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Dynamic Games & Cartels

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Dynamic Games

Dynamic Games & Cartels

- Imperfect information
  - To study cartels, we nee
    games where firm take
  - Example: they set prices simultaneously the
    beginning of every day
  - This is an example of imperfect information
    - When several players make decisions at the same time
    - When a player does not know what others did in the past

Incomplete information =
When players don't know each others' payoff functions

Dynamic Games & Cartels

- Subgame perfect equilibrium
  - In games with imperfect information, we cannot do backwards induction as before
  - But, almost the same
  - Called SPE
- Illustration
  - Before studying cartels
  - Look at simpler problem: Entry deterrence

Entry Deterrence

Entry Deterrence

- Problem
  - Monopoly profits may trigger entry
- Solution
  - Threaten new firms with price war
- Problem
  - Low prices also costly to incumbent
- Question: Credible?

Entry Deterrence

- Timing
  - Time 1: Entrant decides whether to enter
  - Time 2: Firms set prices simultaneously

Entry Deterrence

- Demand
  - Value of first unit V; second unit worthless
  - Perfect substitutes
  - 2 consumers aware of entrant; buy from cheapest
  - 1 consumer not aware; buys from incumbent

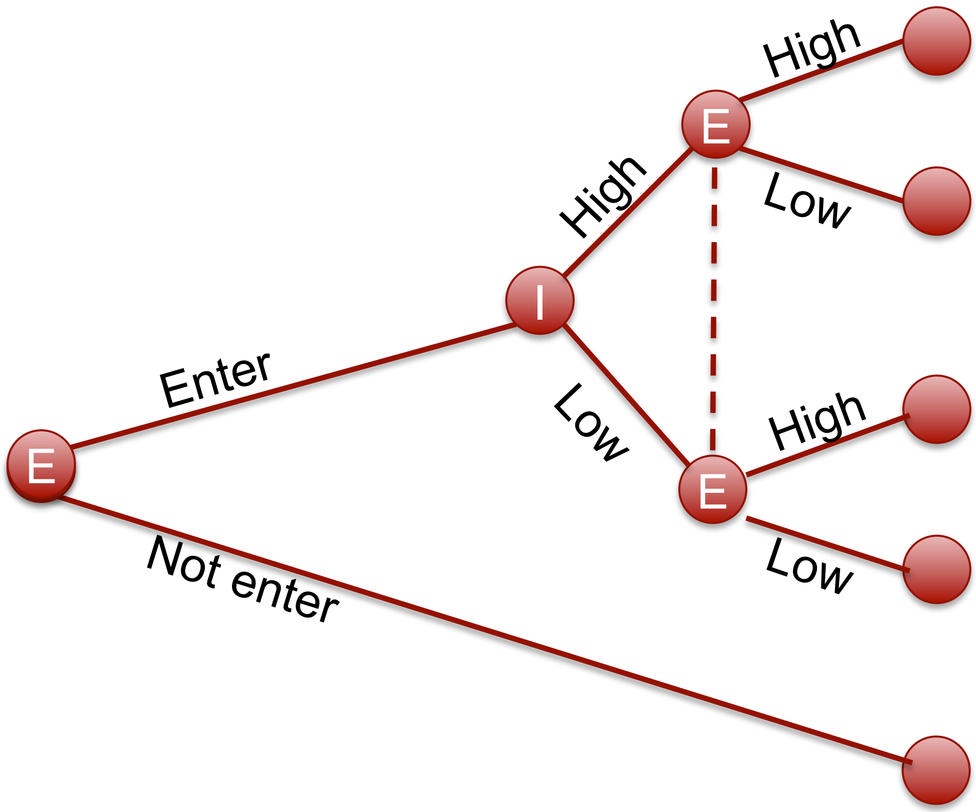
Entry Deterrence

- Technology
  - Incumbent's marginal cost $C_I = 8$
  - Entrant's marginal cost $C_E = 7$
  - Entry cost $K = 2$

Entry Deterrence

- Simplifications
  - If entry, firms can choose between two prices
    - $P^H = V = 10$
    - $P^L = C_I = 8$
  - If no entry, incumbent charges
    - $P^H = V = 10$

