Networks II: Market Design—Lecture 23 Information and Networked Behavior

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Logistics

- HW5 (final homework!) released; due Thursday May 2, 12 noon
- Reminder: Project ‘stuff’
  - Extension to final report deadline:
    - Reports now due Sunday May 5, 12 noon on CMS
    - Class on Thursday May 2nd converted to office hour by Minsu and Yoyo
  - Virtual posters on Piazza also due at same time, on *both* CMS and Piazza
  - Piazza comments on others’ ‘posters’: Tuesday May 7 5pm, on CMS (and of course, Piazza!)—*Individual* submission
  - **See CMS handouts for instruction on reports, posters**

Information asymmetry: Where are we?

What we've seen so far:

- Information asymmetry can cause severe inefficiencies
  - Simple toy example: Used-car market with two car types
  - A richer example: A continuous distribution of qualities ($U[0,1]$)
  - Market failure occured in both examples
- Alleviating inefficiencies from information asymmetry
  - Legal mandates: Enforcing disclosure of information
  - Credible but *voluntary* disclosure:
    - Main idea: Disclosure is **equilibrium decision**!
    - Costless verification with continuum of qualities ($U[0,1]$) : *Full* disclosure in equilibrium, perfect efficiency restored
  - When disclosure is infeasible: Signaling mechanisms (warranties, education, reputations, . . .)

Information asymmetry: Where are we?

- Information asymmetry: What we've seen so far
  - No algorithms, no theorems, no headaches from complex proofs, . . . : What have we learnt?
- What do we *want* to learn?
- Market design: 'What happens' in networked economies, and how to make them better
  - Modeling: Identifying and abstractly *modeling* a real-world phenomenon as an instance of networked behavior
  - Analysis: General principles that apply to this instance
  - Design: Using model, analysis to *design* for desirable outcomes

Information asymmetry: Hidden information

What have we *learnt* so far?

- Creating a model to illustrate an idea
  - Going from allocation to information: Adding to, and subtracting from existing model
- Reasoning about outcomes: Self-fulfilling expectations equilibria
- **Endogeneity** in marketplace:
  - Who participates: Market for Lemons
  - Who reveals quality: Voluntary credible disclosure
- Value of formal analysis; abstract model
  - Even toy examples illustrate **what** factors make markets more susceptible to failure

What have we *learnt* so far?

- Information asymmetry with 'hidden information': **Can** cause severe inefficiencies
  - Market failure occured in both simple and richer example
- Non-existence of a market (no trade):
  - Could be simply because $v_b < v_s$: No failure!
  - Issues with user interfaces (UI)
  - Behavioral economics: Endowment effects
  - Market for Lemons model: Provides an *alternative reason* for why there is no market — one with *market design implications*

Where we are, and what's next

- Information asymmetry: Affects *value from contract*
  - Contrast with 'private' information: Auctions, ...
  - So far: Asymmetry with 'hidden information'
    - Qualities are *exogenous*: One party has *information* pertinent to other party's value from contract
    - eBay: Quality of item being sold
  - Next: Asymmetry with 'hidden action'
    - 'Qualities' are *endogenous*: One party makes *choices* pertinent to other's value from contract
    - eBay: Whether to ship item promptly
- Outline of what's coming up
  - Toy model: Prisoners' dilemma
  - Sustaining efficient outcomes: Repetition
  - Reputation systems: Online markets

Information asymmetry: Moral hazard

A different kind of asymmetric information: Hidden **actions**

- One party takes *unobservable* actions that other party (fully or partially) bears costs of, *post-contract*
  - One party in contract cannot perfectly observe action of other
  - Action choice affects *value from contract* to other party
  - A term used sometimes: "Moral hazard"
- Note: Not same as *strategic behavior*, which is more general
  - Here, a *specific subclass* of strategic behavior: "(Deliberately) do something other than what you (explicitly or implicitly) promised, to improve your own payoff"
  - E.g: Bidding strategically in an auction does not constitute 'moral hazard'
    - Not bidding your true value, versus not paying what you promised

Moral hazard

- Classic examples of 'moral hazard':
  - Risk-taking: Auto insurance (risky driving, lower theft precautions)
  - Effort choices: 'Principal-agent' problems (employer-employee relationships)
  - Lending: Defaults, subprime lending
- 'Moral hazard' settings online:
  - Seller behavior (product quality, shipping, ...)
  - Markets for online services
  - Crowdfunding
  - Crowdsourcing, online labor (Amazon Mechanical Turk, ...)
  - ...

