Signaling
鶴立雞群賽局

Joseph Tao-yi Wang (王道一)
Lecture 11, EE-BGT

The Big Picture

- What have we learned up to now?
  - Camerer (BGT 2003) report Game Theory Experiments (test theory/inspire new theory)

1. Mixed-Strategy Nash Equilibrium (MSE) ☺☺
2. Subgame Perfect Equilibrium (SPE) ☹
3. Bayesian Nash Equilibrium (BNE/Bargaining) ☺☹
4. Sequential Equilibrium (SE) [today] ☺☹
   - Why theory works well in some situations?

The Big Picture

- Why theory works well in simple situations?

1. Learning to play Nash?
2. Limited strategic reasoning
   - Backward Induction fails!
3. Initial response (level-k reasoning)
4. Cannot detect deviations
5. Coordination/pre-game Communication

The Big Picture

- Camerer (BGT 2003) purposely reported various classes of game theory experiments
- Games of Social Preferences (Ch. 2)
- Mixed-Strategy Equilibrium (MSE; Ch. 3)
- Bargaining (Ch. 4)
- Dominant Solvable Games (SPE; Ch. 5), Level-k (new)
  - Learning (Ch. 6)
- Coordination (Ch. 7)
- Signaling and Reputation (SE; Ch. 8)

The Big Picture

- We also saw Risk and Time Preferences...
  - What about Market Behavior? Applications?

1. Auction (auction chapter in EL)
2. Cheap Talk Games (and Lying)
3. Voting Games (special case of MSE!)
4. Market Design
5. Field Experiments
6. Prediction Markets and Bubbles

Applying for Economics Graduate School

An Example of Signaling

Questions

1. Which to apply? MBA or Econ PhD?
2. Most important factor for admission?
3. Are foreigners/females discriminated against?
4. Is mathematics needed in graduate school?
5. Is MA (at NTU) required before PhD?
6. How should I prepare myself now?

Which Program Should I Apply?

- MBA or Econ PhD?
  - This depends on Your Career Interest
- But, MBA is not for newly graduates
  - MBA is designed for people who worked for years and are heading for top management
- Teach undergraduate Economics, but:
  1. Tie it with actual working experience
  2. Socializing with other CEO-to-be's is a plus

Which Program Should I Apply?

- Econ PhD provides rigorous training to modern economic analysis techniques, which is used by:
  - Academics (Economics, Public Policy, Law...)
  - Data Scientist (Amazon, Google, Facebook...)
  - Economics Consulting Firms
  - Public Policy Evaluation
  - Financial Companies (like Investment Banks)
  - International Organizations (APEC, IMF...)

Most Important Factor

- What is the Most Important Factor when I Apply for Graduate School?
  - Petersons Guide surveyed both students and admission committee faculty members
- They find that both agree No.1 factor is:
  - Letter from someone the committee knows
- Why is this No.1?
- Credible Signaling!

Most Important Factor

- No.1:
  - Letter from someone the committee knows
- Who are the people committees know?
- What if I cannot find someone to write?
- Find Other Credible Signals!
  - GPA?
  - GRE or TOEFL?
  - Other Distinct Features (like AWA≥5.0)?

Discrimination and Gender

- Are Foreigners or Females Discriminated?
- Foreigners: Program policy differs!
  - UCLA (8/35) vs. MIT (25/30)
- Women: Only 16% Faculty are Female
  - Does the market favor women? Maybe...
  - Comparison: 33% Math Professors are female
- AEA-PP: CSWEP mentorship RCT to help
  - JEP: Other strategies at every stage

Is Mathematics Needed?

- Advice for Econ PhD Applicants (by Peterson's Guide):
  - "Take a heavy dose of mathematics during undergraduate."
- So, the answer is generally yes.
  - Due to gap between undergrad and graduate studies
- But ability to find economic intuition behind the math is even more essential
  - My first year micro comprehensive exam experience
  - They need Bilingual People!

What Kind of Mathematics is Needed?

Mastering These Instead of Jack of All Traits:

1. Introduction to Mathematical Analysis (I),(II)
   - MATH 2213/2214 (分析導論一二)
   - Thinking process to score A+ is essential!
2. (Introduction to) Linear Algebra (I),(II):
   - MATH 1103/1104 (線性代數一二):
   - Basic Tools of Econometrics
3. Theory of Statistics (I),(II): Casella and Berger (2002)
   - STAT 5004/5005 (統計理論一二):

     = first part of the graduate Econometrics sequence

What Kind of Mathematics is Needed?

1. MATH 2213/2214 分析導論一二
2. MATH 1103/1104 線性代數一二
3. STAT 5004/5005 統計理論一二

- Note: STAT 5004/5005 is a master-level required course and should be taken only after you took the other two courses
  - Also consider MATH 1211/1210 (微積分一二) which uses the Courant and John textbook:
    - Introduction to Calculus and Analysis, Vol.1 and Vol.2

What Kind of Mathematics is Needed?

1. MATH 2213/2214 分析導論一二
2. MATH 1103/1104 線性代數一二

- What is wrong with MATH 1211/1210 (微積分一二)?
  - Unfortunately, the course name does not include real analysis
  - but textbook is Courant and John, Introduction to Calculus and Analysis, Vol.1&2 (微積分與分析導論第一二冊)
  - What about Advanced Calculus I,II from NTNU?
- Does MATH 4018/4022 (線性代數導論一二) count?
  - What about Linear Algebra I, II from NTNU?

Is MA required before I enter PhD?

- No. Most Top-10 have only PhD program
  - Chicago: Give you a master if you can't finish
- But you may not survive studying both math and economics in English...
- Hence, a MA might help since:
  - MA classes are similar to PhD classes
  - You may not be sure if you want to a PhD
  - Condition on passing 1st year, MA is unnecessary, but you may want to hedge...

Is Doing a Pre-Doc required before I enter PhD?

- During the pandemic, many undergraduate students would take on a full time RA jobs (aka Pre-Doc)
  - They get into top Econ PhD programs after 2-year term, crowding out the next generation to take on Pre-Doc's
- In Fall 2024, three Taiwanese Pre-Doc's started their PhD studies at Harvard, Northwestern, and Caltech
- In Fall 2025, a Chicago Pre-Doc went to Princeton
  - Does that mean you also need to do a Pre-Doc?
  - How does doing a Pre-Doc help you create good signals?

How Should I Prepare Myself Now?

- Create Credible Signals! Such As:
- GPA 4.0, ranked 1/160
- Good References
- A Published Research Paper
- Take a Heavy Dose of Mathematics
- Take Graduate Courses in Economics
- Take Economics Courses Taught in English
- AWA 5.0+

What Makes a Signal Work?

- Exercise: Show which types of people can afford the following signals:
  - GPA 4.0, ranked 1/160
  - Good References
  - A Published Research Paper
  - Take a Heavy Dose of Mathematics
  - Take Graduate Level Courses in Economics
  - Take Economics Courses Taught in English
  - AWA 5.0+

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What Makes a Signal Work?

- A Signal must be affordable by certain types of people
  - Cost $<$ Benefit (if receivers decodes it)
- A signal must be too expensive for players of the wrong type to afford
  - Cost $>$ Benefit (even if receivers decodes it)
- Separating Equilibrium: Those who buy and those who don't are different types

What Makes a Signal Work?

