

**MIT 14.01: Principles of Microeconomics**  
**Sp 2025, Lecture 15: Imperfect Competition (part II)**

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# Plan for Today

- A deeper dive into imperfectly competitive settings
- In particular, ones that involve strategic interactions between firms (oligopoly)

# Imperfect Competition and Residual Demand

- Recall our treatment of imperfect competition in Lecture #14 – firm  $f$  takes as given a residual demand function:

$$\underbrace{(\text{residual demand})_f}_{RD_f(p)} = \underbrace{(\text{market demand})}_{D(p)} - \underbrace{(\text{what other firms will supply})}_{S_o(p)}$$

- Then this firm's behavior is characterized by its profit-maximization problem, which has the FOC:

$$MC_f(q_f^*) = p^* + q_f^* \frac{dP_f(q_f^*)}{dq_f} \iff LL_f = \frac{1}{|\varepsilon_{RD_f,p}|}$$

- Where, recall,  $P_f(\cdot)$  is the inverse of the residual demand curve, and  $LL_f \equiv \frac{p^* - MC_f(q_f^*)}{p^*}$  is the price-cost margin (or Lerner index)

## But Where Does Residual Demand Come From?

- That is, what determines “what other firms will supply” (i.e.  $S(p)_o$ )?
  - For our purposes today, the interesting part of  $RD_f(p)$  is the  $S_o(p)$  part, not the market demand  $D(p)$  part
- We saw one answer in Lecture #14: for the case of monopoly,  $S(p)_o = 0$
- But many industries appear to have a “few” firms (not one, not many) in them – we call this *oligopoly*
- This raises a new consideration: how does firm  $f$  predict what other firms will do? And won't the other firms' predicted behavior depend on what they predict firm  $f$  will do, which depends on what they will do ... and so on?
  - This is a form of *strategic interaction* between firms
  - It can get complicated ... but we will cover some important examples in the space of many possibilities (and see 14.20 or 14.27 for more!)

# Sequential Quantity Competition (Stackelberg Competition)

- Suppose there are two firms – a *duopoly*
- And suppose that the interactions take place as follows:
  - Firm 1 (the “leader”) announces how much it will supply:  $q_1$
  - Then firm 2 (the “follower”) decides how much to supply:  $q_2$
  - Then the market clears:  $D(p) = q_1 + q_2$
- What will happen?

## Sequential Quantity Competition (Stackelberg Competition)

- We can work it out via *backward induction*...
- Step 1: what will firm 2 (follower) do as a function of whatever firm 1 decides?
  - If firm 1 chooses  $q_1$  then  $RD_2(p) = D(p) - q_1$
  - So firm 2 chooses  $q_2$  as a function of  $q_1$  – call that function  $q_2 = R_2(q_1)$ , which is firm 2's *best response* function
- Step 2: what will firm 1 (leader) decide in the first place?
  - Firm 1 isn't stupid. It might indeed have *rational expectations* about what firm 2 will do as a result of whatever firm 1 chooses.
  - In particular, suppose firm 1 understands that firm 2 will set  $q_2 = R_2(q_1)$
  - Then firm 1 has the RD curve (i.e.  $q_1 = RD_1(p)$ ) given implicitly by  $q_1 = D(p) - q_2 = D(p) - R_2(q_1)$ . Given this RD curve, firm 1 solves for  $q_1^*$ .
  - Then  $q_1^*$  determines  $q_2^* = R_2(q_1^*)$  and hence  $p$  via  $D(p) = q_1^* + q_2^*$
- Can verify that  $\Pi_1 > \Pi_2$  – that is, it pays to be the leader in this form of competition (i.e. there is a *first-mover advantage*)
  - E.g. some pharma firms even launch generic versions of their own on-patent drugs *before* their drug's patent expires. Why? Maybe they are willing to “cannibalize” their own on-patent profits to get a first-mover advantage in the generics market.

