Signaling
鶴立雞群賽局

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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): (☺☹)
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 different classes of game theory experiments

1. Games of Social Preferences (Ch. 2)
2. MSE (Ch. 3)
3. Bargaining (Ch. 4)
4. SPE and dominant solvable games (Ch. 5)
5. Learning (Ch. 6)
6. Coordination (Ch. 7)
7. SE and Signaling and Reputation (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

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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 of different types

What Makes a Signal Work?

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

Theory of Signaling

- Harsanyi (MS 1967-68)
  - Types: Privately observe a move of Nature
- Bayesian-Nash Equilibrium (simultaneous) or Perfect-Bayesian Equilibrium (sequential)
  - Separating Equilibrium
  - Pooling Equilibrium
  - Semi-pooling Equilibrium
- Refinements: Sequential, Intuitive, Divine, Universal Divine, Never-Weak-BR, Stable

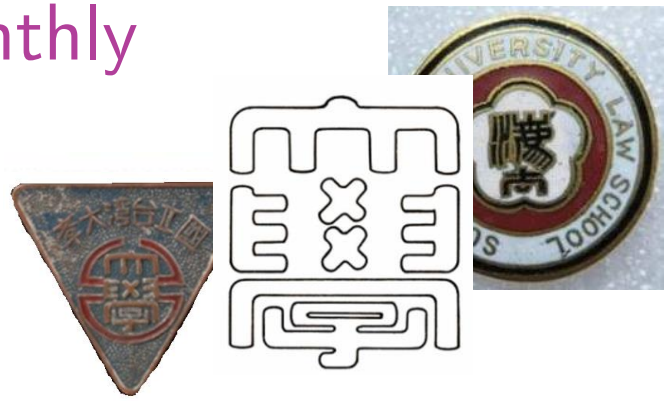
Screening Experiment

1. CHT Telecom has 2 cell phone plans:
   - Plan A: NT$1 per minute
   - Plan B: NT$168 for 300 minutes, NT$1.5 beyond
2. Your monthly usage (based on card received):
   - ♠ Spades: 0-100 minutes
   - ♡ Hearts: 200-300 minutes
   - ♢ Diamonds: 400-500 minutes
   - ♣ Clubs: 600-700 minutes

3. Which plan would you choose? Why?

Signaling Experiment

1. Suppose you are in...
   - National iDaiwan University: Graduates earn 35k
   - Private So-What University: Graduates earn 22k
2. In your senior year, you can choose to:
   - Take master entrance exam for National iDaiwan University: Graduates earn 40k, but need to repay tuition/cram school loans 5k monthly
3. Would you choose apply for a master? Why or why not?



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 D (dull) or C (challenging) job
- Employer payoffs are 125 if she assigns D to L types and C to H types

