2.2 — Cournot Competition

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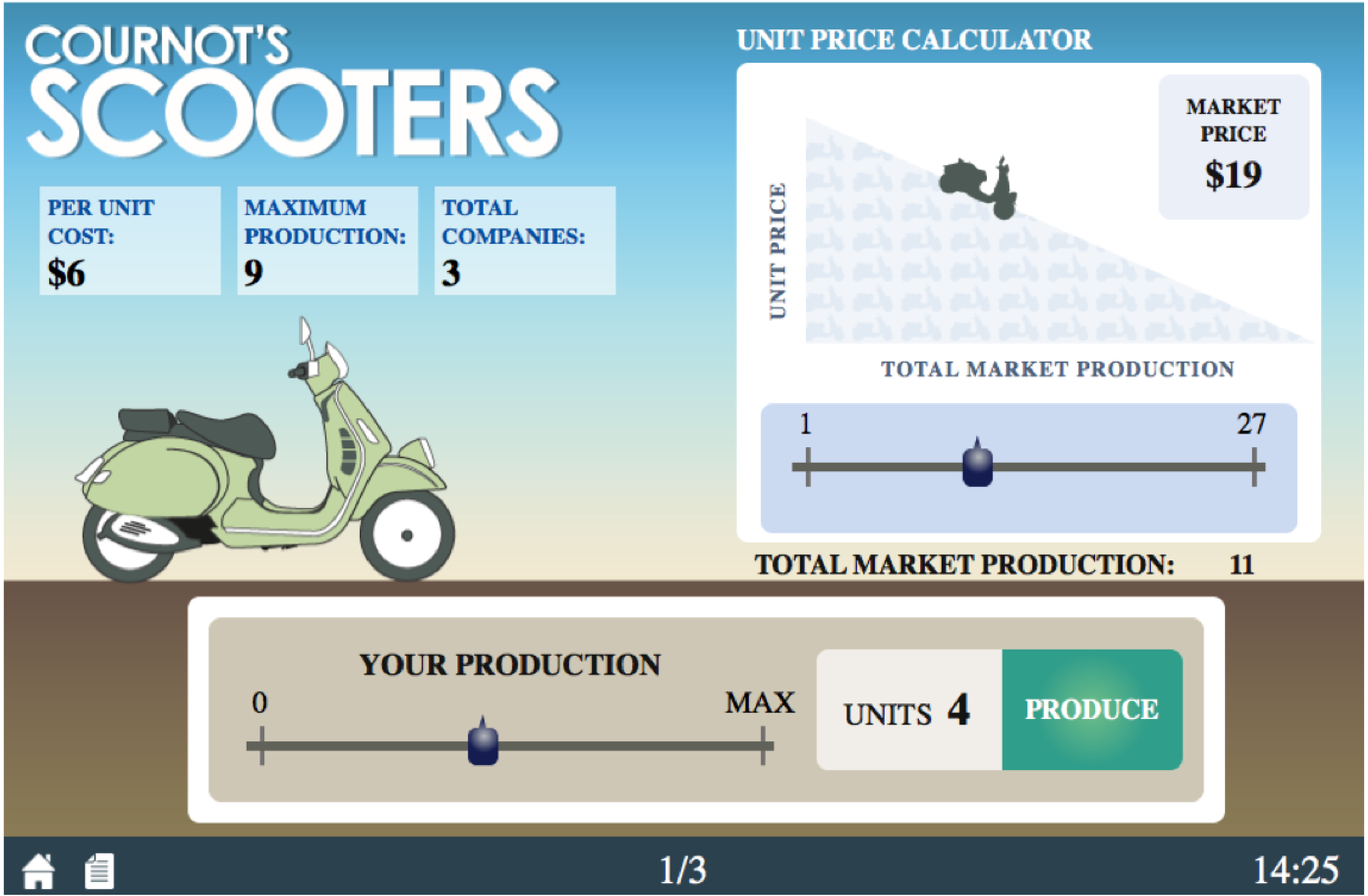
Models of Oligopoly

Three canonical models of Oligopoly

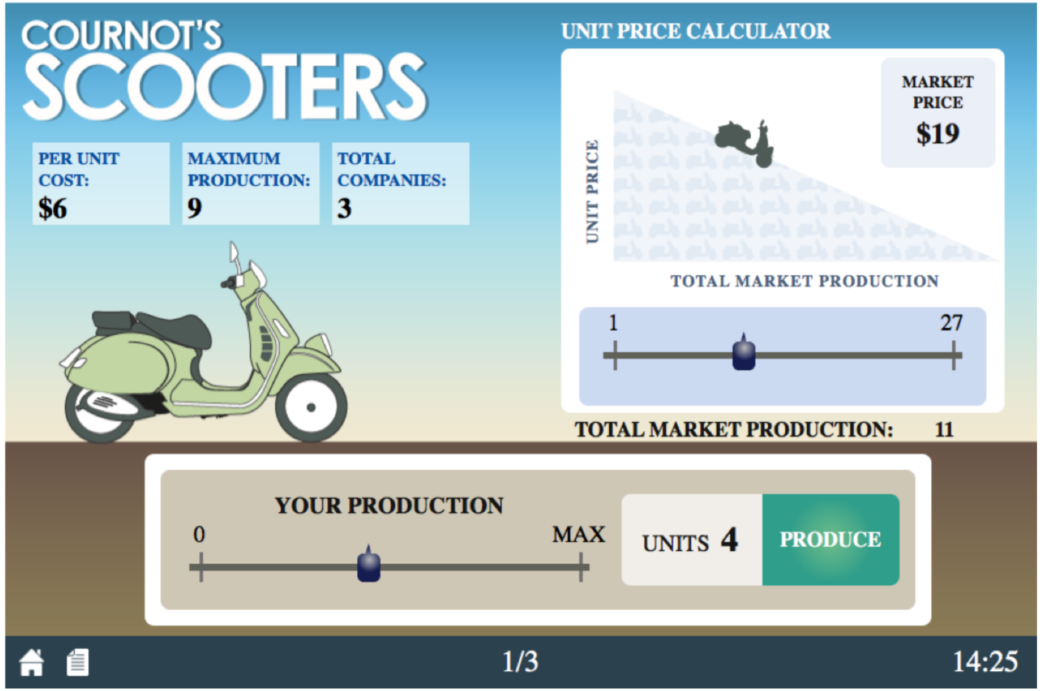
1. Bertrand competition
    - Firms **simultaneously** compete on **price**
2. Cournot competition
    - Firms **simultaneously** compete on **quantity**
3. Stackelberg competition
    - Firms **sequentially** compete on **quantity**

Cournot Competition on Moblab



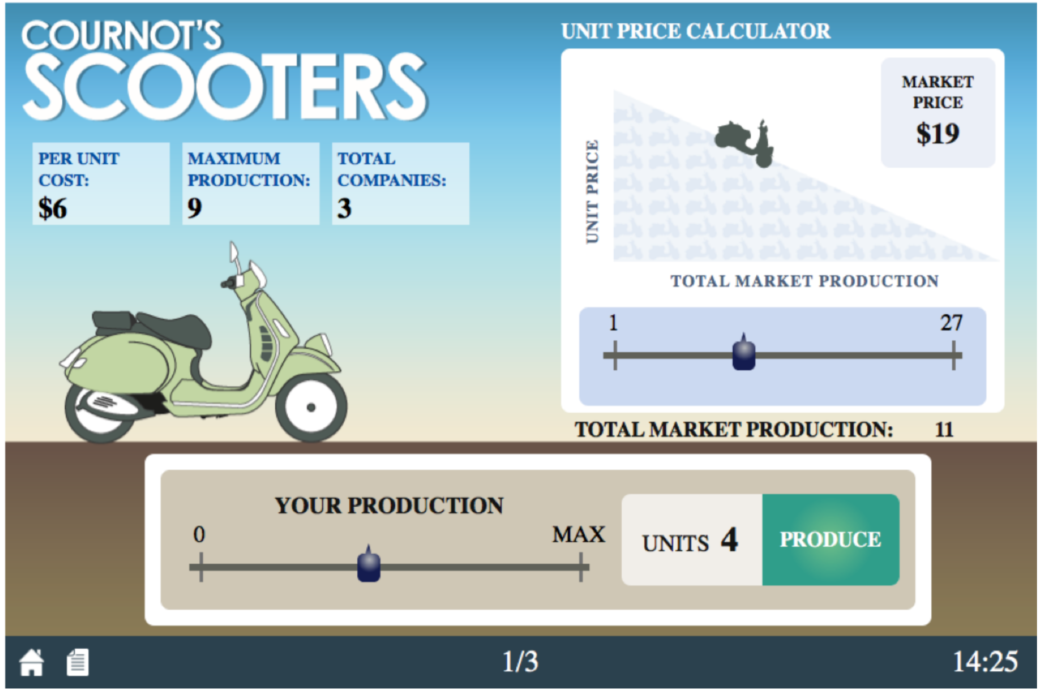
Cournot Competition on Moblab

- Each of you is a firm selling identical scooters
- Each season, each firm chooses its quantity to produce
- You pay a cost for each you produce (identical across all firms)
- Market price depends on *total* industry output
  - More total output $\implies$ lower market price
  - Market price is revealed after all firms have chosen their output



