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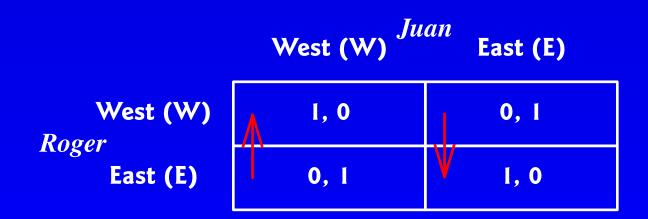
Consider a tennis match between Roger and Juan. Each has two options whether serving or receiving: W or E. Let's say Juan is serving.

	West (W) Juan East (E)		
West (W) Roger	1, 0	0, 1	
East (E)	0, 1	1, 0	

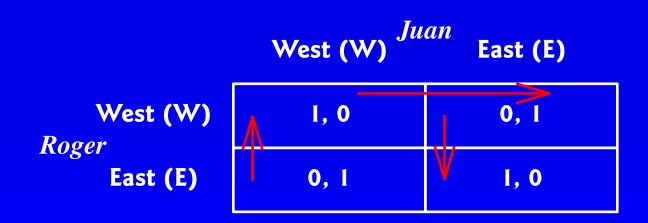
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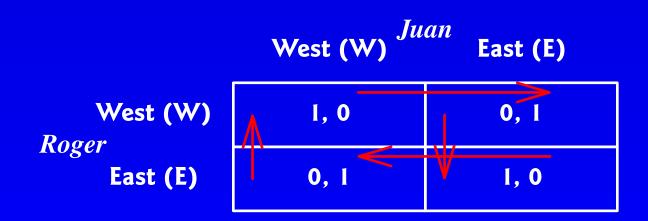
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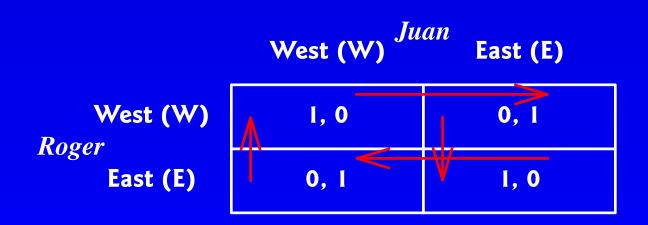


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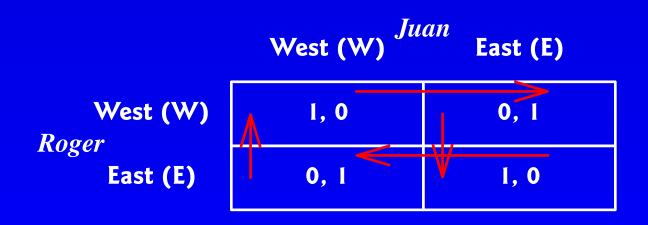
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Juan's best shot depends on what Roger anticipates.

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Juan's best shot depends on what Roger anticipates. And Roger's best move depends on Juan's aim.

Simultaneous-Move Games —

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- Discrete, "pure" strategies (no dice-throwing)
- Either at the same time, or without knowledge of an action already taken.
- : Imperfect information or knowledge

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- e.g. Choice of product design, advertising campaign, features
- e.g. Goalie v. striker; server v. receiver

Contents of This Lecture

- I. The Payoff Matrix
- 2. Nash Equilibrium (N.E.)
- The Prisoner's Dilemma
- 4. Four Methods for Finding the N.E.
 - Each has a dominant strategy
 - One has a dominant strategy
 - Eliminate dominated strategies
 - Best-response analysis
- 5. Other Games
- 6. Four Lessons

(Read Rothschild — Reading 10, in Weeks 2-3 — for next class.)

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I'm deciding what to do, while you are too; what I decide affects you, and what you decide affects me.

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 - A Nash Equilibrium.

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- # rows = # strategies of Mr Row = 4.
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	7			
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U	$-\boldsymbol{\nu}$			

		Le	Ce	Ri
T	T	3, 1	2, 3	10, 2
Row	H	4, 5	3, 0	6, 4
NOW	L	2 , 2	5, 4	12, 3
	В	5 , 6	4, 5	9, 7

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- Non-zero sum (or "positive sum") game: the sum of the payoffs is not constant across cells. By convention, the payoffs are: R,C.
- (See solution on page 7 below.)

A Zero-Sum Payoff Matrix

Gridiron football:

Defense

		Run	Pass	Blitz
	Run	2	5	13
Offense	Short pass	6	5.6	10.5
	Medium pass	6	4.5	1
	Long pass	10	3	-2

- Show the payoffs of one player only (here, Offense).
- Payoffs in yards gained by Offense. (Defense loses that amount.)

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- Payoffs in yards gained by Offense. (Defense loses that amount.) ∴ Zero-sum game.
- N.E. at {Short pass, Pass}, and Offense gains 5.6 yards.

Nash Equilibrium

From p.4 above, a N.E. at {L,M}, payoffs (5,4):

		Le	Ce	Ri
T	T	3, 1	2, 3	10, 2
Row	Н	4, 5	3, 0	6 , 4
NOW	L	2 , 2	5, 4	12, 3
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Why?

Nash Equilibrium

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Row	Н	4, 5	3, 0	6 , 4
NOW	L	2 , 2	5, 4	12, 3
	В	5 , 6	4, 5	9, 7

Why? Because Ce is Column's best response to Row's L, and vice versa.

So {L,Ce} is each player's best response to the other's action.

- .. Neither would change unilaterally.
- ... we have an equilibrium (a N.E.).

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- 4. Could do cell-by-cell inspection to find all N.E., but simpler methods exist.

N.E. as Beliefs

Players need not have best responses to opponents' action which have not yet happened.

Players can think ahead, and form beliefs of what opponents will do.

Then a N.E. can be defined as a set of strategies (one per player) such that:

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Then a N.E. can be defined as a set of strategies (one per player) such that:

- I. each player has correct beliefs about the strategies of the others, and
- 2. the strategy of each is the best strategy for herself, given her beliefs about the others' strategies.

Now: Four Methods to Find N.E.

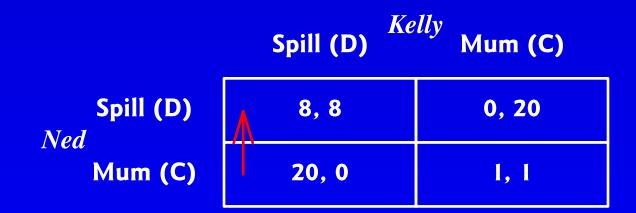
Say you're the Row player:

- 1. Look for a dominant strategy (a row always preferred, no matter which column the other player chooses), and choose it.
- 2. Does the other player have a dominant strategy (column)? If so, expect that strategy.
- 3. Look for dominated actions (rows never preferred, no matter what the other player would choose), and eliminate them.
 - Successively eliminate each other's dominated strategies (rows, columns).
- 4. Use arrows for both of you, and identify any cells with no arrows leaving: best response or N.E.