Inefficiency and moral hazard

- Like hidden information, hidden action can also cause inefficiencies
- Consider a seller S and a buyer B connected, e.g., via an online platform
- Say buyer values seller's item at \$8
- Can locally obtain alternative valued at \$3; priced at \$1
- Seller can sell item 'locally' at \$1 $(v_s = 1)$

Inefficiency and moral hazard

Suppose seller prices item at \$5 in online marketplace:

- If buyer and seller trade on online platform:
  - Payoff to buyer is $8 - 5 = 3$
  - Payoff to seller is 5
- If buyer and seller don't trade online, and use local options:
  - Payoff to buyer is $3 - 1 = 2$
  - Payoff to seller is 1
- Efficient outcome: Buyer and seller on platform should trade
  - $(3, 5)$ dominates $(2, 1)$

Inefficiency and moral hazard

- Moral hazard: Both agents may not keep their side of the bargain!
  - Seller may renege on shipping
  - Buyer may renege on payment
- If seller does not deliver item:
  - Payoff to seller: $5 + 1 = 6$
  - Payoff to buyer: $0 - 5 = -5$
- If buyer does not make payment:
  - Payoff to seller: 0
  - Payoff to buyer: 8

- Denote action of trading and keeping bargain by T, and not keeping bargain by D
  - D for Seller: Not delivering item
  - D for Buyer: Not making payment
- Payoffs can be represented via matrix: Buyer is row player, seller is column player
  - (Collapse cheating and not trading into single action, D)
  - (u_1, u_2): Payoff to buyer is u_1, seller gets payoff u_2

	T	D
T	(3,5)	(-5,6)
D	(8,0)	(2,1)

Equilibrium outcome with moral hazard

- What is the outcome of this game?

	T	D
T	(3,5)	(-5,6)
D	(8,0)	(2,1)

- Dominant strategy for each player: Choose D
- Unique equilibrium outcome: (D,D)
- **Inefficiency**: Both players choose D, resulting in no trade
  - Payoff tuple $(3,5)$ from trading and keeping bargain Pareto-dominates $(2,1)$ from not keeping bargain
- Moral hazard also results in inefficiency: No trade in market!

A related game

- The prisoner's dilemma game: Two prisoners simultaneously choose action Cooperate (C), or Defect (D)
- Payoff matrix

	C	D
C	(r, r)	(s, t)
D	(t, s)	(p, p)

- r: reward, t: temptation, s: sucker, p: punishment
- For each player, $t > r > p > s$
- Unique equilibrium outcome: (D,D)
  - Why $r_i > p_i$?
  - 'Dilemma': Outcome (D,D) is not Pareto-efficient, since both players prefer the payoffs resulting from choosing (C,C)!

Prisoners' dilemma and moral hazard

- Our payoff matrix in moral hazard setting:

	T	D
T	(3,5)	(-5,6)
D	(8,0)	(2,1)

- Payoff structure identical to general prisoner's dilemma: $t_i > r_i > p_i > s_i$ for each player $i = 1, 2$

	C	D
C	(r_1, r_2)	(s_1, t_2)
D	(t_1, s_2)	(p_1, p_2)

  - Unique outcome (D,D) with payoffs (p_1, p_2): (C,C) with payoffs (r_1, r_2) Pareto-dominant

Alleviating inefficiency from moral hazard

- Payoff matrix in our moral hazard situation has same structure as in prisoners' dilemma
- Unique equilibrium: No trade, which is inefficient!
- Moral hazard—unaided—can cause inefficiencies leading to no trade (like hidden information)

- Is efficiency possible as equilibrium outcome—despite strategic players and no centralized coordination?
    - Can repeated interaction between buyer and seller improve matters?

Alleviating inefficiency from moral hazard

- How does repetition affect equilibrium behavior and outcomes?
- Future payoffs *can* depend on current actions, but:

  (i) Do they, **in equilibrium**?

  (ii) How valuable are future payoffs anyway?

- Time for some analysis!

Repeated prisoners' dilemma

- Repeated prisoners' dilemma: PD is repeated at times $t = 0, 1, 2, \ldots, T$
- At each time t: Each agent chooses action cooperate (C) or defect (D)
- Strategies: A player's strategy must specify her choice of action at *every* t, for *all* possible *histories* up to $t - 1$
- Which of these are valid specifications of strategies?
  1. Always play D
  2. Play C until other player plays D
  3. Play C on odd rounds, D on even ones
  4. Play C until other plays D, and then play D on the next round
- [A] All but (1) [B] (2),(4) only [C] (1),(3) only
  [D] None of the four are valid specifications of strategies

Repeated prisoners' dilemma

- $u_t^i(a_t^1, a_t^2)$: Payoff in '*stage*' game at t, with action choices a_t^1, a_t^2
- Payoff in repeated game: $u^i = \sum_{t=1}^{T} u_t^i(a_t^1, a_t^2)$
- Recall single-shot prisoners' dilemma: Unique equilibrium (D,D)
- **Theorem**: The *unique* equilibrium in the finitely repeated prisoners' dilemma with **known** end period T is for both agents to play (D,D) in all periods.