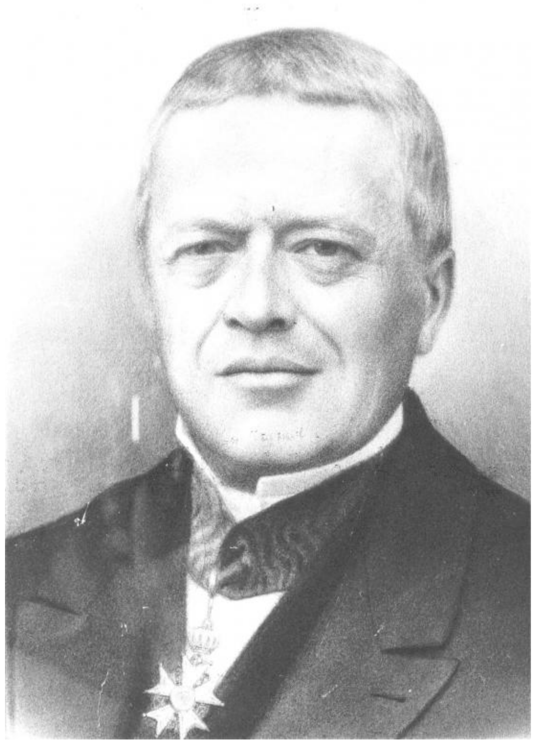
Cournot Competition on Moblab

- We will play 4 times:
    1. You are the only firm (monopoly)
    2. You will be matched with another firm (duopoly)
    3. You will be matched with 2 other firms (triopoly)
    4. The entire class is competing in the same market
- Each instance will have 3 rounds



Cournot's Model

Cournot



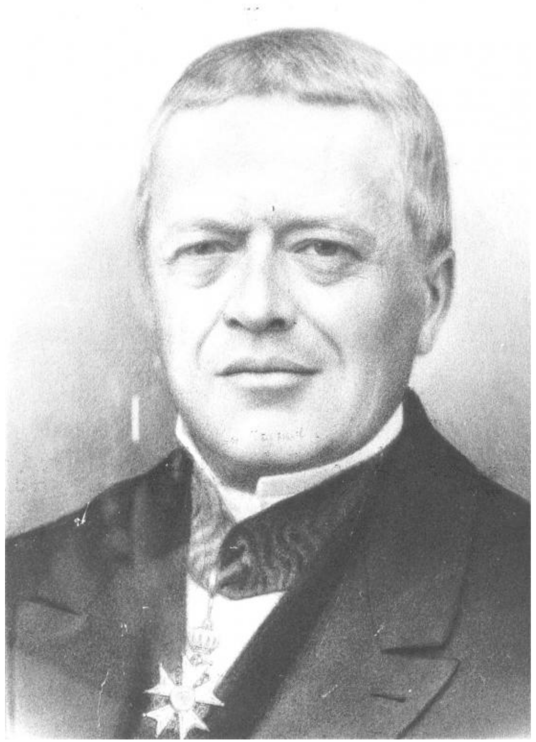
Antoine Augustin Cournot

1801-1877

- 1838 *Researches on the Mathematical Principles of the Theory of Wealth*
- First writer to:
  - ✅ use and advocate mathematics for study of political economy
  - ✅ relate demand and supply as functions of price and quantity
  - ✅ draw a demand and supply graph
  - ✅ use marginal analysis to find profit-maximizing output: where marginal revenue $=$ marginal cost
- Sadly, no influence in his lifetime, but enormous consequence on neoclassical economics

Cournot, Antoine Augustin, 1838, *Researches on the Mathematical Principles of the Theory of Wealth*

Cournot's Model

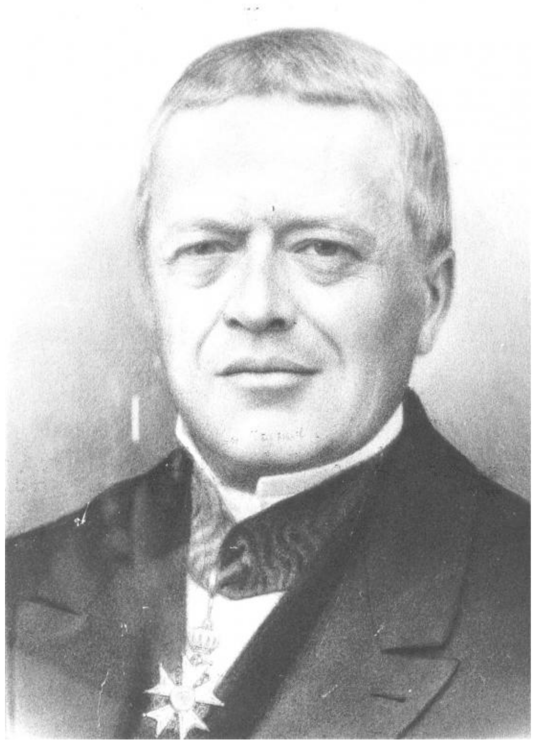


Antoine Augustin Cournot

1801-1877

- Chapter V "Of Monopoly", studies a monopoly supplier of mineral water who prices to maximize profit
    - $MR = MC$

Cournot's Model



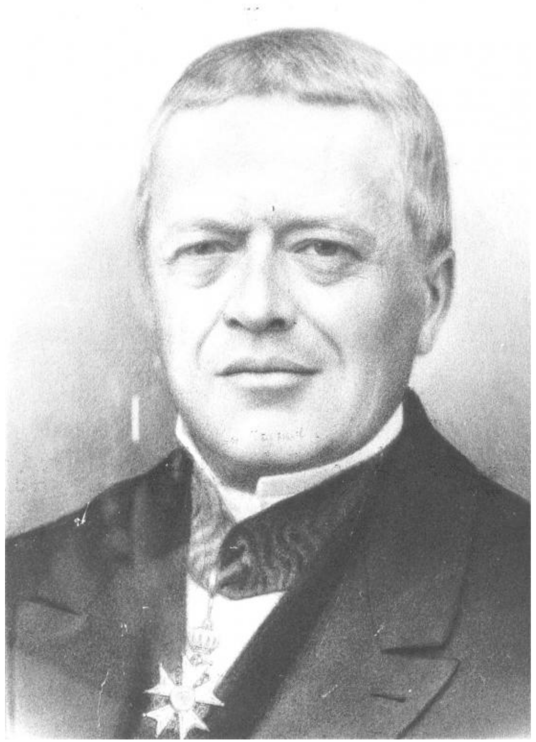
Antoine Augustin Cournot

1801-1877

> "Let us now imagine two proprietors and two springs of which qualities are identical and which on account of their similar positions supply the same market in competition."
>
> "In this case the price is necessarily the same for each proprietor."
>
> "If p is the price, $D = F(p)$ the total sales, D_1 the sales from the spring (1), and D_2 the sales from the spring (2), then $D_1 + D_2 = D$."

