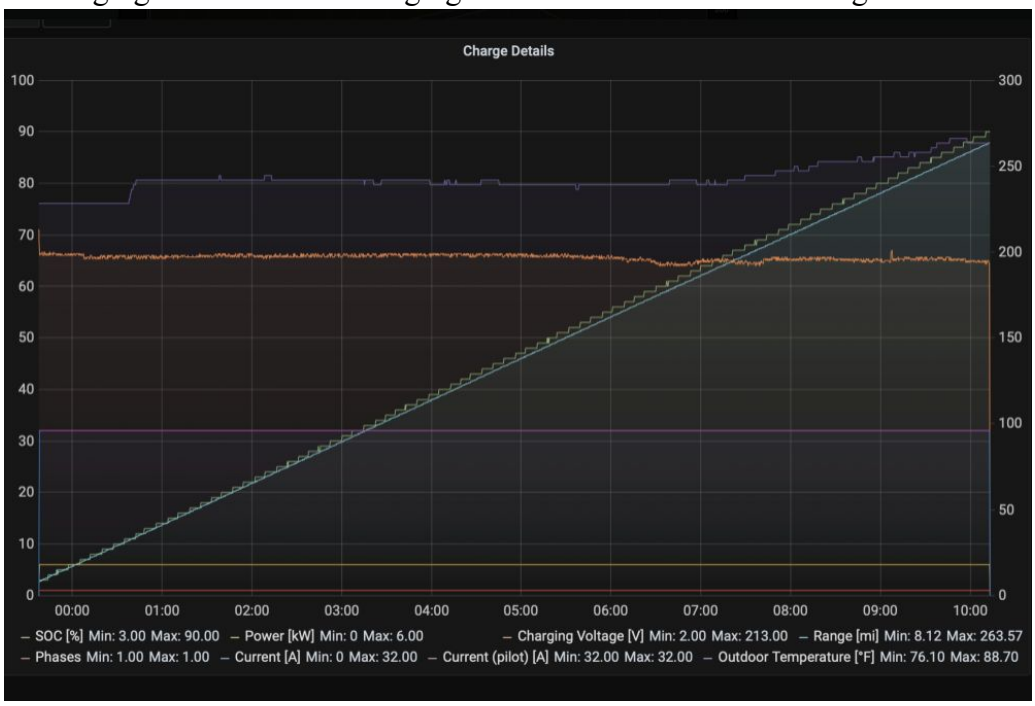

Figure 1: AC Charging from Trevor Mahlmann for his Tesla Model 3 LR Dual Motor over 10 hours at 6kWh (Level 1 Charging)

This graph depicts what is occurring to the vehicle under AC charging over roughly 10 hours at 6kWh. This is most equivalent to what we refer to as Level 1 charging, which often occurs overnight while the consumer is sleeping. 250 miles are added within 10 hours of plug-in. This means roughly 0.4167 miles of driving capability is added every minute of charge time. This is incredibly slow, however is the cheapest option for a consumer due to electricity rates being lower than supercharging rates.

