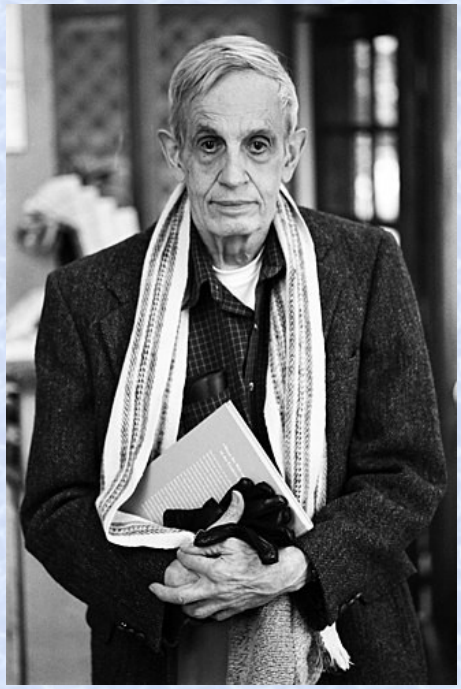
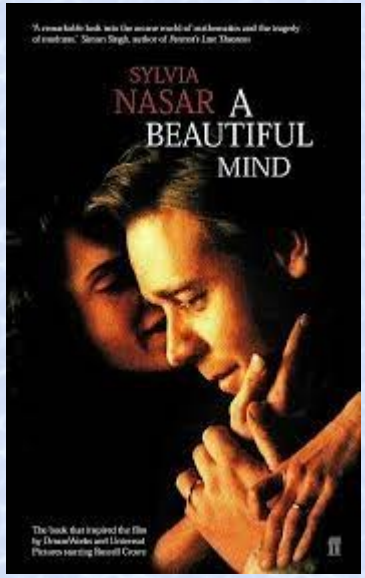
John Nash



Nobel Prize in Economics in 1994

"for [his] pioneering analysis of equilibria in the theory of non-cooperative games"



Coordination Games

Airplane hijacking game

	attack	**wait**
attack	2*,2	0,0
wait	0,0	1*,1

no strategies are dominated: beliefs matter

example of a *coordination game*

Nash Equilibrium

each player plays optimally and correctly guesses what the other player will do

step 1: *best response* what is best to do given beliefs

step 2: equilibrium of beliefs

	attack	**wait**
attack	**2*,2***	0,0
wait	0,0	**1*,1***

Two Nash equilibria: which one?

Pareto ranked, one is “obvious”

Dominant Strategy versus Nash

Players playing dominant strategies is an example of Nash equilibrium

here beliefs do not matter

	Player 2	
Player 1	**don't confess**	**confess**
don't confess	32,32	28,35*
confess	35*,28	**30*,30***

Other Coordination Games

Drive on the left or on the right?

	left	**right**
left	**1*,1***	0,0
right	0,0	**1*,1***

Battle of the sexes

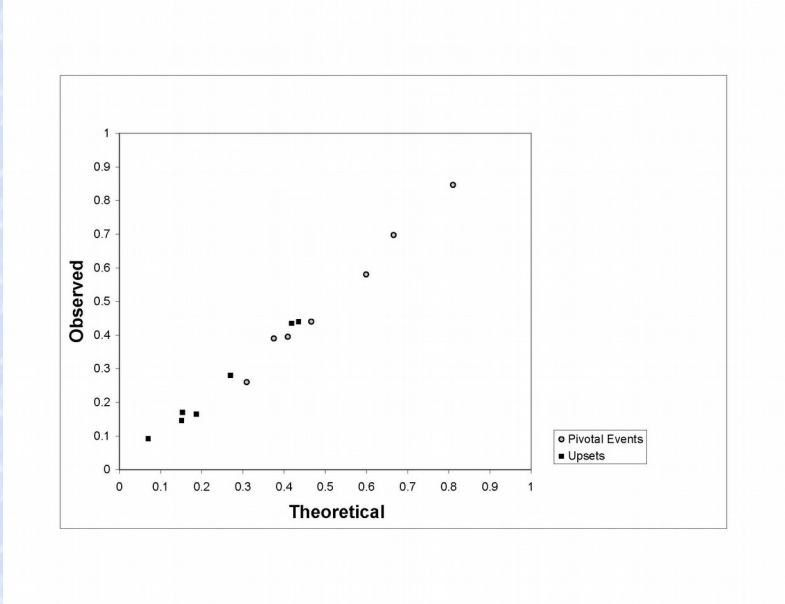
	opera	**match**
opera	**2*,1***	0,0
match	0,0	**1*,2***

Why Nash Equilibrium?

