Now we move to the topic of quantitative change. Not only the question of which direction, but how much in that direction.

We might be interested in the “how much” question. For planning purposes, we may be interested not only in what direction, but how much in a given direction we will move as a result of a given policy.

For this, we will see that the shape of the curves matter. How steep are our curves?

Let us consider a shift in the demand curve. Where the new equilibrium lies will depend on the slope of the supply curve.

Say for example that the price of beef goes up and we are still considering our processed pork example.

We could do it by an equation by equation approach, or a graph by graph approach.

Review the impact of the price of beef going from 4 to 5.

Q=171-20*p+(20*4)+(3*3.33)+(2*12.5)
Q=286-20*p
Compared to:
Q=171-20*p+(20*5)+(3*3.33)+(2*12.5)
Q=306-20*p
If the price of beef goes from 4 to five, and chicken price and income is constant,

<table>
<thead>
<tr>
<th>Price</th>
<th>Quantity if p_b=4</th>
<th>Quantity if p_b=5</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>286-20*5 = 186</td>
<td>306-20*5 = 206</td>
</tr>
<tr>
<td>4</td>
<td>286-20*4 = 206</td>
<td>306-20*4 = 226</td>
</tr>
<tr>
<td>3</td>
<td>286-20*3 = 226</td>
<td>306-20*3 = 246</td>
</tr>
<tr>
<td>2</td>
<td>286-20*2 = 246</td>
<td>306-20*2 = 266</td>
</tr>
<tr>
<td>1</td>
<td>286-20*1 = 266</td>
<td>306-20*1 = 286</td>
</tr>
</tbody>
</table>

Supply curves:

Consider a supply curve defined by \( Q^s=55+50*p \)

Originally given \( Q^s=88+40*p \)

Consider another supply curve defined by \( Q^s=121+30*p \)

<table>
<thead>
<tr>
<th>Price</th>
<th>( Q^s=55+50*p ) “flat”</th>
<th>( Q^s=88+40*p ) “original”</th>
<th>( Q^s=121+30*p ) “steep”</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>55+50*5=305</td>
<td>88+40*5=288</td>
<td>121+30*5=271</td>
</tr>
<tr>
<td>4</td>
<td>55+50*4=255</td>
<td>88+40*4=248</td>
<td>121+30*4=241</td>
</tr>
<tr>
<td>3</td>
<td>55+50*3=205</td>
<td>88+40*3=208</td>
<td>121+30*3=211</td>
</tr>
<tr>
<td>2</td>
<td>55+50*2=155</td>
<td>88+40*2=168</td>
<td>121+30*2=171</td>
</tr>
<tr>
<td>1</td>
<td>55+50*1=105</td>
<td>88+40*1=128</td>
<td>121+30*1=151</td>
</tr>
</tbody>
</table>

[How did I get these supply curves? I wanted them to all pass through $3.30, 220, so I plugged these in and moved the slope from 40 to 50 and then to 30 and in each case solved for the intercept term. To graph them, I solved for p as a function of q – for example p=(1/40)*q-(88/40)]
Add in the issue of demand shift:

What are the different implications?
“flat”
306-20*p=55+50*p
p=$3.59, q=234

“original”
306-20*p=88+40*p
p=$3.63, q=233

“steep”
306-20*p=121+30*p
p=$3.70, q=232

These are made up numbers, but it does show that the underlying numbers that determine the shape of the curve matter for where you end up in equilibrium if things change.
In many cases, we can use a simple measure of sensitivity to capture important information about quantitative change.

This is elasticity, a unitless, summary measure of sensitivity.

**Elasticity.**

The percentage change in one variable as a response to a given percentage change in another variable.

\[
\frac{\% \text{ change } y}{\% \text{ change } x}
\]

Supply Elasticity:

\[
\eta = \frac{\% \Delta Q_s}{\% \Delta p}
\]

eta = % change in quantity supplied divided by % change in price.