## Example: Stackelberg Competition with Linear Demand

- Suppose two firms have zero costs, participate in a market with demand  $D(p) = \frac{a-p}{b}$ , and that firm 1 is the leader. What will be quantities sold by the two firms? How do they compare to the monopolist's level?
- Step 1: solve for the follower's (i.e. firm 2's) best response function  $R_2(q_1)$ :
  - $RD_2(p) = D(p) - q_1$ , so  $\varepsilon_{RD_2,p} = -\frac{p}{bq_2}$ , so FOC:  $\frac{p-c}{p} = \frac{1}{|\varepsilon_{RD_2,p}|}$ , or  $p = bq_2$
  - Use  $q_2 = RD_2(p)$  to get rid of  $p$ :  $q_2 = \frac{a-bq_2}{b} - q_1 \iff q_2 = \frac{a-bq_1}{2b} \equiv R_2(q_1)$

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  - We know that  $q_2^* = R_2(q_1^*) = \frac{a-bq_1^*}{2b}$ , and  $q_1^* = \frac{a}{2b}$ , so  $q_2^* = \frac{a}{4b}$

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- Step 3: solve for  $q_2^*$ :
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- Step 4: compare to monopoly
  - Recall from Lecture #14 that for this same market demand and cost the monopolist would sell  $q^M = \frac{a}{2b}$ . So here the Stackelberg leader ends up selling the same as  $q^M$ .
  - But the follower also produces another  $q^M/2$ , so  $Q \equiv q_1^* + q_2^* = \frac{3}{2}q^M$

## Simultaneous Quantity Choice (Cournot Competition)

- Now suppose that firms 1 and 2 decide on their quantities simultaneously
  - Or, at least, when one decides it doesn't yet know what the other will do
- What will happen?
  - Suppose firm 1 expects that firm 2 will produce  $q_2^e$ , so expects to face  $RD_1(p) = D(p) - q_2^e$ , and hence chooses  $q_1 = R_1(q_2^e)$  where  $R_1(\cdot)$  is firm 1's best response function
  - Symmetrically, if firm 2 expects  $q_1^e$  then it chooses  $q_2 = R_2(q_1^e)$
  - It's as if they are both Stackelberg followers, but based on expected simultaneous actions of the other not actual previous actions of the leader
- But where do these expectations  $q_2^e$  and  $q_1^e$  come from?

## A Game Theory Interlude

- The Cournot (and Stackelberg) models of strategic interaction that we have seen above are examples of *games*.
- Every game has three ingredients (with examples from the “Rock, Paper, Scissors” game):
  - *Players*: e.g. you and me
  - *Actions* (or *strategies*) that players can take: e.g. simultaneously at a given time, each player must say “Rock” or “Paper” or “Scissors” (here, actions are discrete)
  - *Payoffs* each player gets, as function of actions taken by all players: e.g. I win if I say “Rock” and you say “Scissors”, or if I say “Paper” and you say “Rock”, or if I say “Scissors” and you say “Paper”; otherwise, you win
- So what is the Cournot competition game?
  - *Players*: firm 1 and firm 2
  - *Actions* (or *strategies*) that players can take: quantities produced,  $q_1$  and  $q_2$  (here, unlike above, the actions are continuous)
  - *Payoffs* each player gets, as function of actions taken by all players: these are the profits,  $\Pi_1(q_1, q_2) = q_1 [D^{-1}(q_1 + q_2) - AC_1(q_1)]$ ,  
 $\Pi_2(q_2, q_1) = q_2 [D^{-1}(q_1 + q_2) - AC_2(q_2)]$

# Nash Equilibrium

- How do we expect players to play (economic) games?
- A standard assumption is that game play results in a *Nash equilibrium*:
  - A set of actions taken by all agents such that each agent follows their best response to their expectation about all other agents' actions, and those expectations turn out to be correct (i.e. the expected action turns out to be the true action)
  - E.g. in Cournot:  $q_1^* = R_1(q_2^e)$  and  $q_2^* = R_2(q_1^e)$ , and  $q_1^* = q_1^e$  and  $q_2^* = q_2^e$
  - An implication: if the equilibrium actions of others were to be somehow “announced” as “intended actions”, no agent would want to change their own action (won't *unilaterally* deviate) in response to this news
- Does a NE always exist? Yes, for all games. But for some games this is only true if we allow for *mixed strategies* – where the actions are probabilities with which an agent randomizes the actual non-random actions.
  - Something you are familiar with if you've ever played Rock, Paper, Scissors (or watched a penalty shot in pro soccer)
- We'll use a bit of game theory, but see 14.12, 14.15, 14.16 and 14.19 for more!