- Separating Equilibrium consists of a circular argument:
- Signal senders
  - buy signal anticipating receivers decode it
- Receivers
  - get assurance about sender types from the signal and act different with/without it
- This is a self-fulfilling prophecy
  - Spence (Dissertation 1974)

Theory of Signaling

- Harsanyi (MS 1967-68) defines one's Type as privately observing a move of Nature
- Bayesian-Nash Equilibrium (simultaneous)
- Perfect-Bayesian Equilibrium (sequential)
  - Separating Equilibrium
  - Pooling Equilibrium
  - Semi-pooling Equilibrium
- Refinements: Sequential, Intuitive, Divine, Universal Divine, Never-Weak-BR, Stable

Screening（篩選機制）

- "稀ㄟ取踢" Inc. Offers 2 Cell Phone Plans:
  - Plan A: $1 per minute
  - Plan B: $168 monthly for 300min, then $1.5/min
- Based on Last digit of student ID# (or card drawn), you:
  - ♠13: Use 0-100min/mo
  - ♡24: Use 200-300min/mo
  - ♢680: Use 400-500min/mo
  - ♣579: Use 600-700min/mo
- Which plan is cheaper for you?

電信業者	亞太電信	中華電信	台灣之星	LINE MOBILE
方案	168(12.12限定)	469	288	399
月租費	168	469	288	399
上網優惠	21M吃到飽	21M吃到飽	21M吃到飽	21M吃到飽
網內語音	免費	前五分鐘	免費	免費
網外語音	30分鐘	25分鐘	0分鐘	30分鐘
市話		10分鐘		40分鐘
其他優惠	百萬好禮抽獎	無	無	200點+2%
漫遊優惠	無	無	無	指定國家月租抵漫遊
綁約期限	24個月	24個月	12個月	12個月
網內費率	免費	$3/分鐘	免費	免費
網外費率	$2/分鐘	$6/分鐘	$6/分鐘	$6.6/分鐘
市話費率	$2/分鐘	$6/分鐘	$6/分鐘	$6/分鐘
申辦通路	亞太直營/特約門市	網路門市	全通路	官網

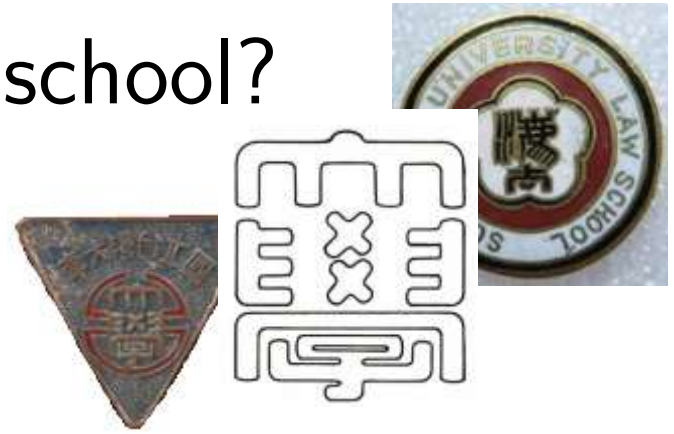
slido

Which Plan is cheaper for you? (尾數是xx的我選擇哪一個方案?)
Plan A：$1 per minute 方案A：一分鐘一塊錢 Plan B：$168 monthly for 300min, then $1.5/min 方案B：月租費168可打300分鐘，之後1.5元/分)

ⓘ Start presenting to display the poll results on this slide.

Signaling (認證標籤)

1. Expected Salary if you graduate from: (假設你高中畢業後考上...)
   - ♡24♢680: National iDaiwan University: 35k/mo (國立愛呆丸大學畢業起薪35k)
   - ♠13♣579: Salty Chicken University: 22k/mo (私立鹹酥雞大學畢業起薪22k)
2. If you go to graduate school at NiDU: (大四上你可選擇報考愛呆丸大學研究所)
   - Expected salary 40k/mo, but need to repay student loans @ 5k/mo
   - (畢業後月薪40k，但須負擔就學貸款(和補習貸款)月繳5k)
3. Would you apply for NiDU graduate school? Why or why not?
   - (請問你會不會報考研究所? 為什麼?)



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BA@NiDU earns 35k/mo 愛呆丸大學畢業月薪35k,
BA@SaltyChickenU earns 22k/mo 鹹酥雞大學畢業月薪22k
MA@NiDU earns 40k/mo (but need to repay student loans@5k/mo) 報考愛呆丸大學研究所畢業月薪40k，但需負擔貸款月繳5k
Would you apply for NiDU's MA program? 就讀xx大學的我，會不會報考研究所?

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If you are a BA@NiDU (♡24♢680) and you DID apply for graduate school, list reasons why you did apply. (如果你是NiDU的學生且決定報考研究所，為什麼你決定要報考？)

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If you are a BA@NiDU (♡24♢680) and you did NOT apply for graduate school, list reasons why you did apply. (如果你是NiDU的學生且決定不考研究所，為什麼你決定要不考？)

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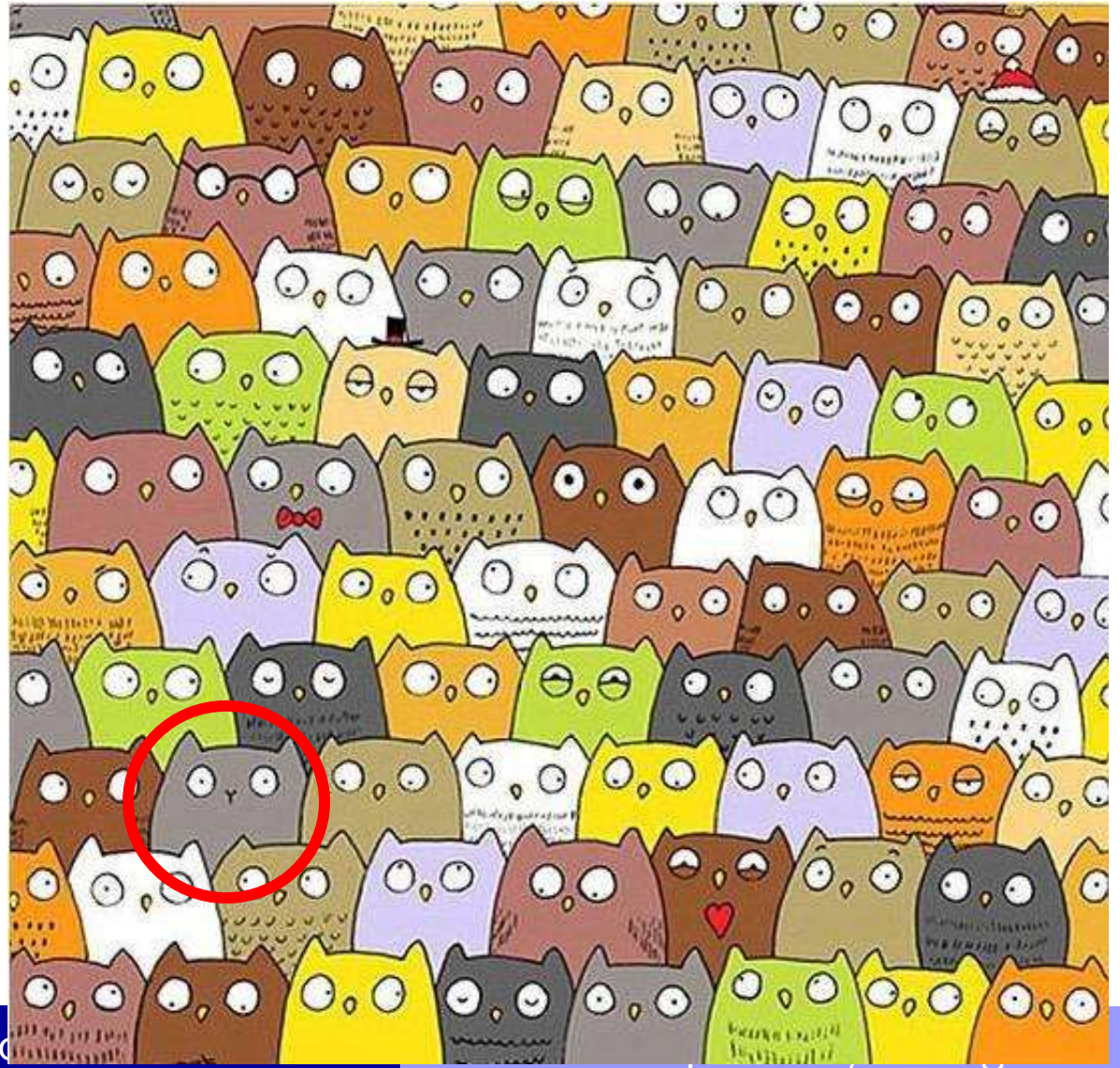
slido