- reasoning versus learning
- at a Nash equilibrium, there is nothing further to learn
- the rush hour traffic game

Learning and Nash Equilibrium

- economists think people are pretty smart
- they are pretty good at learning
- algorithms take ages to converge
- people are quick



Pre-911 Airplane Hijacking Game

	attack	**wait**
attack	**1*,1***	0,0
wait	0,0	**2*,2***

Versus post 911 game

	attack	**wait**
attack	**2*,2***	0,0
wait	0,0	**1*,1***

Case Study: 911

1990s about 18 aircraft hijackings a year

most ended peacefully and the passengers never attacked

after 911 this dropped to just a few aircraft hijacking a year

most ended when the passengers attacked the hijackers

how long did it take to switch from one equilibrium to the other?

one hour and eleven minutes

Duopoly Again

profits

$$\pi_i = [16 - (Q_i + Q_{-i})]Q_i$$

note use of $-i$ to mean “the other player”

the *best response* or *reaction function* for player i maximizes their profit with respect to their own output Q_i based on their belief about their opponent output Q_{-i}

The Best Response

to do this take the partial derivative with respect to Q_i, set it equal to zero and solve for Q_i

$$\partial \pi_i / \partial Q_i = 16 - 2Q_i - Q_{-i} = 0$$

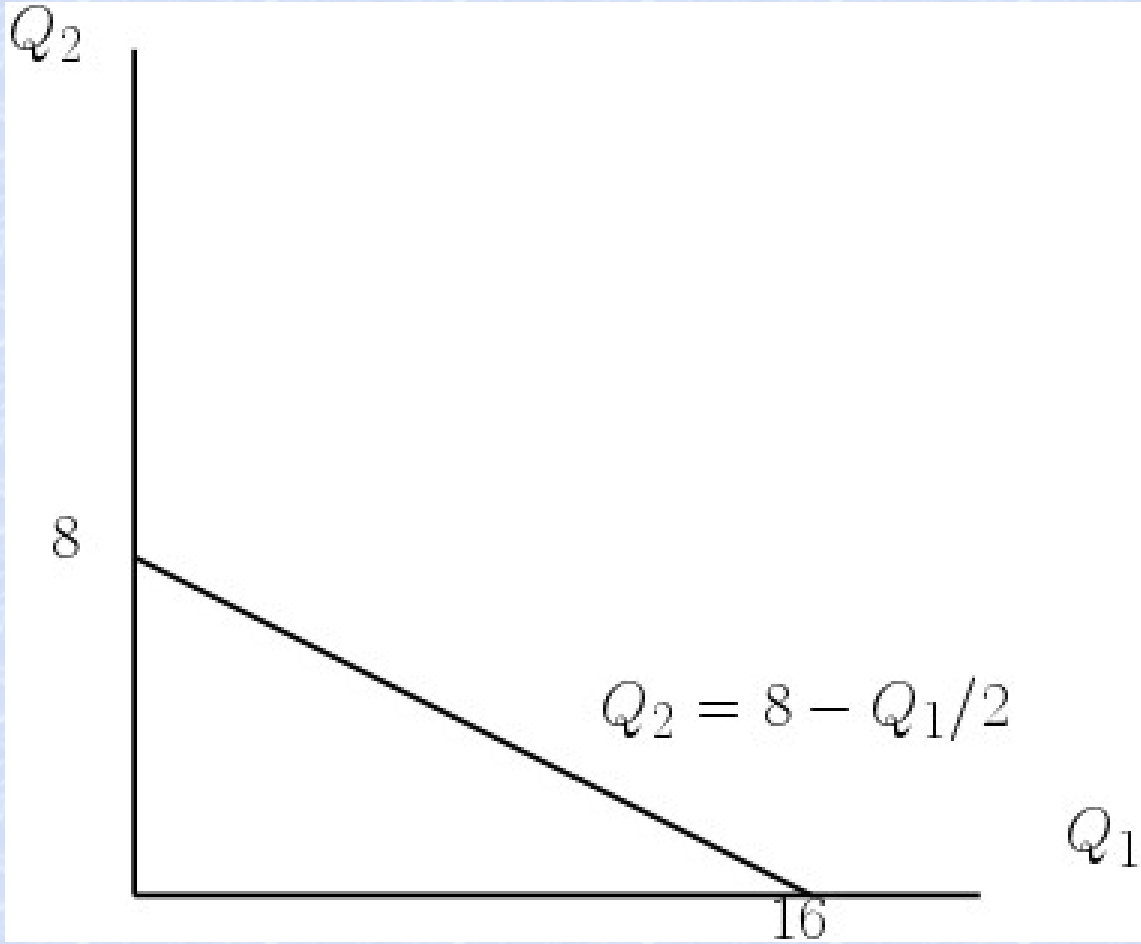
solution is the best response or reaction function