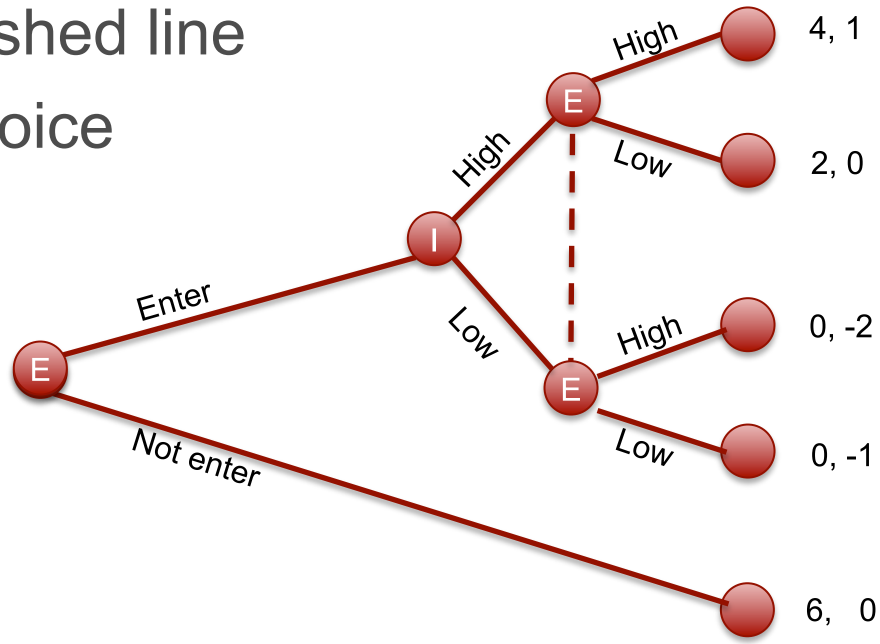
Entry Deterrence



Incumbent, q(p-c)=π	, Entrant q(p-c)=π
2(10-8)=4,	1(10-7)-2=1
1(10-8)=2,	2(8-7)-2=0
3(8-8)=0,	0(10-7)-2=-2
2(8-8)=0,	1(8-7)-2=-1
3(10-8)=6,	0

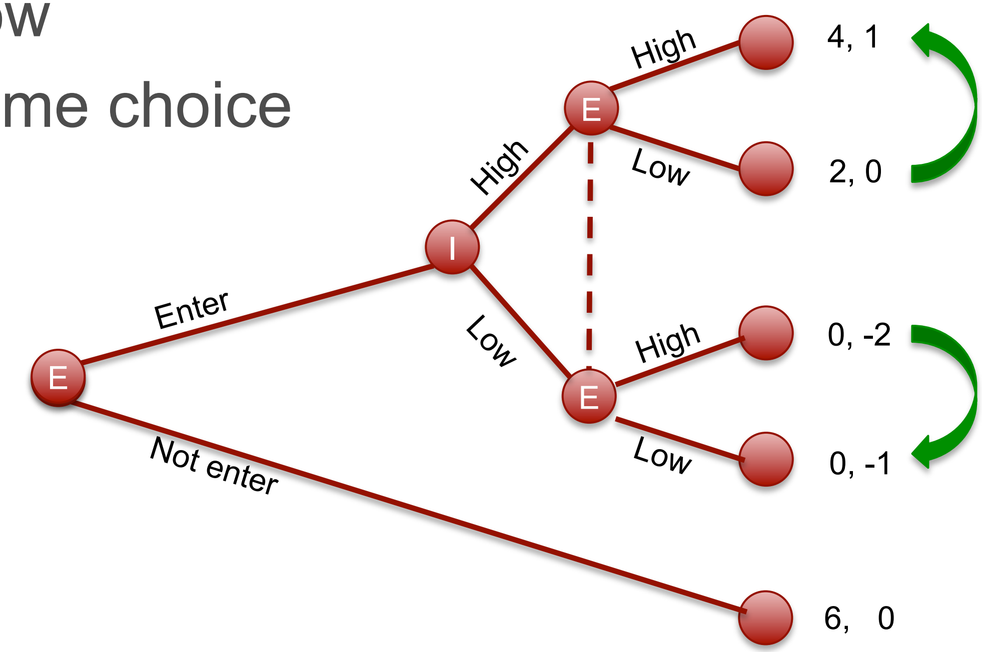
Entry Deterrence

- Imperfect information
  - Pricing decisions simultaneous
  - E doesn't know which node he is at
  - Information set – dashed line
  - Must make same choice