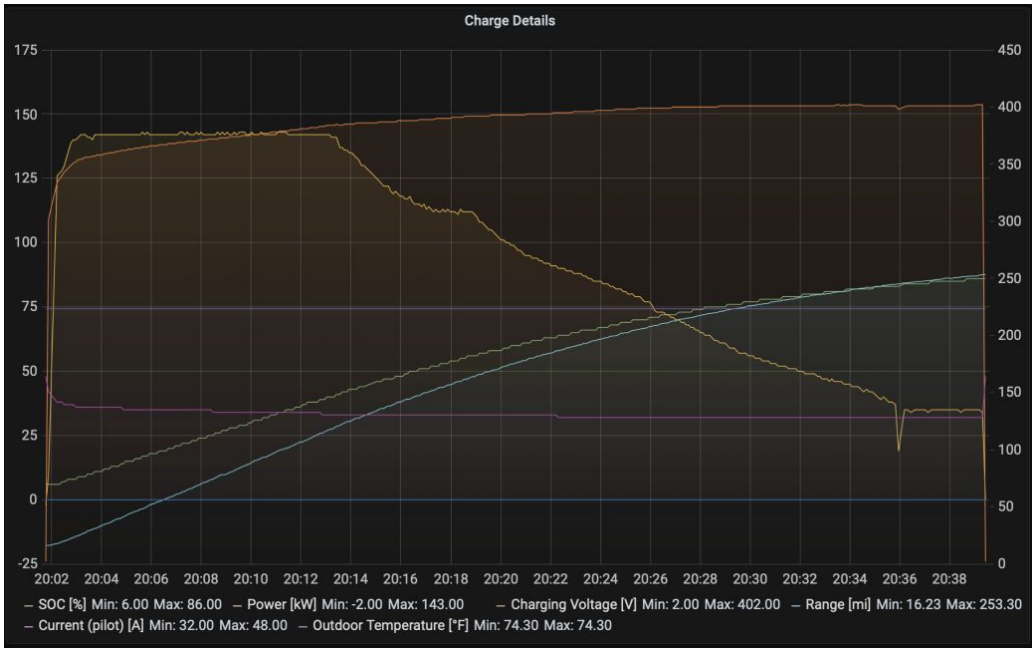

Figure 2: Supercharging Details for Trevor Mahlmann's Tesla Model 3 LR Dual Motor over 36 minutes at 150kWh (Level 2 Charging)

This graph depicts what is occurring to Trevor's vehicle under DCFC - Supercharging, V2 150kW during peak time at a charger. This is most likely equivalent to what we refer to as Level 2 charging. 250 miles are added within 36 minutes of plug-in. This means roughly seven miles of driving capability is added every minute of charge time. This is quite a decent rate of charge, but certainly takes a decent amount of time.

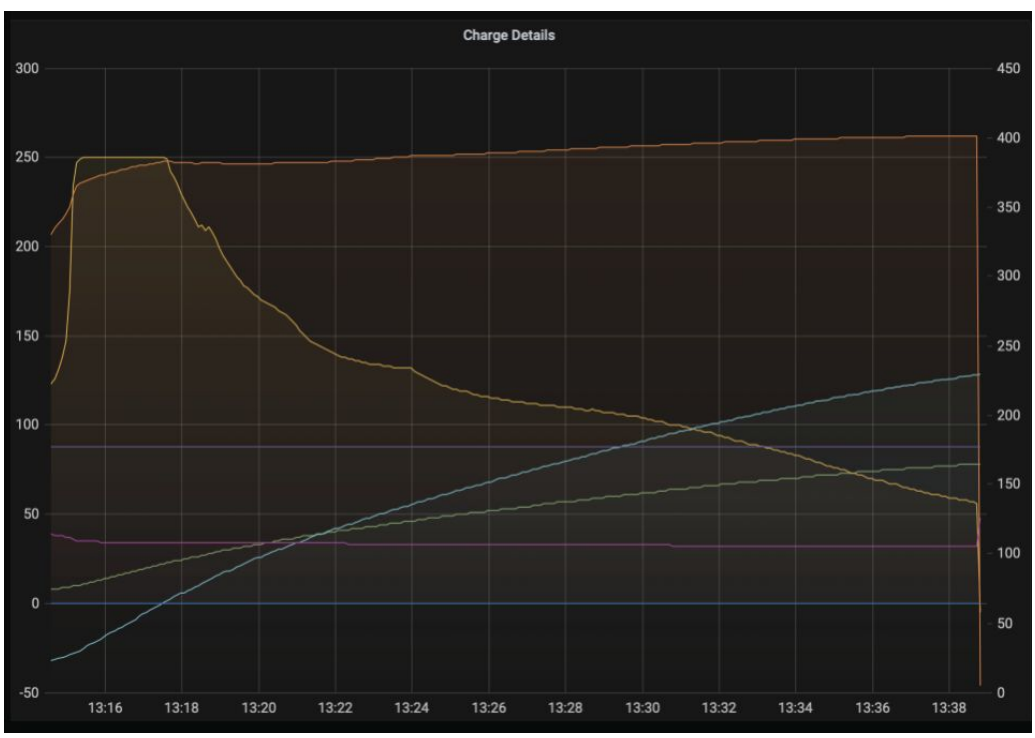

Figure 3: AC Charging from Trevor Mahlmann for his Tesla Model 3 LR Dual Motor over 22.5 minutes at 250kWh (Level 3 Charging)