Which do you think would enhance your future earnings more? (下列哪一個選項「更」能提高你未來收入？)

ⓘ Start presenting to display the poll results on this slide.

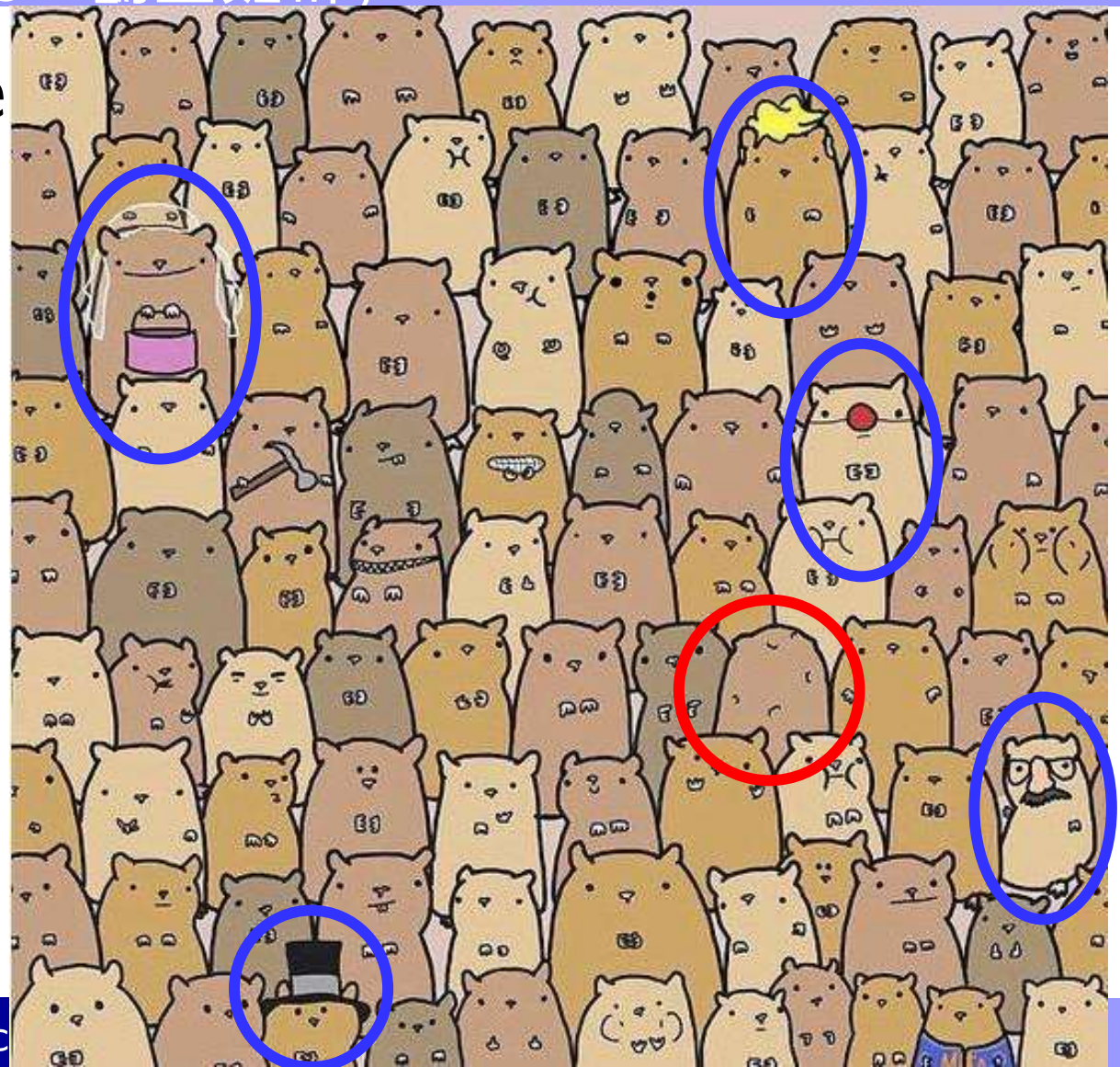
Bad Signaling (認證標籤的反指標: 雞立鶴群)

- Find the cat in these owls
  - 請在貓頭鷹中找一隻貓咪
- Can you find it?
  - 找得到嗎??
- Opposite of a good signal!
  - 知道雞立鶴群的感覺了嗎??



Good Signaling (認證標籤的好例子: 鶴立雞群)

- Find the potato in these mice
  - 請在倉鼠群中找一顆馬鈴薯
- Can you find it?
  - 找得到嗎??
- Which mice did you notice?
  - 有注意到哪一隻倉鼠嗎??



Signaling (鶴立雞群)

- Find the panda in these dogs
  - 請在狗群中找貓熊
- Which dog did you notice? Interview/Application reviews are just like this!
  - 你有注意到哪一隻狗狗嗎? 面試書審就像這樣!