$$Q_i = 8 - \frac{Q_{-i}}{2}$$

equilibrium is where both player's beliefs are correct

that is to say: both are playing a best response at the same time

Best Response Graph



Equilibrium

Solve

$$Q_2 = 8 - Q_1/2, Q_1 = 8 - Q_2/2$$

solution

$$Q_1 = Q_2 = 16/3 = 5\,1/3$$

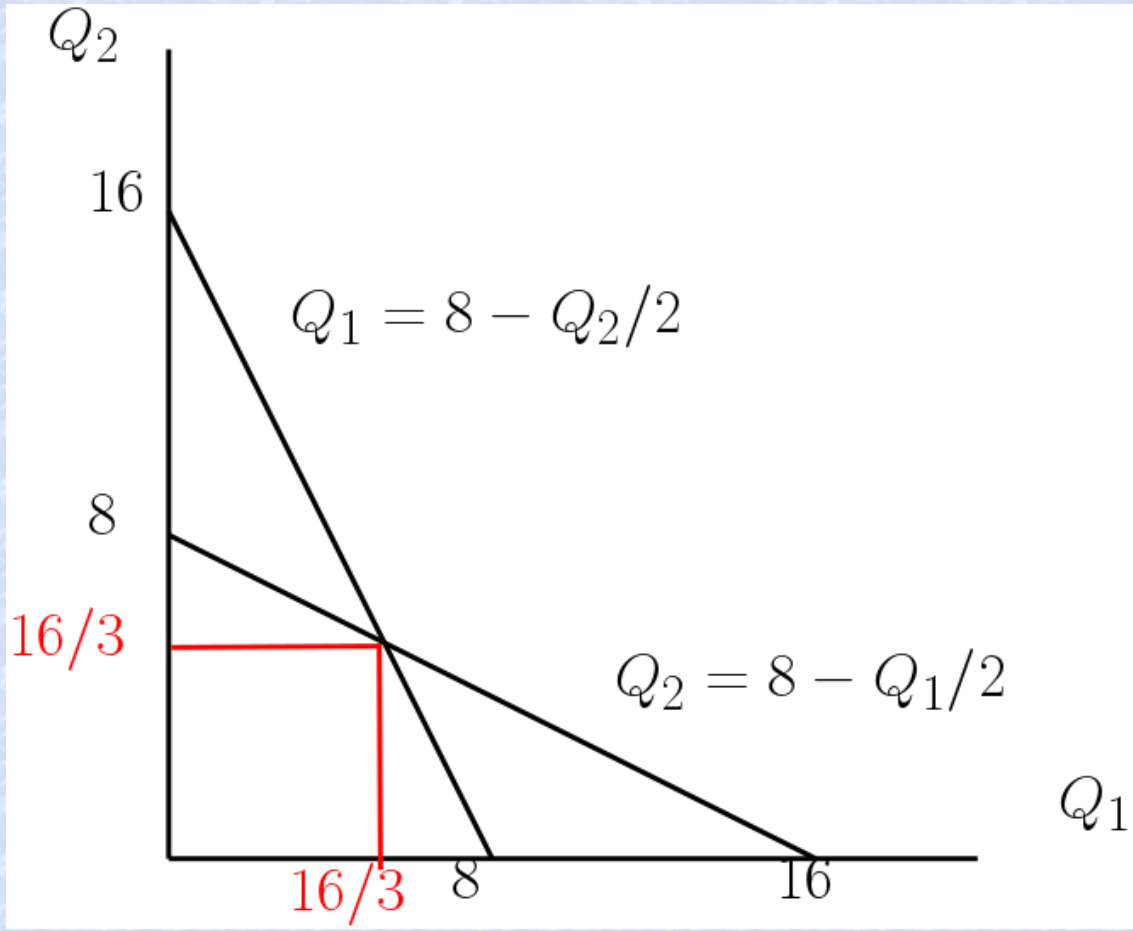
less than monopoly (8) but more than half monopoly

industry output

$$Q = Q_1 + Q_2 = 32/3 = 10\,2/3$$

more than monopoly but 2/3 of competitive (16)