- Chapter VII "Of Competition of Producers"

Cournot's Model



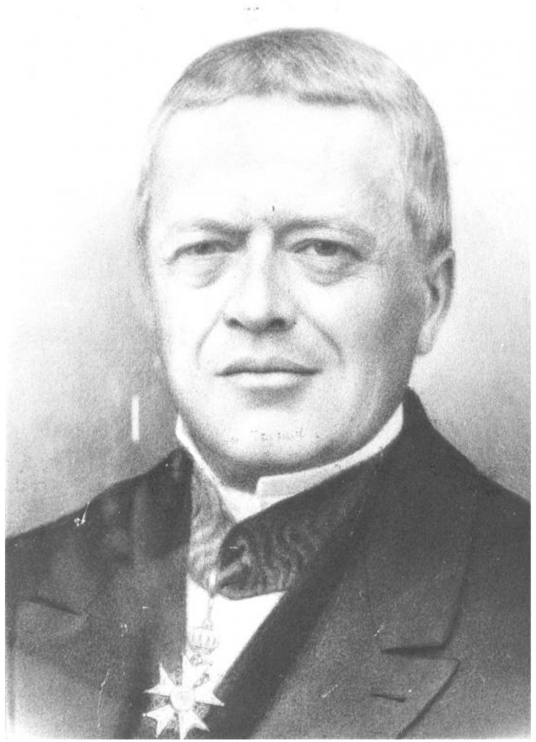
Antoine Augustin Cournot

1801-1877

> "If, to begin with, we neglect the cost of production, the respective incomes of the proprietors will be pD_1 and pD_2 and...each of them independently will seek to make this income as large as possible."
>
> "[But] [p]roprietor (1) can have no direct influence on the determination of D_2."
>
> "All that he can do when D_2 has been determined by proprietor (2) is to choose for D_1 the value which is best for him. This he will be able to accomplish by properly adjusting his price...except as proprietor (2), who seeing himself forced to accept his price and this value of D_2, may adopt a new value for D_2 more favorable ot his interests than the preceding one."

- Chapter VII "Of Competition of Producers"

Cournot Competition



Antoine Augustin Cournot

1801-1877

- We use modern game theory and Nash equilibrium to make Cournot's model a **static game** (for now)
- **"Cournot competition"**: two (or more) firms compete on **quantity** to sell the **same good**
- Firms set their quantities **simultaneously**
- Firms' joint output determines the market price faced by all firms

Cournot Competition: Mechanics

- Suppose two firms (1 and 2), each have an identical constant cost

$$MC(q) = AC(q) = c$$

- Firm 1 and Firm 2 simultaneously set quantities, q_1 and q_2

- Total market demand is given by

$$P = a - bQ$$
$$Q = q_1 + q_2$$

Cournot Competition: Mechanics

- Firm 1's profit is given by:

$$\pi_1 = q_1(P - c)$$
$$\pi_1 = q_1(a - b(q_1 + q_2) - c)$$

- And, symmetrically same for firm 2

- **Note each firm's profits depend (in part) on the output of the other firm!**

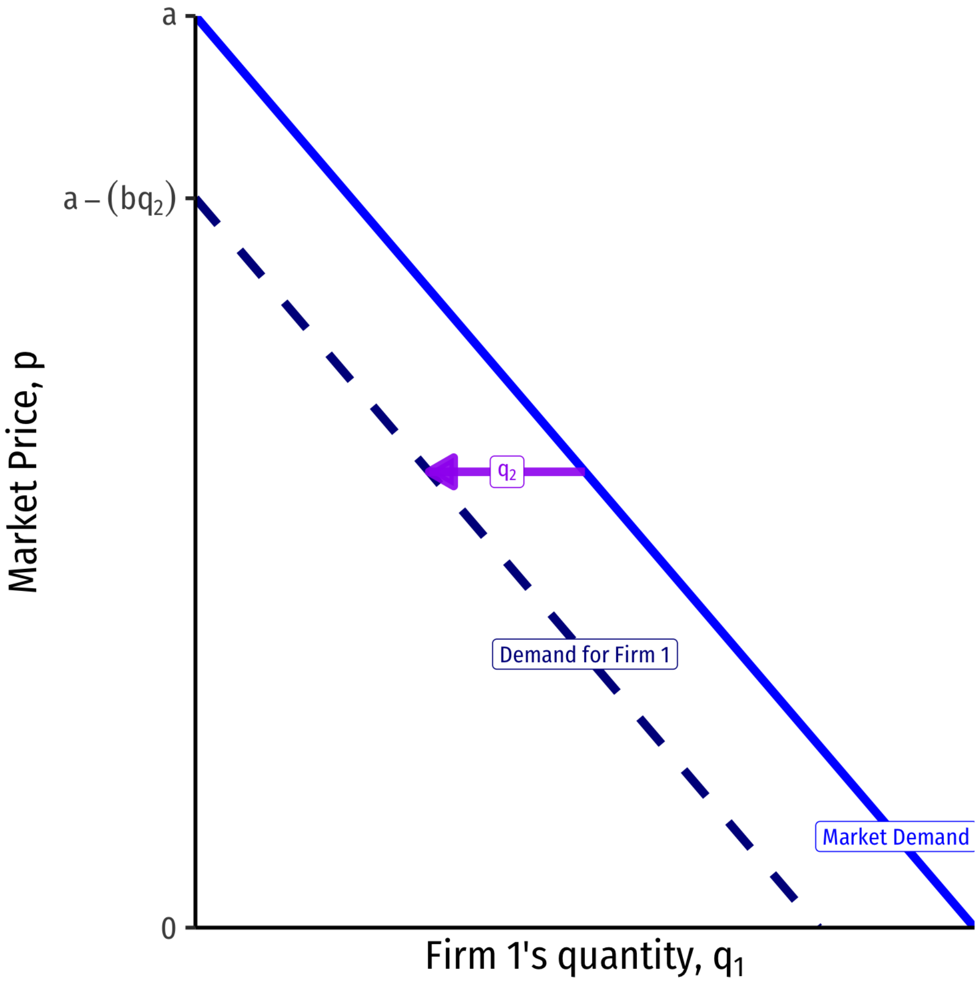
Residual Demand

- Consider the demand each firm faces to be a **residual demand**
- e.g. for firm 1, it's (residual) demand is:

$$p = a - b(q_1 + q_2)$$
$$p = \underbrace{(a - bq_2)}_{intercept} - \underbrace{b}_{slope} q_1$$

- Firm 2 will produce some amount, q_2.
- Firm 1 takes this as given, to find its own residual demand
  - Intercept: $a - bq_2$
  - Slope: b (coefficient in front of q_1)

Residual Demand



- Firm 2 will produce some amount, q_2.
- Firm 1 will take this as a given, a constant
- Firm 1's choice variable is q_1, *given* q_2

Cournot Competition: Example

Example: Assume Coke (c) and Pepsi (p) are the only two cola producers, each with a constant MC=AC=$0.50. The market (inverse) demand curve is given by:

$$P = 5 - 0.05Q$$
$$Q = q_c + q_p$$

$$P = 5 - 0.05Q$$

$$P = 5 - 0.05q_c - 0.05q_p$$

Cournot Competition: Example

$$P = 5 - 0.05q_c - 0.05q_p$$

- Firms maximize profit (as always), by setting $q^* : MR(q) = MC(q)$

Cournot Competition: Example

$$P = \underbrace{5 - 0.05q_p}_{intercept} - \underbrace{0.05}_{slope}q_c$$

- Firms maximize profit (as always), by setting $q^* : MR(q) = MC(q)$
- Solve for Coke's MR(q) first:
  - Take q_p as given, a constant
  - Recall MR is twice the slope of demand