Simple Signaling Game

- Brandts and Holt (AER 1992)
- Worker Types are H or L with $(2/3, 1/3)$
- Seeing own type, Workers can choose to $Skip$ or $Invest$ (in education)
- Seeing this action, Employer assign the worker to a $Dull$ or $Challenging$ job
- Employer payoffs are 125 if she assigns D to L types and C to H types

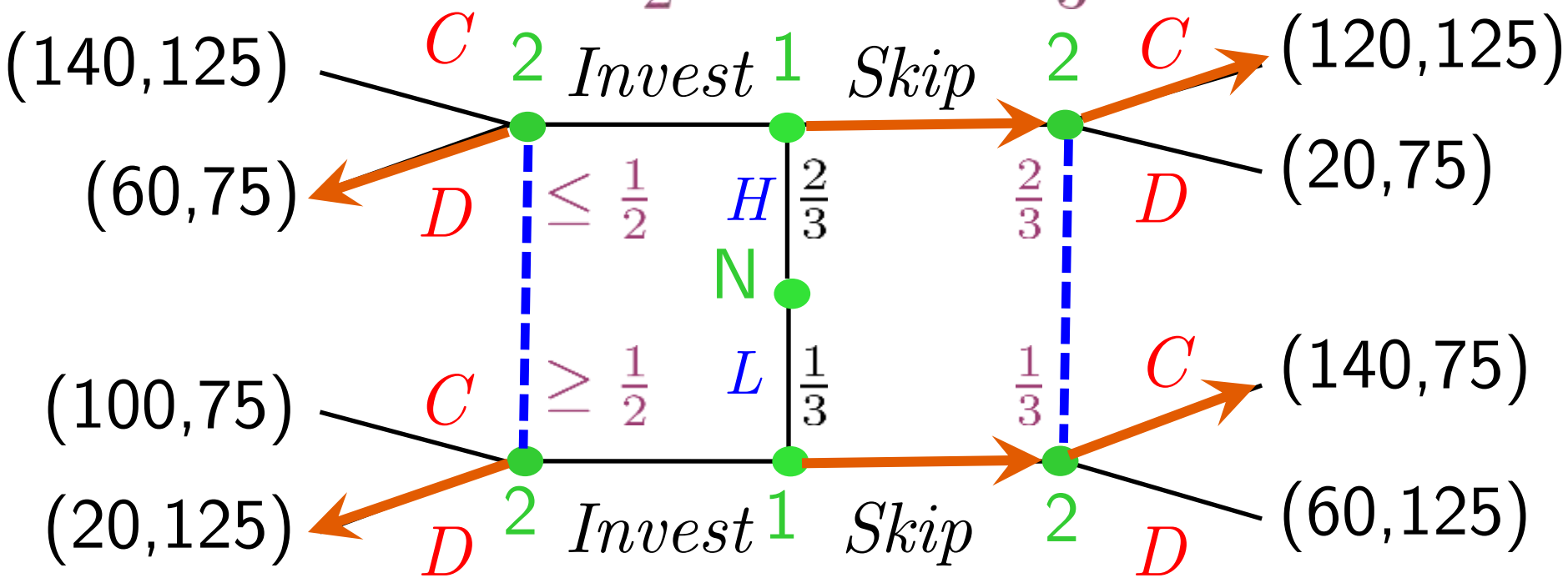
Simple Signaling Game

- Workers get 100 doing C and 20 doing D
  - L types get additional 40 for choosing $Skip$
  - H types get 40 if choose $Invest$, 20 if $Skip$

Type	Action seeing $Skip$		Action seeing $Invest$	
	C^S	D^S	C^I	D^I
Type L	140, 75	60, 125	100, 75	20, 125
Type H	120, 125	40, 75	140, 125	60,75

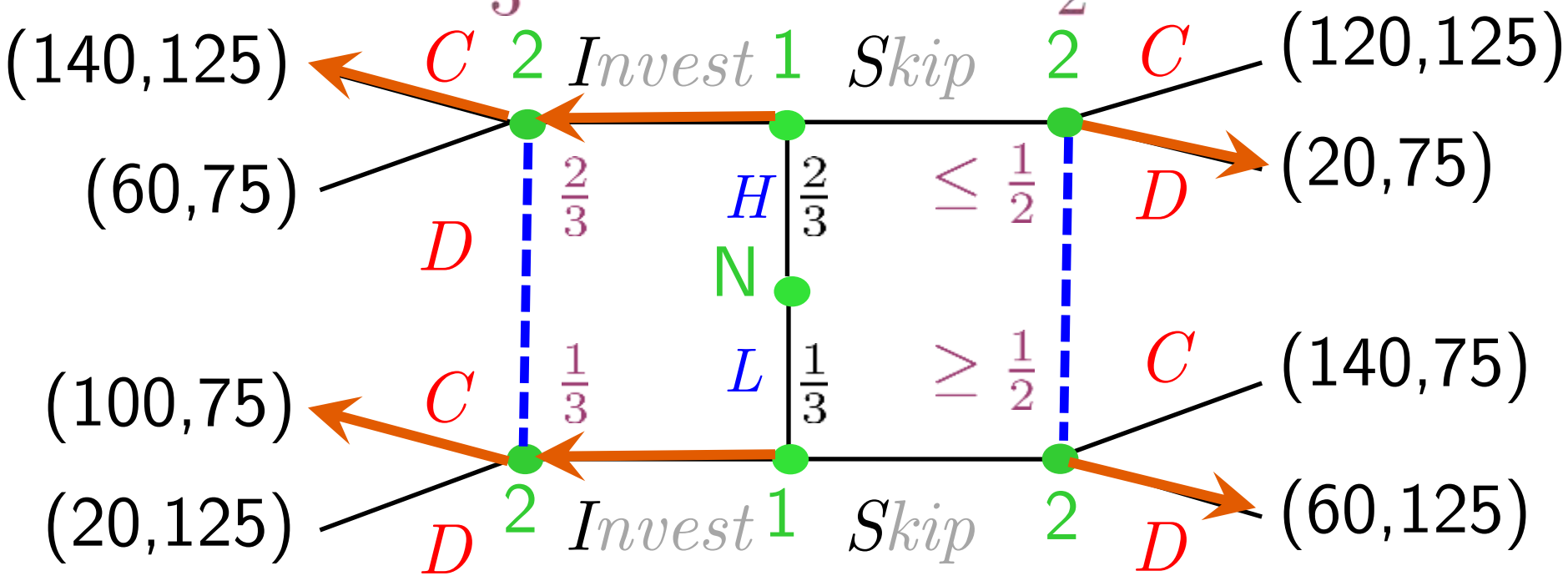
Simple Signaling Game: Extensive Form

- Sequential Equilibrium: $\Big((S|H, S|L), (D|I, C|S)\Big)$
- Beliefs: $\Pr(H|I) \leq p_1 = \frac{1}{2}, \Pr(H|S) = \frac{2}{3}$



Simple Signaling Game: Extensive Form

- Intuitive Equilibrium: $\Big((I|H, I|L), (C|I, D|S)\Big)$
- Beliefs: $\Pr(H|I) = \frac{2}{3}, \Pr(H|S) \leq p_1 = \frac{1}{2}$



Simple Signaling Game

- Two Pooling Equilibria:

1. Sequential Equilibrium
   - Both Types choose $Skip$, Employers assign C
   - Out-of-equil. Belief: choosing $Invest$ means L
   - Hence, Employers assign D if they see $Invest$
2. Intuitive Equilibrium
   - Both Types choose $Invest$, Employers assign C
   - Out-of-equil. Belief: choosing $Skip$ means L
   - Hence, Employers assign D if they see $Skip$