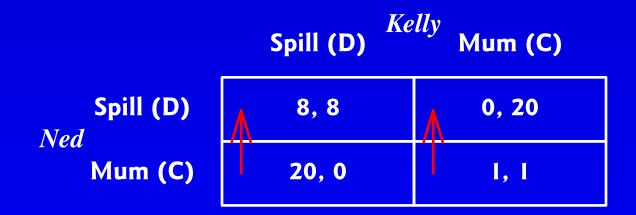
Consider the Prisoner's Dilemma:

	Spill (D) Kelly Mum (C)	
Spill (D) Ned	8, 8	0, 20
Mum (C)	20, 0	1, 1

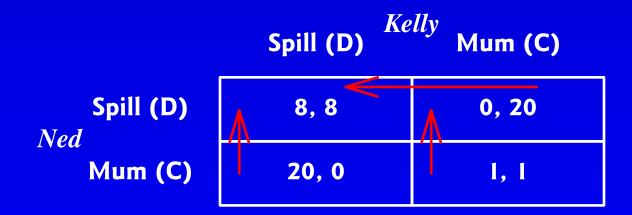
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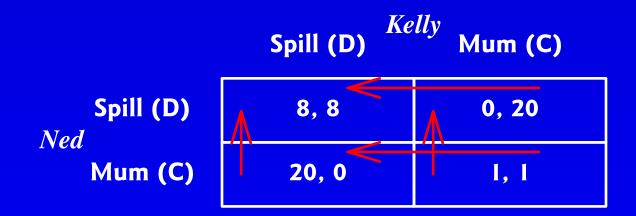
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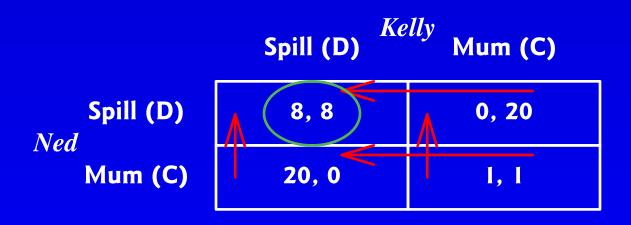
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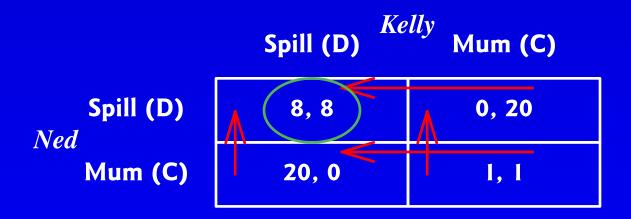


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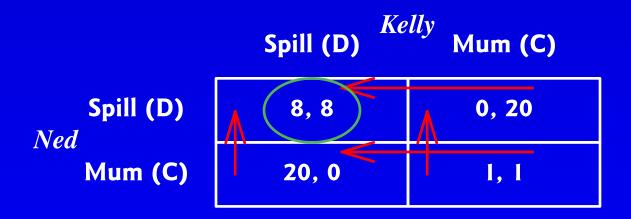
Years of prison (Ned, Kelly).



 Spill the beans (Defect) is better than keeping Mum (Cooperate) for Ned, whatever he believes Kelly will do.

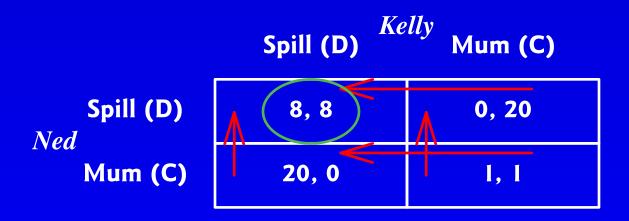


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 - Likewise for Kelly.

• In the Prisoner's Dilemma, both players have a dominant strategy: no matter what the other guy does, Spill the beans (or Defect) is best.

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 - (See Lectures 15, 16 later.)

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Many real-world phenomena are PDs. Examples?

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How to overcome the {D,D} trap? (See Lectures 15, 16 later.)

Ex: The Advertising Game is a P.D.

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David Ogilvy: Half the money spent on advertising is wasted; the problem is identifying which half.

Telstra and Optus independently must decide how heavily to advertise.

Advertising is expensive, but if one telco chooses to advertise moderately while the other advertises heavily, then the first loses out while the second does well.

Let's assume if both Advertise Heavily then Telstra nets \$70,000, while Optus nets \$50,000.

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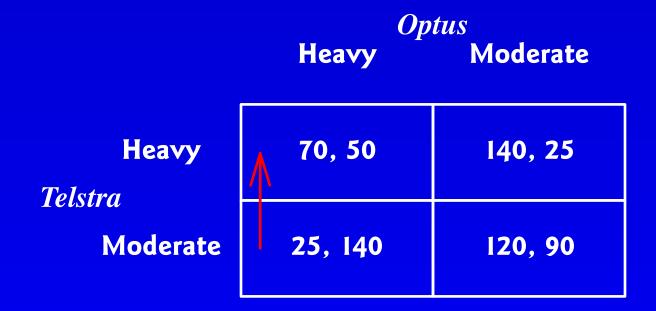
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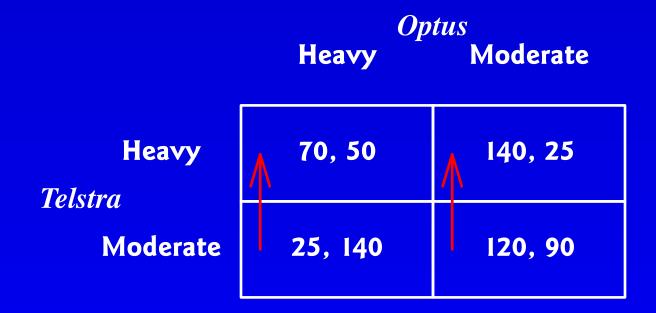
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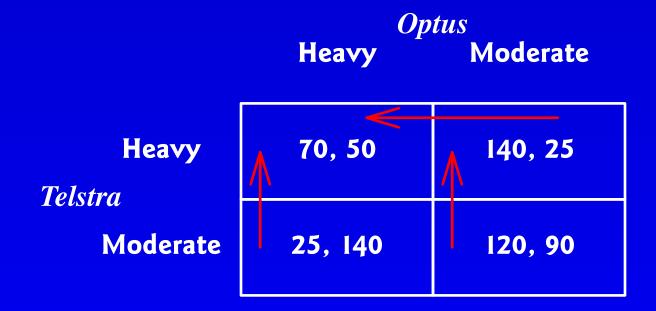
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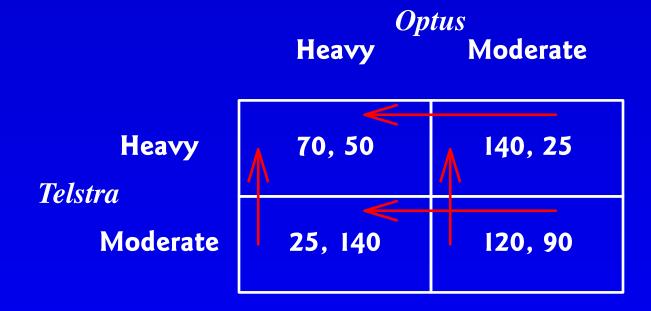
Consider the payoff matrix:

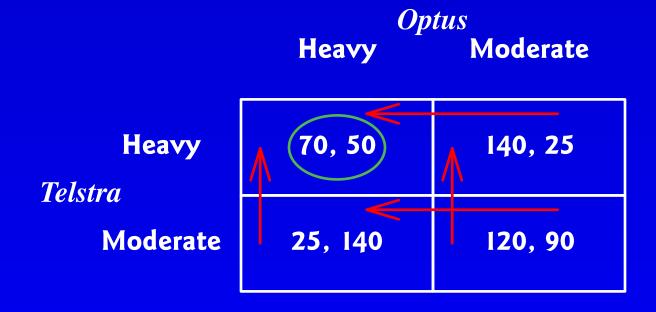
	Optus	
	Heavy	Moderate
Heavy Telstra Moderate	70, 50	140, 25
	25, 140	120, 90



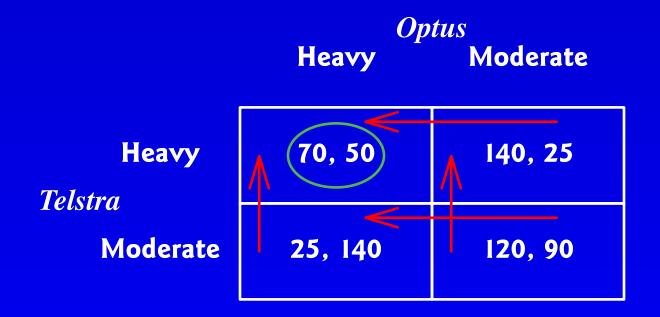






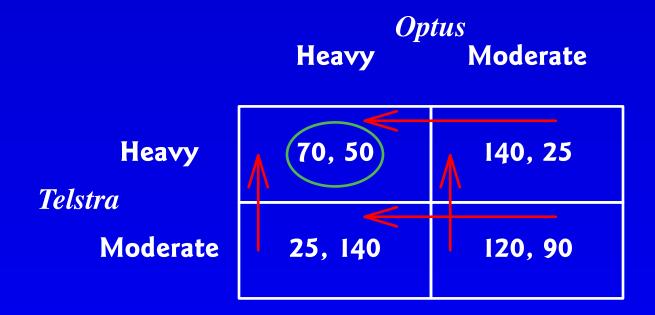


The Advertising Game



Both choose Heavy advertising, although each would be better off with Moderate advertising.

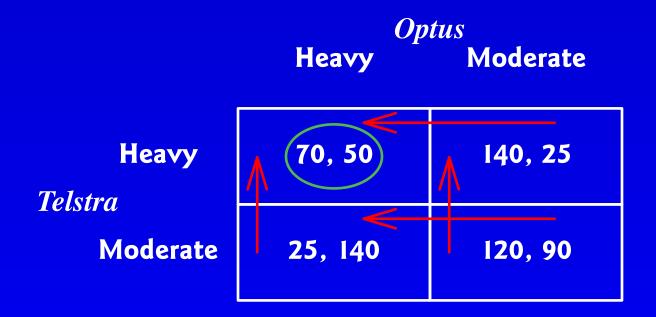
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A Prisoner's Dilemma.

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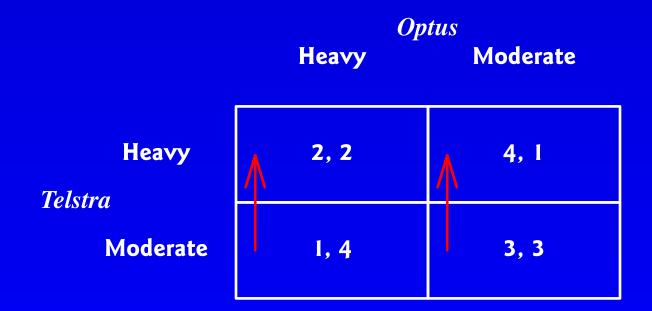
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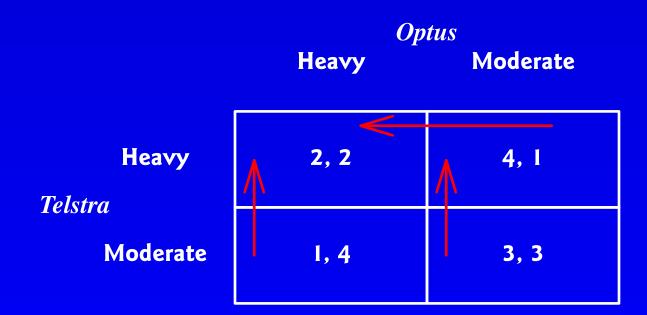
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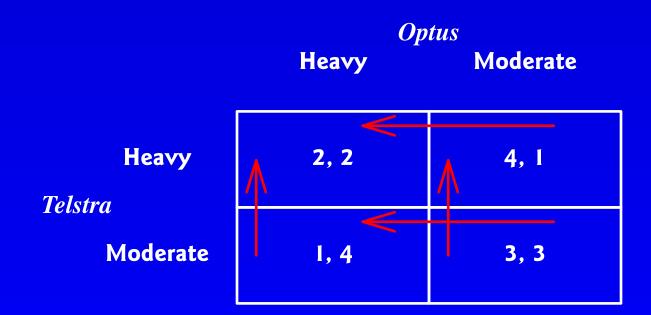
The arrows show each player has a dominant strategy of H.

	Optus	
	Heavy	Moderate
Heavy	2, 2	4, 1
Telstra Moderate	1, 4	3, 3

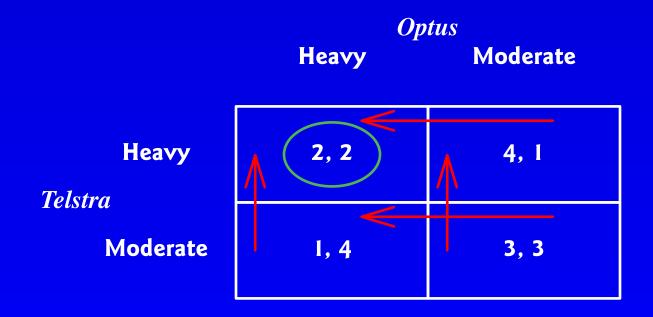
	Optus	
	Heavy	Moderate
Heavy	2, 2	4, I
Telstra Moderate	1, 4	3, 3







Or, could rank outcomes for each player: 4 is best, I is worst.



Important: When strategies are "pure" (deterministic), then we needn't have exact knowledge of the payoffs, just their rankings.