This graph depicts what is occurring to the vehicle under DCFC Supercharging - V3 at 250kW. This is most equivalent to what we refer to as Level 3 charging, and is the fastest rate at which EV's can be charged today. 250 miles are added within minutes of plug-in. This means roughly 11.363 miles of driving capability is added every minute of charge time. DCFC Supercharging at the V3 stations, charging at 250kWh is significantly more expensive however is lightning fast compared to AC Level 1 charging.

Overall, the DCFC Supercharging - V3 at 250kW provides an incredible ability for the vehicle to recharge in a very faster manner. However, as mentioned, the rate at which the consumer must pay for this convenience is roughly five to six times higher than the cost of charging at home, at a very slow 6 KwH off-peak. For the consumer, the best way to charge, strictly monetarily speaking, is to solely charge at home, which is why nearly 80% of all EV owners do so. However, to minimize the amount of money spent and time charging, it is best to combine a mixture of at home charging and supercharger usage.

For the sake of argument, let us assume that the new Tesla is bought for $60,500, the charging costs for *charging only by the supercharger network* are $16 to obtain a fully charged vehicle, and has maintenance costs of $200 per year. In comparison, a new gas-powered vehicle is purchased for $40,000, has maintenance and repair costs of $600 per year (AAA Insurance, 2020) an average tank size of 12.5 gallons, has an average estimated miles per gallon of 20 mpg (enabling 250 miles per gallon), and gas costs $2.60 per gallon. Both scenarios have the consumer filling up their vehicle, with electricity and gas respectively, traveling 250 miles, and filling up once a week. It would take nearly 17 years for the price of the gas car to exceed the cost of the electric vehicle, should the consumer solely use the supercharger network at that rate, holding everything else constant. This was calculated by taking the initial cost of the vehicle plus the sum of maintenance costs and fill up costs each year. Excluding factors such as the Autopilot, Full-Service Driving Capabilities, and other perks of owning a Tesla, unless the consumer is wanting to keep the vehicle far past the average period a car is held for and about six years after the average lifespan of a vehicle, simply the costs of owning an electric vehicle do not make sense and cannot be justified by the money alone.

Initial Cost	Maintence Costs	Fillup Costs			20 mpg vehicle	250 miles	per week									
60500	200	832		1032	12.5 gallons per week											
40000	600	1690		2290	gas price of $2.60											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
61532	62564	63596	64628	65660	66692	67724	68756	69788	70820	71852	72884	73916	74948	75980	77012	78044
42290	44580	46870	49160	51450	53740	56030	58320	60610	62900	65190	67480	69770	72060	74350	76640	78930

Table 3: Lifetime ownership costs for a Tesla Model 3 an average consumer vehicle

The Myth of Range Anxiety - (hint: it's a lie)

According to John, Andrew, and Trevor, there is no thought of range anxiety or worry when comparing their Tesla's to their gas-powered vehicles. Being a Tesla customer means you have access to 3rd party charging plus the 20,000 Tesla stalls. Natively, Tesla's on screen display (OSD) will provide info on the quantity of public superchargers available real time. While the data reported on availability is highly accurate, some chargers do have issues and that's entirely understandable. However, Andrew mentioned that the speed and availability were very reasonably accurate enough to feel comfortable with planning his route. Some may claim that their result in the middle of nowhere may not feel like a lie, however, this is more a direct result

of poor route planning by the driver rather than the capability of the vehicle (both electric and internal combustion, for this matter).

There is full-confidence in Tesla Superchargers being available for charging, but other networks much less so. A supercharger stall stands tall and Tesla signs the spots well to prevent people from parking there. Additionally, the charging network is almost seen as superior to a gas station because they put them frequently near good food options versus gas stations, so consumers can get bathrooms and also good food options /amenities, instead of nasty bathrooms and poorer food options in and near typical gas stations.