Simple Signaling Game

Periods	Message | Type		Action | Message		Equilibrium Predictions	
	$I \mid H$	$I \mid L$	$C \mid I$	$D \mid S$	Intuitive	Sequential
1-4	100%	25%	100%	74%	100%	0%
5-8	100%	58%	100%	100%	100%	0%
9-12	100%	75%	98%	60%	100%	0%
Suggest Actions: $C \mid S$, $D \mid I$						
1-4	50%	13%	60%	46%	100%	0%
5-8	75%	33%	33%	67%	100%	0%

Follow-up Studies

- Banks, Camerer and Porter (GEB 1994)
  - Design 7 games to distinguish pooling equilibrium of:
  - Nash vs. non-Nash
  - Sequential vs. Nash
  - Intuitive vs. Sequential
  - Divine vs. Intuitive
  - Universal Divine vs. Divine
  - NWBR vs. Universal Divine
  - Stable vs. NWBR

Table X of Banks et al. (GEB1994)

Game		More Refined	Less Refined	Non-Nash	N
1	Nash	56% → 76%	-	44% → 24%	150
2	Sequential	61% → 71%	13% → 24%	26% → 5%	150
3	Intuitive	53% → 68%	13% → 4%	34% → 28%	180
4	~~Divine~~	28% → 38%	16% → 8%	56% → 54%	120
5	~~Universal~~ Divine	31% → 27%	36% → 36%	33% → 37%	90
6	~~NWBR~~	30% → 15%	30% → 33%	40% → 52%	120
7	Stable	59% → 56%	13% → 7%	28% → 37%	300

Follow-up Studies

- Results: Subjects do converge to the more refined equilibrium up to intuitive
- After that, subjects conform to neither
  - Except for possibly Stable vs. NWBR
- Is this a test of refinements, or a test of equilibrium selection?
  - Exercise: Show that equilibria in Table 8.3 (adopted from Banks, Camerer and Porter, 1994) satisfy corresponding refinements

Follow-up Studies

- In game 2-6, different types send different messages (violating pooling equilibrium!)
  - No simple decision rule explains this
  - But weak dominance and 1-round IEDS hold
- Are people just level-1?
- Also, how does the convergence work?

Follow-up Studies

- More studies on learning:
- Brands and Holt (IJGT 1993)
  - Subjects lead to play less refined equilibrium
  - Why? Initial random play produces history that supports the non-intuitive equilibrium
- Anderson and Camerer (ET 2000)
  - EWA yields $\delta = 0.54$ (0.05);
  - Do better than choice reinforcement ($\delta = 0$) and weighted fictitious play ($\delta = 1$)

Follow-up Studies

- Potters and van Winden (IJGT 1996)
  - Lobbying
- Cadsby, Frank & Maksimovic (RFS 1990)
  - Corporate Finance
- Cooper, Kagel, Lo and Gu (AER 1999)
  - Ratchet Effect
- Cooper, Garvin and Kagel (RAND/EJ 1997)
  - Belief Learning in Limit Pricing Signaling Games

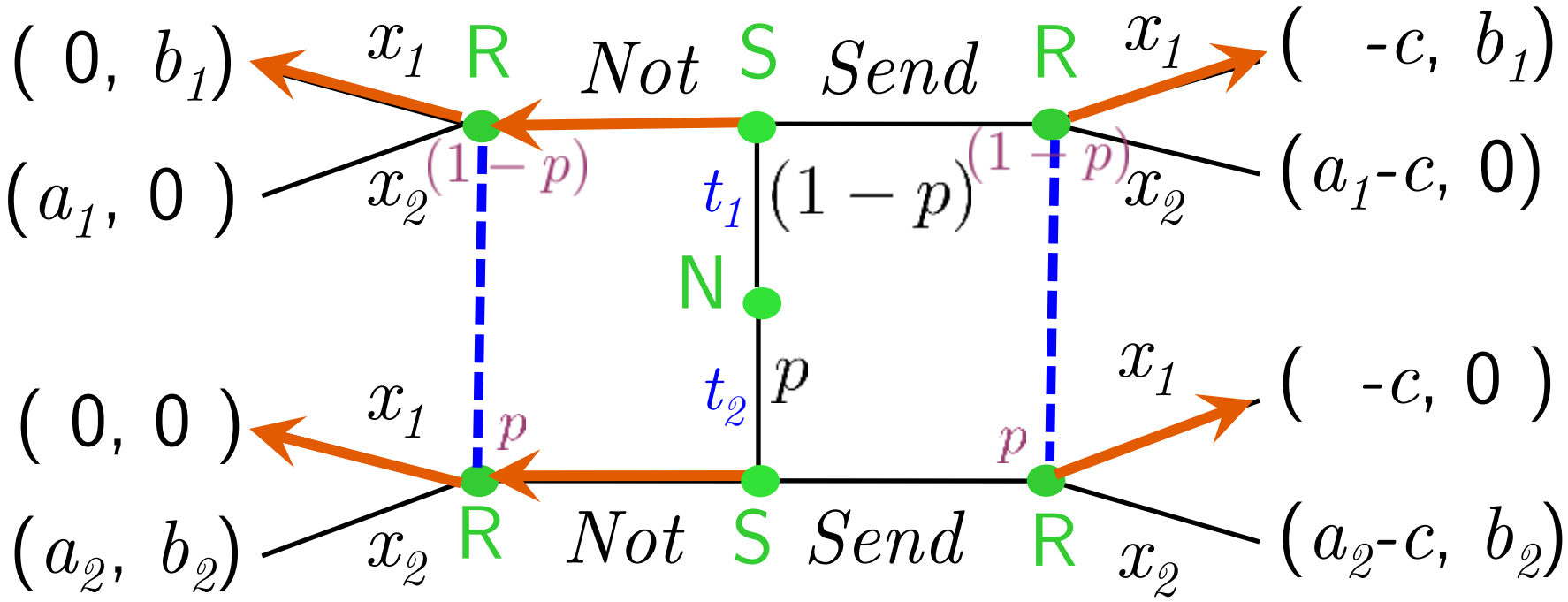
Lobbying: Potters and van Winden (IJGT 1996)

- Lobbyist is type t_1 or t_2 with (1-p, p)
- Lobbyist can send a signal (cost c)
  - Politician chooses action x_1 or x_2 (match type)

Type	No Signal		Costly Signal	
	x_1	x_2	x_1	x_2
t_1(1-p)	0, b_1	a_1, 0	$-c$, b_1	$a_1 - c$, 0
t_2 (p)	0, 0	a_2, b_2	$-c$, 0	$a_2 - c$, b_2

