Signaling
鶴立雞群賽局

Joseph Tao-yi Wang (王道一)
Lecture 12, 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 Equil. (MSE)
2. Subgame Perfect Equilibrium (SPE)
3. Bayesian Nash Equil. (BNE/Auction)
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)
  - 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

Signaling
鶴立雞群賽局

Joseph Tao-yi Wang (王道一)
Lecture 12, EE-BGT

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 Experiment

1. CHT Telecom has 2 cell phone plans:
   - Plan A: NT$1 per minute
   - Plan B: NT$168 for 300 min., NT$1.5 beyond
2. Your monthly usage (via 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:
   - Apply for masters program at 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 $Dull$ or $Challenging$ job
- Employer payoffs are 125 if she assigns D to L types and C to H types

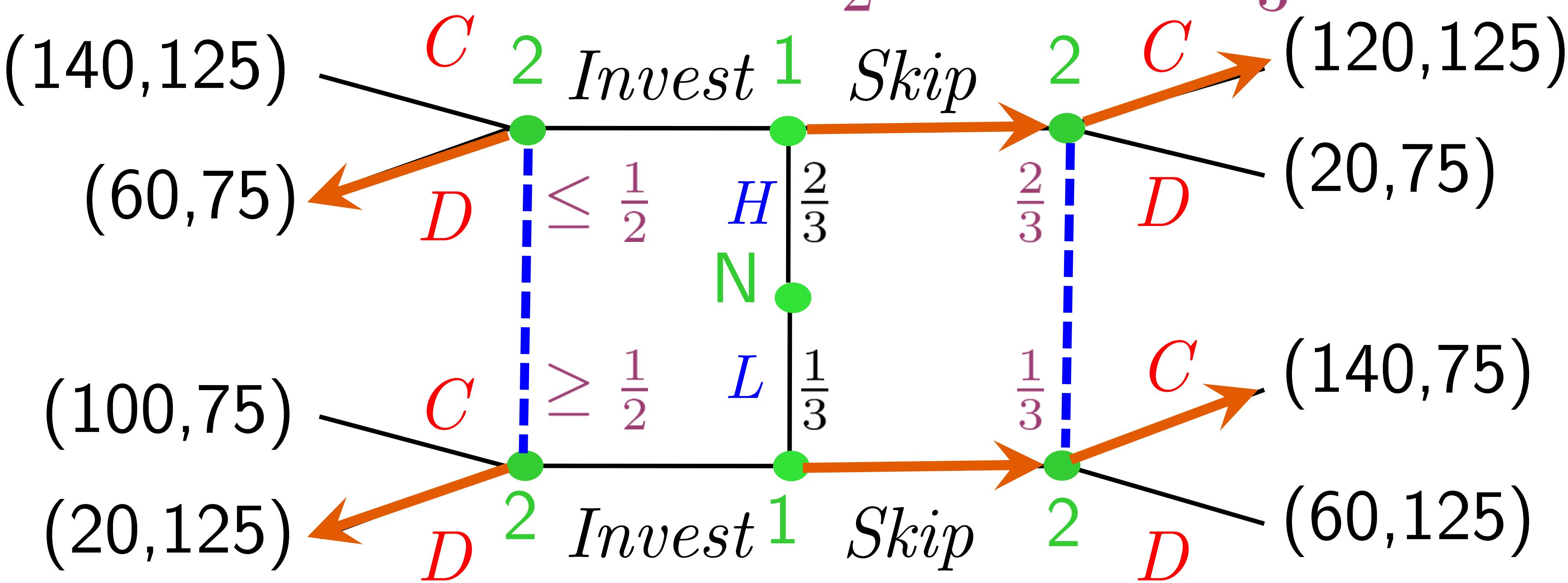
Simple Signaling Game

- 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

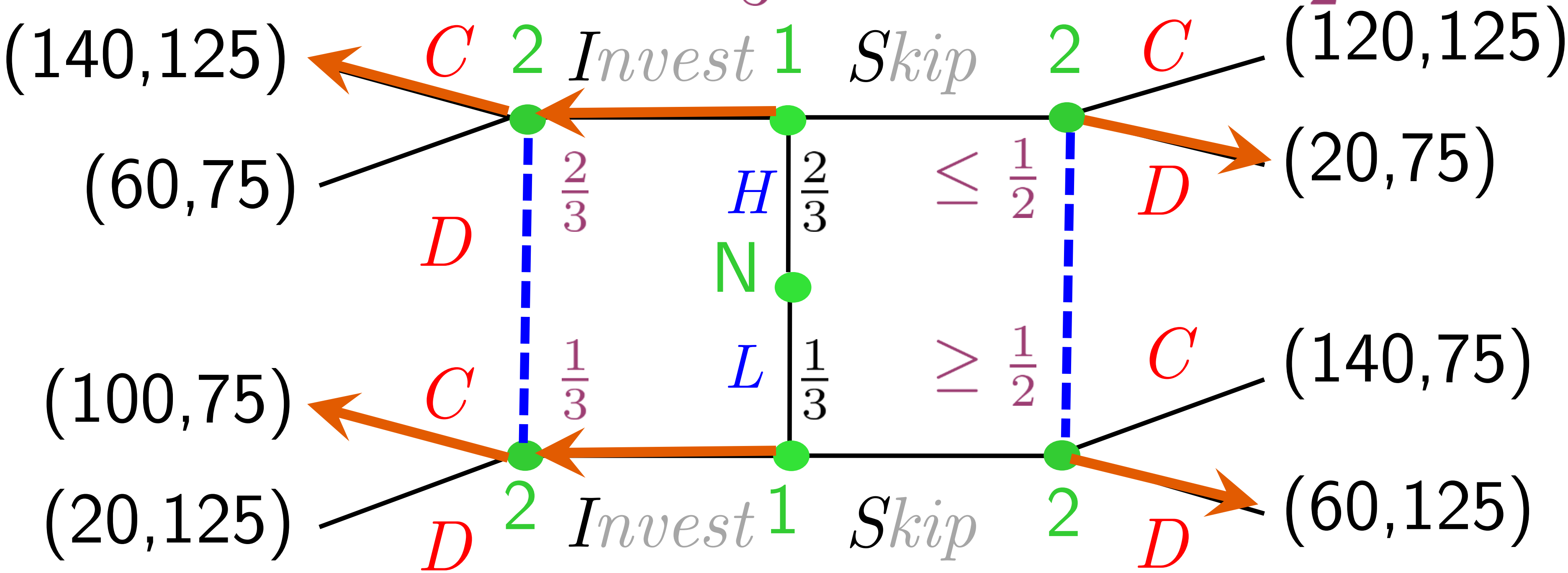
Simple Signaling Game: Extensive Form

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



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	
	$I \mid H$	$I \mid L$	$C \mid I$	$D \mid S$	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 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