# The Prisoners' Dilemma Game

		Prisoner 2	
		Confess	Deny
Prisoner 1	Confess	-3,-3	0,-5
	Deny	-5,0	-1,-1

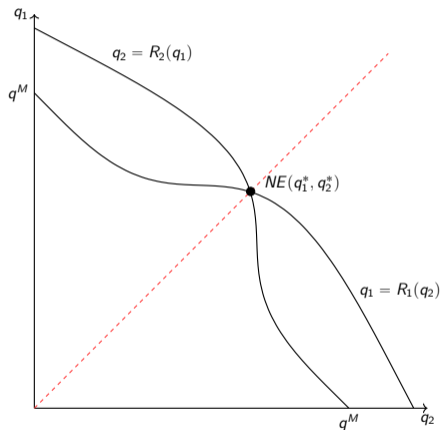
- Consider the following famous game...
- Suppose 2 prisoners (accused of jointly committing a crime) are held in separate cells and each told by the DA:
  - “if both of you confess then you’ll each get 3 years”
  - “if neither of you confesses then you’ll each get 1 year”
  - “if you confess and the other prisoner doesn’t then you go free and he gets 5 years (since you’ll have snitched on him, and the court rewards snitching)”
- This table summarizes the actions and payoffs of this game (with convention that first number is prisoner 1’s payoff, and second number is 2’s payoff)
  - Assuming payoffs  $\Pi_i = -\text{years}$
  - E.g. if actions are  $\{q_1 = \text{deny}, q_2 = \text{confess}\}$  then  $\Pi_1 = -5$  and  $\Pi_2 = 0$

# The Prisoners' Dilemma Game

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- What is the Nash equilibrium for this game?
  - Let  $q_i$  denote either of the two (discrete) actions that prisoner  $i$  can take (i.e. deny or confess)
  - What is prisoner 1's best response,  $q_1^* = R_1(q_2^e)$ ?
  - If  $q_2^e = \text{deny}$  then  $q_1^* = \text{confess}$ . And if  $q_2^e = \text{confess}$  then  $q_1^* = \text{confess}$ .
  - So  $q_1^* = \text{confess}$  is actually the best action for all  $q_2^e$ . (This means this action is a *dominant strategy*. Sometimes happens in a NE but usually not.)
  - Same is true for prisoner 2:  $q_2^* = \text{confess}$
  - So the NE is  $\{q_1^* = \text{confess}, q_2^* = \text{confess}\}$
- Note how the NE outcome is not Pareto Efficient (if these are the only 2 agents in the world)
  - Feasible to make both prisoners better off (than the NE) by moving to the allocation  $\{q_1 = \text{deny}, q_2 = \text{deny}\}$
  - Interactions are not taking place via competitive markets, so no surprise that FWT can fail

## Back to Cournot Competition: What is the Nash Equilibrium?



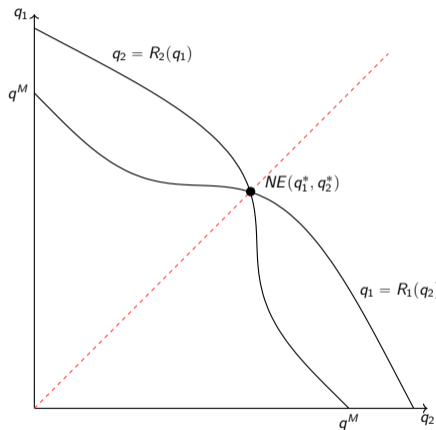
- Once we have solved for the best response functions  $q_1^* = R_1(q_2^e)$  and  $q_2^* = R_2(q_1^e)$ , we set  $q_1^* = q_1^e$  and  $q_2^* = q_2^e$ . Hence, NE  $(q_1^*, q_2^*)$  solves:

$$q_1^* = R_1(q_2^*)$$

$$q_2^* = R_2(q_1^*)$$

- This is illustrated here (for firms with identical but otherwise general cost functions)
  - Can prove that the two best response curves are downward-sloping – firm 1 would always want to sell more if it thinks that firm 2 will sell less
  - The Cournot equilibrium is for each firm to produce the same amount (i.e.  $q_1^* = q_2^*$ ) – since they are identical
- From there, can solve for  $p^* = D^{-1}(q_1^* + q_2^*)$