The symbol for change is delta, \( \Delta \).

\[
\frac{\Delta Q_s}{Q_s}, \quad \frac{\Delta Q}{\Delta p} \cdot \frac{p}{Q}
\]

Alternatively, define it as or
Below one for a supply elasticity we call inelastic. 
1 is unit elastic. 
Above one is elastic. 
Infinity extremes are perfectly elastic, zero is perfectly inelastic.

Note:
1) ______elastic____|_____inelastic____|___elastic____
\[ \infty \quad -1 \quad 0 \quad 1 \quad \infty \]
2) Intuition behind word “elastic”.
3) Calculus link.

When elasticity is between -1 and 1, we call it inelastic.

When elasticity is equal to -1 or 1 we call it a unitary elastic.

When elasticity is less than -1 or greater than 1 we call it elastic.

[absolute value]

When elasticity is negative or positively infinity it is perfectly elastic.

When elasticity is zero it is perfectly inelastic.

Also can speak of elasticity in terms of absolute value: Less than one in absolute value is inelastic, greater than one is elastic.
“flat”
Try the calculation for \( Q_s = 55 + 50p \), that led us to the \( p = \$3.59 \), \( q = 234 \) pair. Remember that we moved from an equilibrium pair of \((3.30, 220)\).

Change in \( q \): 220 to 234 = 14 units \( q \)
Change in \( p \): 3.30 to 3.59 = \$0.29

<table>
<thead>
<tr>
<th>( \frac{\Delta Q_s}{Q_s} )</th>
<th>( \frac{\Delta Q}{\Delta p} \cdot \frac{p}{Q} )</th>
<th>( \eta = \frac{%\Delta Q_s}{%\Delta p} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \frac{14\text{KG}}{220\text{KG}} ) ( \cdot ) ( \frac{$0.29}{$3.30} )</td>
<td>( \frac{14\text{KG}}{220\text{KG}} ) ( \cdot ) ( \frac{$3.30}{220\text{KG}} )</td>
<td>( %\Delta Q = \frac{14\text{KG}}{220\text{KG}} = 6.36% ) ( %\Delta p = \frac{$0.29}{$3.30} = 8.79% )</td>
</tr>
</tbody>
</table>

\( \eta = 0.72 \)
“original”
Consider the original curve. Remember that we moved from an equilibrium pair of (3.30, 220) to the equilibrium pair (3.63, 233) when we used $Q_s = 88 + 40p$.

Change in q: 220 to 233 = 13 units q
Change in p: 3.30 to 3.63 = 33 cents

\[
\begin{align*}
\Delta Q_s &= \frac{233 - 220}{220} = 0.635 \\
\Delta Q &= \frac{233}{220} \\
\Delta p &= \frac{3.63 - 3.30}{3.30} \\
\eta &= \frac{\%\Delta Q_s}{\%\Delta p}
\end{align*}
\]

\[
\begin{align*}
\frac{13}{220} &= \frac{13}{220} \\
\frac{0.33}{3.30} &= \frac{0.33}{3.30} \\
\frac{3.30}{220} &= \frac{3.30}{220} \\
\end{align*}
\]

%$\Delta Q = (13/220) = 5.9\%$
%$\Delta p = (0.33/3.30) = 10\%$

$\eta = 0.59$
“steep”
How about the $Q=121+30*p$ supply curve that took us to $p=$3.70, $q=232$ when demand shifted?
  Change in $q$: 220 to 232 = 12 units q
  Change in $p$: 3.30 to 3.70 = 40 cents

<table>
<thead>
<tr>
<th>$\frac{\Delta Q_s}{Q_s}$</th>
<th>$\frac{\Delta Q}{\Delta p} \cdot \frac{p}{Q}$</th>
<th>$\eta = \frac{%\Delta Q_s}{%\Delta p}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{12KG}{220KG}$</td>
<td>$(\frac{12KG}{$0.40}) \cdot (\frac{$3.30}{220KG})$</td>
<td>$%\Delta Q = (12KG / 220KG) = 5.45%$</td>
</tr>
<tr>
<td>$\frac{$0.40}{$3.30}$</td>
<td></td>
<td>$%\Delta p = ($0.40 / $3.30) = 12.1%$</td>
</tr>
</tbody>
</table>

