Moral Hazard in Electricity Capacity Markets

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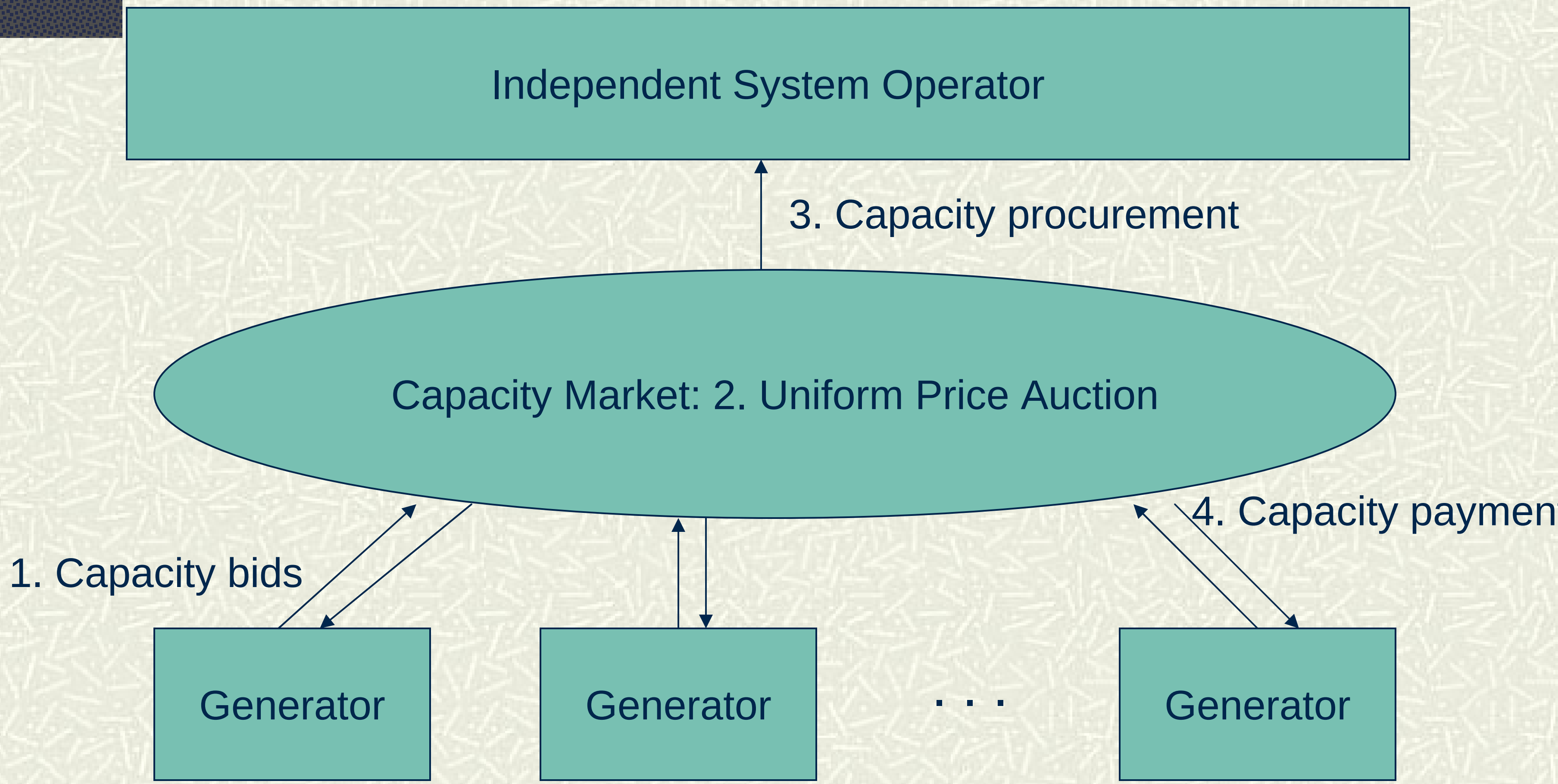
Outline

- Capacity market
- Capacity market model
- Background
- Game model
- Equilibrium analysis
- Numerical examples
- Conclusions

Capacity Market

- Not enough investment incentives in energy only markets
  - Very low scarcity rent
    - Little price response from the demand side
    - Price caps and other market power mitigation mechanisms
  - Volatile prices
- Capacity markets can provide investment incentives.