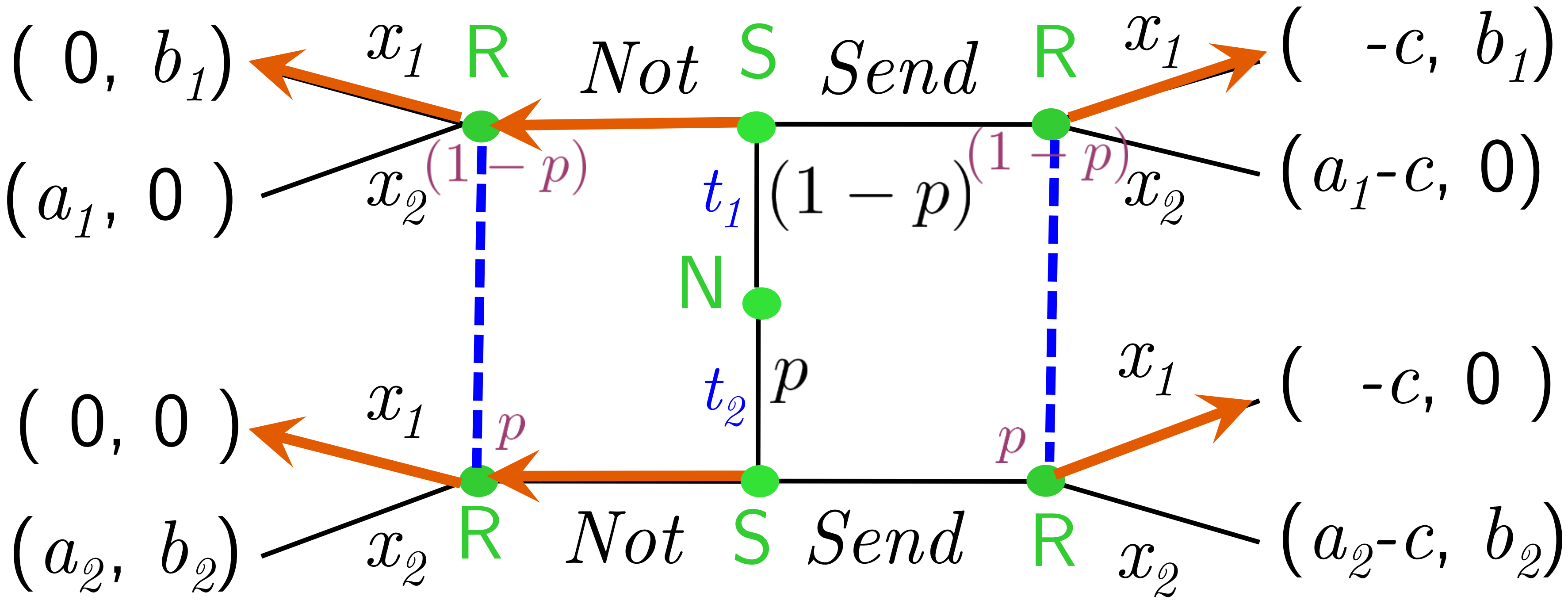
Lobbying: Potters & van Winden (IJGT 1996)

- 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