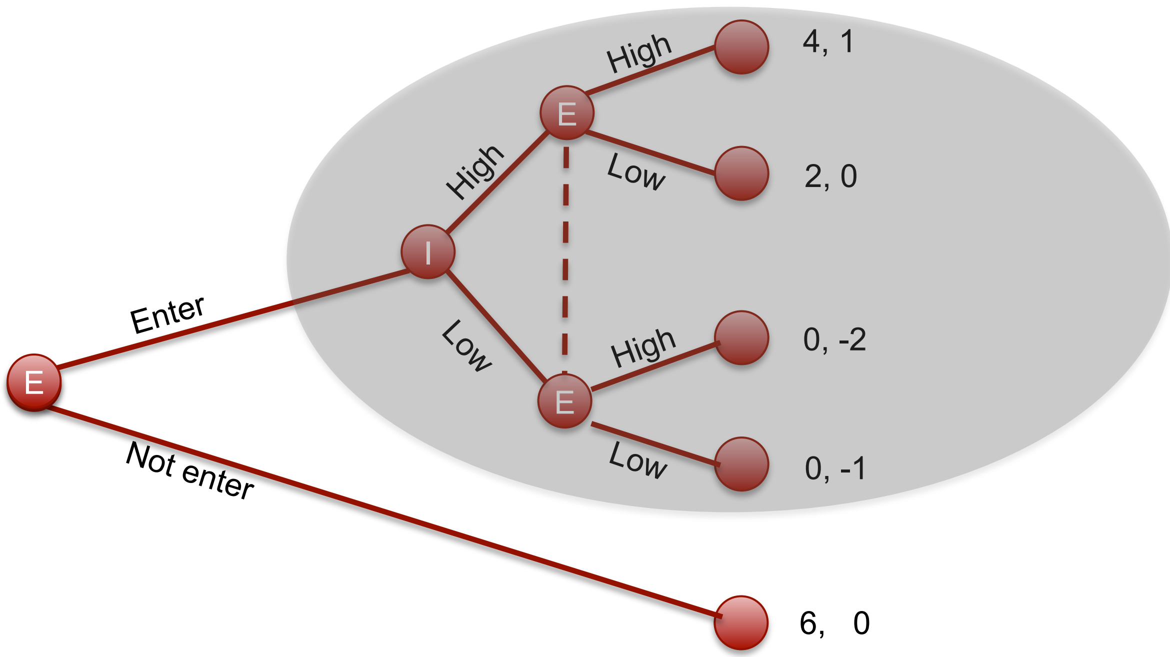
Entry Deterrence

- Backwards induction must be modified
  - E prefers High if High
  - E prefers Low if Low
  - But, must make same choice



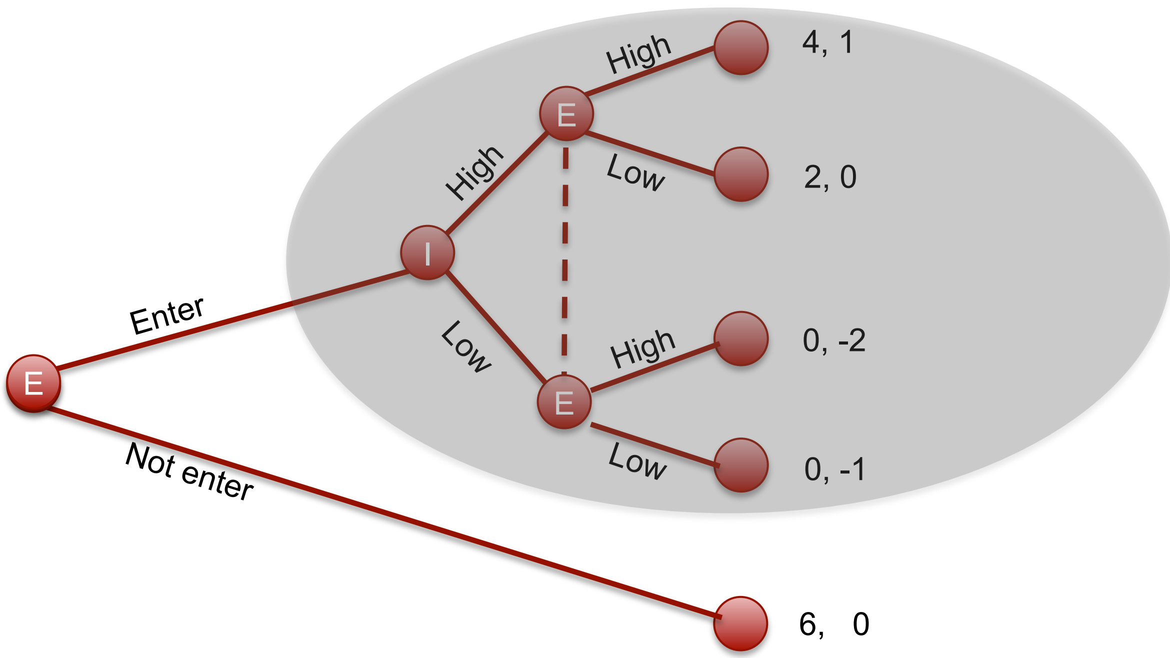
Entry Deterrence

- Decisions in second period constitutes a game tree in itself = Sub-game



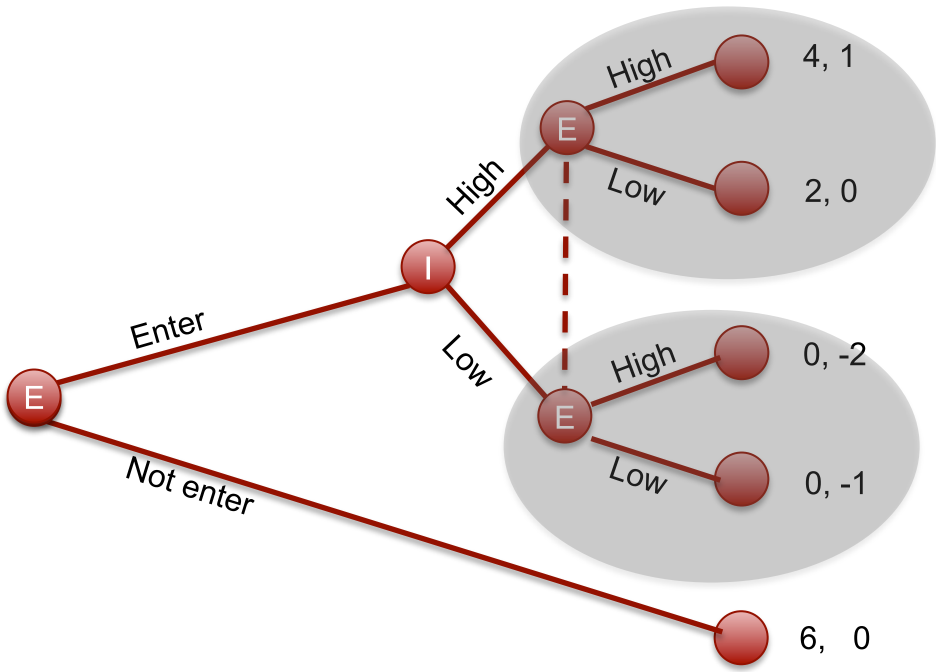
Entry Deterrence

- Sub-game perfect equilibrium
  - An equilibrium of complete game should prescribe equilibrium play in all sub-games
  - Otherwise someone would deviate if sub-game reached