Finitely repeated prisoners' dilemma

Why does this happen? Backwards induction:

- In final period T:
  - Situation strategically equivalent to one-shot prisoners' dilemma: Actions at T do not affect any future payoffs
    - Game stops at T
  - Unique optimal action (at T): Both players choose D
- What happens in $T-1$?
  - Choice of action does not affect payoff at T, since optimal actions at T are (D,D)
  - Agents choose (D,D) at step $T-1$ also
- And so on, . . . , until period 0
- Unique optimal strategy: Play D in every period!

Repetition and sustaining cooperation

- Recall our question: Can repetition support efficient outcome in equilibrium, with strategic players and no centralized coordination?
- What we've just seen: Finite, known-length repetition cannot sustain cooperation
- Coming up: Cooperation can be sustained in an equilibrium in *infinitely* repeated Prisoners' Dilemma (as we'll see!)
- Difference between finite and infinite repetition has two interpretations:
  - Non-finite termination
  - Uncertainty about the future

- Infinitely repeated prisoners' dilemma: PD is played at $t = 0, 1, 2, \ldots$
- Actions: $a^i = (a^i_1, a^i_2, a^i_3, \ldots, a^i_t, \ldots)$ denotes sequence of actions chosen by agents $i = 1, 2$ at time t
  - Each a^i_t is either C or D
  - Payoff to player i from interaction in period t: $u^i_t(a^1_t, a^2_t)$
- Suppose agents choose action sequences a^1 and a^2: Total payoff to player i is

$$u^i = \sum_{t=0}^{\infty} \delta^t u^i_t(a^1_t, a^2_t)$$

  - *Discount factor* δ: $0 \leq \delta \leq 1$
  - δ discounts the future: Weights down future payoffs

Discounting the future

- Utility u in infinitely repeated game: $u = \sum_{t=0}^{\infty} \delta^t u_t$
- $0 \leq \delta \leq 1$: Future payoff less valuable than immediate payoff
- Two interpretations for discount factors:
  - Interest rates or inflation: v earned today is worth $v(1+r)^t$ at a future time t; payoff v_t at time t worth $\frac{v_t}{(1+r)^t}$ today
  - Uncertainty about when game will end: Game stops with probability $1-\delta$ at every period

Infinite repetition and cooperation

- What are equilibria in infinitely repeated prisoners' dilemma game?
- Proposition: Both players choosing action D in every period constitutes a Nash equilibrium pair of strategies
  - Inefficient outcome continues to remain equilibrium
- Is it *possible* to sustain cooperation as equilibrium outcome?
  - Note similarity: Used-car market with two car types
  - Full trade *sustainable* in equilibrium if $g > 2/3$, but not only equilibrium!
- Yes! We'll see two different strategies:
  - 'Grim-trigger' strategy
  - 'Tit-for-tat' strategy

Cooperate equilibrium: Grim Trigger

- 'Grim-trigger' strategy: Cooperate if partner is cooperating, else defect forever
- Denote player 1's actions by a, player 2's by a'
  - Choose $a_t = C$ if $a'_l = C$ for all $l < t$
  - Choose $a_t = D$ if $a'_l = D$ for **any** $l < t$
  - $a_0 = C$
- **Theorem:** Both players choosing the grim-trigger strategy is a Nash equilibrium of the infinitely repeated prisoners' dilemma if $\delta > \delta^*(t, r, p)$. The *equilibrium path* with this strategy leads to **actions** (C,C) in all periods.

Cooperate equilibrium: Tit-for-Tat

- 'Tit-for-Tat' strategy: Choice of action in period t mirrors partner's action in period $t-1$
  - $a_0 = C$
  - Choose $a_t = C$ if $a'_{t-1} = C$
  - Choose $a_t = D$ if $a'_{t-1} = D$

- **Theorem:** Both players choosing the tit-for-tat strategy is a Nash equilibrium of the infinitely repeated prisoners' dilemma if $\delta > \delta^*(t, r, p)$. The *equilibrium path* with this strategy leads to **actions** (C,C) in all periods.

Repetition and sustaining cooperation

- To summarize: Can repetition support efficient outcome in equilibrium, with *strategic* players and no *centralized* coordination?
- Yes—with discounted payoffs in infinitely repeated game!
  - Players can choose strategies which *punish* defection in the past with lower future payoffs
  - Strategies: Incentivize players to not defect in present to gain higher future payoffs
  - When future is valuable, and current action can affect future payoff, taking a short-term view may not be optimal