$$MR_c = 5 - 0.05q_p - 0.10q_c$$

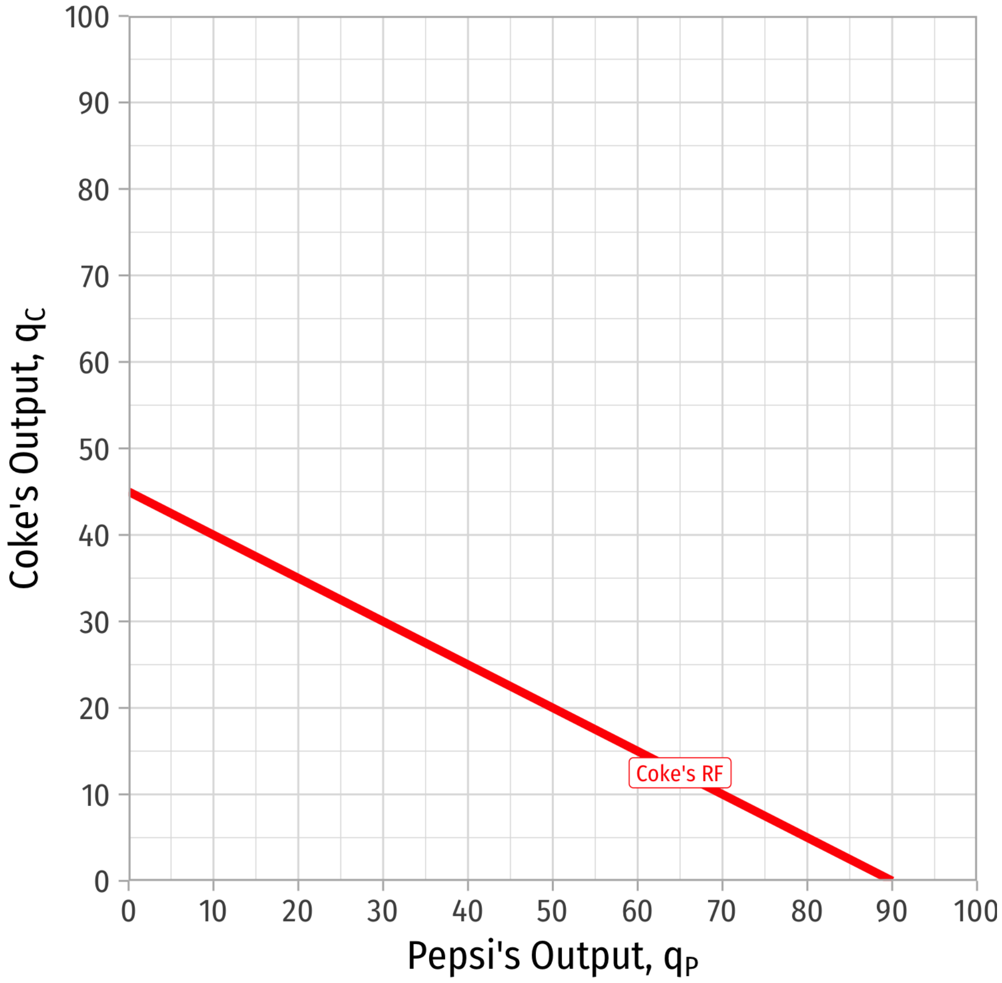
Cournot Competition: Example

- Solve for q^* for each firm (where $MR(q)=MC(q)$), we derive each firm's **reaction function** or **best response function** to the other firm's output

- Symmetric marginal costs and marginal revenues

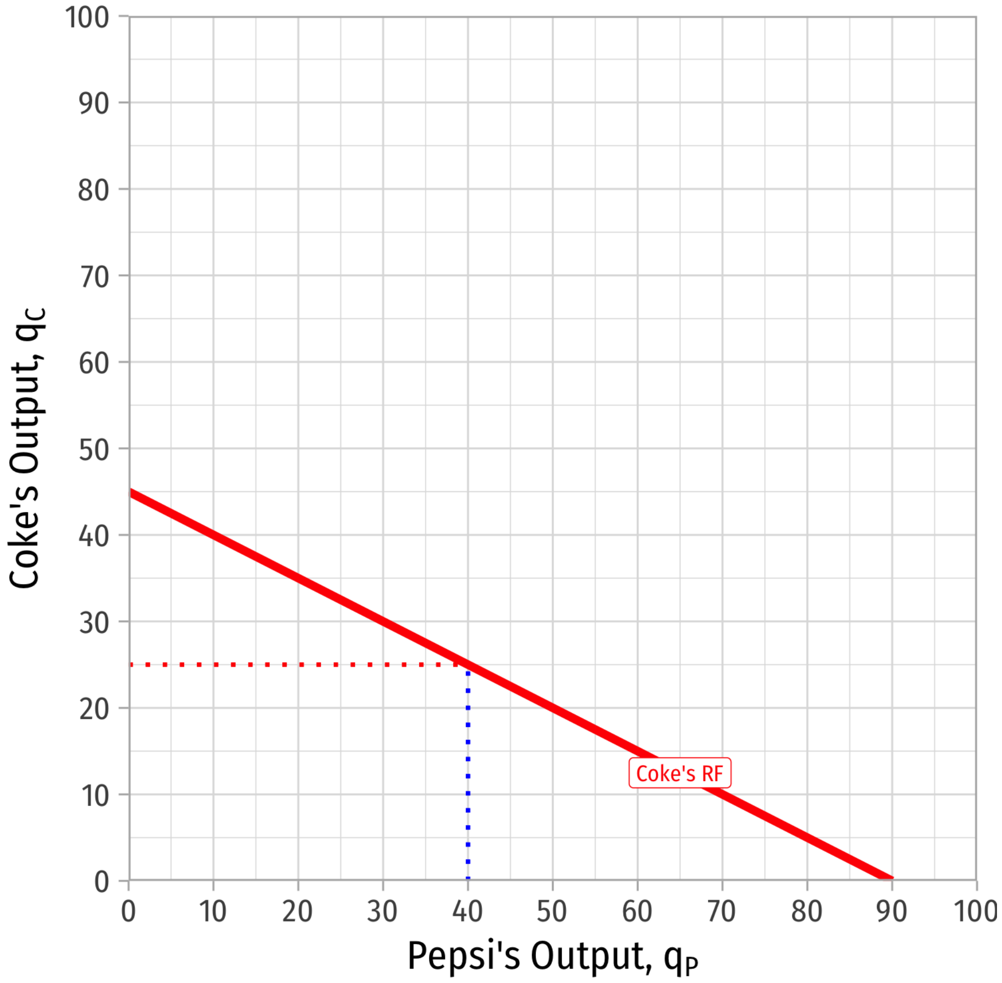
$$\begin{aligned} q_c^* &= 45 - 0.5q_p \\ q_p^* &= 45 - 0.5q_c \end{aligned}$$

Coke's Reaction Curve



We can graph **Coke**'s **reaction curve** to **Pepsi**'s output

Coke's Reaction Curve



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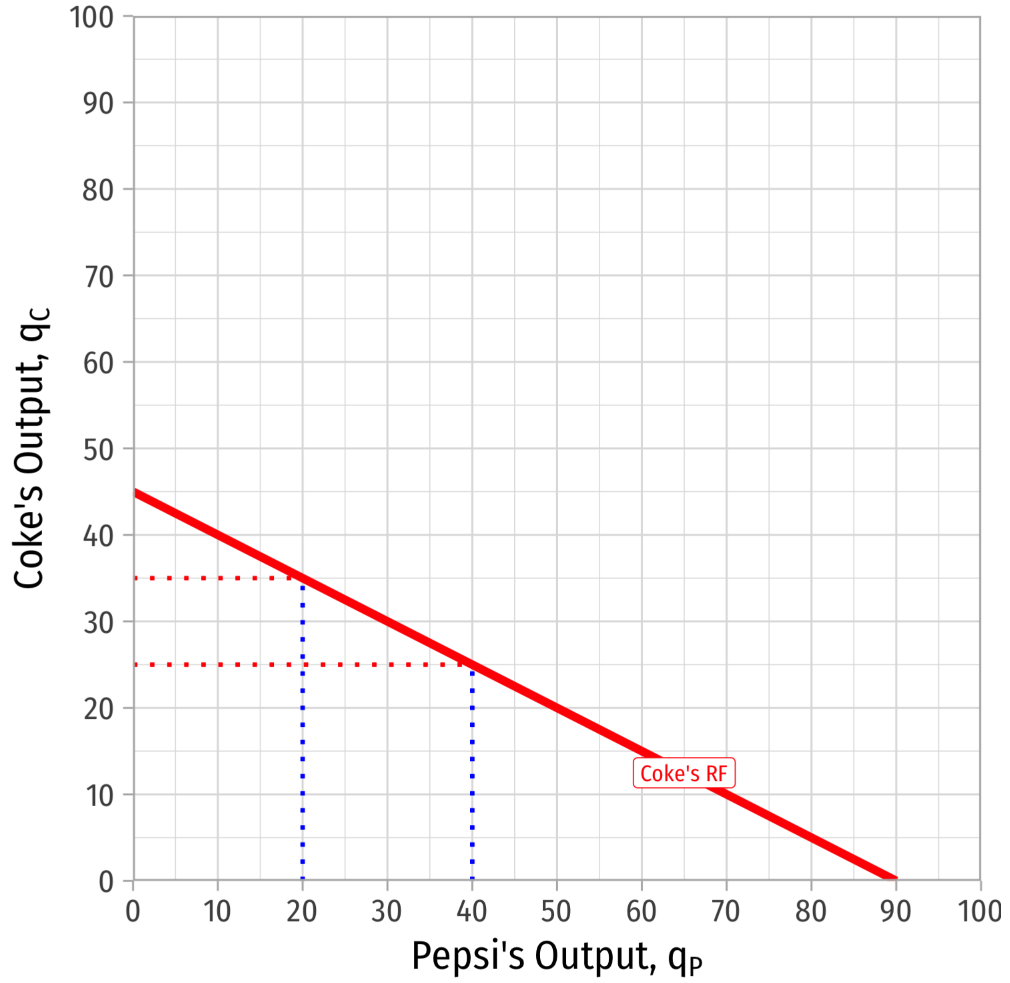
- e.g. if **Pepsi** produces **40**, **Coke**'s best response is **25**