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Strategies:

Allow three choices for each of the two players:



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The payoff matrix (in net returns '000) for simultaneous moves is:

Superiory 4		Beta	
	DNE	Small	Large
DNE	\$18, \$18	\$15, \$20	\$9, \$18
Alpha Small	\$20, \$15	\$16, \$16	\$8, \$12
Large	\$18, \$9	\$12, \$8	\$0, \$0

	DNE	Beta Small	Large
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	DNE	Beta Small	Large
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Alpha Small	\$20, \$15	\$16, \$16	\$8, \$12
Large	\$18, \$9	\$12, \$8	\$0, \$0

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The payoff matrix (Alpha, Beta).



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N.E. at {Small, Small}, although both would prefer {DNE, DNE}.



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Large is a dominated strategy for both players.





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N.E. at {Small, Small}, although both would prefer {DNE, DNE}.

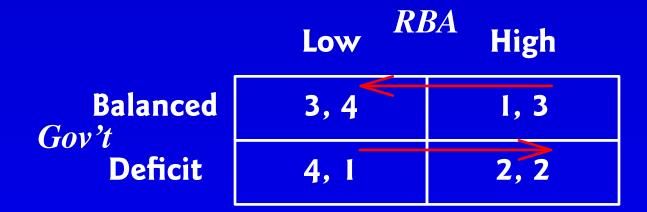
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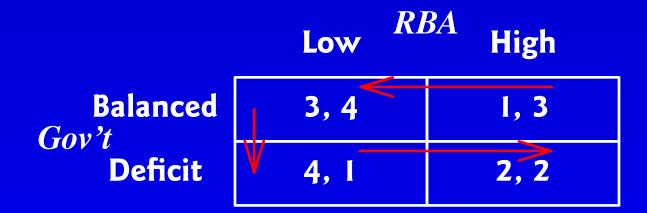
What if the payoffs were the differences in returns? (an envious game)

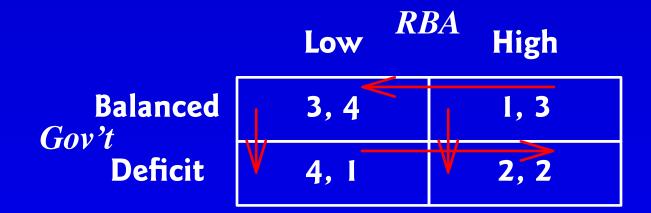
Then the game is changed to an "envious" game..

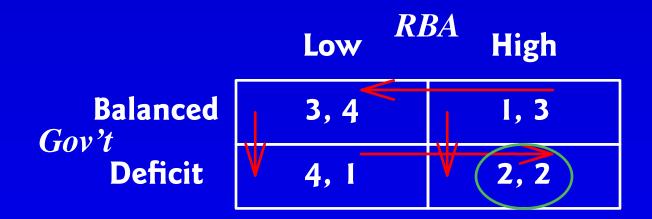
	Low	BA High
Balanced Gov't	3, 4	1, 3
Deficit	4, 1	2, 2

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Balanced Gov't	3, 4	1, 3
Deficit	4, 1	2, 2





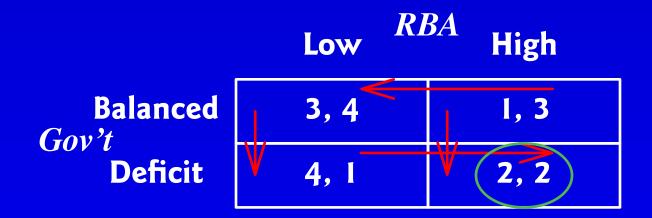




Players:

Gov't: fiscal policy (taxes, govt. expenditure)

RBA: monetary policy (interest rates)



Players:

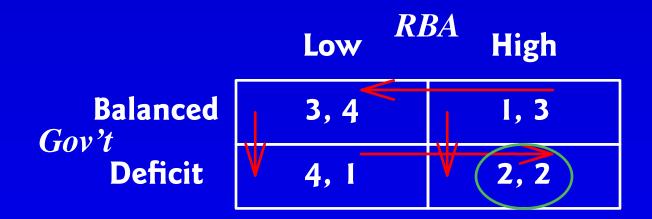
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RBA: monetary policy (interest rates)

Actions:

Gov't: either balanced budget or deficit

RBA: high or low interest rates



Players:

Gov't: fiscal policy (taxes, govt. expenditure)

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Gov't: either balanced budget or deficit

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Preferences?

The RBA's best strategy depends on the Gov't's strategy. Dislikes inflation, High rates.

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... RBA should choose {High}.

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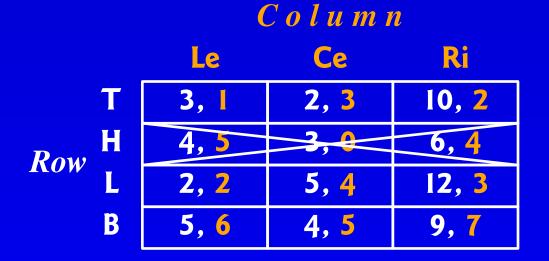
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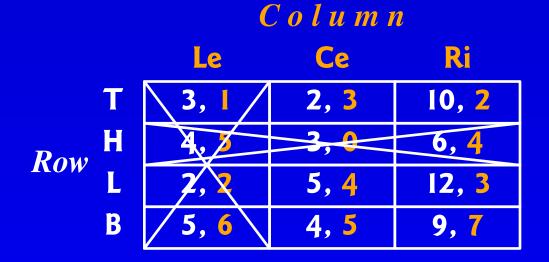
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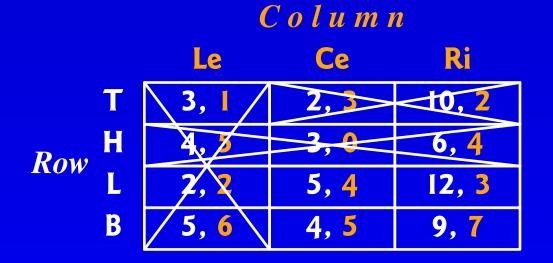
Many countries have a loose fiscal policy and a tight monetary policy at {Deficit, High interest rates}.