Capacity Market Structure



Example: PJM Capacity Market

- Reliability Pricing Model
  - Multi-auction structure
    - Base Residual Auction: held three years prior to the start of the Delivery Year
    - Incremental Auctions: up to three auctions for additional resource commitments prior to the beginning of the Delivery Year
    - Bilateral Market
      - Resource providers' opportunity to cover any auction commitment shortages
      - Load Serving Entities' opportunity to hedge against the Location Reliability Charge

Motivation

- There are studies on market power issue in capacity markets.
  - By reduced capacity bids at competitive price
- In this study, the possibility of the opposite behavior is examined.
  - By exaggerated capacity bids

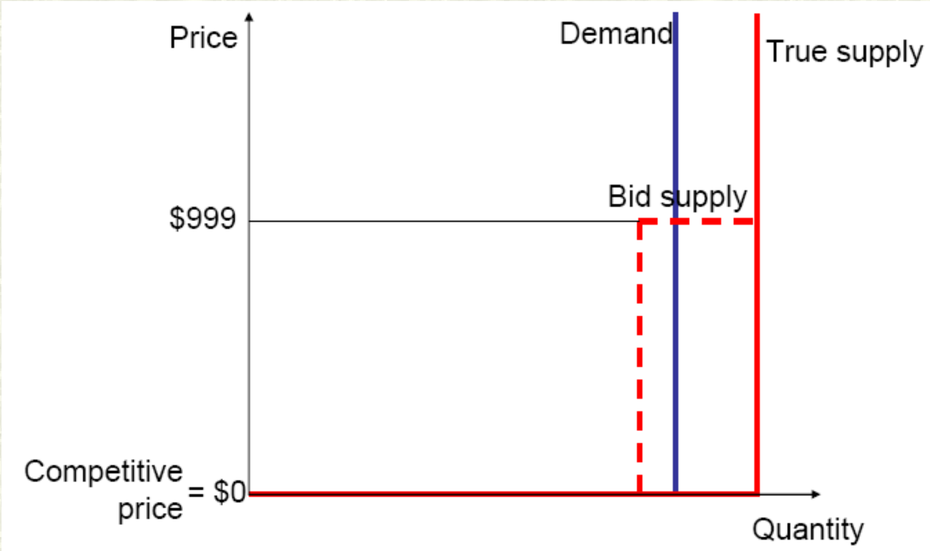
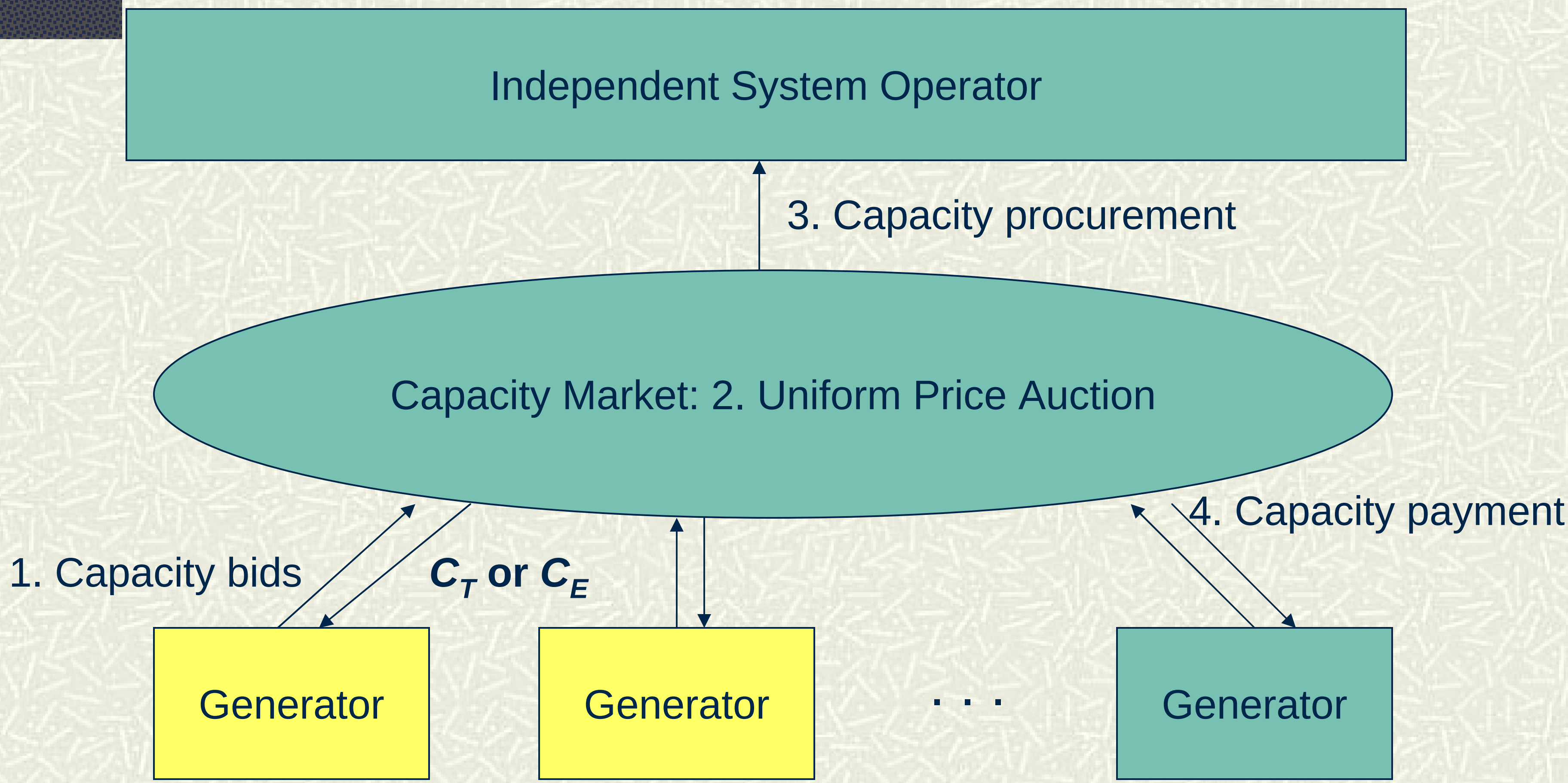