# Cournot Duopoly vs. Monopoly



- Note that if  $q_2^e = 0$  we (of course) have  $q_1^* = q^M$ , the monopolist level of output
  - And similarly for firm 2: if  $q_1^e = 0$  then  $q_2^* = q^M$
- Note that the Cournot equilibrium (marked *NE*) involves more total industry output  $Q^* \equiv q_1^* + q_2^*$  than the monopoly amount  $q^M$ 
  - So duopoly competition leads to greater output, lower prices, and less DWL (as with Stackelberg)
- Intuition:
  - Duopolist producing more raises market price, but duopolist only cares about lost inframarginal revenue on  $q_f$  not entire  $Q$
  - So duopolist doesn't hold back on production as much as a monopolist does

## Example: Cournot Competition with Linear Demand

- Suppose two firms have zero marginal cost, participate in a market with demand  $D(p) = \frac{a-p}{b}$ , and that they simultaneously make production decisions.
- What will be the quantities sold by the two firms?
  - Solve for firm 2's best response function for any given  $q_1^e$ :  $q_2 = R_2(q_1^e)$ , which is the same problem as Stackelberg follower above but for  $q_1^e$ :  $q_2 = \frac{a-bq_1^e}{2b} \equiv R_2(q_1^e)$
  - By symmetry, firm 1's best response function is the same:  $q_1 = \frac{a-bq_2^e}{2b} \equiv R_1(q_2^e)$
  - Nash eq. is where  $q_1^* = R_1(q_2^*)$ ,  $q_2^* = R_2(q_1^*)$ , and  $q_1^* = q_1^e$  and  $q_2^* = q_2^e$
  - So hence  $q_1^* = R_1(q_2^*)$ ,  $q_2^* = R_2(q_1^*)$ , or  $q_1^* = \frac{a-bq_2^*}{2b}$  and  $q_2^* = \frac{a-bq_1^*}{2b}$
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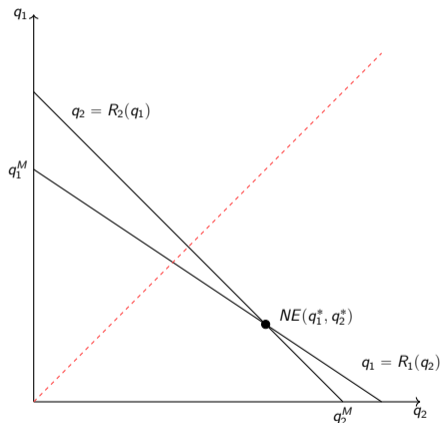
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  - Solving these two equations yields:  $q_1^* = q_2^* = \frac{a}{3b}$
- How do these quantities compare to the Stackelberg and monopolist's levels?
  - Recall, above for Stackelberg we had  $q_1^* = q^M = \frac{a}{2b}$  and  $q_2^* = \frac{a}{4b}$ . So leader sold more than under Cournot, and follower sells less than under Cournot. And total output under Cournot ( $Q = \frac{2a}{3b}$ ) is lower than under Stackelberg ( $Q = \frac{3a}{4b}$ ).

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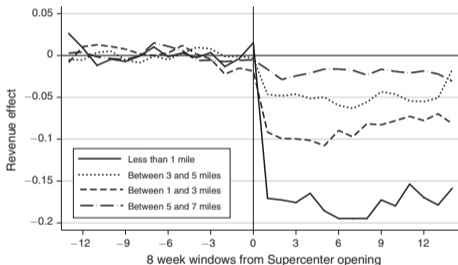
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- Who makes the largest profit?
  - Monopolist (since strictly less constrained version of same problem), followed by Stackelberg leader (less constrained than Cournot), then Cournot, then Stackelberg follower (more constrained than Cournot)

## Cournot Competition with Asymmetric Costs



- Suppose that market demand is linear like in the example we just saw. But the firms have asymmetric (but constant) marginal costs, e.g.  $MC_1 > MC_2$
- The firms' best response functions will still be linear (like in the above example when  $MC_f = 0$ ) but now they are asymmetric
- As we might expect, the lower-cost firm (firm 2 here) will sell relatively more than the other firm
- But the lower-cost firm doesn't completely take over the market – Cournot competition is relatively “weak” in terms of allowing the better firm to “win”