The only pitfall is that it can be challenging to determine wait times when charging was at full capacity, but this was not a frequent occurrence fortunately. Most stops are within 20 minutes, which is confirmed by the data above, just enough to make it to the next charging location. Charging while low is "better bang for the buck" as far as return on investment (ROI) on time investment goes; therefore the vehicle typically runs between 5-10% and 70% charge.

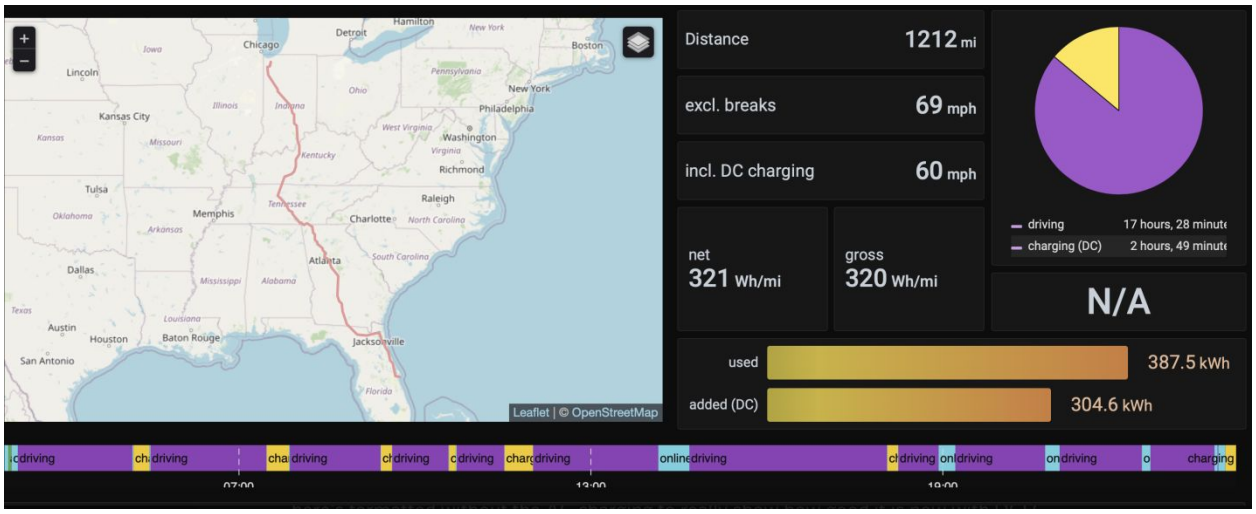

Figure 4: Trevor Mahlmann's trip to FL from IN in his Tesla Model 3 LR Dual Motor

For instance, this is a track of Trevor's most recent road trip from Indiana. Out of the twenty hours it took to arrive, only roughly three hours were spent charging alone. This means about 85% of the entire drive was spent solely on the road - this is excellent! Trevor mentioned that when he made his stops, he was not solely just sitting there doing nothing; only roughly thirty minutes of that was true waiting time. The other time was time spent doing road trip activities like stretching his legs, using the restroom, eating, etc. Factoring in everything except thirty minutes, it is mentioned that only 0.025% of the trip was "wasted" due to having to stop and use a Supercharger.

Fundamentally, the concept of range anxiety for an electric vehicle is no different than that of a combustion engine. Those who claim otherwise have falsely made preconceived ideas, and if anything, more supercharger stations available should help reduce that anxiety.

Impacted Parties

For the benefit-cost analysis of having charging stations, we divided the impacted parties into State, County, and Resident levels. The social costs are the sum of the cost to by a car, the cost of waiting for the vehicle to charge, and the cost of electricity. The benefits are the sum of the benefit by the reduction in carbon emissions and the difference the cost of gas and electricity

for the same distance driven. Net benefits were then found by simply subtracting the costs from the benefits. Also worth noting is that Tesla covers all implementation, maintenance, and upgrade costs to the Supercharger as they consider it their asset. Therefore, the city and state does not have to pay those costs as they are covered by Tesla themselves. The only need is that the Superchargers are near areas that have the capability for high capacity electric output. This is why they are conveniently located near gas stations and large retail complexes. Tesla also implements solar panels to aid in the reduction of their costs. This information came from Tesla - Fremont Director of Manufacturing - Freddy Rivera.