Entry Deterrence

- E's decisions do *not* constitute sub-games
  - Cannot split information sets



Entry Deterrence

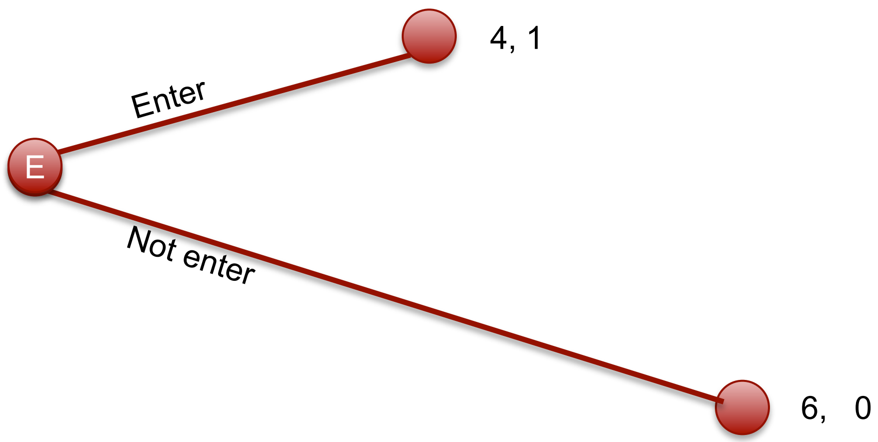
- Normal form of pricing sub-game
  - Incumbent is row-player
  - Both have two strategies (complete plans of actions)

	High	Low
High	4, 1	2, 0
Low	0, -2	0, -1

  - Sole equilibrium: (high, high)
  - Equilibrium payoffs: (4, 1)

Entry Deterrence

- Truncated game



  - Entrant must enter

Entry Deterrence

- Unique sub-game perfect equilibrium predicts
  - Entrant enters
  - Both charge high prices
  - That is: Incumbent's threat to start price war is not credible. Better to exploit captive consumers.
- There are other Nash equilibria. Not credible.

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Cartels

Cartels

- Oligopolistic competition
  - Lower prices and profits
- Q: Why not cooperate instead?
  - Common price policy
  - Share the market
- A: Not feasible
  - Incentive to cheat
  - Agreement not enforced by courts

Cartels

- But, cartels do exist
  - Sweden: Petrol, Asphalt
  - Europe/EU: Sotheby and Christies
  - Generic drugs?

Generic drugs

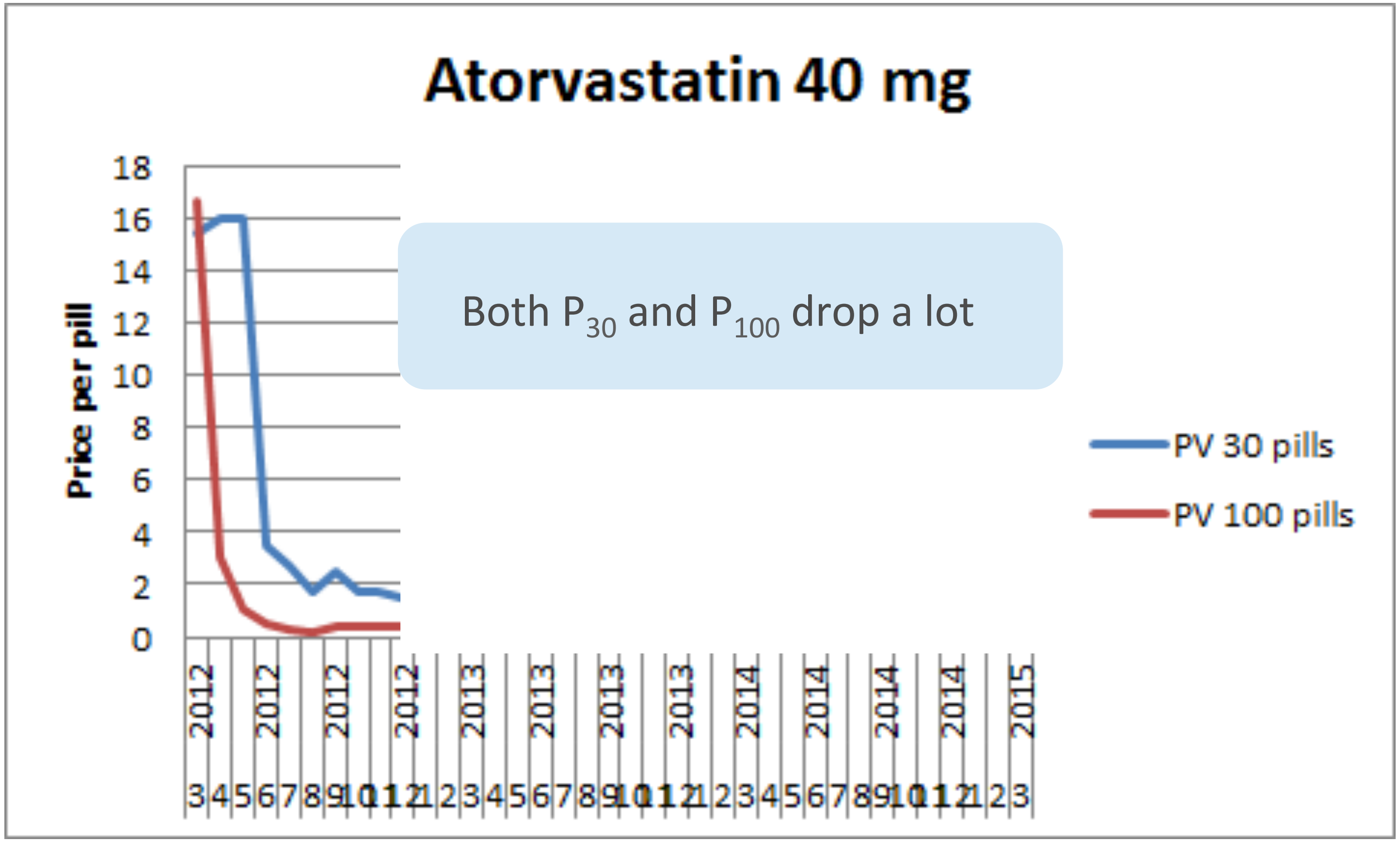
- National auction
  - All drugs without patent
  - Every month
- Idea
  - Lowest price = “product of the month”
  - Large market share
    - Recommended
    - Subsidy does not cover “over-charge”
- But
  - Also “brand name” usually gets market share