Coke's Reaction Curve



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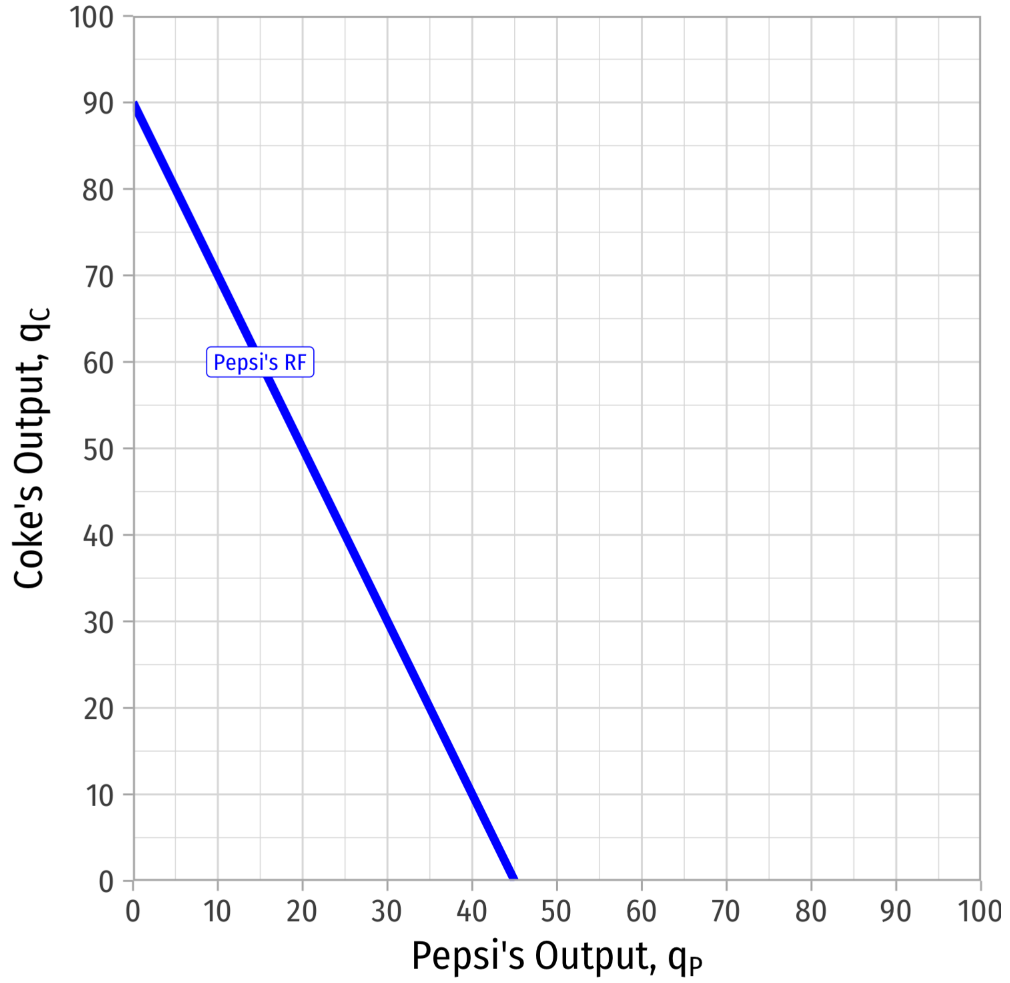
- e.g. if **Pepsi** produces **40**, **Coke**'s best response is **25**
- e.g. if **Pepsi** produces **20**, **Coke**'s best response is **35**

Pepsi's Reaction Curve



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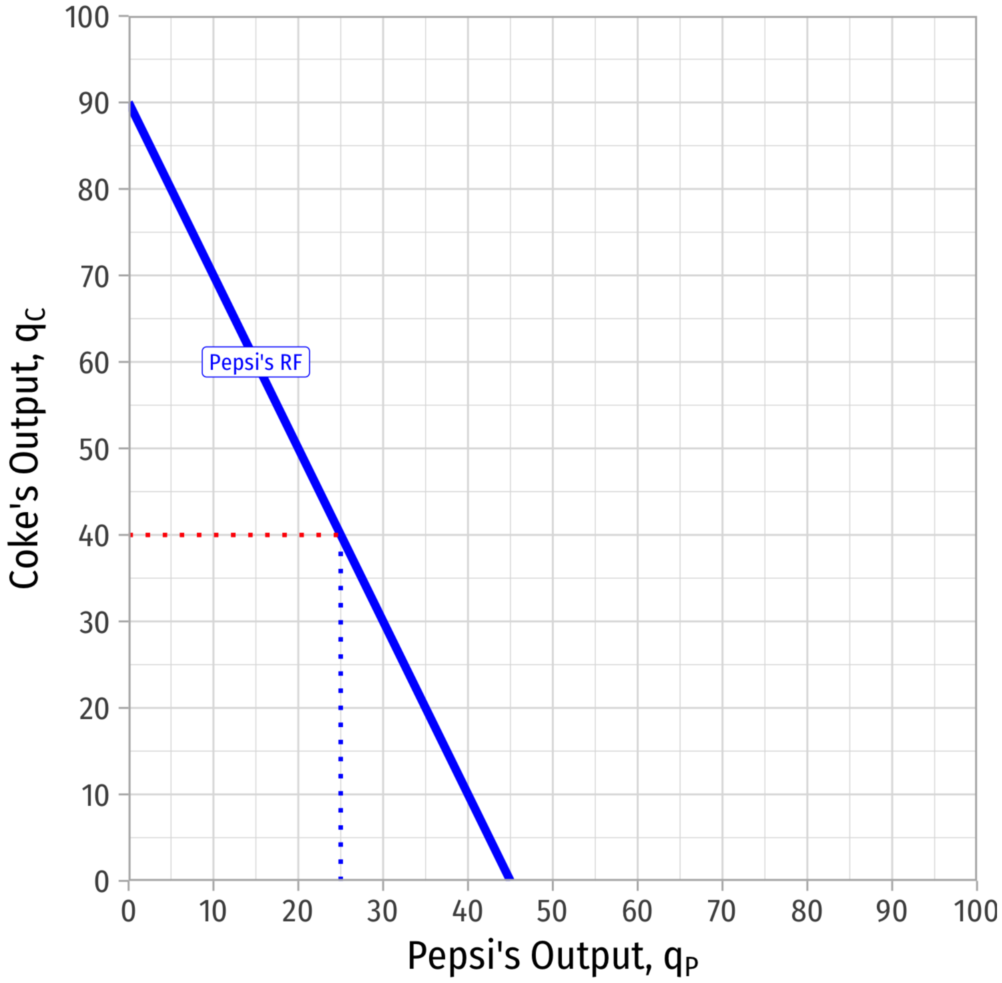
Pepsi's Reaction Curve