Lobbying: Pooling Equilibrium

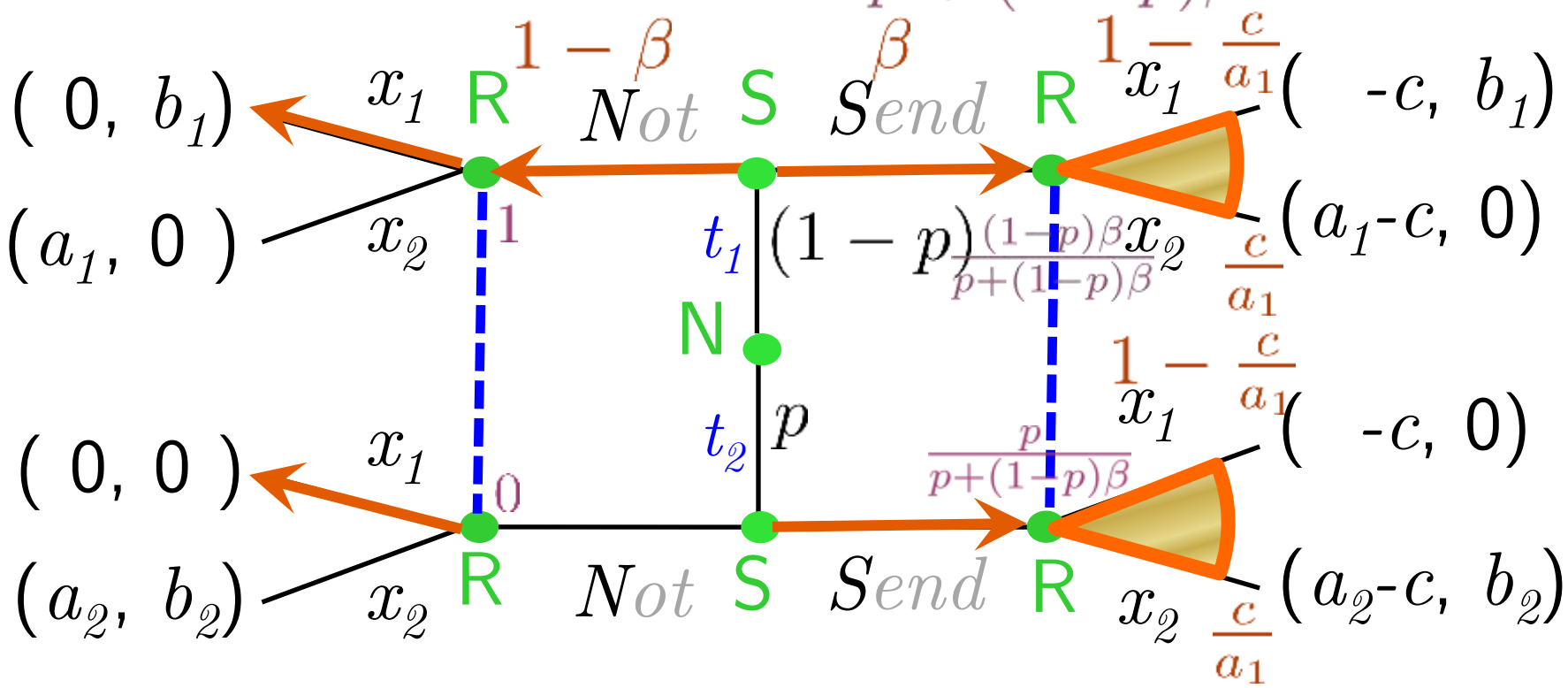
- Equilibrium: $\Big((Not|t_1, Not|t_2), (x_1|Send, x_1|Not)\Big)$
- Beliefs: $\Pr(t_2|Not) = p = \Pr(t_2|Send)$



Lobbying: Semi-Pooling Equilibrium

$$\Big((\beta S + (1-\beta)N | t_1, S | t_2), ((1-\alpha)x_1 + \alpha x_2 | S, x_1 | N)\Big)$$

- Beliefs: $\Pr(t_2|N) = 0; \Pr(t_2|S) = \dfrac{p}{p + (1-p)\beta}$



Lobbying

- If $\beta = \dfrac{pb_2}{(1-p)b_1} < 1$; there are 2 equilibrium:
- Pooling: Both lobbyists do not send signal
  - Politician ignores signal and chooses x_1
  - Intuitive, divine, but not universally divine
- Semi-pooling: type t_2 always sends signal
  - Politicians mix x_1/x_2 (1-c/a_1, c/a_1) if signal
- type t_1 mixes/sends signal with prob. β
  - Universally divine

Treat-ment	Signal Freq. (t_1 , t_2)			x_2 Freq. (no signal, signal)		
	β	Actual	Predict.	c/a_1	Actual	Predict.
1	0.25	38%, 76%	25%, 100%	0.25	2%, 5%	0%, 25%
2(2c)	0.75	46%,100%	75%, 100%	0.25	3%, 79%	0%, 25%
2a(6c)	0.75	83%, 93%	75%, 100%	0.25	11%, 54%	0%, 25%
3	0.25	16%, 85%	25%, 100%	0.75	0%, 53%	0%, 75%
4	0.75	22%, 83%	75%, 100%	0.75	5%, 80%	0%, 75%
Aver.	0.25	27%, 81%	25%, 100%	0.25	5%, 46%	0%, 25%
	0.75	50%, 92%	75%, 100%	0.75	2%, 66%	0%, 75%

Lobbying

- Supporting universally divine equilibrium
- Fictitious Play Learning:

1. $r(m)_{t\text{-}1}$ = past frequency of x_2 after signal
   - Lobbyist should signal if $[r(m)_{t\text{-}1}\ a_1 - c] > 0$
   - Subjects signal 46% if >0, 28% if <0
2. Can do same calculation for politician
   - Subjects choose x_2 77% if >0, 37% if <0

- Potters and van Winden (JEBO 2000)
  - Replicate results with professionals (+ students)

Corporate Finance

- Cadsby, Frank and Maksimovic (RFS 1990)
- Firms are either H or L with (50%, 50%)
  - Worth B_H, B_L if carry project
  - Worth A_H, A_L if pass
- Need capital I to finance the project
- Investors can put up I and get S shares
- Exercise: When will there be pooling, separating, and semi-separating equilibria?

- Example: (Session E)
  - L types worth 375/50 with/without project
  - H types worth 625/200 with/without project
- Capital $I = 300$
- Separating equilibrium: $S = 0.80$
- Pooling equilibrium: $S = 0.60$
- Semi-pooling equilibrium: $S = 0.68$
- Exercise: Show that these are equilibria!

Corporate Finance

- Cadsby et al. ran 10 sessions (Table 8.11)
- Results Support (Pooling) Equilibrium
  - If Unique Pooling: all firms offer shares
  - If Unique Separating: Initially, both offer (pool), but H types learn not to offer (separate)
  - If Multiple Equilibrium: Converge to pooling
- Cadsby, Frank and Maksimovic (RFS 1998)
  - Add costly signals (see Table 8.12 for results)

Ratchet Effect

- Cooper, Kagel, Lo and Gu (AER 1999)
- Firms are either H or L with (50%, 50%)
- Choose output level 1-7
- Planner choose easy or tough target
  - Set easy if $\Pr(\ L \mid \text{output}\ ) > 0.325$
- Pooling: L chooses 1 or 2; H pools with L
- Myopic K firms: Pick 5 (Naïve/get tough)

Exercise: Prove these with payoffs in Table 8.13

Ratchet Effect

- 70-90% L firms choose 2
- Most H firms choose 2 or 5
  - Period 1-12: 54-76% myopic → 80% tough
  - Period 13-36: Convergence to pooling
- Big context effect only for Chinese manager
  - Provide language for learning from experience