Generic drugs

- Example: Atorvastatin
  - Reduces cholesterol
  - Patent expired in 2012
  - Sold in different package sizes, e.g.:
    - 100-pills: large market => many competitors
    - 30-pills: smaller market => fewer competitors

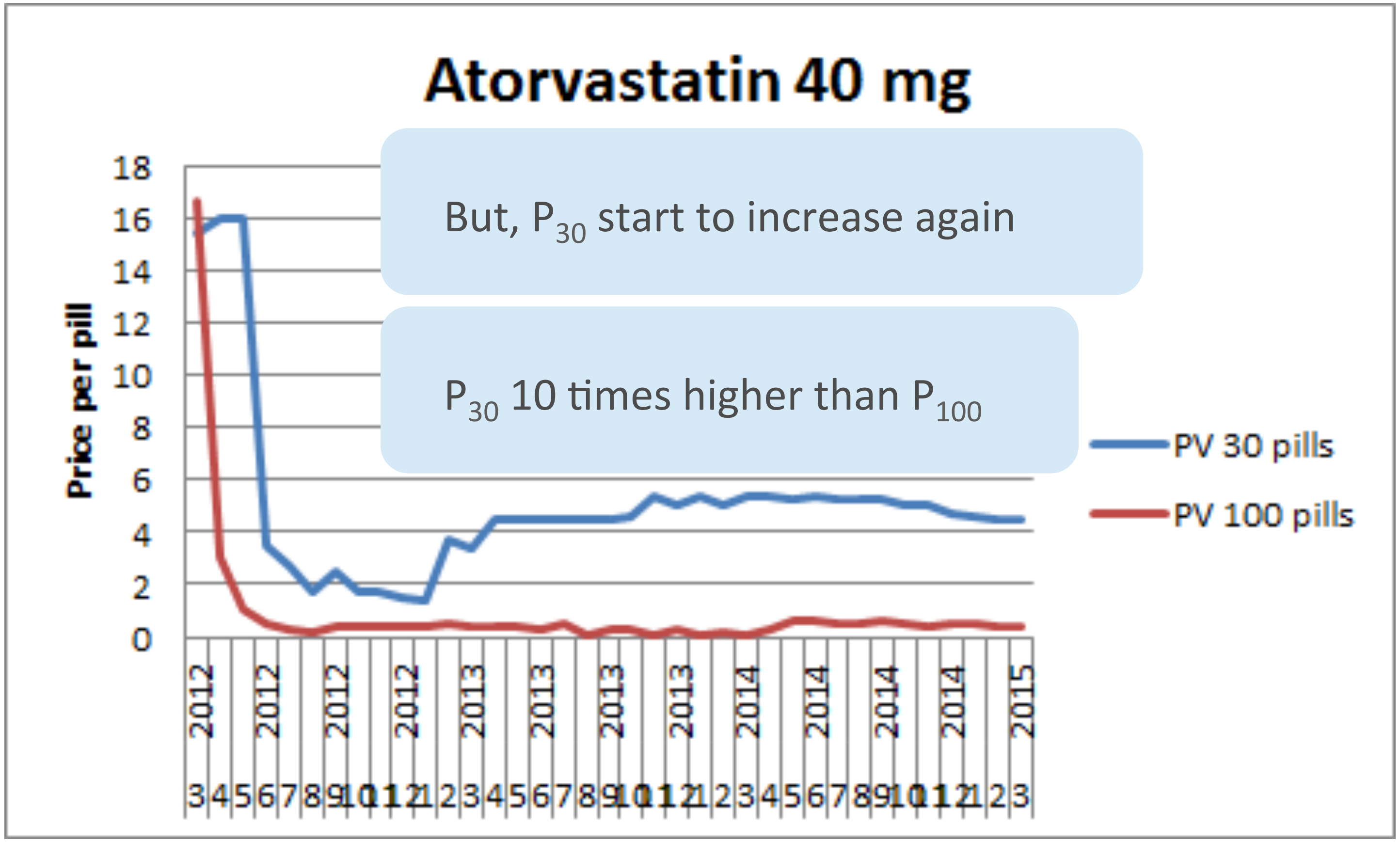
Generic drugs

Price of the product of the month



