# Economics, Law and Ethics
## Part IB CST 75%, Part II CST 50%
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*with many thanks to Ross Anderson*

# Overview

- Auctions:
  - Types of auctions
  - Equivalence
  - What goes wrong
  - Advertising auctions
- Game theory:
  - Cooperation or conflict
  - Strategies
  - Types of games
  - Broader implications

# Auctions

- Around for millennia; standard way of selling livestock, fine art, mineral rights, bonds…
- Many other sales from corporate takeovers to house sales are also really auctions
- Auctions are a big success of the Internet, from eBay to Google
- Some unpleasant side-effects
- Rapidly growing interest in theoretical computer science: auction resources in distributed systems
- Many issues of asymmetric info, signaling, strategic play… – plus some solid theory!

# Types of auction

- English, or ascending-bid: start at reserve price and raise till a winner is left (art, antiques)
- Dutch, or descending-bid: start high and cut till somebody bids (flowers)
- First-price sealed-bid auction: one bid per bidder (government contracts)
- Second-price sealed-bid auction, or Vickrey auction: highest bidder wins and pays second-highest bid (postage stamps)
- All-pay auction: everyone pays at every round until one remaining bidder gets the goods (war, litigation, winner-takes-all market race)

# The Aalsmeer flower auction

# Strategic equivalence

- A Dutch auction and a first-price sealed-bid auction give the same result: the highest bidder gets the goods at his reservation price
- They are ‘strategically equivalent’
- Ditto the English auction and the second-price sealed-bid auction (modulo the bid increment)
- But the two pairs are not strategically equivalent!
  - in a second-price auction it’s best to bid truthfully
  - in a Dutch / first-price auction, you should bid low if you think your valuation is much higher than everybody else’s

# Revenue equivalence

- This is weaker – not ‘who will win’ but ‘how much money on average’
- According to the revenue equivalence theorem, you get the same revenue from any well-behaved auction under ideal conditions
- These include risk-neutral bidders, no collusion, Pareto efficiency (highest value bidder gets goods), reserve price, independent valuations, …
- Then bidders adjust their strategies and the English, Dutch and all-pay auction yield the same
- So when you design an auction, you must focus on any ways the conditions aren’t ideal

# What goes wrong (1)

- In a ‘private-value auction’, each bidder’s value $v_i$ is exogenous (think: sculpture). In a second-price auction, everything you buy is a bargain
- In a ‘public-value auction’, each item has a true price which bidders estimate at $v + \varepsilon_I$ (think mineral leases; spectrum auctions). The buyer is the sucker who overestimated the most!
- This is called ‘the winner’s curse’
- Many real auctions lie somewhere between these two extremes

# What goes wrong (2)

- Bidding rings – bidders collude to buy low, have a private auction later, split the proceeds
- First-price auctions are harder to rig; with second-price, New Zealand bids of $7m and $5000
- Entry detection / deterrence: an early (1991) ITV franchise auction required bidders to draw up a detailed programming plan. In Midlands & Central Scotland, industry knew there was no competition; bids under 1p per head (vs £9–16 elsewhere)
- Predation: ‘we’ll top any other bid’ in takeovers
- Sniping and other boundary effects