Calculations and Sensitivity Analysis

	State	***Lakeland***	***Resident***
Social Cost			
Upfront to buy car = $60,500	$0.00	$0.00	$60,500.00
Cost for waiting = $15/hr	$0.00	$0.00	$429,000.00
Cost for electricity = $0.25/kWh	$0.00	$0.00	$7,150.00
Total Costs	**$0.00**	**$0.00**	**$496,650.00**
Social Benefits	-	-	-
Social Benefit in reduction of Carbon Emissions (Standard = 212)	$110,490,584.00	$1,458,984.00	$212.00
Money saved by not buying gas (cost of gas - cost of electricity)	$0.00	$0.00	$23,270.00
Total Benefits	**$110,490,584.00**	**$1,458,984.00**	**$23,482.00**
	-	-	-
Net Benefits = SB - SC	**$110,490,584.00**	**$1,458,984.00**	**-$473,168.00**

Table 4: Net Benefit Calculations for Current Values

This table indicates the total amount of Social Benefits and Costs for each entity that has standing. The up-front costs to buy a vehicle only pertains to the resident as they are the ones with the asset. The cost for waiting while charging is multiplied by the amount of time to charge per hour, 52 weeks in a year, $15 valued worth of time, and 1,500 cycled charges, the estimated lifespan of a Tesla vehicle, to fully charge. The state and county governments have no standing. The cost for electricity is ultimately always transferred to the consumer for their consumption. The state and county governments have no costs in this because they are already producing electricity for neighboring retail businesses and because Tesla covers all costs of the install, maintenance, servicing, and upgrades to the charger.

For Social Benefits, according to the EPA each consumer, in general, contributes $212 in carbon emissions due to the usage of internal combustion engines. This is assuming that their actions of having a Tesla and using a supercharger forgo all carbon emissions and footprint. The benefits calculated for the county and state are from an extrapolation of data by multiplying by the number of EV owners in each category.

The number of gas stations in FL: 7,043, this gives us a total supply, as charging stations would be used in gas station lots. So with a ratio of 1:74 to users we we can estimate the total amount of EV users in FL using the market ratio, which is 74*(7,043) = 521,182 users in FL. Looking at the Lakeland County level, with 93 gas stations*74 EV users, we can get an estimate of 6,882 total EV users possible in Lakeland.

Taking the amount, in dollars, for carbon reduction multiplied by the 6,882 estimate of EV drivers in Lakeland is how Lakeland's benefit is attained. The state's benefit in carbon reduction is attained by taking the 521,182 possible EV drivers and multiplying the $212 dollars by it. The benefits for the resident for ridding their consumption of gasoline is the average of 7.8 gallons, multiplied by $2.6 / gallon, multiplied by 1,500 fuelings (to mirror that of a Tesla), minus the cost for electricity found in the prior section. Taking the Benefits - Costs, we receive the net benefits. For the state the total net benefits of a supercharger is: **$110,490,584.00,** for the county of Lakeland, the net benefits is **$1,458,984.00** and for the average Tesla owning resident the net benefits are: **-$473,168.00.** Clearly, having a supercharger is in the best interest of the state and county. However, the cost of the resident/owner of the EV is so high because strictly due to the individual's value of their time and how long it takes to charge. However, a reduction in the amount of time, primarily due to advancing technology, should aid in bringing these costs down.