Generic drugs

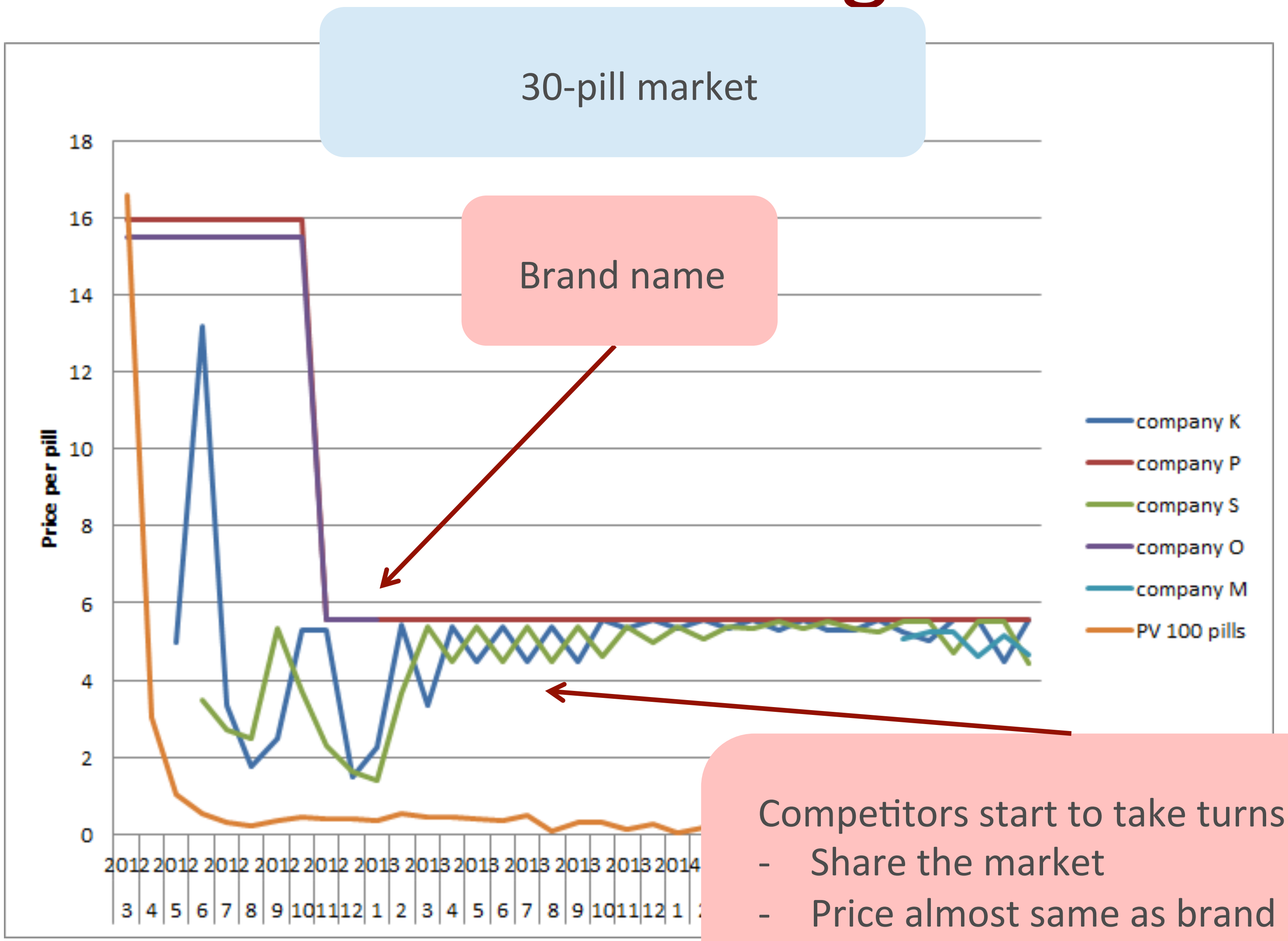
Price of the product of the month



But, P_{30} start to increase again

P_{30} 10 times higher than P_{100}

Generic drugs



Competitors start to take turns
- Share the market
- Price almost same as brand name
- They seem to collaborate !