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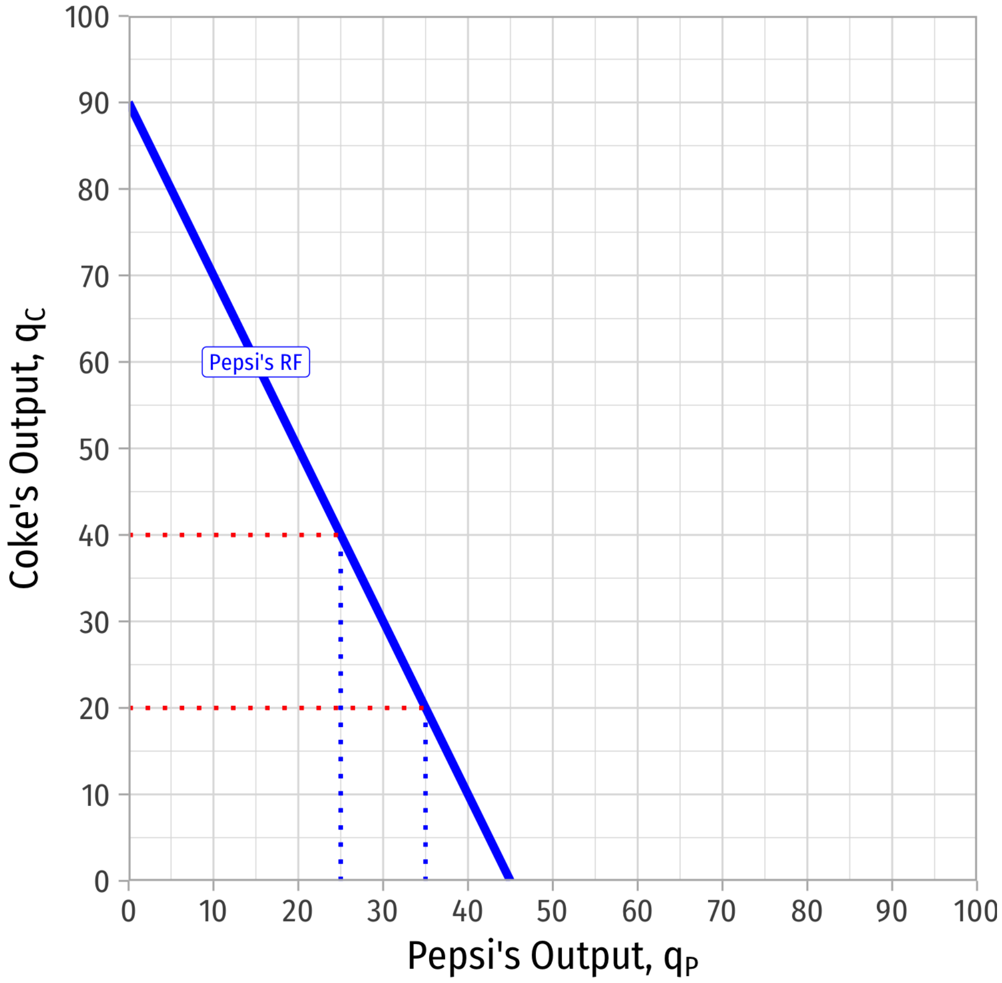
Pepsi's Reaction Curve



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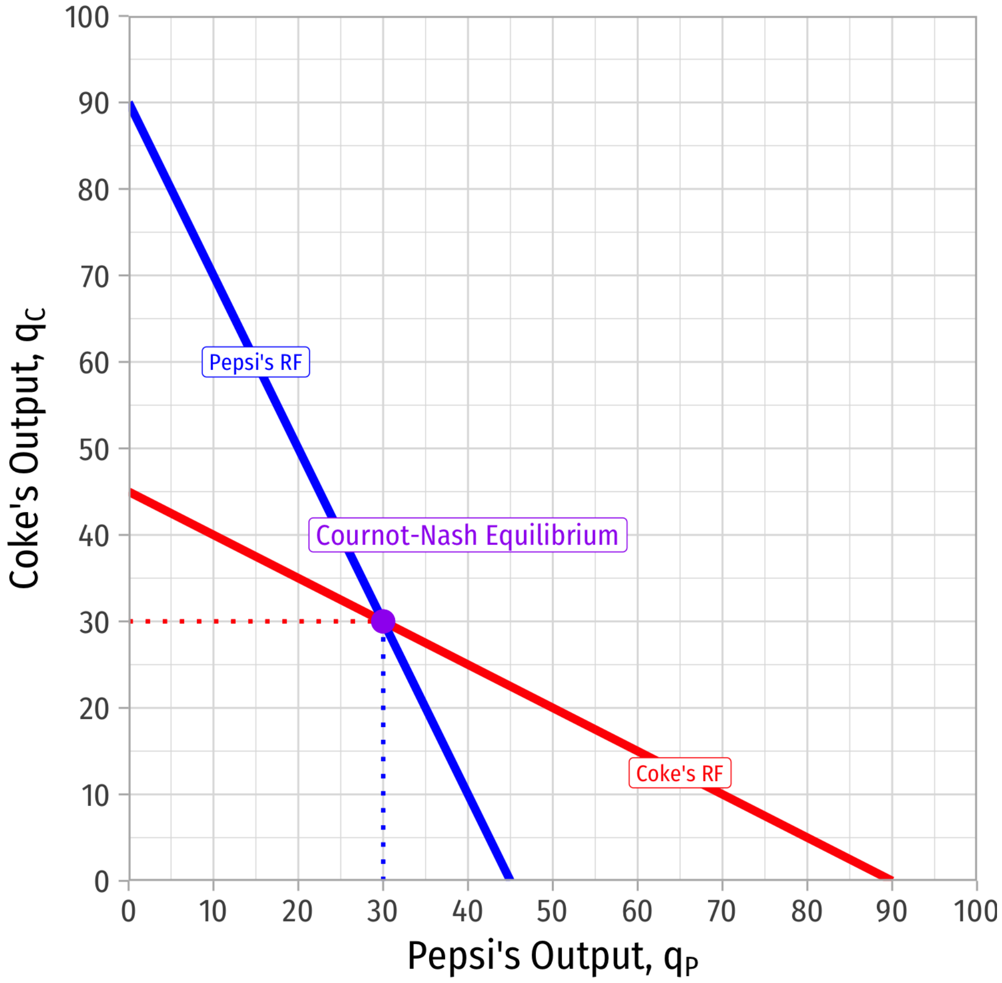
Cournot-Nash Equilibrium, Graphically



Combine both curves on the same graph

- **Cournot-Nash Equilibrium**:

$$(20, 20)$$

  - Where both reaction curves intersect

- Both are playing mutual best response to one another

Cournot-Nash Equilibrium, Algebraically

- **Cournot-Nash Equilibrium** algebraically: plug one firm's reaction function into the other's

$$q_c^* = 30 - 0.5q_p$$
$$q_p^* = 30 - 0.5q_c$$

- The market demand again was

$$P = 200 - 3q_c - 3q_p$$

Cournot-Nash Equilibrium, Algebraically

- Both firms produce 20

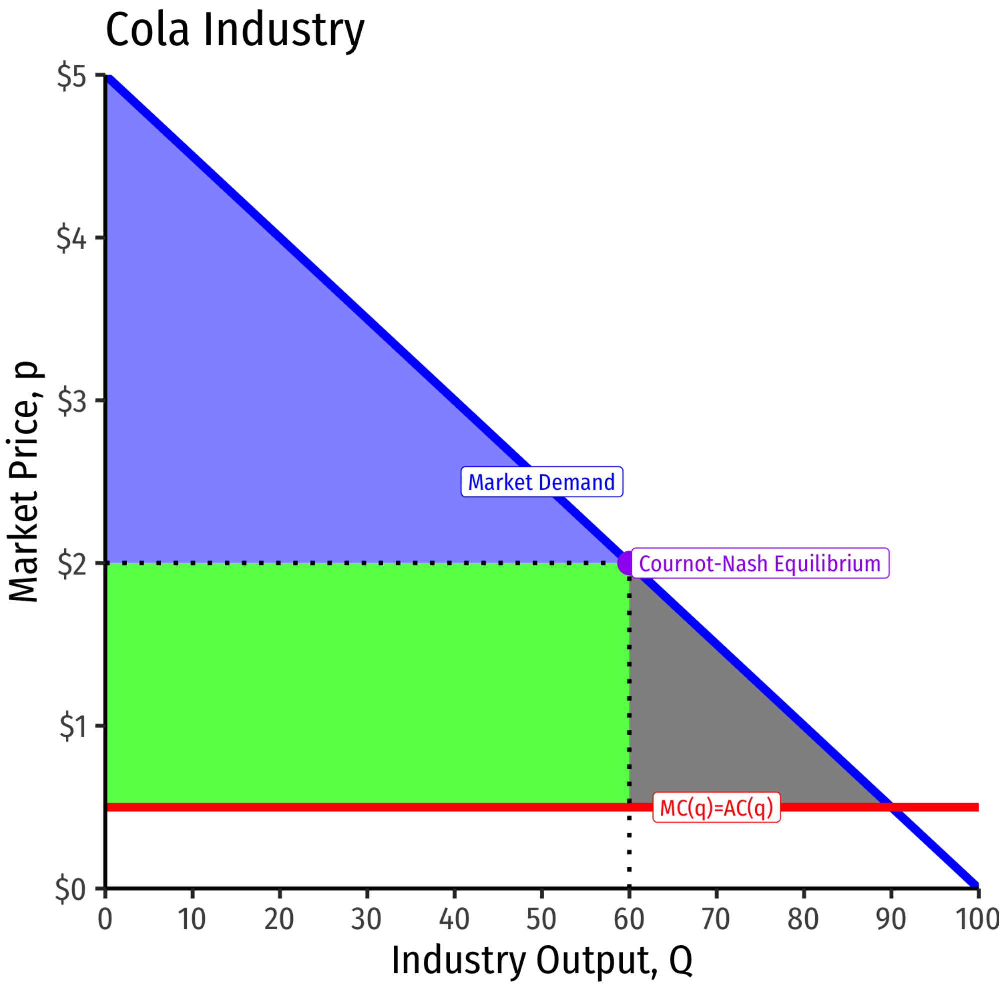
$$P = 200 - 3(20) - 3(20)$$
$$P = \$80$$