The following below is our sensitivity analysis changing the constraints from each section in the benefits and costs:

Default Values are in Green	***Net Benefits***	***% Change Net Benefits from Default***
	Cells in light green are better than default and cells in red are worse than default	*Cells in light green are better than default and cells in red are worse than default*

Key 1: Describes How to Read Tables 5-11

Change in the Time Value	***State***	***Lakeland***	***Resident***	***State***	***Lakeland***	***Resident***
15	$110,490,584.00	$1,458,984.00	-$473,168.00	0.00%	0.00%	0.00%
8.46	$110,490,584.00	$1,458,984.00	-$286,124.00	0.00%	0.00%	39.53%
13	$110,490,584.00	$1,458,984.00	-$415,968.00	0.00%	0.00%	12.09%
50	$110,490,584.00	$1,458,984.00	-$1,474,168.00	0.00%	0.00%	-211.55%
100	$110,490,584.00	$1,458,984.00	-$2,904,168.00	0.00%	0.00%	-513.77%

Table 5: Net Benefits when the Value of Time is Changed

In the table above, it analyzes how much the net benefits change given that there is a change in an individual's value of their time. The numbers show that should a person value their time less, the net benefits for the residents/owners of the EV improve between 12.09% and ~40%. However, should they value their time much higher, like most millionaires and others of high social standing would, the net benefits of charging drastically decrease. Due to the higher cost of purchasing an EV over an ICE vehicle, EV owners are more likely to be those that place a higher value on their time. Changing the value of an individual's time has a significant result on net benefits. The value of time is highly sensitive.

Change in the Cost for Electricity	***State***	***Lakeland***	***Resident***	***State***	***Lakeland***	***Resident***

0.25	$110,490,584.00	$1,458,984.00	-$473,168.00	0.00%	0.00%	0.00%
0.2	$110,490,584.00	$1,458,984.00	-$470,308.00	0.00%	0.00%	0.60%
0.23	$110,490,584.00	$1,458,984.00	-$472,024.00	0.00%	0.00%	0.24%
0.3	$110,490,584.00	$1,458,984.00	-$476,028.00	0.00%	0.00%	-0.60%

Table 6: Net Benefits when the Cost of Electricity is Changed

Holding everything else constant, the team looked at what an impact in the cost for electricity and how that would affect the overall benefits. In the calculations above, the team used an average of $0.25 per Kilowatt hour for charging. This number was a result of conversations with Trevor Malhmann, Andrew Kaylor, and John Kraus. Of course a lower rate per kilowatt hour of charge improves the net benefits for a consumer. However, the rate at which this occurs is marginally low. Should the price increase, consumers are impacted, but not by more than ~$4,000.00. The best thing for consumers would be for the cost-rate of supercharging to decrease over time, which is likely to occur due to more consumers and Tesla's master plan of everyone driving affordable, electric vehicles. The numbers indicate these numbers are not too sensitive.

Change in the Charge Time for 250 Miles	***State***	***Lakeland***	***Resident***	***State***	***Lakeland***	***Resident***
22	$110,490,584.00	$1,458,984.00	-$473,168.00	0.00%	0.00%	0.00%
21	$110,490,584.00	$1,458,984.00	-$453,018.00	0.00%	0.00%	4.26%
20	$110,490,584.00	$1,458,984.00	-$432,868.00	0.00%	0.00%	8.52%
15	$110,490,584.00	$1,458,984.00	-$332,118.00	0.00%	0.00%	29.81%
10	$110,490,584.00	$1,458,984.00	-$231,368.00	0.00%	0.00%	51.10%

Table 7: Net Benefits when the Time to Charge to 250 Miles is Changed

The team also looked at the charging rate. Currently, it takes roughly 22 minutes on DCFC charging to obtain 250 miles from empty. Any reduction in charging time significantly affects the net benefits that consumers experience. A one minute decrease in charging time improves net benefits by 4.26%. Should Tesla be able to have a vehicle that can supercharge within ten minutes, holding everything else constant, the net benefits a consumer would witness would increase by nearly 51%! The team is optimistic that reduction in charging times are likely to occur due to the rapid advancement in battery and charging technologies. Eve though battery capacities will also increase in the future, the technology to charge faster is evolving more rapidly and thus charging times will only ever decrease. These numbers are very sensitive as charging time is one of the largest costs that consumers experience.