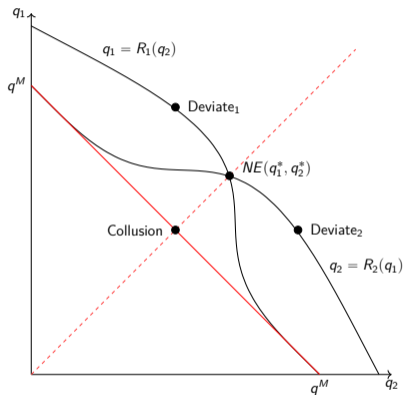
# The Effects of Competition: When Walmart Comes to Town



Arcidiacono (*Am. Ec. J.: Policy*,  
2020)

- Authors have weekly price data at all US grocery store sales from 2001-11
- Difference-in-differences estimates on sales of non-Walmart stores in:
  - “Treatment”: locations where Walmart entered
  - “Control”: locations where Walmart didn’t enter
- If “location” = “1 mile radius” then Walmart causes drop in sales of almost 20% in nearby stores
- Within a 1-mile radius cell, many of these grocery stores would have been near-monopolists that (after Walmart entry) are now near-duopolists

# Collusion

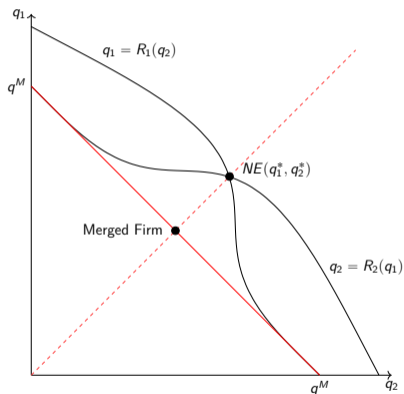


- Suppose two identical duopolists were to *collude*:
  - Agree on an amount of total production  $Q^{\text{collude}}$
  - And on a sharing rule (e.g.  $q_f = \frac{1}{2} Q^{\text{collude}}$ ).
- What  $Q^{\text{collude}}$  would they agree on?
  - The best they could hope for is  $Q^{\text{collude}} = q^M$
  - That is, best action is to (collectively) be a monopolist
- This would be good for the two firms and bad for the consumer relative to competition (and create DWL)

## The Colluders' Dilemma

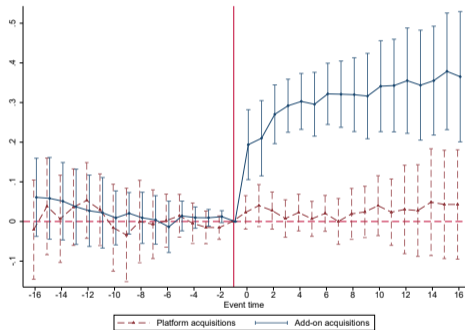
- Why *wouldn't* the firms do this?
  - It's illegal under US (and most countries') law
  - How to sustain the cooperation?
- Can think of the action of colluding in the Cournot game as similar to the action of "Deny" in the Prisoners' Dilemma game
  - As we have seen, the only NE in the Cournot game is for the firms both not to collude ( $q_f = \frac{1}{2}q^M$  is not on the best response curves so, by definition, the firms would each want to deviate to the points labeled "Deviate<sub>f</sub>" in above figure)
- But in the real world, potential colluders are plausibly playing a *repeated game* – e.g this same game period after period, perhaps forever
- Repeated games are complicated (infinite set of strategies!) But one result is the *folk theorem* of infinitely repeated games:
  - If players value the future sufficiently highly then permanent cooperation (i.e. both play "collude", forever) is a NE
- E.g. the OPEC countries (a *cartel* controlling about one third of global oil production) have managed to sustain collusion for 65 years and counting...

# Mergers and Acquisitions



- Suppose, rather than illegally colluding, the duopolists just merge (or one acquires the other) to become a monopoly
- In our model above this is good for the firms and bad for the consumers (and raises DWL)
  - For this reason, many countries often block such mergers (and break up a monopoly formed when one duopolist exits)
- But in a more realistic model with min. efficient scale (MES) that is large relative to demand then mergers have two effects:
  - Reduce competition (increase DWL)
  - Decrease costs (decrease DWL)
- Merger review/litigation therefore always challenging (and prone to lobbying)