Cartels

- Q: Collaboration - What do we miss?
  - Markets are long lived
  - Changes the situation dramatically

Agenda

- Issues
  - How can cartels enforce their agreements?
  - What markets are at risk?
  - How can we fight cartels?

First a little bit of game-theory…

"Folk Theorem"

Folk theorem

- Repeated game theory
  - Model to explain how people can cooperate

Folk theorem

- Recall “prisoners’ dilemma”
  - Two players
  - Two strategies: Cooperate and Cheat
  - Payoff matrix:

	Cooperate	Cheat
Cooperate	10, 10	-1, 18
Cheat	18, -1	0, 0

Folk theorem

- Unique Nash equilibrium: both cheat

	Cooperate	Cheat
Cooperate	10, 10 →	-1, 18
Cheat	↓ 18, -1 →	↓ 0, 0

– In fact: cheat is dominating strategy

Folk theorem

- Now repeat PD game infinitely many times
  - t = 1, 2, 3, …..
  - Payoff = discounted sum of period payoffs
  - Complete and "almost perfect" information
- Strategy
  - Instruction telling player what to do at every decision node

Folk theorem

- Define: Trigger strategy
  - Period 1: Cooperate
  - Period t = 2, 3, ….
    - Cooperate, if <u>both</u> have cooperated <u>all</u> previous periods
    - Cheat, otherwise
- Note
  - This is only a definition – a possible way to behave
  - If both follow TS, then cooperation (at every t)
  - Question: when would players behave like this?

Folk theorem

- Game theoretic details
  - Need to study if TS is Sub-game perfect equilibrium
  - Problem: No last period
  - We will skip these "details"
  - Take short-cut

Folk theorem

- Analysis
  - Assume A follows TS
  - Does B want to follow TS (in every subgame)?
  - If so, (TS, TS) is SPE
- Need to consider two cases (types of subgames)
  - When nobody has cheated in the past
  - When somebody has cheated in the past

Folk theorem

- Assume: nobody has cheated in the past

Follow TS

$$U^{cooperate} = 10 + \delta \cdot 10 + \delta^2 \cdot 10 + \delta^3 \cdot 10 + ... = 10 \cdot \frac{1}{1-\delta} \qquad (\delta < 1)$$

Cheat

$$U^{cheat} = 18 + \delta \cdot 0 + \delta^2 \cdot 0 + \delta^3 \cdot 0 + ... = 18$$

No deviation if

$$U^{cooperate} \geq U^{cheat} \Leftrightarrow \qquad 10 \cdot \frac{1}{1-\delta} \geq 18 \Leftrightarrow \qquad \delta \geq \frac{4}{9}$$

Folk theorem

- Assume: somebody has cheated in the past

Follow TS

$$U^{cooperate} = 0 + \delta \cdot 0 + \delta^2 \cdot 0 + \delta^3 \cdot 0 + ... = 0$$

Cheat (nothing to gain even in the short run)

$$U^{cheat} = 0 + \delta \cdot 0 + \delta^2 \cdot 0 + \delta^3 \cdot 0 + ... = 0$$

Folk theorem

- Folk theorem
  - IF a game (e.g. prisoners’ dilemma) is **repeated** infinitely many times, and
  - IF the players are **sufficiently patient**,
  - THEN, they can enforce **cooperative** outcomes, simply by threating not to cooperate anymore if somebody cheats.

Folk theorem

- Examples
  - Externalities
  - Public goods
  - Cartels
  - …

Folk theorem

- But, multiple equilibria
  - Also the strategy "Always cheat" is a subgame-perfect equilibrium
- Conclusion
  - Folk-theorem shows conditions under which cooperation **might** arise, not that it must arise

How cartels work

How can they enforce their agreements?

How cartels work

- Setup
  - Players: Two firms
  - Actions: Set prices in each period (Bertrand)
  - Time: $t = 1, 2, 3, \ldots$ (infinite)
  - Information: Complete and "almost perfect"
  - Payoff: $\Pi_i = \Sigma_t \, \delta^{t-1} \, \pi_i(p^t_1, p^t_2)$ [$\delta < 1$ is discount factor]

How cartels work

- Definitions π = period profit of a firm

π^N	=	All firms compete (Nash equilibrium)	$p = c$
π^C	=	All firms charge cartel (= monopoly) price	p^m
π^D	=	Best one-stage deviation when all other firms charge cartel price	$p < p^m$

$\pi^D > \pi^C > \pi^N$

How cartels work

- Trigger Strategy - Definition
  - Start out charging the monopoly price
  - If no firm has cheated in the past,
    - set monopoly price
  - If someone has cheated in the past,
    - set price equal to one stage Nash (in Bertrand $p = c$)

How cartels work

- Claim
  - If A behaves according to TS, it is in B's interest to also follow TS in every subgame, and vice versa.
- Note
  - No incentives to deviate → [TS, TS] = SPE
  - Monopoly price will prevail
  - Cooperation hinges on threat of price war

How cartels work

- Proof – Cooperative phase
  - Assume no one has deviated in the past
  - Assume B sticks to TS
  - Q: Does A have incentive to deviate?