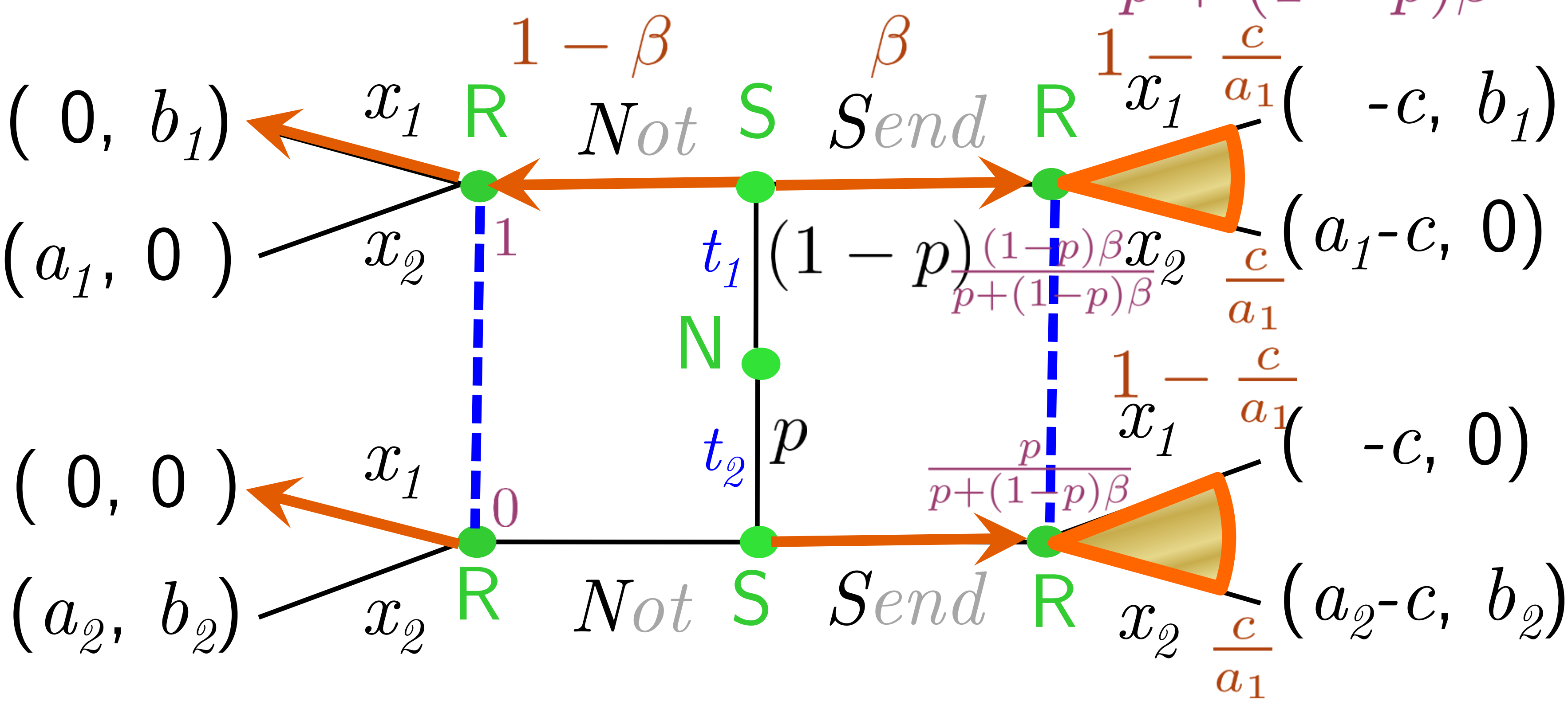
- Equilibrium: $\Big((Not|t_1, Not|t_2), (x_1|Send, x_1|Not)\Big)$
- Beliefs: $\Pr(t_2|Not) = p = \Pr(t_2|Send)$