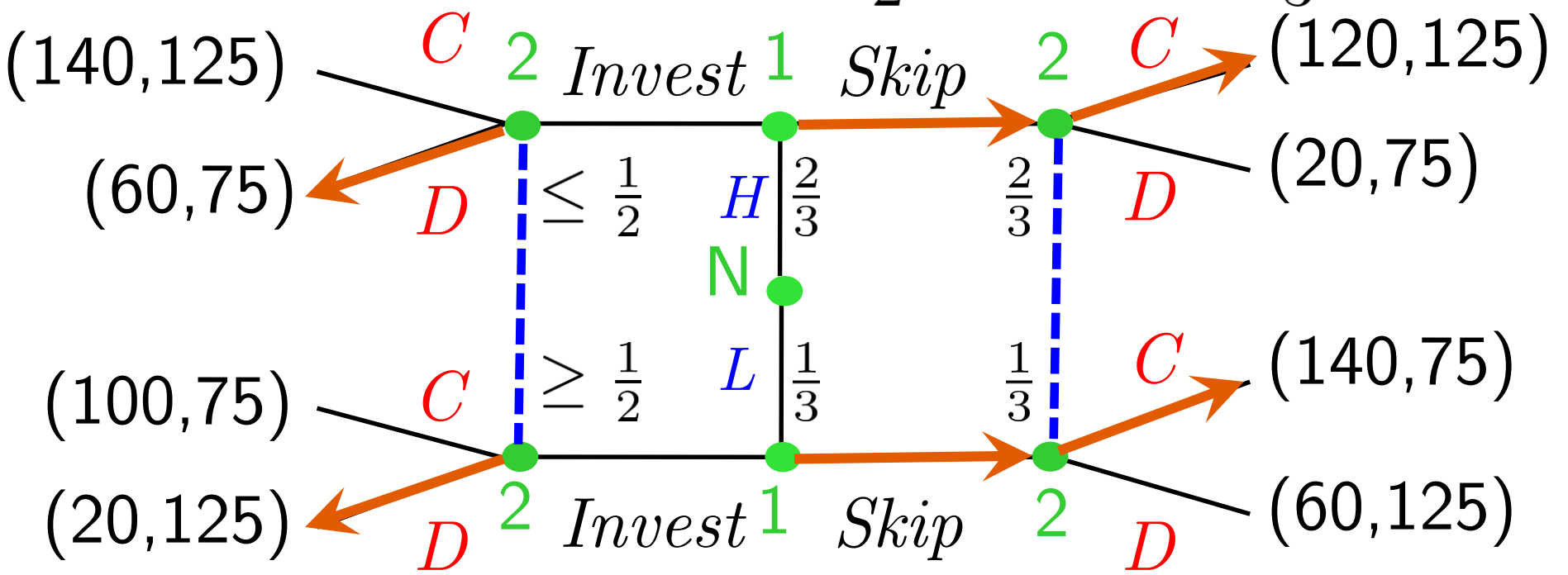
Simple Signaling Game

- Workers get 100 doing C and 20 doing D
  - L types get additional 40 for taking action $Skip$
  - H types get 40 if take action $Invest$, 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	~~20~~40, 75	140, 125	60,75