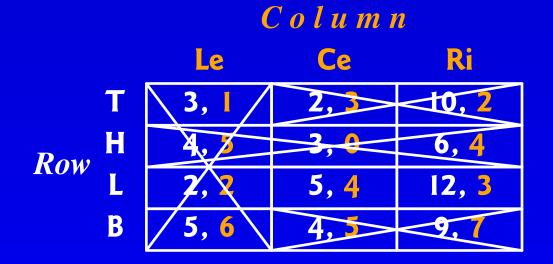
Calumn

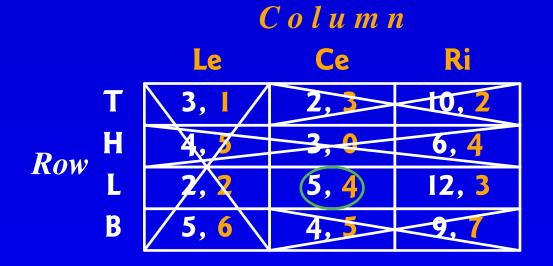
		Le	Ce	Ri
Row	T	3, I	2, 3	10, 2
	H	4, 5	3, 0	6, 4
	L	2 , 2	5, 4	12, 3
	В	5, 6	4, 5	9, 7

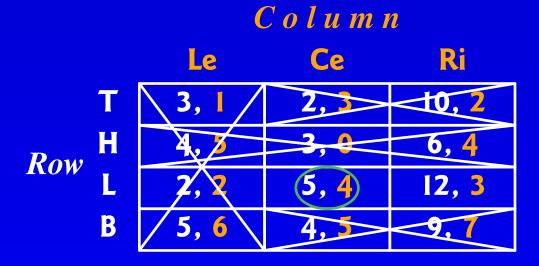




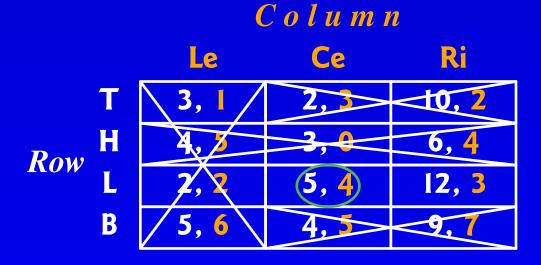




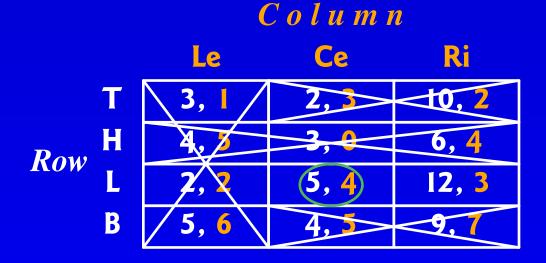




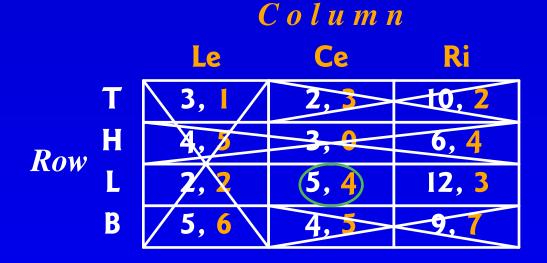
For Row, H is dominated (by B): eliminate H;



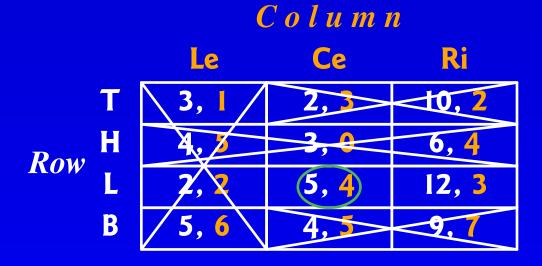
For Row, H is dominated (by B): eliminate H; For Column, Le is dominated (by Ri);



For Row, H is dominated (by B): eliminate H; For Column, Le is dominated (by Ri); For Row, T and B are now dominated (by L).



For Row, H is dominated (by B): eliminate H; For Column, Le is dominated (by Ri); For Row, T and B are now dominated (by L). Which now leaves Row with L, and Column chooses Ce.



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Not every game is dominance solvable, but the POM perhaps becomes smaller.

What if there are ties?

It's possible to eliminate using weak dominance (\leq) instead of strict dominance (\leq), but this successive elimination of weakly dominated strategies might throw out some N.E.

(See Dixit & Skeath, p. 97.)

Dixit & Skeath use circles to show the best response. Row looks at for highest payoff in each column, and Column looks for the best payoff in each row.

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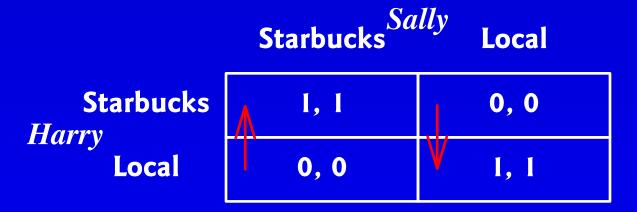
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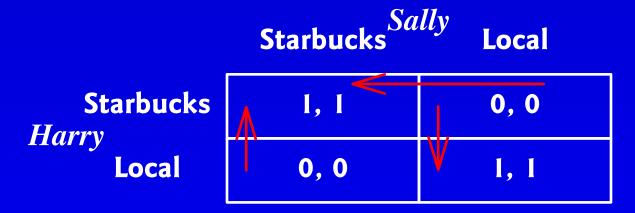
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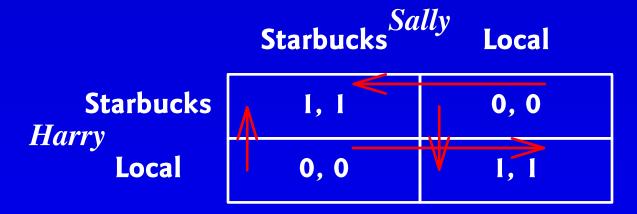
In Lecture 5, we derive best-reponse curves with continuous strategies.

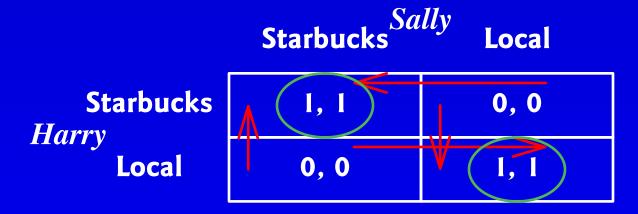
	Starbucks Sally Local	
Starbucks Harry	1, 1	0, 0
Local	0, 0	1, 1

	Starbucks Sa	lly Local
Starbucks Harry	1, 1	0, 0
Local	0, 0	1, 1

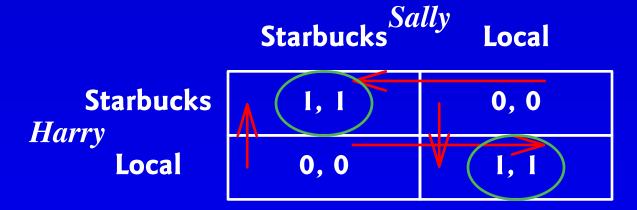






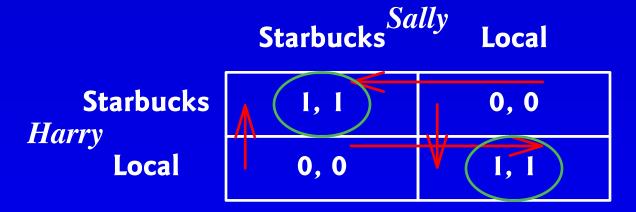


Common interests, but independent choices \rightarrow issues.