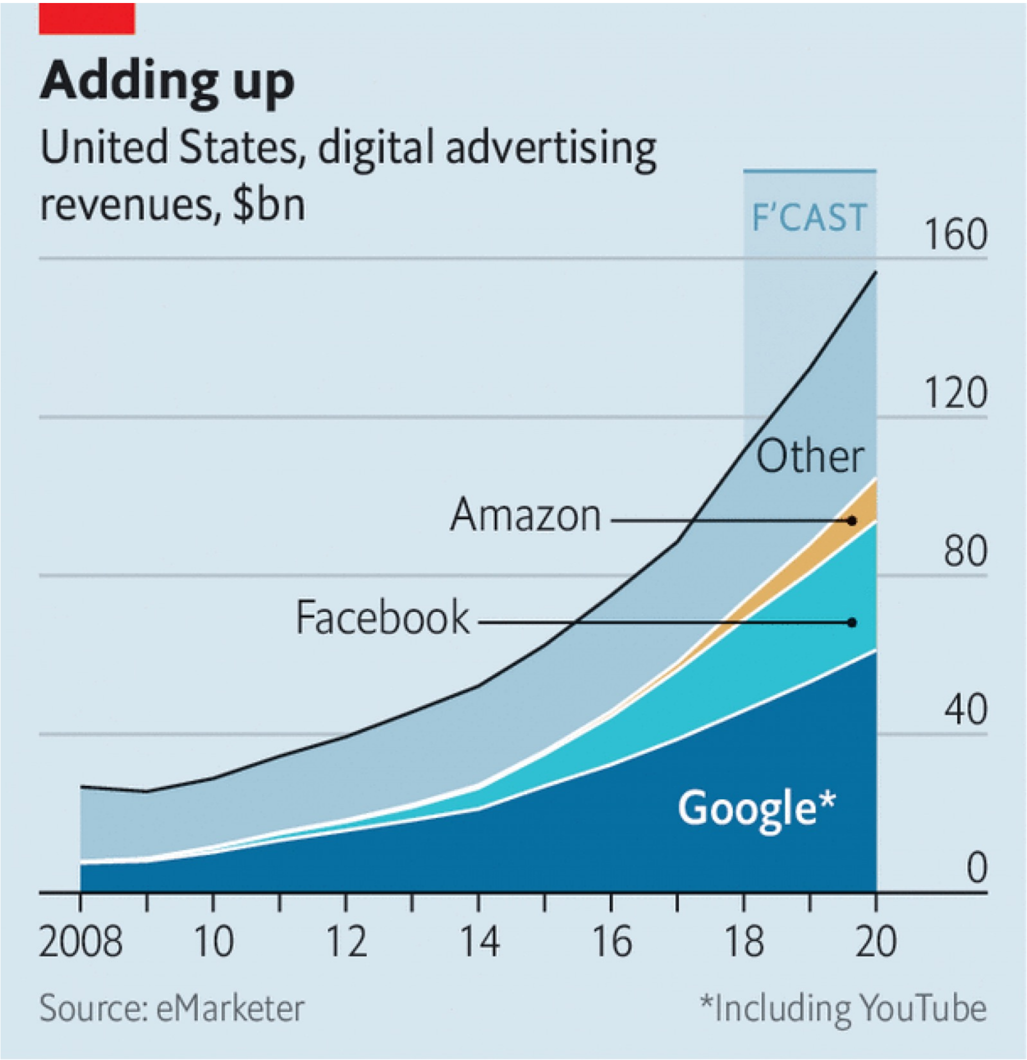
# What goes wrong (3)

- Risk aversion: if you prefer a certain profit of £1 to a 50% chance of £2, you'll bid higher at a first-price auction
- Signaling games: show aggression by a price hike
- E.g. in simultaneous auctions, as in the USA, signal "we want SF, LA, SD and if you compete with us there we'll push prices up in your patch")
- Budget constraints: if bidders are cash-limited, all-pay auctions are more profitable
- Externalities between bidders – e.g. arms sales

# Combinatorial auctions

- Externalities lead to preferences for particular bundles of goods: landing slots at airports, spectrum, mineral rights…
- Bid (\$x for A+B+C) or (\$y for A+D+E) or…
- Critical app for CS: routing in presence of congestion (bid for AB and BC, or AD and DC…)
- The allocation problem is NP-complete; practical algorithms work up to a few thousand objects
- Also: how can we make the auction strategy-proof (i.e. truth-telling is the best strategy)?
- New field of ‘algorithmic mechanism design’