Equilibrium : Graph



The Cournot Model

- an *oligopoly* market with n identical firms facing constant marginal cost *c*
- demand given by $p = a - bQ$

so that the competitive solution is $(a - c)/b$ units of output and the monopoly solution is $(a - c)/2b$ units of output

Nash (Cournot) Equilibrium

Profits of a firm

$$\pi_i = (a - c - b\textstyle\sum_j Q_j)Q_i$$

Best response of a firm

$$\partial\pi_i/\partial Q_i = (a - c) - b\textstyle\sum_j Q_j - bQ_i = 0$$

NOW and only NOW we use the equilibrium condition

symmetry: $Q_i = (1/n)Q$

plug in and solve

$$(a - c) - bQ - (b/n)Q = 0$$

$$Q = \frac{n}{n+1}\frac{a-c}{b}$$

Characteristics of the Equilibrium

$$Q = \frac{n}{n+1}\frac{a-c}{b}$$

when $n = 1$ this gives the usual monopoly solution

as $n \to \infty$ this approaches the competitive solution

Next: changing gears, comparative advantage

The Sustainable Economy

- 3000 people
- eat and produce bread and butter
- each wants 1 slab of butter for each loaf of bread
- each has a single unit of labor which can be used to produce either 6 loaves of bread or 3 slabs of butter

Sustainable Trade

suppose everyone produces butter

9000 slabs of butter, no good because there is no bread

move some people into producing bread

each switch reduces slabs of butter by 3 and increases loaves of bread by 6.

when 1/3 of the people have switched, everyone getting two loaves of bread and two slabs of butter

price, or exchange rate: 2 loaves for 1 slab

example: a bread producer produces 6 loaves, eats 2, takes the other 4 and trades with a butter producer for 2 slabs of butter

everyone is happy.

The Evil of AI

machine learning and artificial intelligence arrive

half the people are AI enhanced

they can produce more of everything: 12 loaves or 12 slabs

suppose everyone produces butter

22,500 slabs, but no bread

people need to be switched into producing bread

who should be switched, the enhanced or the unenhanced?

switching an enhanced means giving up 12 slabs for 12 loaves

switching 4 unenhanced means giving up 12 slabs for 24 loaves

better to switch the unenhanced into bread productionless productive than the enhanced, but have a **comparative advantage** in bread production

Crushing the Poor

suppose all the unenhanced produce bread and the enhanced produce only butter

18,000 slabs, but only 9,000 loaves

some of the enhanced will have to produce bread

move 375 into bread production, so that 1125 produce butter

butter production is 13,500 slabs and so is bread production

now: one bread trades for one butter.

an enhanced takes half their 12 loaves or slabs and exchanges it for 6 of the other, so consumes 6 of each.

an unenhanced takes half their 6 bread loaves and trades it for 3 slabs and consumes 3 of each

in the sustainable economy everyone consumed 2 of each

Oligarchy

Perhaps the enhanced should try to exclude the unenhanced from taking advantage?

enhanced trading only among themselves could produce 6 loaves and 6 slabs each, which is to say they get no benefit from excluding the unenhanced.

this is the **first welfare theorem**

it holds for realistic economies as well as toy economies

does not depend upon the details of the production technology or on people's preferences over goods and services

groups benefit from trading with groups that have a different comparative advantage than they do, and groups cannot benefit all their members by just trading among themselves

Comparative Advantage Counts

it is not absolute advantage that matters, but **comparative advantage**.

the enhanced have an absolute advantage at everything

the unenhanced are comparatively better at making bread

hence they should specialize in making bread

concept developed by David Ricardo in 1817

many politicians and pundits have yet to catch up

Concepts

- coordination game
- **Nash equilibrium**
- **best response**, reaction function
- **oligopoly**
- **Cournot equilibrium**

Skill

Given the description of a game

find the payoff matrix game

find the Nash equilibrium

Given information about consumer utility and the costs of firms

find the Cournot equilibrium