Limit-Pricing Signaling Games

- Cooper, Garvin and Kagel (RAND 1997)
  - Belief Learning in Limit Pricing Signaling
- Monopolist A has cost M_H or M_L (50-50)
  - Sets price and corresponding Q=1-7 (deter entry)
- Entrant B only sees Q (not M_H/M_L)
  - Chooses OUT (earn 250) or IN
  - Treatment I: IN earns 300/74 if cost is M_H/M_L
- Risk neutral B choose IN if $\Pr(M_H) \geq 0.78$

Limit-Pricing Signaling: Monopolist Profit

A's Choice Q	A's profit if cost M_H			A's profit if cost M_L	
	IN (X)	Out (Y)		IN (X)	Out (Y)
1	150	426		250	542
2	168	444	BR if B not react to Q	276	568
3	150	426		330	606
4	132	408		352	628
5	56	182		334	610
6	-188	-38		316	592
7	-292	-126		213	486

Limit-Pricing Signaling

B's Choice Q	B's profit (Treatment I)		
	if A is M_H	A is M_L	EV
IN (X)	300	74	187
Out (Y)	250	250	250

BR if B not react to Q

- Myopic Maxima: BR
  - M_H Monopolist A chooses Q=2
  - M_L Monopolist A chooses Q=4
- Separating Equilibrium:
  - M_H Monopolist A chooses Q=2 (vs. B: IN)
  - M_L Monopolist A chooses Q=6/7 (vs. B: OUT)
- Pooling Equilibrium:
  - M_H / M_L Monopolist A chooses same Q (=1-5)
  - Entrant choose OUT since EV=187 $<$ 250

Limit-Pricing Signaling: Treatment I

Round 1-12 (Inexperienced Subjects)

Q	A's Q if M_H	A's Q if M_L	B's IN%
1	2%	1%	33%
2	69% (Median)	4%	57%
3	6%	5%	30%
4	21%	76% (Median)	13%
5	2%	6%	0%
6	-	3%	33%
7	-	3%	0%

Limit-Pricing Signaling: Treatment I

Round 13-24 (Inexperienced Subjects)

Q	A's Q if M_H	A's Q if M_L	B's IN%
1	3%	-	67%
2	50% (Median)	-	64%
3	10%	2%	74%
4	36%	86% (Median)	10%
5	1%	8%	15%
6	-	2%	50%
7	-	2%	0%

Limit-Pricing Signaling: Treatment I

Round 25-36 (Inexperienced Subjects)

Q	A's Q if M_H	A's Q if M_L	B's IN%
1	6%	-	33%
2	38%	-	64%
3	10% (Median)	1%	30%
4	47%	91% (Median)	9%
5	-	6%	25%
6	-	1%	0%
7	-	1%	0%

Limit-Pricing Signaling

B's Choice Q	B's profit (Treatment I)		
	if A is M_H	A is M_L	EV
IN (X)	300	74	187
Out (Y)	250	250	250

BR if B not react to Q

- Start with Myopic Maxima:
  - M_H Monopolist A chooses Q=2
  - M_L Monopolist A chooses Q=4
- Learn to play Pooling Equilibrium:
  - M_H / M_L Monopolist A chooses same Q=4
  - Entrant choose OUT since EV=187 $<$ 250
  - Experienced Subjects: Stronger Convergence!

Limit-Pricing Signaling: Treatment I

Round 1-12 (Experienced Subjects)

Q	A's Q if M_H	A's Q if M_L	B's IN%
1	2%	-	100%
2	41%	-	59%
3	2%	-	100%
4	55% (Median)	100%	3%
5	-	-	-
6	-	-	-
7	-	-	-

Limit-Pricing Signaling: Treatment I

Round 13-24 (Experienced Subjects)

Q	A's Q if M_H	A's Q if M_L	B's IN%
1	2%	-	0%
2	28%	-	91%
3	2%	2%	50%
4	68% (Median)	98%	6%
5	-	-	-
6	-	-	-
7	-	-	-

Limit-Pricing Signaling: Treatment I

Round 25-36 (Experienced Subjects)

Q	A's Q if M_H	A's Q if M_L	B's IN%
1	3%	-	100%
2	23%	2%	70%
3	5%	-	50%
4	69% (Median)	98%	6%
5	-	-	-
6	-	-	-
7	-	-	-

Limit-Pricing Signaling

B's Choice Q	B's profit (Treatment II)		
	if A is M_H	A is M_L	EV
IN (X)	500	200	350
Out (Y)	250	250	250

- Myopic Maxima: BR
  - M_H Monopolist A chooses Q=2
  - M_L Monopolist A chooses Q=4
- Separating Equilibrium:
  - M_H Monopolist A chooses Q=2 (vs. B: IN)
  - M_L Monopolist A chooses Q=6/7 (vs. B: OUT)
- Pooling No Longer Equilibrium:
  - M_H / M_L Monopolist A chooses same Q (=1-5)
  - Entrant choose IN since EV=350 $>$ 250

M_L Monopolist always want to separate from M_H

Limit-Pricing Signaling: Treatment II

Round 1-12 (Inexperienced Subjects)

Q	A's Q if M_H	A's Q if M_L	B's IN%
1	6%	-	100%
2	39%	4%	91%
3	6% (Median)	8%	83%
4	48%	67% (Median)	52%
5	-	15%	44%
6	1%	6%	33%
7	-	-	-

Limit-Pricing Signaling: Treatment II

Round 13-24 (Inexperienced Subjects)

Q	A's Q if M_H	A's Q if M_L	B's IN%
1	2%	-	0%
2	28%	-	91%
3	2%	2%	50%
4	68% (Median)	98%	6%
5	-	-	-
6	-	-	-
7	-	-	-

Limit-Pricing Signaling: Treatment II

Round 25-36 (Inexperienced Subjects)

Q	A's Q if M_H	A's Q if M_L	B's IN%
1	-	-	-
2	33%	12%	94%
3	13%	6%	100%
4	54% (Median)	67% (Median)	63%
5	-	-	-
6	-	15%	33%
7	-	-	-

Limit-Pricing Signaling: Treatment II

- Start with Myopic Maxima
  - M_H Monopolist A chooses Q=2
  - M_L Monopolist A chooses Q=4

Same as Treatment I

- Learn to Separate
  - M_H Monopolist A chooses Q=4 to mimic M_L
  - M_L Monopolist A start to chooses Q=6
- Experienced converge to Separating EQ
  - M_H Monopolist A chooses Q=2 (vs. B: IN)
  - M_L Monopolist A chooses Q=6 (vs. B: OUT)

Limit-Pricing Signaling: Treatment II

Round 1-12 (Experienced Subjects)

Q	A's Q if M_H	A's Q if M_L	B's IN%
1	3%	-	100%
2	43%	4%	95%
3	13% (Median)	2%	100%
4	41%	37%	79%
5	-	9% (Median)	0%
6	-	48%	14%
7	-	-	-

Limit-Pricing Signaling: Treatment II

Round 13-24 (Experienced Subjects)

Q	A's Q if M_H	A's Q if M_L	B's IN%
1	5%	-	100%
2	40%	-	100%
3	5% (Median)	5%	100%
4	40%	22%	85%
5	10%	7%	57%
6	-	66% (Median)	7%
7	-	-	-

Limit-Pricing Signaling: Treatment II

Round 25-36 (Experienced Subjects)

