Perfectly Competitive Markets

1. What is Perfect Competition?
2. Supply Decision
3. Short-Run Equilibrium
4. Long-Run Equilibrium
Introduction

• Nakao Growers, Inc. is one of the largest of the 250 rose growers in the United States
• It accounts for less than 5% of US production
• Typical rose grower accounts for less than 1%
• Its production decisions have no effect on the market price
  – key decision is how many rose stems to produce given the market price

Why Study Perfect Competition?

• Many other markets are approximately perfectly competitive, such as
  – most agricultural products
  – minerals and metals
  – oil tanker shipping
• Tools and concepts that we will develop here will also be useful when we study other market structures
  – profit maximization
  – role of marginal revenue and marginal costs
  – entry/exit decisions
What is Perfect Competition?

1. uniform products: consumers regard them as identical
2. buyers and sellers have perfect information about prices
3. buyers and sellers too small to influence product and input prices
4. firms (existing and potential) have equal access to resources

The Law of One Price
Price Taking Behavior
Free Entry

Profit Maximization

- What are “economic profits”?  
  - Sales Revenue - Economic (opportunity) Cost  
- Example: You operate your own business

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales revenue</td>
<td>$1M</td>
</tr>
<tr>
<td>Cost of supplies and labor</td>
<td>$850K</td>
</tr>
<tr>
<td>Your best outside offer</td>
<td>$200K</td>
</tr>
</tbody>
</table>

Accounting profit = $1M − $850K = $150K

Economic profit = $1M − $850K − $200K = −$50K
Profit Maximization

• Owner is an investor who put his $500K down to start the business
• Best return he could get alternatively is 12% - or $60K a year
• Economic cost includes this return as opportunity cost of capital

\[ \text{Economic profit} = \$1M - \$850K - \$60K = \$90K \]

Profit Maximization

• Economic profit is given by
\[ \pi(Q) = TR(Q) - TC(Q) \]
\[ = PQ - TC(Q) \]
• The firm chooses \( Q \) to maximize profits
• Remember:
  \[ MR > MC \] → Produce more
  \[ MR < MC \] → Produce less
  \[ MR = MC \] → Optimal
Example

\[ TC(Q) = 24Q - .9Q^2 + (.05/3)Q^3 \]

\[ P = 15 \]

\[ TR(Q) = 15Q \]

\[ \pi(Q) = 15Q - 24Q + .9Q^2 - (.05/3)Q^3 \]

\[ MC(Q) = 24 - 1.8Q + .05Q^2 \]

\[ MR(Q) = 15 \]

\[ MC(Q) = MR(Q) \]

\[ 15 = 24 - 1.8Q + .05Q^2 \]

\[ Q = 6 \text{ or } Q = 30? \]

Profit Maximization

- Two conditions for profit maximization:
  - \[ P = MC(Q) \]
  - MC is increasing
- Is that it?
- You have to check the endpoint \( Q = 0 \)
- \( \pi(0) = 0 < \pi(30) \)
Supply Decision of a Firm

\[ P = MC(Q^*) \]

First order condition

Second order condition

\[ \pi(Q^*) \geq \pi(0) \] Produce \( Q^* \)

\[ \pi(Q^*) < \pi(0) \] Produce 0

Short-Run Equilibrium

Short-run:

- there are fixed inputs (costs)
- number of firms in the industry is fixed

\[ STC(Q) = \begin{cases} SFC + NSFC + TVC(Q), & Q > 0 \\ SFC, & Q = 0 \end{cases} \]

\( STC \) = short-run total costs
\( SFC \) = sunk fixed costs
  - not avoidable even when \( Q = 0 \)
\( NSFC \) = non-sunk fixed costs
  - can be avoided by setting \( Q = 0 \)
\( TVC \) = total variable costs
  - non-sunk
Offshore Oil Rigs

There are numerous independent contractors hired by petroleum companies (e.g. Shell) to operate offshore oil rigs.