Change in the Carbon Offset Value	***State***	***Lakeland***	***Resident***	***State***	***Lakeland***	***Resident***
212	$110,490,584.00	$1,458,984.00	-$473,168.00	0.00%	0.00%	0.00%
100	$52,118,200.00	$688,200.00	-$473,280.00	-52.83%	-52.83%	-0.02%
150	$78,177,300.00	$1,032,300.00	-$473,230.00	-29.25%	-29.25%	-0.01%
250	$130,295,500.00	$1,720,500.00	-$473,130.00	17.92%	17.92%	0.01%
300	$156,354,600.00	$2,064,600.00	-$473,080.00	41.51%	41.51%	0.02%

Table 8: Net Benefits when the Carbon Offset Value is Changed

Another area to investigate was impacts if the ~$212 in Carbon Offset values given by the EPA were incorrect. The values of $100 and $150 were used in case the $212 was an overestimation. The calculated net benefit shows that it nearly has no impact on the resident but drastic impacts for the state of Florida and Lakeland County. Should the value the team went with, the net benefits are negatively affected by nearly 52% and ~30%. The same is true with its opposite. Should the $212 be an underestimation, and a higher value, such as $250 or $300 be more accurate, net benefits increase by ~18% and ~41.5%. The values of offsetting carbon are very sensitive towards the final values.

Percent Change in the Quantity of EV Drivers	***State***	***Lakeland***	***Resident***	***State***	***Lakeland***	***Resident***
0	$110,490,584.00	$1,458,984.00	-$473,168.00	0.00%	0.00%	0.00%
-30	$77,343,408.80	$1,021,288.80	-$473,168.00	-30.00%	-30.00%	0.00%
-20	$88,392,467.20	$1,167,187.20	-$473,168.00	-20.00%	-20.00%	0.00%
-5	$104,966,054.80	$1,386,034.80	-$473,168.00	-5.00%	-5.00%	0.00%
5	$116,015,113.20	$1,531,933.20	-$473,168.00	5.00%	5.00%	0.00%
10	$121,539,642.40	$1,604,882.40	-$473,168.00	10.00%	10.00%	0.00%
30	$143,637,759.20	$1,896,679.20	-$473,168.00	30.00%	30.00%	0.00%

Table 9: Net Benefits when a Quantity of Drivers Switch to an EV

Another constraint observed was the quantity of EV drivers in the state and county. The values on the far left indicate a percent change on our projections. Because these values are a percent change and benefits and costs are being calculated on an individual level, these directly correspond to the percent change in net benefits seen at the county and state level. As such, these values are only as sensitive as the rest of the calculation.

Change in the Gas Cost	***State***	***Lakeland***	***Resident***	***State***	***Lakeland***	***Resident***
$2.60	$110,490,584.00	$1,458,984.00	-$473,168.00	0.00%	0.00%	0.00%
$1.00	$110,490,584.00	$1,458,984.00	-$491,888.00	0.00%	0.00%	-3.96%
$2.00	$110,490,584.00	$1,458,984.00	-$480,188.00	0.00%	0.00%	-1.48%
$3.00	$110,490,584.00	$1,458,984.00	-$468,488.00	0.00%	0.00%	0.99%
$3.50	$110,490,584.00	$1,458,984.00	-$462,638.00	0.00%	0.00%	2.23%

Table 10: Net Benefits when the Cost of Gas Changes

Another constraint worthy of analysis is looking at variations in gas prices. Should the gas prices for the consumer be higher where they live, for instance New York or California, the consumer will save a significant amount of money by switching to electric. Ridding themselves of paying higher gas prices increases their net benefits by ~1-2.25%. However, should gas be significantly cheaper where they live, for instance like Texas and other states in the Midwest, the change of gas cost significantly affects their net benefits. A resulting dropoff between 1.5-4% in net benefits occurs. This could be indicative of why EV adoption is higher in states with higher gas rates, like California and New York, and less adoption occurs in other states, like Texas. However an exterior analysis would be needed to confirm those hypotheses. Ultimately, higher

gas prices positively affect the net benefits a consumer experiences by having an EV and utilizing supercharger capabilities.

