# An Introduction to Mechanism Design

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#### Theory of Mechanism Design –

"engineering" part of economic theory

- much of economic theory devoted to:
  - understanding existing economic institutions
  - explaining/predicting outcomes that institutions generate
  - positive, predictive
- mechanism design reverses the direction
  - begins by identifying desired outcomes (goals)
  - asks whether institutions (mechanisms) could be designed to achieve goals
  - if so, what forms would institutions take?
  - normative, prescriptive

### For example, suppose

- mother wants to divide cake between 2 children, Alice and Bob
- goal: divide so that each child is happy with his/her portion
  - Bob thinks he has got at least half
  - Alice thinks she has got at least half
     call this *fair division*
- If mother knows that the kids see the cake in same way she does, simple solution:
  - she divides equally (in her view)
  - gives each kid a portion

- But what if, say, Bob sees cake differently from mother?
  - *she* thinks she's divided it equally
  - but *he* thinks piece he's received is smaller than Alice's
- difficulty: mother wants to achieve *fair division* 
  - but doesn't have enough information to do this on her own
  - in effect, doesn't know which division is fair

• Can she design a mechanism (procedure) for which outcome will be a fair division?

(even though she doesn't know what is fair herself ?)

- Age-old problem
  - Lot and Abraham dividing grazing land

#### Age-old solution:

- have *Bob* divide the cake in two
- have *Alice* choose one of the pieces

Why does this work?

- Bob will divide so that pieces are equal in his eyes
  - if one of the pieces were bigger, then Alice would take that one
- So whichever piece Alice takes, Bob will be happy with other
- And Alice will be happy with her own choice because if she thinks pieces unequal, can take bigger one

Example illustrates key features of mechanism design:

- mechanism designer herself *doesn't know* in advance what outcomes are optimal
- so must proceed indirectly through a mechanism
  - have participants *themselves* generate information needed to identify optimal outcome
- complication: participants don't care about *mechanism designer's goals* 
  - have their own *objectives*
- so mechanism must be *incentive compatible* 
  - must reconcile social and individual goals

Second Example:

Suppose government wants to sell right (license) to transmit on band of radio frequencies

(real-life issue for many governments)

- several telecommunication companies interested in license
- goal of government: to put transmitting license in hands of company that values it most ("efficient" outcome)
- but government doesn't know how much each company values it (so doesn't know best outcome)

# Government could ask each company how much it values license

- but if company thinks its chances of getting license go up when it states higher value, has incentive to *exaggerate* value
- so no guarantee of identifying company that values it most

- government could have
  - each company make a bid for license
  - high bidder wins license
  - winner pays bid
- but this mechanism won't work either
  - companies have incentive to *understate*
- suppose license worth \$10m to Telemax, then
  - if Telemax bids \$10m and wins, gets \$10m - \$10m = 0
- so Telemax will bid *less* than \$10m
- but if all bidders are understating, no guarantee that winner will be company that values license most

#### Solution:

- every company makes bid for license
- winner is high bidder
- winner pays second-highest bid
  - so if 3 bidders and bids are
    - \$10m, \$8m, and \$5m,
    - winner is company that bids \$10m
  - but pays only \$8m
- Now company has no incentive to understate
  - doesn't pay bid anyway
  - if understates, may lose license
- Has no incentive to overstate
  - If bids \$12m, will now win if other company bids \$11m
  - But overpays
- So best to bid *exactly* what license worth
- And winner will be company that values license most

# Final Example

Consider society with

- 2 consumers of energy Alice and Bob
- Energy authority must choose public energy source
  - gas
  - oil
  - nuclear power
  - coal

#### Two states of world

- state 1 consumers weight future lightly (future relatively unimportant)
- state 2 consumers weight future heavily (future relatively important)

Alice – cares mainly about convenience

- In state 1: favors gas over oil, oil over coal, and coal over nuclear
- In state 2: favors nuclear over gas, gas over coal, and coal over oil
  - technical advances expected to make gas, coal, and especially nuclear easier to use in future compared with oil
- Bob cares more about safety
  - In state 1: favors nuclear over oil, oil over coal, and coal over gas
  - In state 2: favors oil over gas, gas over coal, and coal over nuclear
    - disposal of nuclear waste will loom large
    - gas will become safer