Figure from "A Capacity Market that Makes Sense," Peter Cramton and Steven Stoft, *Electricity Journal*, 18, 43-54, 2005.

Market Model for Analysis



Two identical strategic generators

The other generators bid truthfully.

Market Model for Analysis

- Only two identical strategic generators considered
  - The other generators bid truthfully.
  - Two strategies
    - True capacity C_T and exaggerated C_E $(C_T < C_E)$
  - The residual demand is less than $2C_T$.
- Penalty F for not following ISO's dispatch instructions
  - Relevant only for exaggerated bids

Market Results

- Awards and prices

	C_T	C_E
C_T	$(C^A_{TT}, C^A_{TT}), P_{TT}$	$(C^{A,T}_{ET}, C^{A,E}_{ET}), P_{ET}$
C_E	$(C^{A,E}_{ET}, C^{A,T}_{ET}), P_{ET}$	$(C^A_{EE}, C^A_{EE}), P_{EE}$

- Assumptions
  - $C^A_{TT} <= C_T$
  - $C^{A,E}_{ET} > C_T,\ C^{A,T}_{ET} < C_T$
  - $C^{A,T}_{ET} < C^A_{TT}$

Capacity Payments and Penalty

- Capacity payments = price × awards
  - $\pi_{TT} = P_{TT} C^{A}{}_{TT}$
  - $\pi^{E}{}_{ET} = P_{ET} C^{A,E}{}_{ET}$, $\pi^{T}{}_{ET} = P_{ET} C^{A,T}{}_{ET}$
  - $\pi_{EE} = P_{EE} C^{A}{}_{EE}$
- Failure to follow ISO's dispatch instruction as a probabilistic event
  - $Prob_{ET}$, $Prob_{EE}$ ($Prob_{ET} < Prob_{EE}$)

Expected Payoffs

	C_T	C_E
C_T	(π_{TT}, π_{TT})	$(\pi^T{}_{ET}, \pi^E{}_{ET} - Prob_{ET}F)$
C_E	$(\pi^E{}_{ET} – Prob_{ET}F, \pi^T{}_{ET})$	$(\pi_{EE} – Prob_{EE}F, \pi_{EE} – Prob_{EE}F)$

- Generators aim to maximize their expected payoffs.

Background

- Moral hazard
  - Principal cause: asymmetries of information between entities
  - Entities can take advantage of other entities' 'observability' problem.
- Game theory
  - Analysis of conflict situations
  - Nash equilibrium is the most popular solution concept
    - No player has incentive to unilaterally deviate from the equilibrium

Game Model

- Conflict situation
- Players: generators
  - Only two strategic generators are considered.
- Strategies: capacity market bids
  - Only two strategies are considered
    - Truthful capacity bid: C_T
    - Exaggerated capacity bid: C_E
- Payoffs: expected value of (capacity payments – dispatch penalty)

Equilibrium Analysis

	C_T	C_E
C_T	(π_{TT}, π_{TT})	$(\pi^T{}_{ET}, \pi^E{}_{ET} - Prob_{ET}F)$
C_E	$(\pi^E{}_{ET} – Prob_{ET}F, \pi^T{}_{ET})$	$(\pi_{EE} – Prob_{EE}F, \pi_{EE} – Prob_{EE}F)$

- Two cases of pure-strategy Nash equilibrium
  - (C_T, C_T): Truthful bid case
    - $\pi_{TT} > \pi^E{}_{ET} – Prob_{ET}F$ and $\pi^T{}_{ET} > \pi_{EE} – Prob_{EE}F$
    - Preferable equilibrium from ISO's point of view
    - F can be set very high, but market participants may not agree.
  - (C_E, C_E): Moral hazard case
    - $\pi_{TT} < \pi^E{}_{ET} – Prob_{ET}F$ and $\pi^T{}_{ET} < \pi_{EE} – Prob_{EE}F$
    - Highly probable when $Prob_{ET}$ and $Prob_{EE}$ are small.
      - More conservative procurement will provide smaller $Prob_{ET}$ and $Prob_{EE}$

Parameters for Numerical Example

- $C_T = 100MW$, $C_E = 110MW$
- $C^A{}_{TT} = 100MW$, $C^{A,E}{}_{ET} = 108MW$, $C^{A,T}{}_{ET} = 80MW$, $C^A{}_{EE} = 104MW$
- $F = \$10,000$
- $P_{TT} = P_{ET} = P_{EE} = 10\$/MW$

Numerical Examples

- $Prob_{ET} = 0.05,\ Prob_{EE} = 0.1$

	C_T	C_E
C_T	**($1,000, $1,000)**	($800, $580)
C_E	($580, $800)	($40, $40)

- $Prob_{ET} = 0.005,\ Prob_{EE} = 0.01$

	C_T	C_E
C_T	($1,000, $1,000)	($800, $1,030)
C_E	($1,030, $800)	**($940, $940)**

Conclusions

- A possible weakness of a simple capacity market design, moral hazard, has been demonstrated.
- Two player game model was used for equilibrium analysis.
- The more conservative ISO's capacity procurement, the higher the risk of moral hazard.