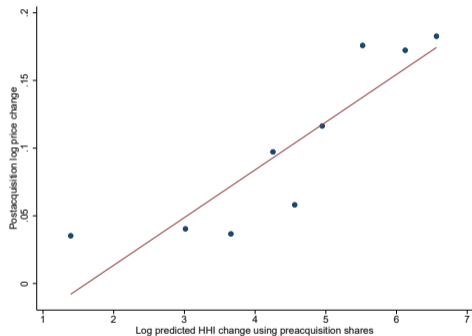
# Some Painful Effects of Mergers



Asil et al (2024)

- One subtle form of merger/acquisition is where an investor acquires several firms in an industry (converting it from, say, a duopoly of 2 independent firms to now effectively 1 unified monopolist)
- Here, authors look at (in a diff-in-diff analysis) effects on prices charged (to hospitals) by anesthesia firms of:
  - In red: first being acquired by a financial entity (e.g. hedge/private equity fund)
  - In blue: being the second (or more) firm acquired by the same entity
- On average, second acquisition causes anesthesia firm to raise prices by 35% (within 16 quarters)

# Some Painful Effects of Mergers



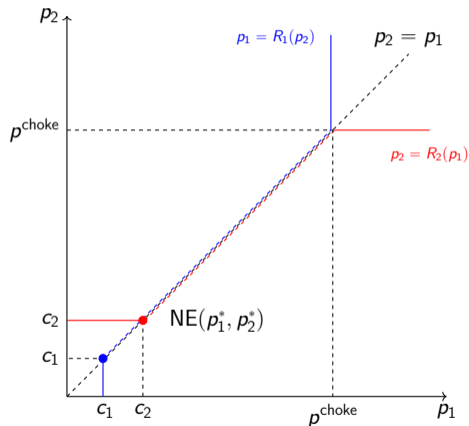
Asil et al (2024)

- Authors also estimate the size of the price jump (upon second acquisition) separately by market
- These estimated jump sizes correlate (as seen here on y-axis) with the corresponding rise in the (ownership-based) concentration measure (the so-called “HHI”, x-axis) that the acquisition caused
- This suggests that if the acquisition takes place:
  - In a sea of many other competitors (far left of x-axis) it has no effect on prices
  - Where it is really consolidating the market (far right of the x-axis, e.g. from duopoly to monopoly) then big effect

## Simultaneous Price Choice (Bertrand Competition)

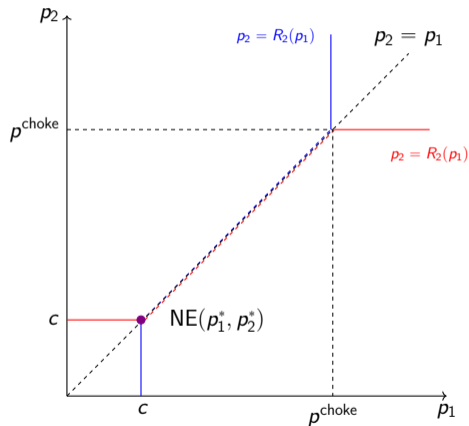
- Cournot competition (“compete in quantities”) has a natural appeal in some industries where capacity is costly to install and hard to change (e.g. hotels)
- Other industries rely less on installed capacity. In these cases it is perhaps more realistic to imagine that they compete in prices (e.g. two gas stations across the street from one another).
- This is called *Bertrand competition*. In a basic version, the setup is:
  - Two firms
  - Firm  $f$  has constant marginal costs given by  $c_f$ ; say,  $c_1 < c_2$
  - Firm  $f$ 's action is to charge a price  $p_f$  and then sell as much as the consumer wants at that price—that is, the firms “compete in prices”
  - The firms make an identical (i.e. “homogeneous”) product so the consumer just buys from the cheapest seller (and buys half from each of them if  $p_1 = p_2$ )
  - Consumer's demand is  $D(p)$  and this has a *choke price*  $p^{\text{choke}}$  at which  $D(p^{\text{choke}}) = 0$
  - $c_2$  is lower than the price that firm 1 would charge if it were a monopolist