State 1		State 2	
<u>Alice</u>	<u>Bob</u>	<u>Alice</u>	<u>Bob</u>
gas	nuclear	nuclear	oil
oil	oil	gas	gas
coal	coal	coal	coal
nuclear	gas	oil	nuclear

- energy authority
  - wants source that makes good compromise between consumers' views
  - so, oil is social optimum in state 1
  - gas is social optimum in state 2
- but suppose authority *does not know* state
  - then doesn't know whether oil or gas better

State 1		State 2	
<u>Alice</u> gas	<u>Bob</u> nuclear	<u>Alice</u> nuclear	<u>Bob</u> oil
oil	oil	gas	gas
coal	coal	gas coal	coal
nuclear	gas	oil	nuclear
oil optimal		gas optimal	

- authority could ask Alice or Bob about state

- but Alice has incentive to say "state 2" *regardless* of truth always prefers gas to oil gas optimal in state 2
- Bob always has incentive to say "state 1"

always prefers oil to gas

oil optimal state 1

So, simply asking consumers to reveal actual state too naive a mechanism

State 1			State 2	
<u>Alice</u> gas oil coal nuclear	Bob nuclear oil coal gas		<u>Alice</u> nuclear gas coal oil	Bob oil gas coal nuclear
social optimum: oil		social op		

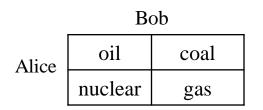
Authority can have consumers participate in the mechanism given by table

	Bob				
Alice	oil	coal			
	nuclear	gas			

- Alice can choose top row or bottom row
- Bob can choose left column or right column
- outcomes given by table entries
- If state 1 holds
  - Alice will prefer top row if Bob plays left column
  - Bob will always prefer left column
  - so (Alice plays top, Bob plays left) is Nash equilibrium
  - neither participant has incentive to change unilaterally to another strategy
  - In fact, it is unique Nash equilibrium

- so good prediction of what Alice and Bob will do

State 1		State 2	
<u>Alice</u>	<u>Bob</u>	<u>Alice</u>	<u>Bob</u>
gas	nuclear	nuclear	oil
oil	oil	gas	gas
coal	coal	coal	coal
nuclear	gas	oil	nuclear
social optir	num: oil	social opt	imum: gas



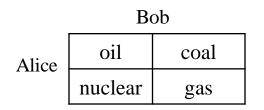
So, in state 1:

• expect that

Alice will play top strategy Bob will play left strategy

- outcome is oil
- oil is social optimum

State 1		State 2	
<u>Alice</u> gas oil coal nuclear social opti	Bob nuclear oil coal gas mum: oil	<u>Alice</u> nuclear gas coal oil social opt	Bob oil gas coal nuclear imum: gas
social optimum: oil		social optimum: gas	



Similarly, in state 2:

• expect that

Alice will play bottom strategy Bob will play right strategy

- outcome is gas
- gas is social optimum

State 1		State 2	
<u>Alice</u> gas oil coal nuclear social optim	Bob nuclear oil coal gas num: oil	Alice nuclear gas coal oil social op	Bob oil gas coal nuclear timum: gas
Bob			
Alice	oil	coal	
7 mee	nuclear	gas	

- Thus, in *either state*, mechanism achieves social optimum, even though
  mechanism designer doesn't know the state herself
  - Alice and Bob interested in own ends (not social goal)
- We say that mechanism *implements* the designer's goals (oil in state 1, gas in state 2)

- Have shown you mechanisms in the cake, telecommunication, and energy examples
- But analysis may seem a bit *ad hoc*
- Examples prompt questions:
  - is there a *general* way of determining whether or not a given goal is implementable?
  - if it *is* implementable, can we find a mechanism that implements it?
- Answer: yes to both questions see Maskin "Nash Equilibrium and Welfare Optimality," 1977

- Have looked at 3 applications of mechanism design theory
- Many other potential applications
- 1) International treaty on greenhouse gas emissions
- 2) Policies to prevent financial crises
- 3) Design of elections