How cartels work

- If A sticks to TS

$$V^{+} = \pi^{C} + \delta\pi^{C} + \delta^{2}\pi^{C} + \ldots = \frac{1}{1-\delta}\pi^{C}$$

- If A deviates one period
  - Maximum profit during the period is π^D
  - Then, war starts: π^N

$$V^{D} = \pi^{D} + \delta\pi^{N} + \delta^{2}\pi^{N} + \ldots = \pi^{D} + \frac{\delta}{1-\delta}\pi^{N}$$

How cartels work

- No incentive to deviate if

$$V^{+} \geq V^{D}$$

How cartels work

- No incentive to deviate if

$$V^{+} \geq V^{D}$$

$$\pi^{C} + \frac{\delta}{1-\delta}\pi^{C} \geq \pi^{D} + \frac{\delta}{1-\delta}\pi^{N}$$

How cartels work

- No incentive to deviate if

$$V^{+} \geq V^{D}$$

$$\pi^{C} + \frac{\delta}{1-\delta}\pi^{C} \geq \pi^{D} + \frac{\delta}{1-\delta}\pi^{N}$$

$$\delta \geq \frac{\left(\pi^{D} - \pi^{C}\right)}{\left(\pi^{D} - \pi^{C}\right) - \left(\pi^{N} - \pi^{C}\right)} \equiv \underline{\delta}$$

How cartels work

- No incentive to deviate if

Gain from cheating today

$$\delta \geq \frac{\left(\pi^{D} - \pi^{C}\right)}{\left(\pi^{D} - \pi^{C}\right) - \left(\pi^{N} - \pi^{C}\right)} \equiv \underline{\delta}$$

Loss from cheating tomorrow

How cartels work

- Example: Bertrand competition with homogenous goods

$$\pi^N = 0 \qquad \pi^C = \pi^{monopoly} / 2 \qquad \pi^D = \pi^{monopoly}$$

$$\delta \geq \frac{\pi^{monopoly} - \pi^{monopoly} / 2}{\left[\pi^{monopoly} - \pi^{monopoly} / 2\right] - \left[0 - \pi^{monopoly} / 2\right]} = \frac{1}{2}$$

How cartels work

- Proof – Punishment phase
  - Assume someone has deviated in the past
  - Assume B sticks to TS
  - Q: Does A have incentive to deviate?

How cartels work

- Proof – Punishment phase
  - If A also sticks to TS
    - $V^{-} = \pi^N + \delta\, \pi^N + \delta^2\, \pi^N + \ldots = \pi^N/(1-\delta)$
  - If A deviates one period
    - Maximum profit during the period is still π^N
    - Subsequent periods: war still continues, giving profit π^N
    - $V^d = \pi^N + \delta\, \pi^N + \delta^2\, \pi^N + \ldots = \pi^N/(1-\delta)$

How cartels work

- Q: Conclusion
  - Cartels self-enforcing
  - If firms *sufficiently patient*
- Policy implications
  - Not sufficient to deny firms legal enforcement
  - Necessary to make collusion illegal and punish

How cartels work

- Competition is also possible
  - Competitive Strategy: Always set price equal to cost
  - If A follows CS, B has incentive to follow CS
  - CS is also SPE
- What should we predict?
  - Economics has no answer today
- Economics still useful
  - Delineate necessary conditions for collusion (e.g. interest rate).

What Markets have High Risk of Cartels?

Which Markets?

- Factors facilitating collusion
  - Discount factor (interest rate)
  - **Concentration**
  - Entry barriers
  - Frequency of interaction
  - Transparency
  - Business cycles and fluctuations
  - Firm differences
- How to use the list
  - Identify potentially problematic industries
  - In cases, analyze if allegations plausible

Which Markets?

Concentration

- If a duopoly firm cheats
    - » Gain (first period):
    - » Loss (subsequently):

Which Markets?

Concentration

- If a duopoly firm cheats
  - » Gain (first period): $\pi^m/2 \quad = \pi^m - \pi^m/2$
  - » Loss (subsequently): $-\pi^m/2 \quad = 0 - \pi^m/2$

Which Markets?

Concentration

- If a duopoly firm cheats
  - » Gain (first period): $\pi^m/2 \quad = \pi^m - \pi^m/2$
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- If a triopoly firm cheats
  - » Gain (first period):
  - » Loss (subsequently):

Which Markets?

Concentration

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  - » Gain (first period): $\pi^m/2 = \pi^m - \pi^m/2$
  - » Loss (subsequently): $-\pi^m/2 = 0 - \pi^m/2$

- If a triopoly firm cheats
  - » Gain (first period): $2\pi^m/3 = \pi^m - \pi^m/3$
  - » Loss (subsequently): $-\pi^m/3 = 0 - \pi^m/3$

Which Markets?

Concentration

- If a duopoly firm cheats
  - » Gain (first period): $\pi^m/2$ $= \pi^m - \pi^m/2$
  - » Loss (subsequently): $-\pi^m/2$ $= 0 - \pi^m/2$

- If a triopoly firm cheats
  - » Gain (first period): $2\pi^m/3$ $= \pi^m - \pi^m/3$
  - » Loss (subsequently): $-\pi^m/3$ $= 0 - \pi^m/3$

- Prediction
  - Low concentration → more tempting to cheat → cartels less stable