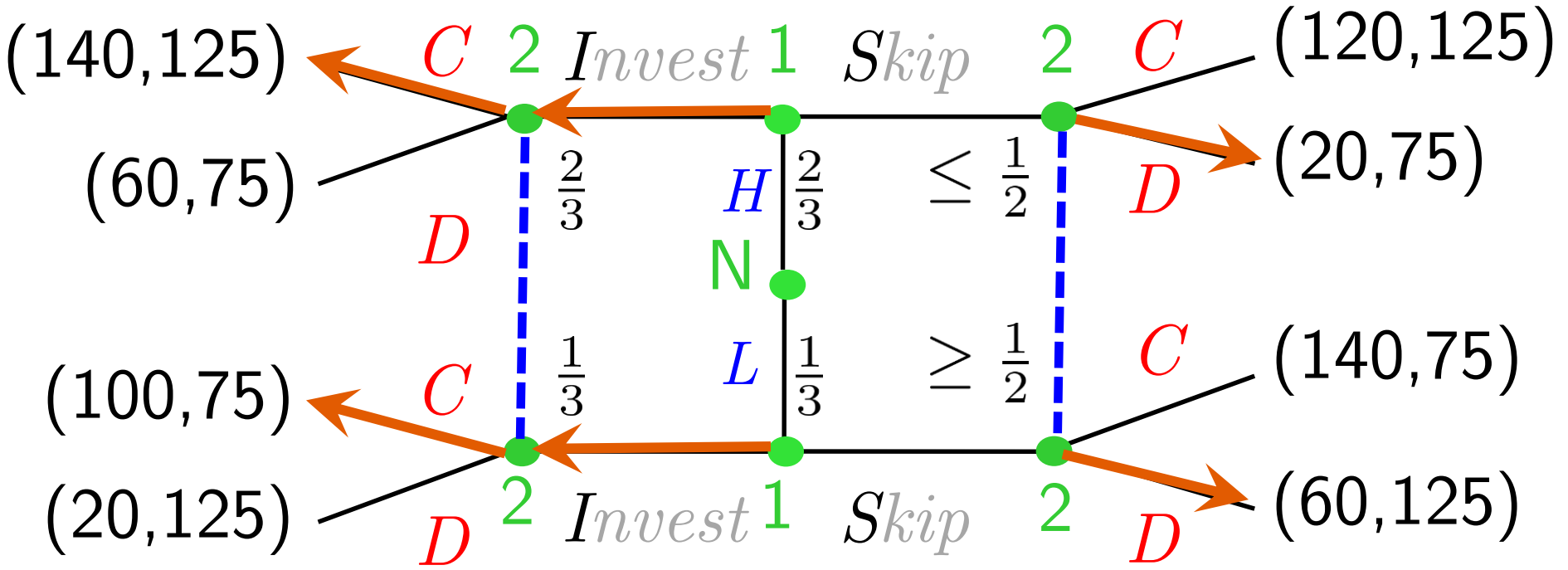
Simple Signaling Game: Extensive Form

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

Simple Signaling Game

Periods	Message | Type		Action | Message		Equilibrium Predictions	
	$I \mid H$	$I \mid L$	$C \mid I$	$D \mid S$	Intuit.	Seq.
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, separating pooling equil. 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:Banks, Camerer & Porter (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 show that 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 how equilibria in Table 8.3 (adopted from Banks, Camerer and Porter, GEB 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);
  - Does 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

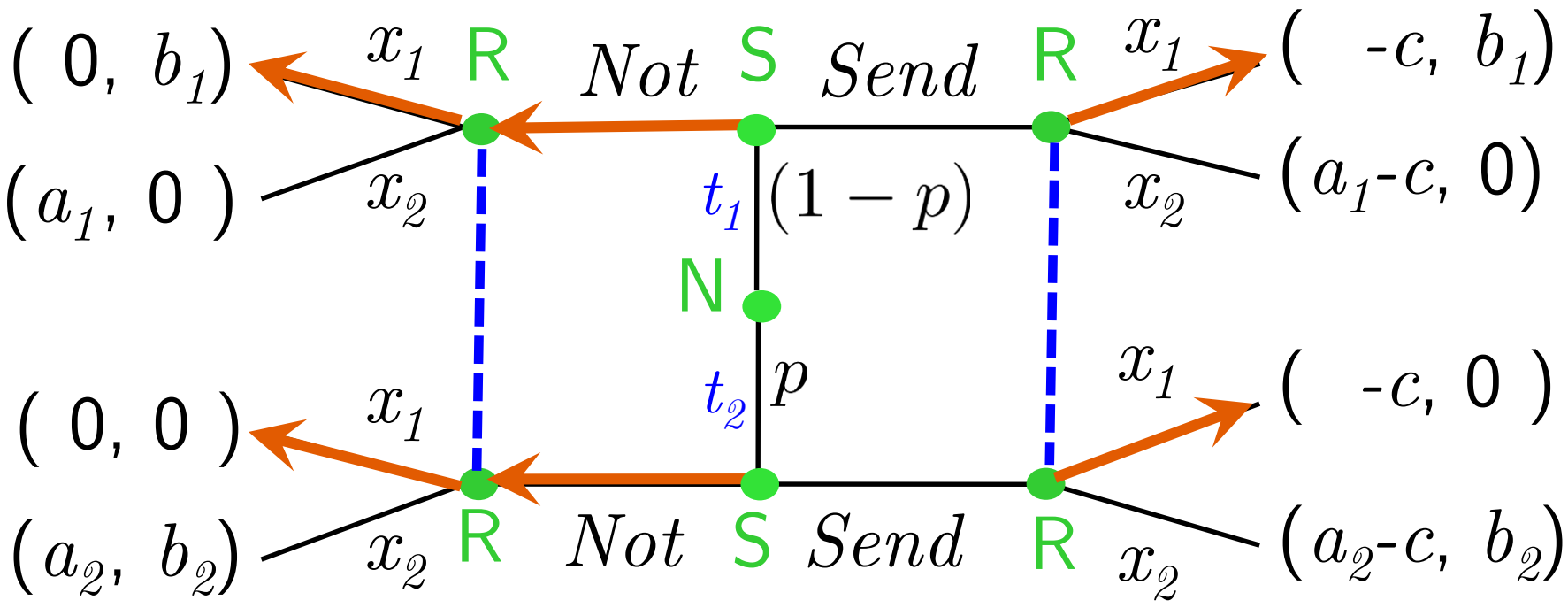
Lobbying: Potters & van Winden (IJGT 1996)