# Ad auctions

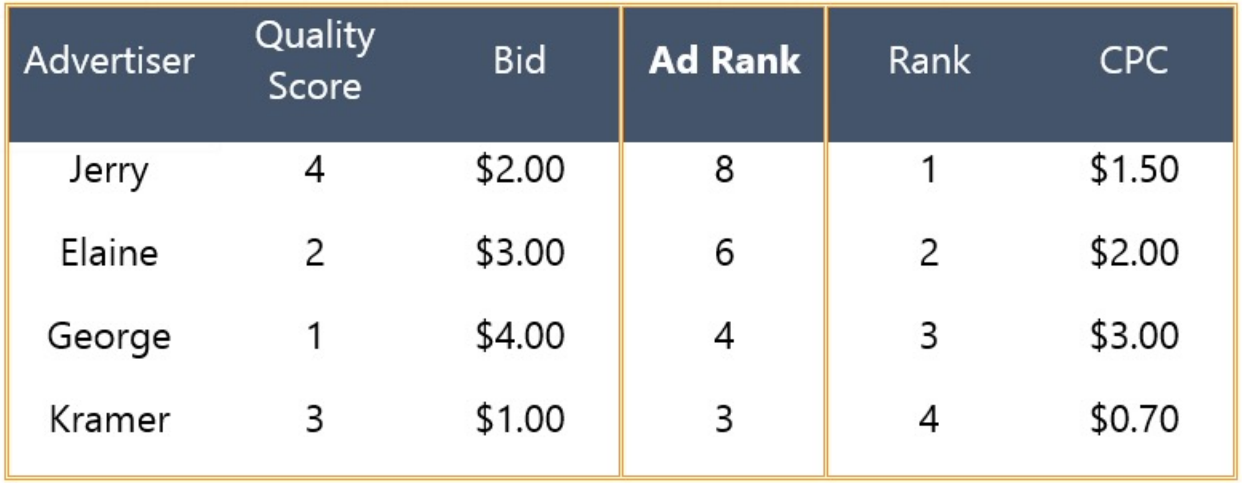


The Economist

# Ad auctions (2)

- Pioneered by Google
- Basic idea: second-price auction mechanism but tweaked to optimise platform revenue
- Bidders bid prices $p_i$, platform estimates ad quality $e_i$, and then ad rank $a_i = p_i.e_i$
- Ad quality $e_i$ = relevance . clickthrough rate
- So how do we work out who wins the auction and how much they pay?

# Ad auctions (3)



| Advertiser | Quality Score | Bid | **Ad Rank** | Rank | CPC |
|---|---|---|---|---|---|
| Jerry | 4 | $2.00 | 8 | 1 | $1.50 |
| Elaine | 2 | $3.00 | 6 | 2 | $2.00 |
| George | 1 | $4.00 | 4 | 3 | $3.00 |
| Kramer | 3 | $1.00 | 3 | 4 | $0.70 |

- Here George bids $4 and Jerry $2 but Jerry wins the auction because of higher ad quality – the platform expects he'll get four times the clicks
- Jerry pays a cost per click of only $1.50 (bid times competitor ad rank / own ad rank)

# Ethical aspects of ad auctions

- Translated to social media, ad ‘quality’ can easily segue into ‘virality’
- Then if your ads are good clickbait, and your followers follow them, you pay less
- See Martinez ‘How Trump conquered Facebook – without Russian ads’ (web page)
- Many sites tend to serve ever more provocative and extreme content...