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

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:

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 w/ professionals (+ students)

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?

Corporate Finance

- 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
  - Unique Pooling: all firms offer shares
  - Unique Separating: Initially, both offer (pool), but H types learn not to offer (separate)
  - Multiple Equilibrium: Converge to pooling
- Cadsby, Frank & 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 w/ 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 & 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	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

BR if B not react to Q

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

Limit-Pr

- Myopi
  - M_H Monopolist A chooses Q=2
  - M_L Monopolist A chooses Q=4

BR if B not react to Q

- 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

Q	A's Q if M_H	A's Q if M_L	B's IN%
Round 1-12 (Inexperienced Subjects)			
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

Q	A's Q if M_H	A's Q if M_L	B's IN%
Round 13-24 (Inexperienced Subjects)			
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

Q	A's Q if M_H	A's Q if M_L	B's IN%
Round 25-36 (Inexperienced Subjects)			
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-Pr

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

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

BR if B not react to Q

- 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

Q	A's Q if M_H	A's Q if M_L	B's IN%
Round 1-12 (Experienced Subjects)			
1	2%	-	100%
2	41%	-	59%
3	2%	-	100%
4	55%	100%	3%
5	-	-	-
6	-	-	-
7	-	-	-

(Median)

Limit-Pricing Signaling: Treatment I

Q	A's Q if M_H	A's Q if M_L	B's IN%
Round 13-24 (Experienced Subjects)			
1	2%	-	0%
2	28%	-	91%
3	2%	2%	50%
4	68%	98%	6%
5	-	-	-
6	-	-	-
7	-	-	-

(Median)

Limit-Pricing Signaling: Treatment I

Q	A's Q if M_H	A's Q if M_L	B's IN%
Round 25-36 (Experienced Subjects)			
1	3%	-	100%
2	23%	2%	70%
3	5%	-	50%
4	69%	98%	6%
5	-	-	-
6	-	-	-
7	-	-	-

(Median)