$\eta=0.45$
Which was the most sensitive to a change in price when we think of % change in quantity? The one with the highest elasticity has the highest change in the quantity supplied for a given % change in price. That is our $55+50*p$ supply curve (‘flat’). Which has the lowest elasticity? The steepest has the least % change in Q for the given % change in price.

This is a general pattern to keep in mind, but don’t get too caught up in. A flatter curve as drawn above has more response in quantity for a given change in price than a steeper curve. Steep curves tend to be inelastic (price change does not bring about much change in quantity).
In demand analysis, we are often interested in the price elasticity of the quantity demanded.

What is the percentage change in the quantity demanded, divided by the percentage change in the price?

Use the Greek letter epsilon, \( \varepsilon \).
Recall that the symbol for change is delta, \( \Delta \).

\[
\varepsilon = \frac{\%\Delta Q_d}{\%\Delta p} = \frac{\Delta Q}{\Delta p} \cdot \frac{Q}{p}
\]

Can state this in an equivalent fashion.

\[
\varepsilon = \left( \frac{\Delta Q}{\Delta p} \right) \cdot \left( \frac{p}{Q} \right)
\]

Now, in our demand shift case, we don’t have the information we need for the elasticity calculation from the previous example where we calculated a supply elasticity.

NOTE: THE PRICE ELASTICITY OF DEMAND IS ABOUT MOVEMENT ALONG A DEMAND CURVE, NOT A SHIFT IN A DEMAND CURVE. We had a demand shift giving us two points on the supply curve in each case above to work with. Now for the demand
elasticity, I have to generate some kind of supply shift to get a similar story going.

So, go back to our original story yet again.

\[ Q^d = 286 - 20p \]
\[ Q^s = 88 + 40p \]

Remember, this took us to the equilibrium point \( p = 3.30, \) \( q = 220. \)

Compare alternative demand curves, as I did before for the alternative supply curves. I will pick one steeper, one flatter.
Supply ->
If we have the given supply shift, we can see along the alternative demand curves. Recall that the processed pork supply curve was a function of the hog price. Assume the hog price decreases from $1.50 to $1.00. This leads to a downward shift in supply (I can produce more pork at a given selling price since my input cost decreased).

\[ Q_s = 118 + 40p \] according to the information in the book.
(and again recall $3.30, 220 is how we start)

Consider three alternative demand curves.

“flat”
The flattest case is \( Q_d = 484 - 80p \)? Solve for the new equilibrium, find \( p = $3.05, q = 240 \).

Change in \( q \) is 20.
Change in \( p \) is -$0.25.

\[
\begin{array}{c|c|c}
\frac{\Delta Q_D}{Q_D} & \frac{\Delta Q}{\Delta p} \cdot \frac{p}{Q} & \varepsilon = \frac{\% \Delta Q_D}{\% \Delta p} \\
\hline
\frac{20KG}{220KG} & \left( \frac{20KG}{-80.25} \right) \cdot \left( \frac{$3.30}{220KG} \right) & \% \Delta Q = \left( \frac{20KG}{220KG} \right) = 9.1\% \\
\frac{-80.25}{$3.30} & & \% \Delta p = \left( \frac{-80.25}{$3.30} \right) = -7.6\% \\
\end{array}
\]

\( \varepsilon = -1.2 \)
The original case $Q_d=286-20*p$? Solve for the new equilibrium, find $p=2.80$, $q=230$.

Change in $q$ is 10.
Change in $p$ is -$0.50$.