# Cooperation or conflict

- One way of getting what you want is to make it, or make something else of value and trade for it – ‘Economics’
- Another way is to just take it, whether by force or via the ballot box – ‘Politics’
- Choices between cooperation and conflict are made at all sorts of levels all the time
- They can evolve in complex combinations
- The main tool we use to analyse them is game theory

# Game theory

- The study of problems of cooperation and conflict among independent decision-makers
- We focus on games of strategy, rather than chance
- We abstract to players, choices, payoffs, strategies
- There are
  - games of perfect information (such as chess and go)
  - games of imperfect information (which are often more interesting to analyse)

# Strategic form

- Example: matching pennies. Alice and Bob throw H or T. If they’re different, Alice gets Bob’s penny; else he gets hers. The strategic form is

Bob

Alice

| | H | T |
|---|---|---|
| H | -1, 1 | 1, -1 |
| T | 1, -1 | -1, 1 |

- This is an example of a zero-sum game: Alice’s gain = Bob’s loss

# Dominant strategy equlibrium

- In the following game, Bob's better off playing left; similarly Alice is always better off playing bottom

Bob

Alice

| | Left | Right |
|---|---|---|
| Top | 1, 2 | 0, 1 |
| Bottom | 2, 1 | 1, 0 |

- A strategy is an algorithm: input state, output play
- Here, each player's optimal play is a constant
- The is called a 'dominant strategy equilibrium'

# Nash equlibrium

- Consider this game:

Bob

| | | Left | Right |
|---|---|---|---|
| Alice | Top | 2, 1 | 0, 0 |
| | Bottom | 0, 0 | 1, 2 |

- Each player’s optimal strategy depends on what they think the other will do
- Two strategies are in Nash equilibrium when A’s choice is optimal given B’s, and vice versa
- Here there are two: top left and bottom right
- This game is sometimes called ‘Battle of the sexes’

# Pure v mixed strategies

- With deterministic algorithms, some games have no Nash equilibrium

Bob

Alice

| | scissors | paper | stone |
|---|---|---|---|
| scissors | 0,0 | 1, -1 | -1, 1 |
| paper | -1, 1 | 0,0 | 1, -1 |
| stone | 1, -1 | -1, 1 | 0,0 |

- Alice plays scissors → Bob will play stone → Alice will play paper …
- Fix: randomised algorithm. Called a ‘mixed’ strategy; deterministic algorithms are called ‘pure’

# Prisoners' dilemma

- Two prisoners are arrested on suspicion of planning a robbery. The police tell them separately: if neither confesses, one year each for gun possession; if one confesses he goes free and the other gets 6 years; if both confess then each will get 3 years

Benjy

Alfie

| | confess | deny |
|---|---|---|
| confess | -3, -3 | 0, -6 |
| deny | -6, 0 | -1, -1 |

- (confess, confess) is the dominant strategy equilibrium
- It's obviously not optimal for the villains!
- Is this a problem? If so, what's the solution?

# Prisoners' dilemma (2)

- You might answer 'serves them right'!
- But this can't apply to all instances of the dilemma
  - Defence spending
  - Fishing quotas
  - Free riders in file-sharing systems
  - Reducing carbon emissions
  - …
- Tough but inescapable conclusion: if the game is truly as described, there is no escape. Both will cheat rather than cooperate, with bad outcome
- To fix it, you need to change the game somehow!

# The evolution of cooperation

- If PD played repeatedly, there's a fix!
- 'Tit-for tat': cooperate at round 1, then at round n do what the other guy did at n-1
- Simulation competitions run by Bob Axelrod played off many iterated-game strategies; tit-for-tat did consistently well
- In the presence of noise, tit-for-tat gets locked into (defect, defect). So: forgive the other guy occasionally
- People have realised in the last 30 years or so that strategy evolution explains a lot of behaviour

Try out a game of prisoners' dilemma on your friends/family (see Hannah Fry's Christmas lecture *Secrets and Lies* at https://www.rigb.org/christmas-lectures/watch/2019/secrets-and-lies/how-to-get-lucky from 37:00 for an example)

How did you get on?

# Price-fixing

- If it costs $250 to fly someone LHR-JFK, do airlines compete and charge $255 or collude and charge $500?
- Competition laws forbid price-fixing cartels, but the same behaviour can arise implicitly
- Try charging $500 and see what other airlines do. If they ‘defect’ by competing, play tit-for-tat
- If you’re the regulator, how do you cope?