Two N.E., with equal payoffs: need to coordinate.

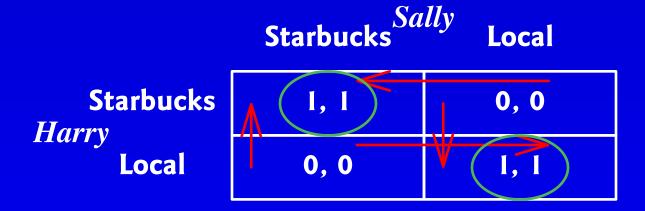
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How?

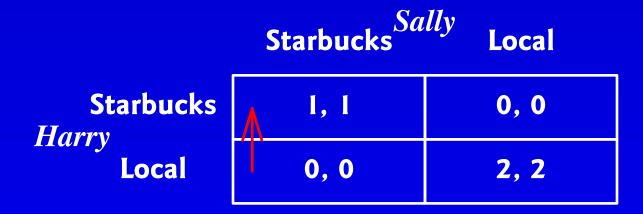
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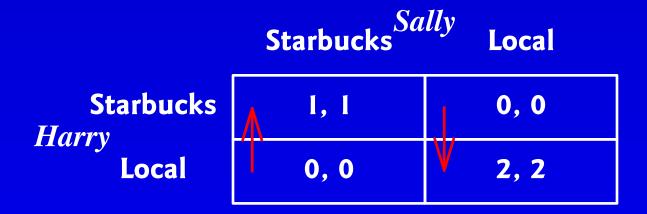


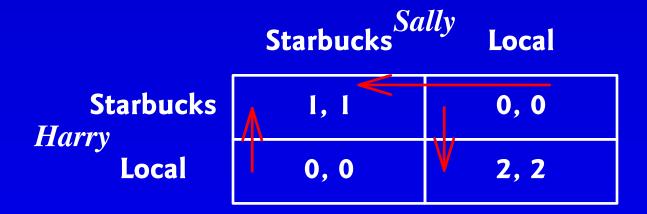
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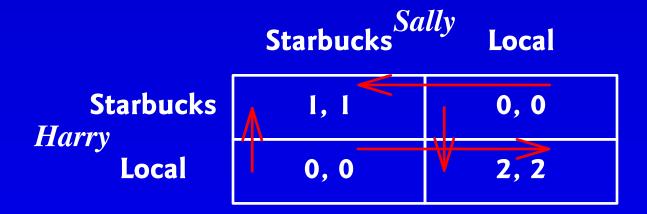
How? Without communication, to a focal point.

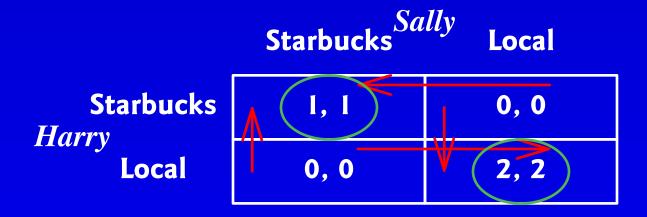
	Starbucks Sa	lly Local
Starbucks Harry	1, 1	0, 0
Local	0, 0	2, 2

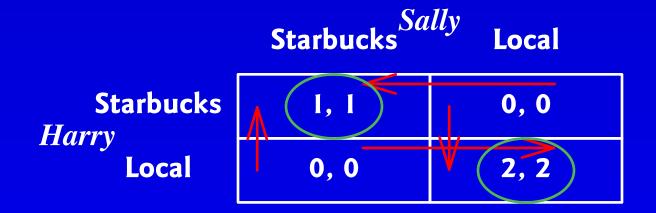




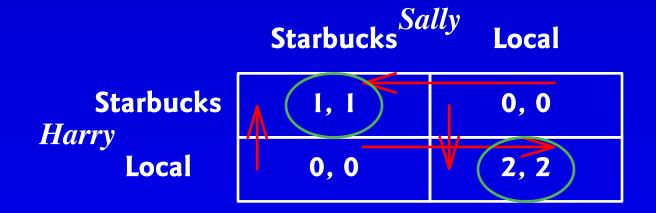




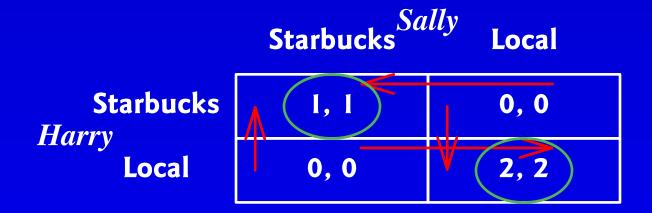




Now a shared preference for the Local, over Starbucks.



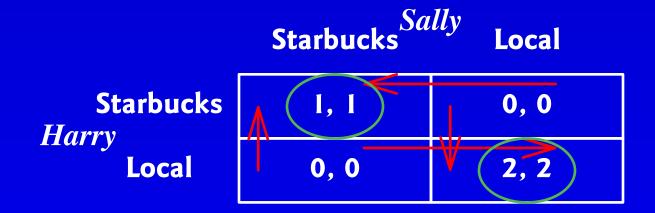
Now a shared preference for the Local, over Starbucks. This needs to be common knowledge.



Now a shared preference for the Local, over Starbucks.

This needs to be common knowledge.

But also need a convergence of expectations of actions.



Now a shared preference for the Local, over Starbucks.

This needs to be common knowledge.

But also need a convergence of expectations of actions.

Need enough certainty or assurance to get to (Local, Local).

A coordination game:

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e.g. video VHS v. Sony's Betamax;

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now the competing standards for digital audio disks: SACD (Sony & Philips) v. DVD-A (Toshiba, Matsushita, Pioneer etc.)

and DVD recording: DVD+R, DVD-R, DVD-RAM.

and the high-definition DVD: Blu-ray DVD v. HD-DVD.

The Players & Actions:

- > a man (Hal) who wants to go to the Theatre and
- > a woman (Shirl) who wants to go to a Concert.

While selfish, they are deeply in love, and would, if necessary, sacrifice their preferences to be with each other.

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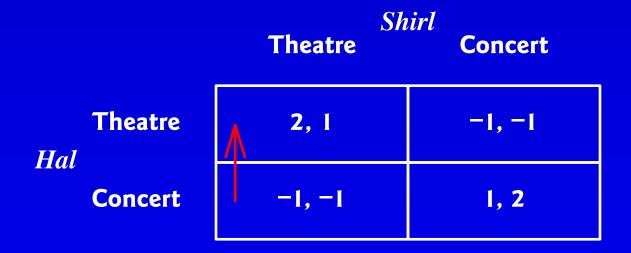
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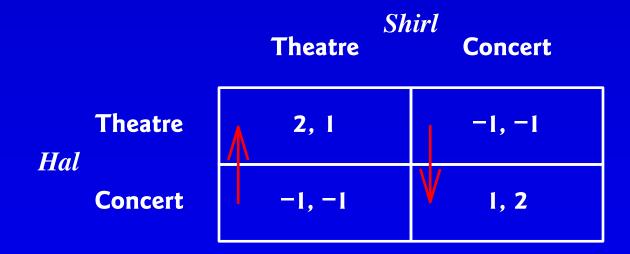
The payoff matrix (measuring the scale of happiness) is below.