<table>
<thead>
<tr>
<th>$\frac{\Delta Q_d}{Q_d}$</th>
<th>$\frac{\Delta Q}{\Delta p}$ \cdot $\frac{p}{Q}$</th>
<th>$\varepsilon = \frac{% \Delta Q_d}{% \Delta p}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{10KG}{220KG}$</td>
<td>$\left( \frac{10KG}{-0.50} \right) \cdot \left( \frac{3.30}{220KG} \right)$</td>
<td>$% \Delta Q = \frac{10KG}{220KG} = 4.5%$</td>
</tr>
<tr>
<td>$-0.50$</td>
<td>$% \Delta p = \left( -\frac{0.50}{3.30} \right)$</td>
<td>$% \Delta p = -15.2%$</td>
</tr>
</tbody>
</table>

$\varepsilon = -0.3$
“steep”
Solve for $Q_d = 253 - 10*p$. If you solve this one for the new equilibrium after the shift, you get $p = 2.70$, $q = 226$.

Change in $q$: 220 to 226 = 6 units $q$
Change in $p$: 3.30 to 2.70 = $-0.60$

<table>
<thead>
<tr>
<th>$\Delta Q_D$</th>
<th>$\Delta Q \cdot \frac{p}{Q}$</th>
<th>$\varepsilon = \frac{% \Delta Q_D}{% \Delta p}$</th>
</tr>
</thead>
</table>
| $\frac{6KG}{220KG}$ | $\frac{6KG}{-0.60}$ \cdot $\frac{3.30}{220KG}$ | $\% \Delta Q = \frac{6KG}{220KG} = 2.7\%$
| $-0.60$ | $\frac{-0.60}{3.30}$ | $\% \Delta p = \frac{-0.60}{3.30} = -18.2\%$

$\varepsilon = -0.15$

For supply elasticities we found: 0.72, 0.59, 0.45.
For demand elasticities we found: -1.2, -0.3, -0.15

Place these on number line, contrast:
Supply elasticities tend to be on the positive side.
Demand elasticities are always on the negative side.
Inelastic and elastic areas.
Realize that a calculated elasticity may only be applicable in the neighborhood of the equilibrium, not for the entire demand curve.

Note that these calculations are for a given point on the curve. Take the example of the baseline curve, that had a constant slope of $-(1/20)$. $Q^d=286-20*p$ that is expressed as inverse demand of $p=14.3-0.05*q$.

<table>
<thead>
<tr>
<th>Price</th>
<th>Quantity if $p_b=4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>286-20*5 = 186</td>
</tr>
<tr>
<td>4</td>
<td>286-20*4 = 206</td>
</tr>
<tr>
<td>3</td>
<td>286-20*3 = 226</td>
</tr>
<tr>
<td>2</td>
<td>286-20*2 = 246</td>
</tr>
<tr>
<td>1</td>
<td>286-20*1 = 266</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Δp</th>
<th>ΔQ</th>
<th>p</th>
<th>Q</th>
<th>ε</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-20</td>
<td>1</td>
<td>266</td>
<td>-0.08</td>
</tr>
<tr>
<td>1</td>
<td>-20</td>
<td>2</td>
<td>246</td>
<td>-0.16</td>
</tr>
<tr>
<td>1</td>
<td>-20</td>
<td>3</td>
<td>226</td>
<td>-0.27</td>
</tr>
<tr>
<td>1</td>
<td>-20</td>
<td>4</td>
<td>206</td>
<td>-0.39</td>
</tr>
</tbody>
</table>
A constant slope is not the same as a constant elasticity.

Elasticity is a result relevant to the area around your equilibrium.
Two other elasticities used in demand analysis: now we are looking at sensitivity of “shifts” in the curve, rather than sensitivity in terms of movement along in response to a shift. A change in the all else equal set of variables.