- Find profit for each firm:

$$\pi_c = q_c(P - c)$$
$$\pi_c = 20(80 - 20)$$
$$\pi_c = 1,200$$

- Symmetrically for Pepsi, $\pi_p = 1,200$

Cournot-Nash Equilibrium, The Market



Cournot Collusion

- Suppose now both firms **collude** to act like a monopolist, who sets the entire market:

$$\begin{aligned} MR &= MC \\ 5 - 0.1Q &= 0.50 \\ 45 &= Q^* \end{aligned}$$

- The monopoly price will then be:

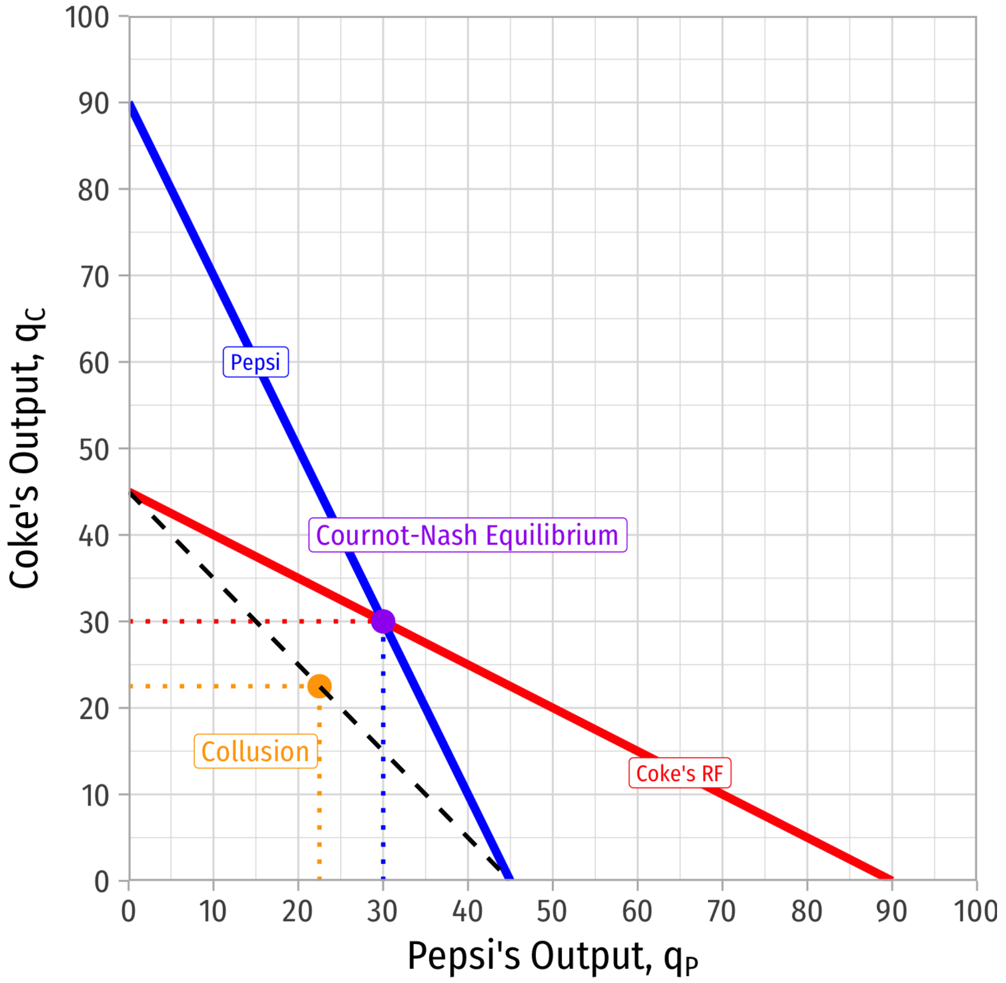
$$\begin{aligned} P &= 5 - 0.05(45) \\ P &= \$2.75 \end{aligned}$$

- Total profit will then be:

$$\Pi = 45(\$2.75 - \$0.50) = \$101.25$$

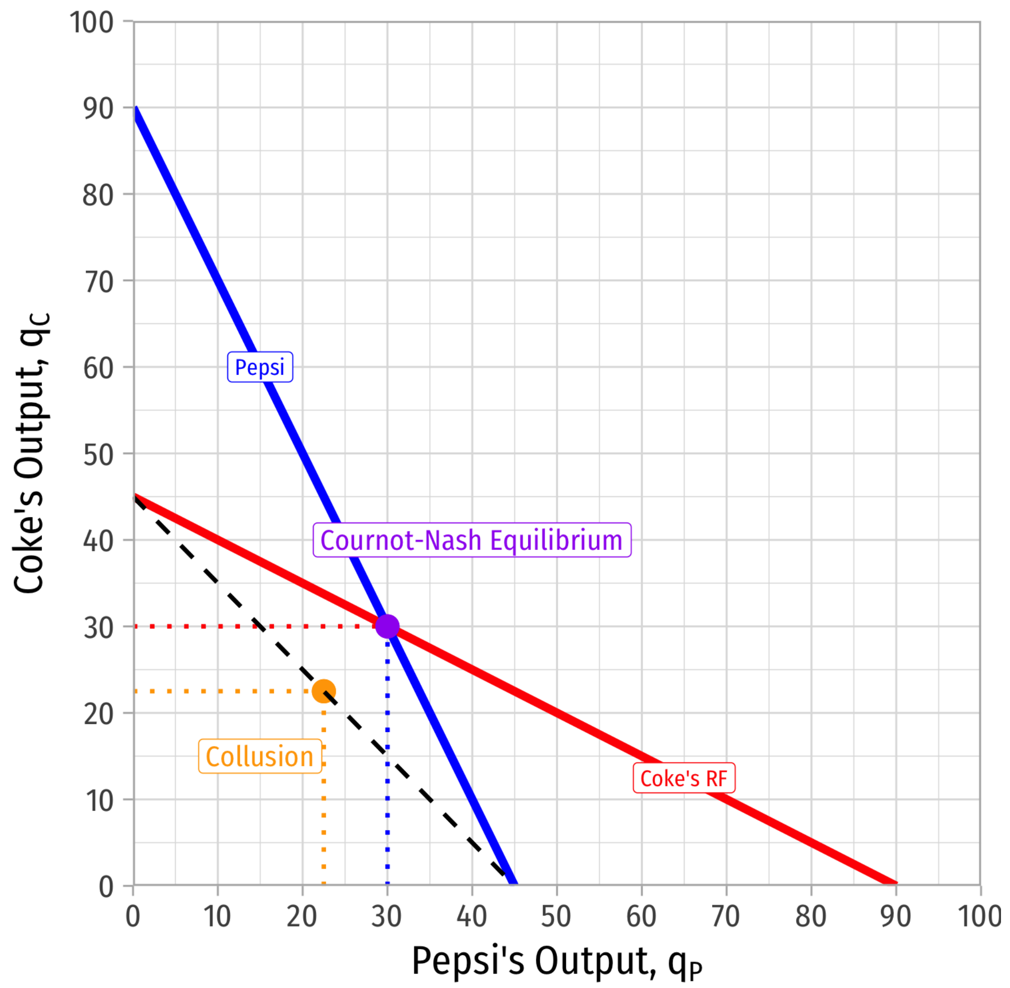
with $50.625 going to each firm

Cournot Collusion



- **Cournot Competition**: each firm produces 30 and earns $45.00
- **Collusion/Monopoly**: each firm produces 22.5 and earns $50.63