- Lobby group is type t_1 or t_2 with (1-p, p)
- Lobby group 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

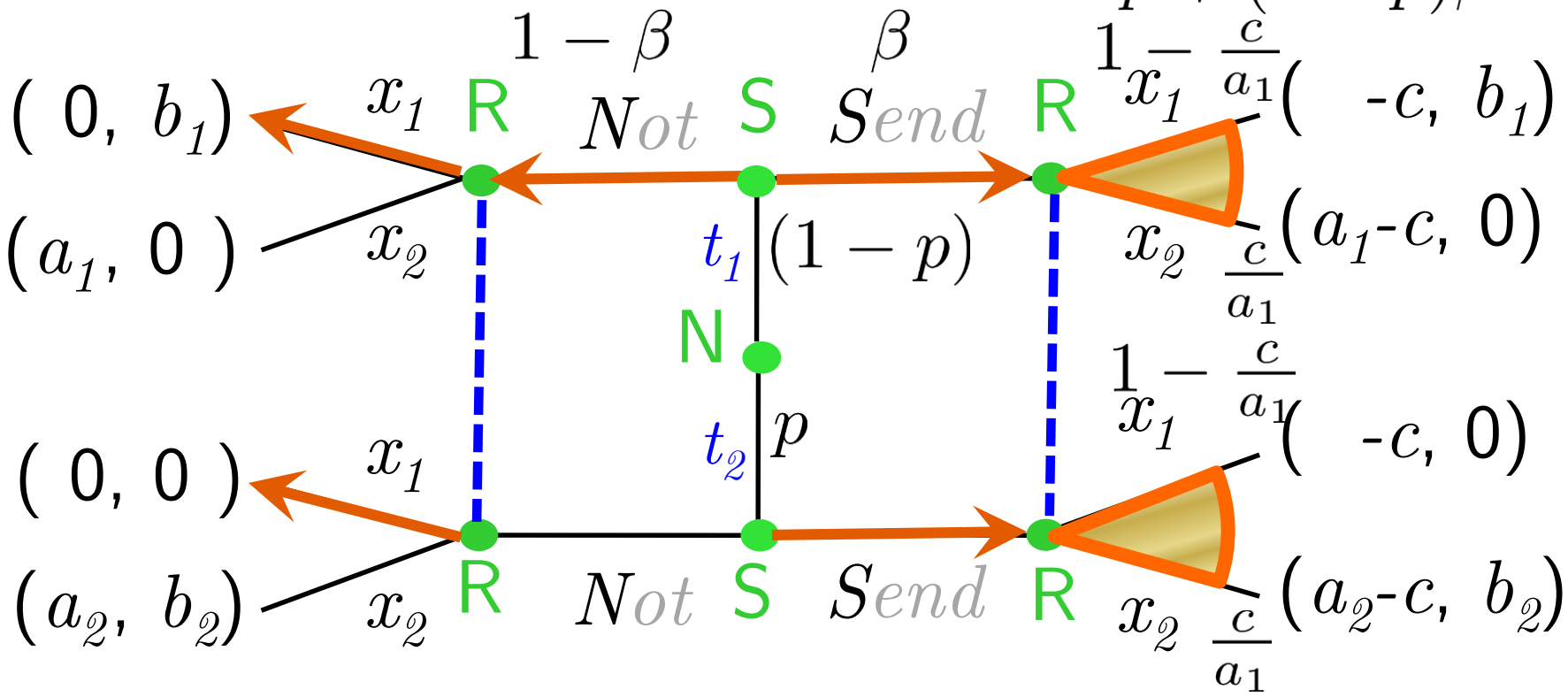
- Equilibrium: $\Big((Not|t_1, Not|t_2), (x_1|Send, x_1|Not)\Big)$
- Beliefs: $\Pr(t_2|Not) = p = \Pr(t_2|Send)$