Income Elasticity
What is the percentage change in the quantity demanded, divided by the percentage change in the income level that brings about this change in quantity demanded?

\[ \xi = \frac{\Delta Q}{\Delta Y} \cdot \frac{Q}{Y} \]

\(\xi\) is the greek symbol used here.
Take the example of the pigs again. Recall the baseline equation:

\[ Q = 171 - 20 \cdot p_p + 20 \cdot p_b + 3 \cdot p_c + 2 \cdot Y \]

\[ P_b=4, P_c=3.333, Y=12.5 \]

Assume a one unit change in income from 12.5 to 13.5, so you can use the coefficient on the income variable in the quantity demanded equation.

Also, recall the baseline equilibrium result of: \((p^*, q^*) = ($3.30, 220)\).

\[ 220 = 171 - 20 \cdot 3.30 + 20 \cdot 4 + 3 \cdot 3.33 + 2 \cdot 12.5 \]
\[ 222 = 171 - 20 \cdot 3.30 + 20 \cdot 4 + 3 \cdot 3.33 + 2 \cdot 13.5 \]

Change in q? 2.

Q? 220.

Change in Y? We assumed it to be 1.

Y? 12.5.
\[ \frac{\Delta Q_D}{Q_D} \cdot \frac{Y}{\Delta Y} = \varepsilon = \frac{\% \Delta Q_D}{\% \Delta Y} \]

\[
\begin{array}{c|c|c}
\frac{2KG}{220KG} & \left( \frac{2KG}{1.00} \right) \cdot \left( \frac{12.50}{220KG} \right) & \% \Delta Q = (2KG / 220KG) = .91% \\
\frac{1.00}{12.50} & & \% \Delta Y = ($1.00 / $12.50) = 8.0% \\
\end{array}
\]

\[ \xi = \frac{25}{220}, \text{or} \quad 0.114 \]

A normal good is one for which the income elasticity is positive.

An inferior good is one for which the income elasticity is negative.

Inferior goods tend to be things like staple foods. Not a "bad", mind you, but something that you will consume less of as your income increases.

Brazil 1974-75. Income elasticity for cassava, -1.59, for rice, 0.172, for milk 0.147, for eggs, 0.630.

Shows the relationship between income and quantity demanded holding prices constant.

Example of economic models of the demand for children: are children a normal or inferior good?
Cross Price Elasticity
What is the percentage change in the quantity demanded, divided by the percentage change in the price of another good that brings about this change in quantity demanded?

\[ \varepsilon = \frac{\Delta Q_1}{\Delta p_2} \frac{Q_1}{p_2} \]

\[ Q = 171 - 20 \cdot p_p + 20 \cdot p_b + 3 \cdot p_c + 2 \cdot Y \]

\[ p_b = 4, \ p_c = 3.333, \ Y = 12.5 \]

Where there are two goods: good one and good two. Think of the pork example, and think a one unit change in the price of beef.

\[ 220 = 171 - 20 \cdot 3.30 + 20 \cdot 4 + 3 \cdot 3.333 + 2 \cdot 12.5 \]

\[ 240 = 171 - 20 \cdot 3.30 + 20 \cdot 5 + 3 \cdot 3.333 + 2 \cdot 12.5 \]
Change in $Q$? 20.
$Q$? 220.
Change in price of beef? We pick 1 dollar for ease of computation.

$$\frac{\Delta Q_D}{Q_D} \cdot \frac{p}{\Delta p} \cdot \frac{\Delta Q}{Q}$$

$$\varepsilon = \frac{\% \Delta Q_D}{\% \Delta p}$$

<table>
<thead>
<tr>
<th>$\frac{20KG}{220KG}$</th>
<th>$\frac{$1.00}{$4.00}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{20KG}{$1.00}$</td>
<td>$\frac{$4.00}{220KG}$</td>
</tr>
<tr>
<td>%$\Delta Q = \left( \frac{20KG}{220KG} \right)$ = 9.1%</td>
<td>%$\Delta p = \left( \frac{$1.00}{$4.00} \right)$ = 25%</td>
</tr>
</tbody>
</table>

Mix ingredients, and you get 0.36. If you want to practice, try the chicken price changing by one dollar and you should get 0.045.