Cournot Collusion

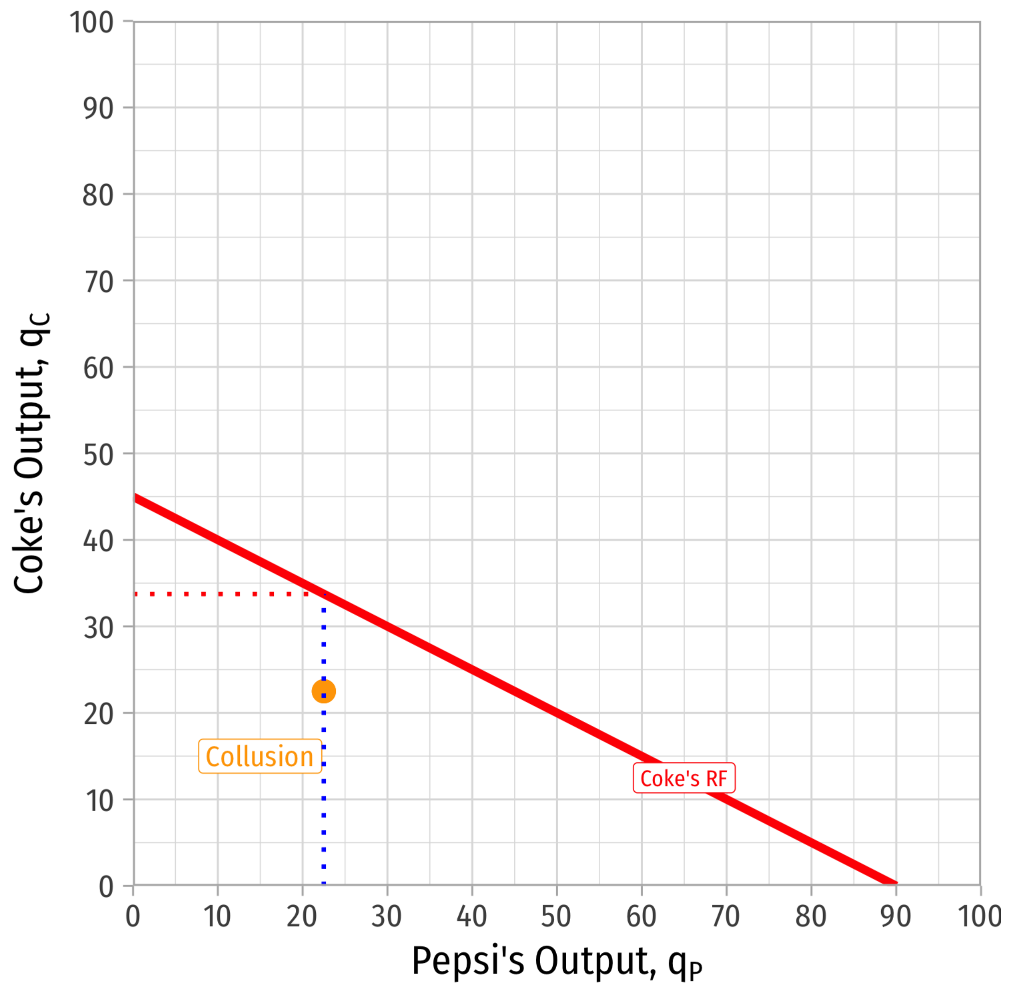


- **Cournot Competition**: each firm produces 30 and earns $45.00

- **Collusion/Monopoly**: each firm produces 22.5 and earns $50.63

- **But is collusion a Nash equilibrium?**

Cournot Collusion



- Read either firm's reaction curve at the collusive outcome
- Suppose Coke knows Pepsi is producing 22.5 (as per the cartel agreement)
- Coke's best response to Pepsi's 22.5 is to produce 33.75

Cournot Collusion

- This (cheating the agreement) would bring market price to

$$
\begin{aligned}
P &= 5 - 0.05(q_c + q_p) \\
P &= 5 - 0.05 * (33.75 + 22.50) \\
P &= 5 - 0.05 * (56.25) \\
P &= \$2.1875
\end{aligned}
$$

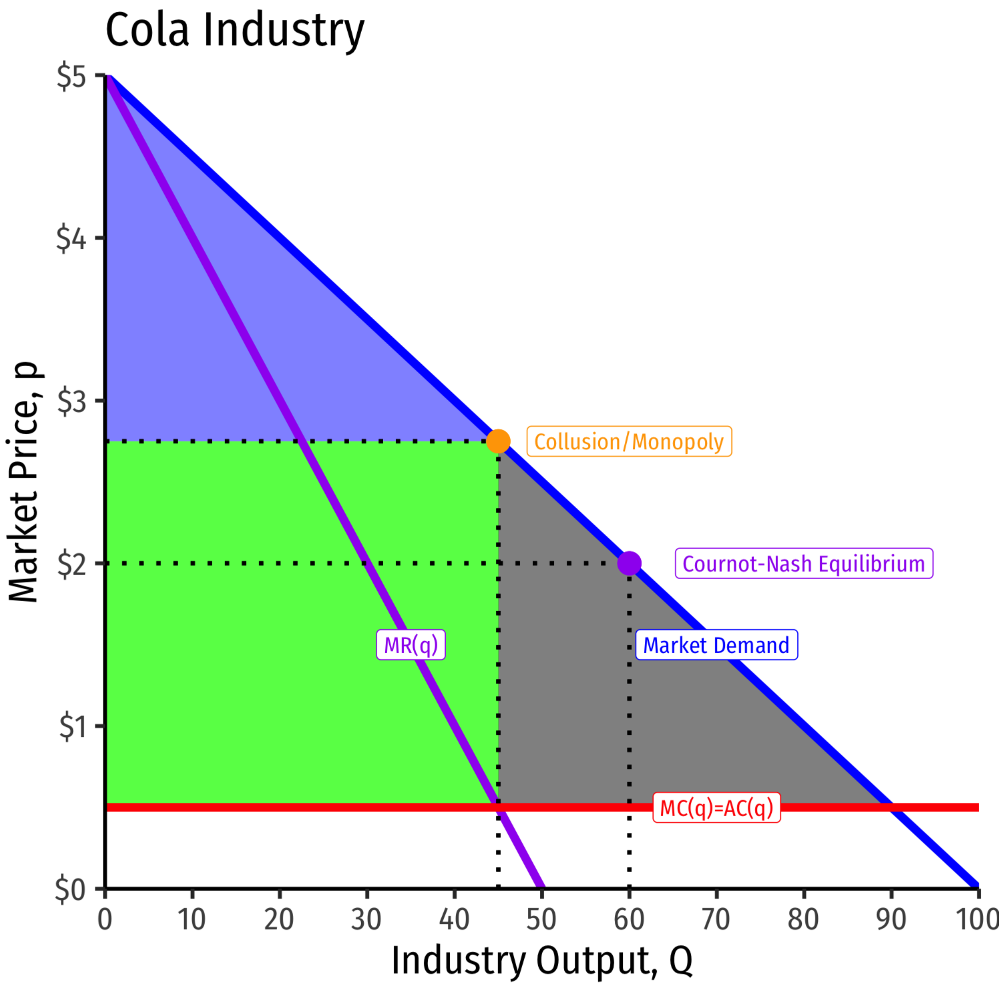
- Coke's profit would be:

$$
\begin{aligned}
\pi_c &= q_c(P - c) \\
\pi_c &= 33.75(2.1875 - 0.50) \\
\pi_c &= \$56.95
\end{aligned}
$$

- Pepsi's profit would be:

$$
\begin{aligned}
\pi_p &= Pq_p(P - c) \\
\pi_p &= 22.5(2.1875 - 0.50) \\
\pi_p &= \$37.97
\end{aligned}
$$

Cournot Collusion, The Market



Cournot Competition, You Try

Example: Suppose Firm 1 and Firm 2 have a constant $MC = AC = 8$. The market (inverse) demand curve is given by:

$$P = 200 - 2Q$$
$$Q = q_1 + q_2$$

1. Find the Cournot-Nash equilibrium output and profit for each firm.

2. Find the output and profit for each firm if the two were to collude.