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

- For $\beta = \frac{pb_2}{(1-p)b_1} < 1$; there are 2 equilibrium:
- Pooling: Lobby groups both don't send signal
- Politician ignores signal and chooses x_1
  - Intuitive, divine, but not universally divine
- Semi-pooling: type t_2 always send signal
- Politicians mix x_1/x_2 @(1-c/a_1, c/a_1) if signal
- type t_1 mixes by sending signal with prob. β
  - Universally divine

Lobbying

Treatment	Signal Freq. (t_1, t_2)			x_2 Freq. (no sig., sig)		
	β	Actual	Pred.	c/a_1	Actual	Pred.
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:
  - Past frequency of x_2 after signal is $r(m)_{t\text{-}1}$
- Should signal if $[r(m)_{t\text{-}1}\ a_1 - c] > 0$
  - Subjects signal 46% if >0, 28% if <0
  - Politicians choose x_2 77% if >0, 37% if <0
- Potters and van Winden (JEBO 2000)
  - Similar results; little difference between students and professionals

Corporate Finance

- Cadsby, Frank & 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:
- 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 equilibrium (pooling if multi.)
  - When unique pooling: all firms offer shares
  - When unique separating: Initially, both offer (pool), but H types learn not to offer (separate)
  - When multiple: Converge to pooling equilibrium
- 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 Eq: L chooses 1 or 2; H pools with L
- Myopic K firms: Naively pick 5 (& 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
  - Provides language to foster learning from experience
- Cooper, Garvin and Kagel (Rand/EJ 1997)
  - Belief Learning in Limit Pricing Signaling Games

Reputation Formation

- Camerer and Weigelt (Econometrica 1988)
- 8 period trust game
- Borrower: 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 (Econometrica 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

Applying for Economics Graduate School

An Example of Signaling

Questions

1. What should I apply? MBA or Econ PhD?
2. What's the most important factor if I apply?
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?

What Program Should I Apply?

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

What Program Should I Apply?

- Econ PhD provides you the rigorous training to modern economic analysis techniques
- This is used by
  - Academics (Economics, Public Policy, Law,...)
  - Economics Consulting Firms
  - Public Policy Evaluation
  - Financial Companies (like Investment Banking)
  - International Organizations (APEC, IMF, etc.)

Most Important Factor

- What is the Most Important Factor when I Apply for Graduate School?
- Petersons Guide surveyed both students & admission committee members (faculty)
- 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 such as AWA 5.0 or higher?

Discrimination and Gender

- Are Foreigners or Females Discriminated?
- Foreigners:
  - Different Programs have different policy
  - UCLA (8/35) vs. MIT (25/30)
- Women: Only 16% of 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:
  - Take a heavy dose of mathematics during undergraduate. - Peterson's Guide
- So, the answer is generally yes.
  - There is a gap between undergrad & graduate
- But, the ability to find economic intuition behind the math is even more essential
  - My first year micro comp. experience...
- They need Bilingual People!

Is Mathematics Needed?

- What Kind of Math is Needed?
- Introduction to Real Analysis (aka Advanced Calculus): Score A or A+
  - The thinking process required for you to score A/A+ is what's important
- Linear Algebra: Basic Tool for Econometrics
- Advance Statistical Inference: ...Econometrics
- The more the better, but mastering these three is better than being a jack of all traits...

Is MA required before I enter PhD?

- No. Most Top-10 have only PhD programs
  - Chicago: Give you a master if you cannot finish
- But you may not be able to 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 go for PhD
- Condition on passing 1st year comp's, MA is unnecessary, but you may want to hedge...

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 Level Courses in Economics
- Take Economics Courses Taught in English

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+