A complement of a good is one for which the cross price elasticity is negative. (A 1% increase in the price of bacon leads to a -% change in the quantity demanded of eggs).

A substitute of a good is one for which the cross price elasticity is positive. (A 1% increase in the price of bacon leads to a + % change in the quantity demanded of sausage).
What have we found with the beef example here – a complement or a substitute for processed pork?
What does an elasticity mean?

Let’s go back to demand elasticities.

Goods that are relatively price inelastic mean that a large change in price leads to a relatively small change in the quantity demanded of the good.

Goods that are relatively price elastic mean that a small change in price leads to a relatively large change in the quantity demanded.

What determines the degree of elasticity?

1) Closeness of substitutes.
2) Time period over which these substitutes can be obtained.
Long run versus short run elasticities.

Goods tend to be more price inelastic in the short run, and more elastic in the long run.

<table>
<thead>
<tr>
<th></th>
<th>Short Run</th>
<th>Long Run</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>-0.2</td>
<td>-0.5</td>
</tr>
<tr>
<td>HH Electricity</td>
<td>-0.1</td>
<td>-1.9</td>
</tr>
<tr>
<td>Air Travel</td>
<td>-0.1</td>
<td>-2.4</td>
</tr>
<tr>
<td>Intercity bus travel</td>
<td>-2.0</td>
<td>-2.2</td>
</tr>
</tbody>
</table>

Elasticity example:

Washington DC needed money in 1980, and they increased the excise tax on gasoline sold in the district by 6%. If we use the short run elasticity example here, what percent reduction in demand should we predict?

\[-0.2 = \frac{\text{change in } Q}{6\%}\], a 1.2% reduction.

In the long run, a 3% reduction.

What happened? Well, six months after implementing the policy, sales of gasoline in the district had reduced 33%. What is the implied price elasticity of demand? \[-33\%/6\%, \text{ or } -5.5\].

They repealed the tax after five months. What went wrong?
The competitive model.

Willingness to pay (WTP). The maximum amount a consumer will spend for an extra unit of the good.

As we derived a demand curve for an individual’s preferences, we can interpret the demand curve tracing out the consumer’s marginal willingness to pay at different levels of consumption.

Consumer surplus (CS) – the monetary difference between what the consumer is willing to pay for a given quantity of good and what the good costs.

[show graph]

Relies on the fact that the demand curve is downward sloping and that the price for purchasing is the same for all units.

The area under the demand curve and above the price line.

The area below the price line is expenditure (p times q).
Producer surplus. The difference between the minimum amount necessary for the seller to be willing to produce the good and the selling price.

[show graph]

Relies on the fact that the supply curve is derived from the underlying marginal cost curve.

Producer surplus is revenue minus variable cost. Since profit is revenue minus cost, the difference between profit and producer surplus is fixed cost in the short run, and there is no difference in the long run.
The maximum societal welfare comes from maximizing consumer surplus plus producer surplus.

Why are there gains to trade?

[show graph of when quantity is too low]

[ show graph of when quantity is too high]
Pareto optimality. An allocation of resources is Pareto optimal when it is not possible through any feasible changes in the resource allocation to benefit one person without making at least one other person worse off.

If an allocation is not Pareto optimal, it is not economically efficient. An allocation is inefficient when it is possible through some feasible change in the allocation of resources to make at least one person better off without making any other person worse off.

If an economy does not arrive at a Pareto optimal outcome, it has suffered from market failure.

An outcome Pareto improves on another outcome if it makes at least one person better off using existing resources without making any other person worse off.

See figure 4.1 on page 56
1) *Specific tax.* For every unit of the good purchased, the government collects a given amount per unit.

We can distinguish between a tax placed on consumers and a tax placed on producers. A specific tax is often denoted as a tax of size tau (τ).

Import tariff: tax on imports of size tau, tax is not imposed on domestic producers.