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

Limit-Pr

- Myopi
  - M_H Monopolist A chooses Q=2
  - M_L Monopolist A chooses Q=4

M_L Monopolist always want to separate from M_H

- 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

Limit-Pricing Signaling: Treatment II

Q	A's Q if M_H	A's Q if M_L	B's IN%
Round 1-12 (Inexperienced Subjects)			
1	6%	1%	80%
2	71% (Median)	7%	88%
3	12%	3%	60%
4	11%	72% (Median)	53%
5	-	9%	40%
6	-	6%	50%
7	-	2%	0%

Limit-Pricing Signaling: Treatment II

Q	A's Q if M_H	A's Q if M_L	B's IN%
Round 13-24 (Inexperienced Subjects)			
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

Q	A's Q if M_H	A's Q if M_L	B's IN%
Round 25-36 (Inexperienced Subjects)			
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

Q	A's Q if M_H	A's Q if M_L	B's IN%
Round 1-12 (Experienced Subjects)			
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

Q	A's Q if M_H	A's Q if M_L	B's IN%
Round 13-24 (Experienced Subjects)			
1	5%	-	100%
2	40%	-	100%
3	5% (Median)	5%	100%
4	40% (Median)	22%	85%
5	10%	7%	57%
6	-	66% (Median)	7%
7	-	-	-

Limit-Pricing Signaling: Treatment II

Q	A's Q if M_H	A's Q if M_L	B's IN%
Round 25-36 (Experienced Subjects)			
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

Q	A's Q if M_H	A's Q if M_L	B's IN%
Round 1-12 (Experienced Subjects)			
1	-	-	-
2	56% (Median)	-	96%
3	2%	-	100%
4	38%	26%	63%
5	3%	-	50%
6	-	75% (Median)	8%
7	-	-	-

100% Anticipation

Q	A's Q if M_H	A's Q if M_L	B's IN%
Round 13-24 (Experienced Subjects)			
1	9%	-	100%
2	76% (Median)	2%	100%
3	4%	-	100%
4	12%	13%	92%
5	-	-	-
6	-	84% (Median)	0%
7	-	-	-

100% Anticipation

Q	A's Q if M_H	A's Q if M_L	B's IN%
Round 25-36 (Experienced Subjects)			
1	2%	-	0%
2	78% (Median)	-	100%
3	7%	3%	100%
4	15%	12%	92%
5	-	-	-
6	-	88% (Median)	5%
7	-	-	-

0% Anticipation

Q	A's Q if M_H	A's Q if M_L	B's IN%
Round 1-12 (Experienced Subjects)			
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

Q	A's Q if M_H	A's Q if M_L	B's IN%
Round 13-24 (Experienced Subjects)			
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

Q	A's Q if M_H	A's Q if M_L	B's IN%
Round 25-36 (Experienced Subjects)			
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 (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. 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?

What 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

What Program Should I Apply?

- Econ PhD provides rigorous training to modern economic analysis techniques
- This 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$\geq$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:
  - Take a heavy dose of mathematics during undergraduate. - Peterson's Guide
- So, the answer is generally yes.
  - Due to gap between undergrad & graduate
- But ability to find economic intuition behind the math is even more essential
  - My first year micro comp. exam experience
  - They need Bilingual People!

What Kind of Mathematics is Needed?

- Mastering these better than jack of all traits:

1. MATH2213/2214 (分析導論一二)
   - Introduction to Mathematical Analysis (I),(II)
   - Thinking process to score A+ is essential!
2. MATH1103/1104 (線性代數一二)
   - Linear Algebra (I),(II): Tools of Econometrics
3. STAT5004/5005 (統計理論一二)
   - Theory of Statistics (I),(II): Casella and Berger (2002) = first part of graduate Econometrics

What Kind of Mathematics is Needed?

1. MATH2213/2214 (分析導論一二)
2. MATH1103/1104 (線性代數一二)
3. STAT5004/5005 (統計理論一二)

- Note: STAT5004/5005 is a master-level required course and should be taken only after you took the other two courses
  - Also consider MATH1211/1210 (微積分一二) which uses the Courant and John textbook:
    - Introduction to Calculus and Analysis, Vol.1&2

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...

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

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+