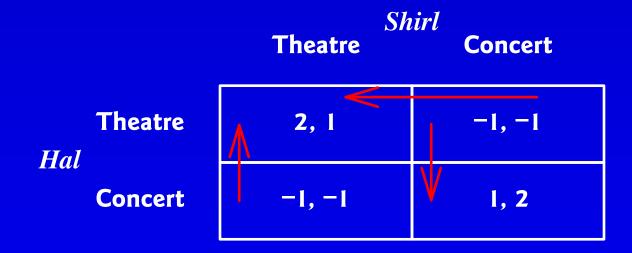
What are all equilibria?

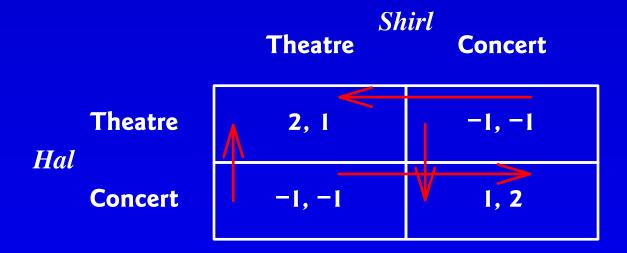
(i.e. Which pairs of actions are mutually best response?)

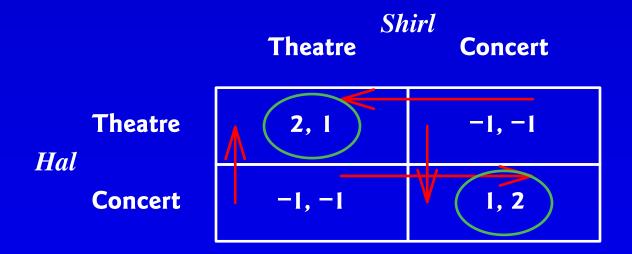
		Theatre Shirl Concert	
Hal	Theatre	2, 1	-1, -1
	Concert	-1, -1	I, 2



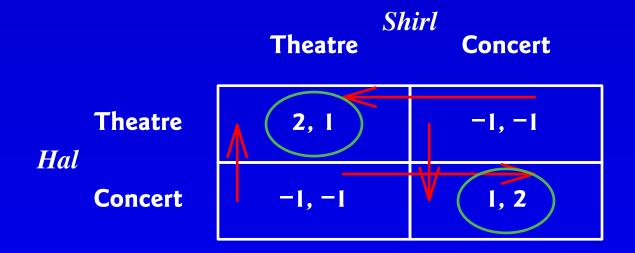








The payoff matrix (Hal, Shirl).



The payoff matrix (Hal, Shirl).

A non-cooperative, positive-sum game, with two Nash equilibria.

There is no iterated dominant strategy equilibrium.

There are two Nash equilibria:

- > (Theatre, Theatre): given that Hal chooses Theatre, so does Shirl.
- > (Concert, Concert), by the same reasoning.

There is no iterated dominant strategy equilibrium.

There are two Nash equilibria:

- > (Theatre, Theatre): given that Hal chooses Theatre, so does Shirl.
- > (Concert, Concert), by the same reasoning. How do the players know which to choose?

(A coordination game.)

Players' choices.

If they do not talk beforehand, Hal might go to the Concert and Shirl to the Theatre, each mistaken about the other's beliefs.

Players' choices.

If they do not talk beforehand, Hal might go to the Concert and Shirl to the Theatre, each mistaken about the other's beliefs.

Focal points?

Players' choices.

If they do not talk beforehand, Hal might go to the Concert and Shirl to the Theatre, each mistaken about the other's beliefs.

Focal points?

Repetition?

Each of the Nash equilibria is collectively rational (efficient): no other strategy combination increases the payoff of one player without reducing that of the other.

>

> Battle over an industry-wide standard.

>

- > Battle over an industry-wide standard.
- > The choice of language used in a contract when two firms want to formalise a sales agreement but prefer different terms.

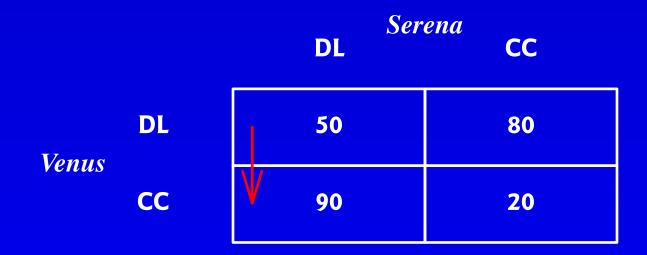
- > Battle over an industry-wide standard.
- > The choice of language used in a contract when two firms want to formalise a sales agreement but prefer different terms.
- ➢ Bought a DVD player recently? DVD, CDV, MP3, CD, DVD+, etc. Digital audio disks: SACD (Sony & Philips) v. DVD-A (Toshiba, Matsushita, Pioneer) Emerging standards mean choice and decisions for early adopters.

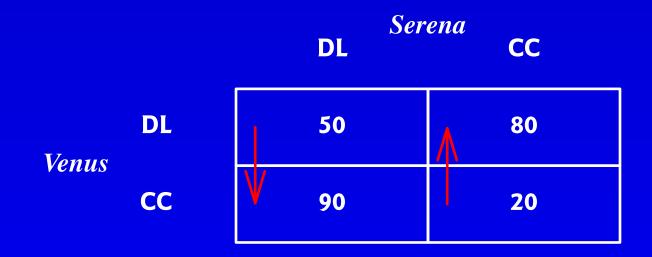
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- > others?

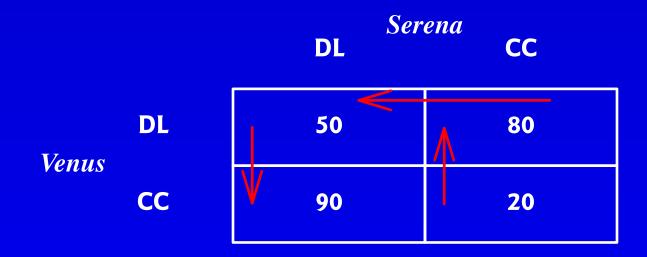
No Equilibrium in Pure Strategies?

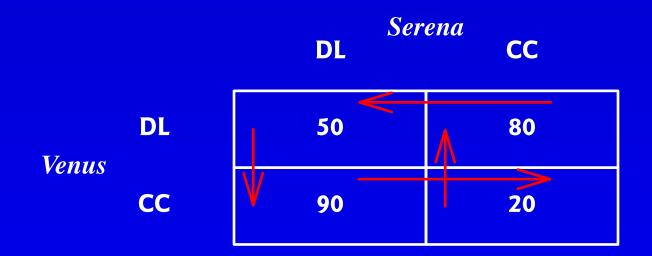
		DL Serena CC	
Venus	DL	50	80
	CC	90	20

No Equilibrium in Pure Strategies?