For a contractor quantity of output is the number of wells drilled within a particular period of time.

<table>
<thead>
<tr>
<th>Variable Costs</th>
<th>Fixed Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drilling Supplies</td>
<td>Maintenance</td>
</tr>
<tr>
<td>Fuel</td>
<td>Food</td>
</tr>
<tr>
<td></td>
<td>Medical Care</td>
</tr>
<tr>
<td></td>
<td>Wages</td>
</tr>
<tr>
<td></td>
<td>Insurance</td>
</tr>
</tbody>
</table>

Which of the fixed costs are sunk depends on the period of time during which the rig will stay idle (i.e., produce zero output).
Offshore Oil Rigs

*Hot stacking:* rig is taken out of service temporarily (perhaps for a few weeks), but remains fully staffed and ready on short notice to begin drilling again
- all fixed costs are sunk

*Warm stacking:* rig is taken out of service temporarily for a longer period of time (perhaps for a few months)
- some maintenance and some labor costs are non-sunk

*Cold stacking:* rig is taken out of service for a significant amount of time. The crew is laid off and the doors are welded shut.
- only insurance costs are sunk

---

Short-Run Supply when NSFC = 0

This implies TFC = SFC

Profit maximization conditions: Given P supply is given by the following conditions

1. \( P = MC(Q) \)
2. MC increasing

3. \( \pi(Q) > \pi(0) \) \( \iff \) \( PQ - TVC(Q) - TFC > - TFC \)

\( PQ > TVC(Q) \)

\( P > AVC(Q) \)
Price is $P_1$

$P = MC \implies Q = Q_1$

MC increasing

$P > AVC(Q_1)$

$S(P_1) = Q_1$

Price is $P_2$

$P = MC \implies Q = Q_2$

MC increasing

$P > AVC(Q_2)$

$S(P_2) = Q_2$

Price is $P_3$

$P = MC \implies Q = Q_3$

MC increasing

$P < AVC(Q_3)$

$S(P_3) = 0$

$P_s = \text{shut-down price (min AVC)}$

For any price below $P_s$ supply is zero
1. **Positive Economic Profits**

2. **Negative Economic Profits**

3. Min **AVC** = 0.25

4. **Example: Oil Rig Contractor**

   - **STC(Q) = 8 + 0.25Q + 0.5Q^2**
   - **SAC(Q) = 8/Q + 0.25 + 0.5Q**
   - **AVC(Q) = 0.25 + 0.5Q**
   - **SMC(Q) = 0.25 + Q**

\[ P = \text{SMAC}(Q) \]
\[ P = 0.25 + Q \]
\[ Q = P - 0.25 \]

**1.** MC is always increasing

\[ S(P) = \begin{cases} 
  P - 0.25, & \text{if } P \geq 0.25 \\
  0, & \text{if } P < 0.25 
\end{cases} \]

To find min **AC**, set **AC** = **MC** and solve

\[ 0.25 + Q = \frac{8}{Q} + 0.25 + 0.5Q \]
\[ 0.5Q = \frac{8}{Q} \]
\[ Q^2 = 16 \implies Q = 4 \]

Min **AC** = \[\frac{8}{4} + 0.25 + 0.625 = 4.25\]

**P = 10.25** -> **S = 10** -> **SAC = 6.05**

**Profits** = \[(10.25 - 6.05)10 = 42\]
Short-Run Supply when NSFC > 0

TFC = SFC + NSFC

Profit maximization conditions: Given P supply is given by the following conditions

1. \( P = MC(Q) \)
2. MC increasing
3. \( \pi(Q) > \pi(0) \)

\[
PQ - TVC(Q) - TFC > - SFC
\]

\[
PQ > TVC(Q) + NSFC
\]

\[
P > AVC(Q) + NSFC/Q
\]

average nonsunk cost (ANSC)