Q	A's Q if M_H	A's Q if M_L	B's IN%
1	8%	-	100%
2	49% (Median)	-	100%
3	4%	3%	100%
4	32%	14%	80%
5	6%	3%	100%
6	-	80% (Median)	12%
7	-	-	-

Limit-Pricing Signaling Game: Follow-Up

- Follow-up Study vary Treatment II:
  - Cooper, Garvin and Kagel (EJ 1997)
  - Treatment II: Q=6-7 give M_H negative profit

1. 0% Anticipation:
   - Q=6-7 give M_H monopolist positive profit
   - Not obvious M_H monopolist will not choose it
2. 100% Anticipation:
   - Q=6-7 not allowed for M_H
   - Obvious M_H monopolist will not choose it

Treatment II: Q=6-7 Very Bad for M_H

A's Choice Q	A's profit if cost M_H		A's profit if cost M_L	
	IN (X)	Out (Y)	IN (X)	Out (Y)
1	150	426	250	542
2	168	444	276	568
3	150	426	330	606
4	132	408	352	628
5	56	182	334	610
6	-188	-38	316	592
7	-292	-126	213	486

0% Anticipation: Q=6-7 Positive Profit

A's Choice Q	A's profit if cost M_H		A's profit if cost M_L	
	IN (X)	Out (Y)	IN (X)	Out (Y)
1	150	426	250	542
2	168	444	276	568
3	150	426	330	606
4	132	408	352	628
5	56	182	334	610
6	38	162	316	592
7	20	144	213	486

100% Anticipation: Q=6-7 Not Allowed

A's Choice Q	A's profit if cost M_H		A's profit if cost M_L	
	IN (X)	Out (Y)	IN (X)	Out (Y)
1	150	426	250	542
2	168	444	276	568
3	150	426	330	606
4	132	408	352	628
5	56	182	334	610
6	X	X	316	592
7	X	X	213	486

Cooper, Garvin and Kagel (EJ 1997)

- 100% Anticipation Results:
  - Experienced Subjects swiftly converge to Separating Equilibrium:
  - M_H Monopolist A chooses Q=2 (vs. B: IN)
  - M_L Monopolist A chooses Q=6 (vs. B: OUT)
- 0% Anticipation Results:
  - Even Experienced Subjects Stay at Pooling Equilibrium:
  - All Monopolists choose Q=4

100% Anticipation

Round 1-12 (Experienced Subjects)

Q	A's Q if M_H	A's Q if M_L	B's IN%
1	-	-	-
2	56% (Median)	-	96%
3	2%	-	100%
4	38%	26%	63%
5	3%	-	50%
6	-	75% (Median)	8%
7	-	-	-

100% Anticipation

Round 13-24 (Experienced Subjects)

Q	A's Q if M_H	A's Q if M_L	B's IN%
1	9%	-	100%
2	76% (Median)	2%	100%
3	4%	-	100%
4	12%	13%	92%
5	-	-	-
6	-	84% (Median)	0%
7	-	-	-

100% Anticipation

Round 25-36 (Experienced Subjects)

Q	A's Q if M_H	A's Q if M_L	B's IN%
1	2%	-	0%
2	78% (Median)	-	100%
3	7%	3%	100%
4	15%	12%	92%
5	-	-	-
6	-	88% (Median)	5%
7	-	-	-

0% Anticipation

Round 1-12 (Experienced Subjects)

Q	A's Q if M_H	A's Q if M_L	B's IN%
1	2%	5%	100%
2	38%	5%	95%
3	11% (Median)	22%	67%
4	49%	68% (Median)	42%
5	-	3%	100%
6	-	-	-
7	-	4%	?

0% Anticipation

Round 13-24 (Experienced Subjects)

Q	A's Q if M_H	A's Q if M_L	B's IN%
1	2%	-	100%
2	26%	2%	92%
3	18%	9%	56%
4	51% (Median)	33% (Median)	69%
5	3%	28%	17%
6	1%	6%	50%
7	-	9%	33%

0% Anticipation

Round 25-36 (Experienced Subjects)

Q	A's Q if M_H	A's Q if M_L	B's IN%
1	2%	-	100%
2	38%	-	94%
3	23% (Median)	8%	86%
4	33%	52% (Median)	72%
5	4%	30%	47%
6	-	-	-
7	-	9%	50%

Reputation Formation

- Camerer and Weigelt (Econometrica 1988)
- 8 period trust game
- Borrower Type: Normal (X) or Nice (Y)
- (New) Lender each period: $Lend$ or $Don't$
- Borrower chooses to $Default$ or $Repay$
  - Normal types $Default$; Nice types $Repay$

Reputation Formation

Lender Strategy	Borrower Strategy	Lender Payoff	Borrower Payoff	
			Normal (X)	Nice (Y)
$Lend$	$Default$	-100	150	0
	$Repay$	40	60	60
$Don't$	-	10	10	10

Reputation Formation

- What does the equilibrium look like?
- Last Period:
  - Lend if $\mathrm{P}_8(\text{Nice}) > \tau = 0.79$
  - Normal borrowers $Default$; Nice ones $Repay$
- Period 7:
  - Normal borrowers weigh between $Default$ now (and reveal) and $Default$ later

Conditional Frequency of Lending

Round		1	2	3	4	5	6	7	8
3-5	Predict	100	100	100	100	64	64	64	64
	Actual								
6-8	Predict	100	100	100	64	64	64	64	64
	Actual								
9-10	Predict	100	100	100	64	64	64	64	64
	Actual								

Conditional Frequency of Lending

Round		1	2	3	4	5	6	7	8
3-5	Predict	100	100	100	100	64	64	64	64
	Actual	94	96	96	91	72	59	38*	67
6-8	Predict	100	100	100	64	64	64	64	64
	Actual	96	99	100	95*	85*	72	58	47
9-10	Predict	100	100	100	64	64	64	64	64
	Actual	93	92	83	70	63	72	77	33

Conditional Frequency of Repay (by X)

Round		1	2	3	4	5	6	7	8
3-5	Predict	100	100	100	81	65	59	44	0
	Actual								
6-8	Predict	100	100	73	68	58	53	40	0
	Actual								
9-10	Predict	100	100	73	67	63	56	42	0
	Actual								

Conditional Frequency of Repay (by X)

Round		1	2	3	4	5	6	7	8
3-5	Predict	100	100	100	81	65	59	44	0
	Actual	95	97	98	95*	86*	72	47	14
6-8	Predict	100	100	73	68	58	53	40	0
	Actual	97	95	97*	92*	85*	70*	48	0
9-10	Predict	100	100	73	67	63	56	42	0
	Actual	91	89	80	77	84*	79*	48	29

Follow-up Studies

- Neral and Ochs (ECMA 1992)
  - Similar repeated trust games
- Jung, Kagel and Levin (RAND 1994)
  - Entry deterrence in chain-store paradox
- Camerer, Ho and Chong (JET 2002)
  - Sophisticated EWA (strategic teaching!)

Conclusion

- Cooper, Garvin and Kagel (EJ 1997)
  - "We do not suggest that game theory be abandoned, but rather as a descriptive model that it needs to incorporate more fully how people actually behave."
- Possible improvements:
  - QRE, level-k or Cognitive Hierarchy
  - Learning (EWA or belief learning)

Conclusion

The End