# Simultaneous Price Choice (Bertrand Competition)



- The firms'  $RD_f(\cdot)$  functions are discontinuous, so FOCs aren't very useful
- But we can intuit the best response functions:
  - Firm 1:
    - For  $p_2^e \leq c_1$ , charge  $p_1 = c_1$
    - For  $p_2^e \in [c_1, p^{\text{choke}}]$  charge  $p_1 = p_2^e - \epsilon$  where  $\epsilon$  is "tiny" (i.e. just undercut firm 2 and capture the whole market)
    - For  $p_2^e > p^{\text{choke}}$  charge  $p_1 = p^{\text{choke}}$  (i.e. sell nothing)
  - And firm 2 is analogous
- As usual, the NE  $(p_1^*, p_2^*)$  is where the two best response functions cross
  - This happens at  $p_1^* = c_2 - \epsilon$  (where  $\epsilon \rightarrow 0$ ) and  $p_2^* = c_2$
  - So the price is approximately  $c_2$ , but firm 1 captures the whole market

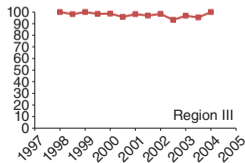
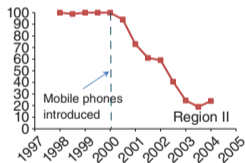
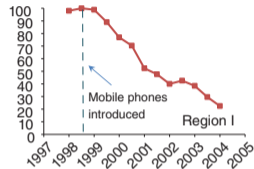
# The Bertrand Paradox



- If  $c_1 = c_2 = c$  (i.e. identical firms) then NE is  $p_1^* = p_2^* = c$ 
  - This is the perfectly competitive price! So  $DWL = 0$ .
  - Perhaps paradoxical: adding one firm takes us from monopoly to perfect competition
- This didn't happen under Cournot competition
  - Under Cournot, need  $N \rightarrow \infty$  to get to perfectly competitive outcome
  - So price competition is in a sense "more aggressive" than quantity competition
- But more complex if production not CRTS:
  - If IRTS (e.g. a fixed cost): neither firm would even enter!
  - If DRTS (e.g. max capacity): can't credibly threaten to undercut and steal whole market

# The Effects of Competition: When Cellphones Come to Town

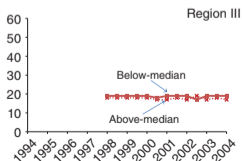
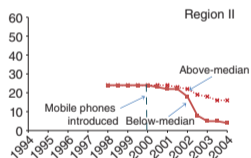
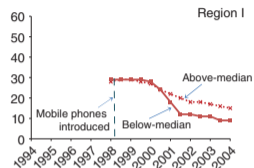
Panel C. Percent who buy boats in their own village



- Study by Jensen and Miller (*Am. Ec. Rev.*, 2018)
- Setting: regions of Kerala (India), c. 2000 when cellphone towers first start rolling out to the region
  - Regions I and II got tower (at different times), Region III didn't
- Other work has documented how the arrival of cell towers:
  - Allowed fishermen to call ahead to village markets other than their own (before coming to shore after fishing) and hence learn where arbitrage opportunities are highest
  - So towers effectively promoted inter-village travel among fishermen
- This figure: extent to which local fishermen now shop elsewhere for their boats

# The Effects of Competition: When Cellphones Come to Town

Panel B. Number of firms,  
by baseline life-span



- This figure: now that fishermen are shopping around more, composition of firms selling boats has changed
- In particular, the lower quality boat firms (those who sell boats with below-median life-spans) exited the market much more than the higher-quality boat firms
- This is a bit like asymmetric costs Bertrand competition in action: if we went from monopoly to duopoly, the lower cost (i.e. higher quality) firm would take over the market and cause the high-cost firm to exit

## Concluding Remarks

- **Key concepts from today's lecture:**
  - Oligopoly: market with a small number of firms, so strategic interactions across firms are important
  - Duopoly: market with two firms
  - Stackelberg competition: when one firm (leader) can commit to a quantity and the other firm (follower) cannot
  - Best response function: a firm's best action as a function of the other firm's action
  - Cournot competition: when two firms simultaneously commit to a quantity
  - A game (a model of strategic interaction): has players, each of whom has actions, and each gets a payoff as a function of own and others' actions
  - Nash equilibrium: actions that are best responses to the correct expectations of others' actions
  - Prisoners' (colluders') dilemma game: classic game where NE is not PE
  - Collusion: two firms agree to act like a monopolist
  - Bertrand competition: when two firms simultaneously commit to a price
- **Next lecture:**
  - Imperfect competition in firms' input (e.g. labor) market rather than output market