Example: Oil Rig Contractor

\[
SFC = $6\text{ mil}
\]

\[
NSFC = $2\text{ mil}
\]

\[
TVC(Q) = 0.25Q + 0.5Q^2
\]

\[
STC(Q) = 8 + 0.25Q + 0.5Q^2
\]

\[
SAC(Q) = \frac{8}{Q} + 0.25 + 0.5Q
\]

\[
AVC(Q) = 0.25 + 0.5Q
\]

\[
ANSC(Q) = \frac{2}{Q} + 0.25 + 0.5Q
\]

\[
SMC(Q) = 0.25 + Q
\]

\[
\text{min ANSC} = 2.25
\]

\[
P = 2.25
\]

\[
S(P) = \begin{cases} 
P - 0.25, & \text{if } P \geq 2.25 \\
0, & \text{if } P < 2.25 
\end{cases}
\]

To find min ANSC, set MC = ANSC and solve

\[
0.25 + Q = \frac{2}{Q} + 0.25 + 0.5Q
\]

\[
0.5Q = \frac{2}{Q}
\]

\[
Q^2 = 4 \implies Q = 2
\]

\[
\text{min AC} = \frac{3}{2} + 0.25 + 0.5(2) = 2.25
\]
Supply when all costs are sunk:
if price is below $0.25 mil the oil rig is hot stacked

Supply when some costs are nonsunk:
if price is expected to stay under $2.25 mil for a significant amount of time the rig is warm (or cold) stacked.

\[
\text{min SAC 4.25} \quad \text{if price is expected to stay below $4.25 mil for a long period of time, the rig should shut down and the contractor should leave the business.}
\]

Short-Run Market Supply Curve
Number of firms is fixed: market supply is the sum of individual supplies

There are 100 of each type of firms

\[
S(P) = \begin{cases} 
0, & P < 0.25 \\
100(P - 0.25), & 0.25 \leq P < 0.50 \\
100(2P - 0.75), & 0.50 \leq P < 0.75 \\
100(3P - 1.50), & P \geq 0.75 
\end{cases}
\]

This assumes that the input prices do not change as market supply changes.
Short-Run Market Equilibrium

Typical oil rig contractor

\[ S(P) = \begin{cases} 
P - 0.25, & \text{if } P \geq 0.25 \\
0, & \text{if } P < 0.25 
\end{cases} \]

Market Supply (100 identical firms)

\[ S(P) = \begin{cases} 
100(P - 0.25), & \text{if } P \geq 0.25 \\
0, & \text{if } P < 0.25 
\end{cases} \]

Market Demand

\[ D(P) = 825 - 100P \]

Market Equilibrium

\[ 825 - 100P = 100P - 25 \]

\[ P = 4.25 \]

\[ Q = 400 \]

Short-Run Market Equilibrium: Comparative Statics

Initially the firms are making zero profits.

But now suppose the market demand curve shifts up. The new demand function is given by

\[ D'(P) = 975 - 100P \]

New market Equilibrium

\[ 975 - 100P = 100P - 25 \]

\[ P = 5 \]

\[ Q = 475 \]
Short-Run Market Equilibrium: Comparative Statics

Suppose the market demand curve shifts down. The new demand function is given by

\[ D'(P) = 575 - 100P \]

New market Equilibrium

\[ 575 - 100P = 100P - 25 \]
\[ P = 3 \]
\[ Q = 275 \]

Suppose the market demand curve shifts down. The new demand function is given by

\[ D'(P/) = 400 - S \]
\[ D(P/) = 275 - 3Q \]
\[ 400 - S = 275 - 3Q \]
\[ S = 100 + 100Q - 275Q \]
\[ S = 100 + 100Q - 275Q \]

Long-Run Firm Supply

In the long-run a firm adjust its scale (plant size, etc.) and output level to maximize profits.

Suppose the price is 100.
With its given plant size the firm maximizes its profits by producing 75 units.

If the firm expects the price to stay at 100, however, it can increase its profits by increasing the plant size and producing 150 units.