# Stag hunt

- People can hunt rabbits on their own, but have to work together to hunt a stag. If your buddy runs off after a rabbit, the stag will escape

Frank

Bernard

| | chase hare | hunt stag |
|---|---|---|
| chase hare | 2, 2 | 5, 0 |
| hunt stag | 0, 5 | 10, 10 |

- Difference from PD: (stag, stag) is now a Nash equilibrium
- You'll only chase a rabbit if you believe your buddy will defect
- Thus while PD is payoff-dominant, stag hunt is risk-dominant

# Volunteer’s dilemma

- Multi-player chicken: if one person volunteers, everyone else benefits, but if no-one volunteers then everyone suffers a big loss

Everyone else

Me

| | someone acts | no-one acts |
|---|---|---|
| act | benefit - cost | benefit - cost |
| don’t act | benefit | big loss |

- The Arab Spring: “If everyone goes on the street and says ‘the government is finished’, it’s finished. If you go on the street and say ‘the government is finished’, you’re finished”
- Evolution of leadership: first move = fitness signal

# Chicken

- In 'Rebel without a cause', Jim (James Dean) and Buzz (Corey Allan) drive stolen cars at a canyon and try to jump out last to prove their manhood

Jim

Buzz

| | jump | drive on |
|---|---|---|
| jump | 2, 2 | 1, 3 |
| drive on | 3, 1 | 0, 0 |

- Here, (1,3) and (3,1) are Nash equilibria
- Bertrand Russell suggested this as a model of nuclear confrontation in the Cold War
- But what about the iterated version?

# Game theory and evolution

- John Maynard Smith proposed the ‘Hawk-dove’ game as a simple model of animal behaviour. Consider a mixed population of aggressive and docile individuals:

| | Hawk | Dove |
|---|---|---|
| Hawk | (v-c)/2, (v-c)/2 | v, 0 |
| Dove | 0, v | v/2, v/2 |

- Food v at each round; doves share; hawks take food from doves; hawks fight (with risk of death c)
- If v > c, whole population becomes hawk (dominant strategy)
- What happens if c > v?

# Game theory and evolution (2)

- If c > v, a small number of hawks will prosper as most interactions will be with doves. Equilibrium reached at hawk probability p setting hawk payoff = dove payoff

| | Hawk | Dove |
|---|---|---|
| Hawk | (v-c)/2, (v-c)/2 | v, 0 |
| Dove | 0, v | v/2, v/2 |

- I.e. $p(v-c)/2 + (1-p)v = (1-p)v/2$

$\Leftrightarrow pv - pc + 2v - 2pv = v - pv$

$\Leftrightarrow -pc = -v$

$\Leftrightarrow p = v/c$

# Broader implications

- Nash, Axelrod, Maynard Smith and others opened up many applications
- Politics: models of conflict, and of when religions are dominated by fundamentalists
- Criminologists: model the Mafia as alternative contract enforcement, and tattoos as signalling
- Computer science: how do you get AS operators to tell the truth about Internet routing? How do you get them to secure BGP? Will bitcoin converge, fork or collapse? ...

# Broader implications (2)

- In pre-state societies, if you see a man you don't recognise, you'd better kill him first (Diamond, "The World Until Yesterday")
- Now we live in largely peaceful societies (Pinker, "The Better Angels of our Nature")
- Evolutionary basis of morality: fairness from tit-for-tat, hierarchy from hawk-dove, maybe conservative / liberal preferences too (Haidt)
- Cooperation developed by states, religions, literature, markets, rights, TV …

# Broader implications (3)

- If institutions that involve social cooperation are replaced by online mechanisms, what happens then?
- TV caused people to become more solitary when it replaced clubs, churches and pubs as the social focus (“Bowling Alone”)
- What if more of our cooperative social mechanisms are replaced by echo chambers?
- The spread of broadband was correlated with a rise in political polarisation...