Change in the Gallons Needed to Drive 250 Miles	State	Lakeland	Resident		State	Lakeland	Resident
7.8	$110,490,584.00	$1,458,984.00	-$473,168.00		0.00%	0.00%	0.00%
5	$110,490,584.00	$1,458,984.00	-$484,088.00		0.00%	0.00%	-2.31%
7	$110,490,584.00	$1,458,984.00	-$476,288.00		0.00%	0.00%	-0.66%
8	$110,490,584.00	$1,458,984.00	-$472,388.00		0.00%	0.00%	0.16%
12	$110,490,584.00	$1,458,984.00	-$456,788.00		0.00%	0.00%	3.46%
15	$110,490,584.00	$1,458,984.00	-$445,088.00		0.00%	0.00%	5.93%

Table 11: Net Benefits when the Gallons of Gas Needed to Drive 250 Miles Changes

Lastly, the team looked at potential variances in the quantity of gas needed to drive 250 miles. Should the car be highly fuel efficient and have incredible miles per gallon, it negatively affects the net benefit a consumer faces - between ~0.66 - 2.3%. However, most of the cars today on the market are not this fuel efficient. Additionally, Tesla's Model 3 and Model S, are capable of driving a much further distance. Though solely an EPA estimate, it is rumored that the Model S can drive over 400 miles before needing a charge - which is incredible for the EV market! Should the consumer be switching over from a less fuel efficient vehicle, such as a Hummer, Jeep, or Cadillac, the estimates are that they are to receive a greater benefit by having an electric vehicle and using supercharging capabilities. The less fuel efficient the vehicle was prior to switch, the greater the net benefits a consumer is set to experience.

Overall, the numbers indicate that it is certainly in the benefit of the Florida state government and Lakeland County to install a supercharger as they only experience benefits from this. All costs are directly covered by Tesla or transferred to the end consumer of the supercharging station. For consumers, they have a negative net benefit. However, this is primarily due to the amount of time needed to wait and the individual's self-proclaimed value of their time. However, this is an area in which the market is moving and battery and charging technology is exponentially becoming better and more efficient. The ideal situation for the supercharger is that of: having a consumer that undervalues their time, pays roughly $0.2-$0.25 per kilowatt hour for charging, an incredibly fast charging capability, high value in the carbon that is offset, an underestimation of EV drivers in the state and county, more expensive gas prices and poor MPG of an older vehicle prompting a change to a Tesla-built electric vehicle. The future is bright for the county and state should they implement this supercharger station.

Conclusion

Overall, there are varying options that the state and county can undertake. The costs for the county and state are nothing as Tesla covers the costs for implementation and views the charger as their asset. The bulk of the costs are primarily on the consumer. However, consumers are leading this market shift and appear to be "ok" or unaware of the costs that they are facing. The biggest costs that consumers experience are a direct result of the amount of time spent charging and their personal value of their time. However, technology will become better and charging times should decrease as Tesla grows. The costs also offset how these decisions affect the derived benefits to the consumer and the planet. Adding more superchargers enables the

ability to grow the electric vehicle market and therefore meet future demand. It is best to invest now for the future's sake, rather than investing in the future.

Moreover, the demand for electric vehicles is taking the world and automobile market by storm as climate change becomes more prevalent. This is strengthened by the fact that more companies, almost weekly, are moving towards creating Electric Vehicles and having their products more "green." Tesla is incredibly exclusive due to the capability of the supercharger network and the requirements to charge at one of their stations. Consumers who are buying an Electric Vehicle, specifically a Tesla, at some point will be using the network. To aid in quelling range anxiety and reduce the amount of charging time, more superchargers must be built. Lakeland, and Florida Polytechnic in particular, is in a great location due to their geographical proximity to I-4, a route with lots of demand for vehicle usage. As the future becomes the present, Florida Polytechnic and Lakeland have the ability to become leaders at the forefront of this change and fight against climate change, as well as have their own Tesla Supercharger on campus. Since the bulk of charging is done at home and the benefits that the state and county will experience, it is a "no-brainer" to place a supercharger in Lakeland County.

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