Long-run supply is given by the long-run MC curve.

However, if the price is expected to stay below the min AC (30 in the figure), the firm does better by exiting the industry.

So, in the long-run:
\[ P = MC \quad \text{if } P > \text{min AC} \]
and
\[ \text{supply} = 0 \quad \text{if } P < \text{min AC} \]
Long-Run Market Equilibrium

In the short-run
1. firms operate with a given plant size
2. the number of firms in the industry is fixed

Firms might make positive or negative economic profits

In the long-run
1. firms adjust plant size
2. there is entry if there are positive profits
3. there is exit if there are negative profits

Firms make zero economic profits

1. Each firm maximizes its long-run profits
   \[ P^* = MC(Q^*) \]
   \[ P^* = AC(Q^*) \]
   \[ P^* = \min_Q AC(Q) \]

2. Each firm’s economic profit is zero
   \[ P^* = AC(Q^*) \]
   \[ P^* = MC(Q^*) \]
   \[ P^* = \min Q AC(Q) \]

3. Market demand equals market supply
   \[ D(P^*) = n^* Q^* \]

Long-Run Market Equilibrium: Example

Each existing firm and potential entrant is identical

Long-run costs:
\[ AC(Q) = 40 - Q + 0.01Q^2 \]
\[ MC(Q) = 40 - 2Q + 0.03Q^2 \]

Market demand:
\[ D(P) = 25,000 - 1,000P \]

\[ P^* = MC(Q^*) \iff P^* = 40 - 2Q^* + 0.03(Q^*)^2 \]
\[ P^* = AC(Q^*) \iff P^* = 40 - Q^* + 0.01(Q^*)^2 \]
\[ P^* = \min Q AC(Q) \iff 40 - 2Q^* + 0.03(Q^*)^2 = 40 - Q^* + 0.01(Q^*)^2 \]
\[ Q^* = 50 \iff P^* = 40 - 50 + 0.01(50)^2 \]
\[ = 15 \]

\[ D(P^*) = n^* Q^* \iff n^* = \frac{25,000 - 1,000P^*}{Q^*} \iff n^* = \frac{25,000 - 1,000 \times 15}{50} \]
\[ = 200 \]
Initially the industry is in equilibrium. Price is $15 and each firm produces 50,000 units per year. There are 200 firms and total market output is 10 million units per year.

There is a shift in demand. $D(P) = 33,000 - 1,000P$

Suppose at the new short-run equilibrium price is $23. Each firm produces 52,000 units per year. There are still 200 firms and total market output is 10.4 million units per year.

Each firm makes positive economic profits.

New firms enter. Market supply shifts right until it reaches $S_b$.

At the new long-run equilibrium each firm produces 50,000 units again and the market output is 18 million units per year. There are now 360 firms in the industry.

Long-run supply is a horizontal line at $15.$

---

**Long-Run Market Supply**

Initially the industry is in equilibrium. Price is $15 and each firm produces 50,000 units per year. There are 200 firms and total market output is 10 million units per year.

There is a shift in demand. $D(P) = 33,000 - 1,000P$

Suppose at the new short-run equilibrium price is $23. Each firm produces 52,000 units per year. There are still 200 firms and total market output is 10.4 million units per year.

Each firm makes positive economic profits.

New firms enter. Market supply shifts right until it reaches $S_b$.

At the new long-run equilibrium each firm produces 50,000 units again and the market output is 18 million units per year. There are now 360 firms in the industry.

Long-run supply is a horizontal line at $15$.

---

**Supply Decisions: Summary**

**Short-Run: Price is for the short-run.**

How much should you produce?

$P = SMC(Q)$ for $P \geq \text{min ANSC}$

$Q = 0,$ for $P < \text{min ANSC}$

**Long-Run: Price is expected stay at this level in the long-run.**

How much should you produce?

Should you withdraw capacity from the industry?

Should you add capacity?

Should you enter the industry?