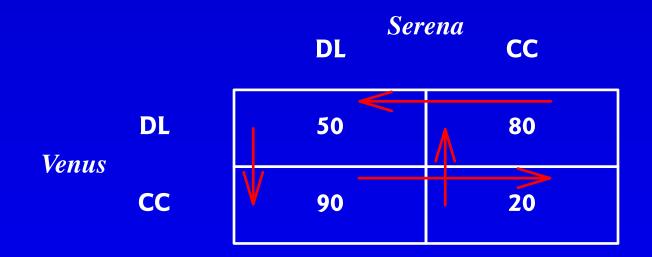






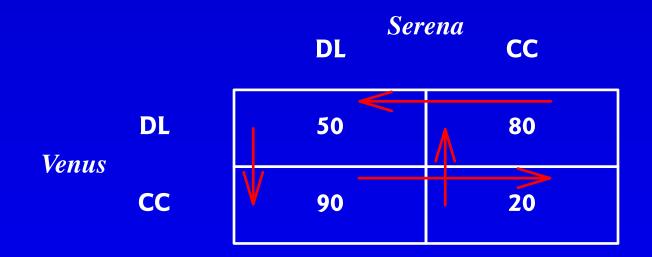


Zero-sum game: serving Venus's percentage of wins against Serena.



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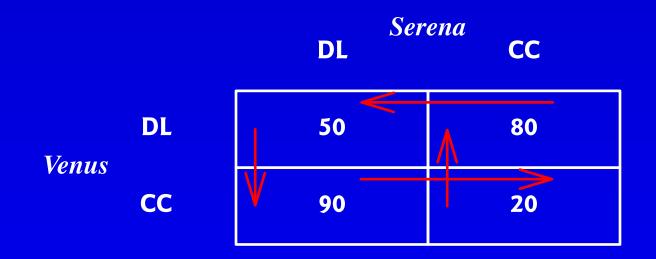
Play Down the Line, or Cross Court.



Zero-sum game: serving Venus's percentage of wins against Serena.

Play Down the Line, or Cross Court.

.. No N.E. in pure strategies.



Zero-sum game: serving Venus's percentage of wins against Serena.

Play Down the Line, or Cross Court.

.. No N.E. in pure strategies. Why?

(See Lecture 11 later.)

Here "Bomber" and "Alien" are matched.

Veer Straight

Blah, Blah Chicken!, Winner

Bomber

Veer
Alien
Straight

Here "Bomber" and "Alien" are matched.

Veer Straight

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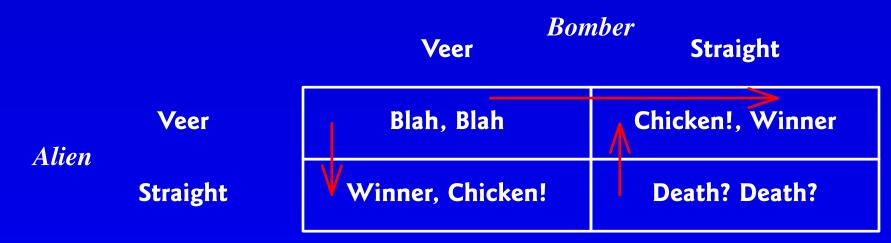
Veer Blah, Blah Chicken!, Winner

Alien

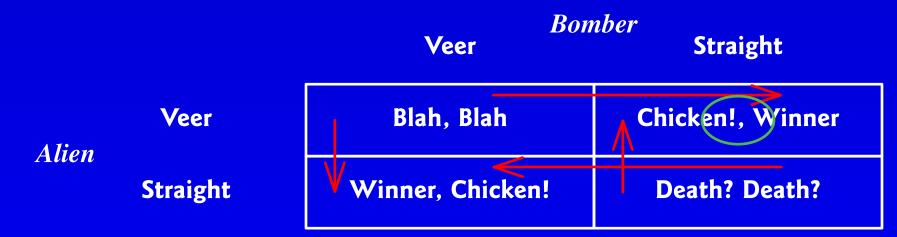
Straight

Winner, Chicken! Death? Death?

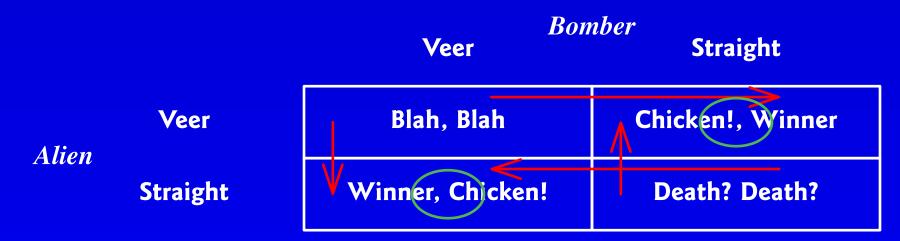






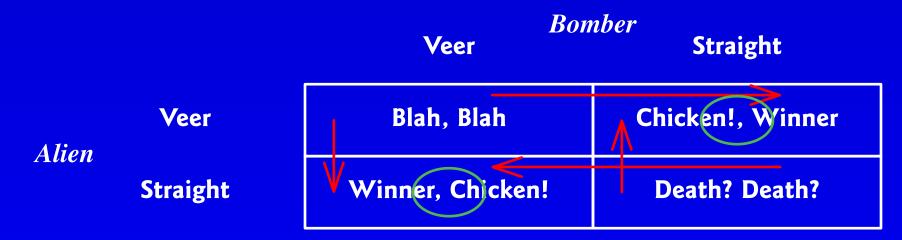


Here "Bomber" and "Alien" are matched.



No dominant strategies: what's best for one depends on the other's action.

Here "Bomber" and "Alien" are matched.



No dominant strategies: what's best for one depends on the other's action.

Nash Equilibrium where?

Six Steps to Help:

- I. What is the strategic Issue?
- 2. Who are the Players?
- 3. What are each player's strategic Objectives?
- 4. What are each player's potential Actions?
- 5. What is the likely Structure of the game?
 - simultaneous or sequential (who's on first?)?
 - one-shot or repeated?
- 6. Simultaneous: Rank each player's Outcomes across all combinations of the actions of both.

Rule 1: Look ahead and reason back.

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Rule 2: If you have a dominant strategy, then use it.

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Rule 3: Eliminate any dominated strategies from consideration, and go on doing so successively.

- Rule 1: Look ahead and reason back.
- Rule 2: If you have a dominant strategy, then use it.
- Rule 3: Eliminate any dominated strategies from consideration, and go on doing so successively.
- Rule 4: Look for an equilibrium, a pair of strategies in which each player's action is the best response to the other's.