$P = MC(Q)$, for $P \geq \text{AC}$

Exit (withdraw capacity), for $P < \text{AC}$

Enter (add capacity), if $P > \text{AC}$
Exit Decision: Redeployment Value

What happens if you can sell (or use otherwise) your fixed capital once you exit?

Suppose for example that you can sell your fixed capital for $1 million and cost of capital is 20%.

That corresponds to

\[ \text{annual redeployment value} = 0.20 \times 1,000,000 = 200,000 \text{ per year} \]

By not exiting you are losing the opportunity to earn $200,000 per year and you should include this in your costs (i.e., $200,000 is the opportunity cost of your fixed capital)

Exit decision is still the same: exit if \( P < \text{min AC} \)

However, you have to include the redeployment value (per period) in your total costs.

---

Entry Decision: Capital Charge

Suppose you need to make a fixed investment of $1 million to enter the industry (e.g., buy a tanker). What is the opportunity cost of that investment decision?

It is the highest return you could earn if you invested somewhere else. The most common way is to calculate the annual flow using the capital cost. If for example the cost of capital is 20%, then

\[ \text{Annual capital charge} = 0.20 \times 1,000,000 = 200,000 \text{ per year} \]

You have to include annual capital charge as part of your total costs in entry decisions. The resulting total cost is known as full-reinvestment total cost (FR-TC) and the average cost as FR-AC.

Enter only if \( P > \text{min FR-AC} \)

In general annual redeployment value < annual capital charge

This implies that long-run entry price is larger than the long-run exit price

If price is larger than the exit but smaller than the entry price, then there will be no exit but also no new capacity addition and no entry. Capacity will wear out and not replaced. In the very long-run (which may be a long time in certain industries) price will tend towards the entry price of min FR-AC.
Example: Oil Rig Contractor

TC(Q) = 8 + 0.25Q + 0.5Q²
Redeployment value = $100 million
Cost of capital = 10%
Annual redeployment value = $10 million
Initial capital investment for entry = $240 million
Annual capital charge = $24 million

AC(Q) = 18/Q + 0.25 + 0.5Q
AVC(Q) = 0.25 + 0.5Q
FR-AC(Q) = 32/Q + 0.25 + 0.5Q
MC(Q) = 0.25 + Q

Min AC = 6.25 at Q = 6 → Exit price = 6.25
Min FR-AC = 8.25 at Q = 8 → Entry price = 8.25

Suppose there are 100 firms in the industry

Firm supply
\[ S_i(P) = \begin{cases} P - 0.25, & \text{if } P \geq 0.25 \\ 0, & \text{if } P < 0.25 \end{cases} \]

Short-run Market supply
\[ S(P) = \begin{cases} 100(P - 0.25), & \text{if } P \geq 0.25 \\ 0, & \text{if } P < 0.25 \end{cases} \]

Market demand
\[ D(P) = 1625 - 100P \]

Short-run equilibrium at P = 8.25 and Q = 800
P = min FR-AC → No new firms want to enter
P ≥ min AC → No existing firms want to exit

This is also the long-run equilibrium.
Suppose that demand for oil increases and therefore the market demand curve shifts up. The new demand function is given by

\[ D'(P) = 2025 - 100P \]

There are still 100 firms in the industry, each producing 10 units per year. But \( P > \min FR-AC \) → Incentives for entry and/or capacity expansion

As industry capacity expands, the short-run market supply shifts right and price decreases.

As long as price is bigger than \( \min FR-AC \), supply continues to shift right

New L-R equilibrium: \( P = 8.25 \) and \( Q = 1,200 \). If capacity is added only by new firms, then there must be \( 1,200/8 = 150 \) firms in the industry.

There is an adverse demand shock

At the new short-run equilibrium price is less than \( \min AC \)

Some of the existing firms exit

Supply shifts left until the new equilibrium is reached at price 6.25.

As capacity wears out it is not replaced. Supply continues to shift left and price increases gradually.