

Electricity markets and game theory

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20/03/2017



What we'll cover

- Explain the basic assumptions of game theory
- Describe utility functions and find the Nash equilibrium of simple games
- Explain how electricity markets can be gamed
- Model the outcome and impact of gaming in simple market setups
- Explain how gaming is essential in a pay-as-bid market

Point of note: Discussion will be confined to deterministic production (but can be generalized).

But first ...

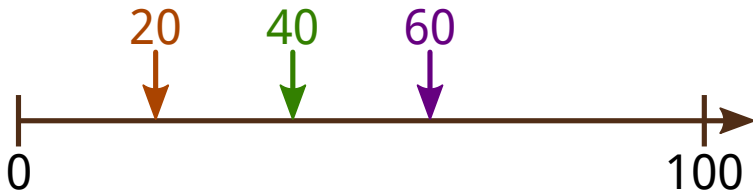


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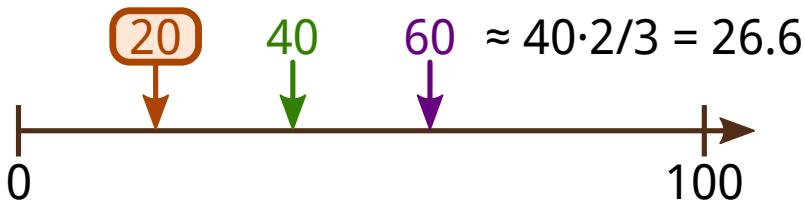
The person who picks the number closest to $\frac{2}{3}$ rds of the average of all numbers picked will win a prize.

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Go to bit.ly/elmacourse1 and type in your guess.

(Please set your browser to accept cookies.)



What's in a game?

(Of the game-theoretic kind)

- Multiple players

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- Multiple players
- Each player chooses a strategy
- Each player's utility depends on the chosen strategy of all players
- Each player attempts to choose a strategy which maximizes their utility

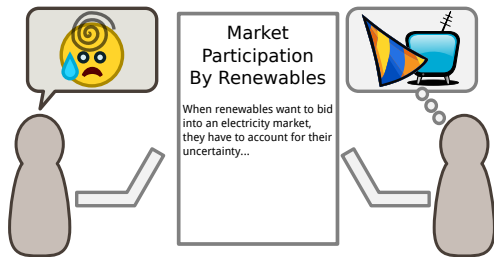
Games are everywhere

Game	Players	Strategy	Utility
Guess 2/3rd	All of you	Chosen number	Win prize

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Guess 2/3rd	All of you	Chosen number	Win prize
Buying Car	You, Dealers	Bid/Offers Shopping	Car quality Price Profit

A classic game

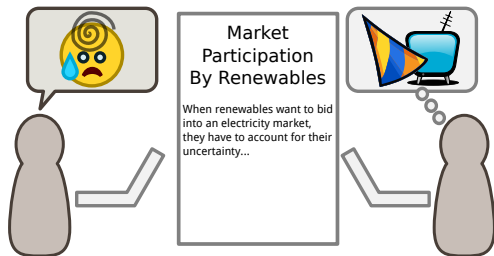


You and your partner are working on the report.

You can choose to either stay up late and work hard, or slack off and hope your partner does most of the work.

Q: Should you work hard?

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- If you both work hard, you get a 12.
- If one of you slacks off, you get a 7.
- If both of you slack off, you get a 2.

What ends up happening?

A combination of strategies is called a Nash Equilibrium if no player wants to change just their own strategy.



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(1928–2015)

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			Partner	
			WH	SO
You	WH	<u>12,12</u>	7,7	
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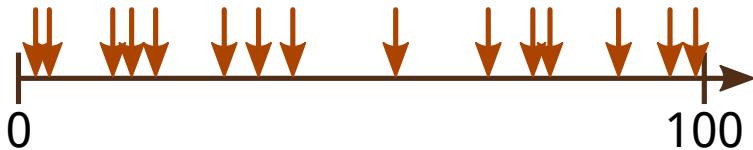


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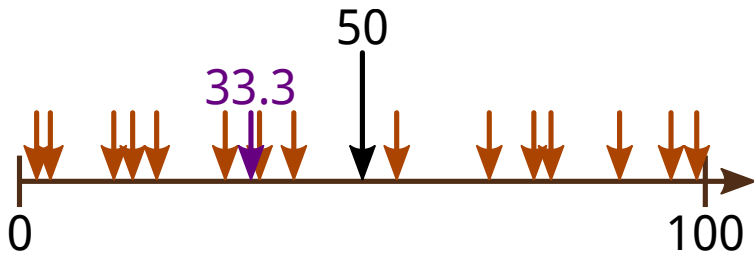
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	\leftarrow, \uparrow		Partner	
		WH	SO	
You	WH	6,6	1,7	
	SO	7,1	<u>2,2</u>	

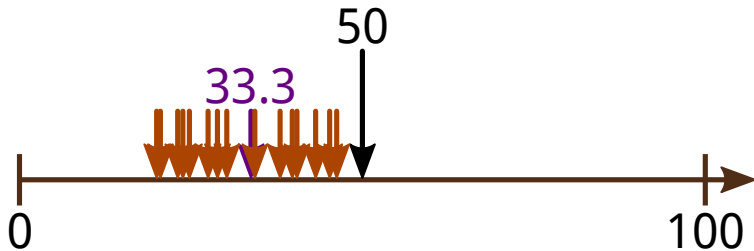
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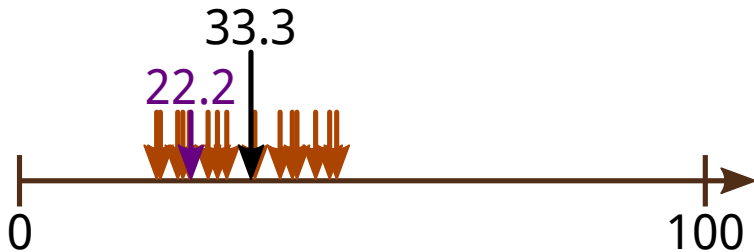
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Nash equilibrium may not be realized in real life!

Gaming in electricity markets

Producers bid an amount of energy and a price they will sell it at.

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Remember: It is perfectly legal to bid any amount into the market at any price. (You have to deliver though...)

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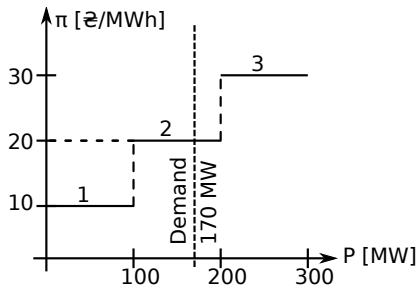
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Open questions: How can we detect use of market power? Can we quantify their impact?

Basic strategies in power markets

Market players game using their price and production.



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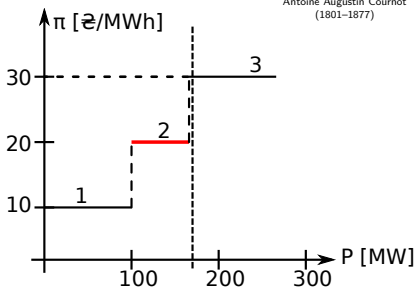


Antoine Augustin Cournot
(1801-1877)

Market players game using their price and production.

Cournot strategy: Withhold production

→ More expensive marginal producer → ??? → Profit!



Basic strategies in power markets



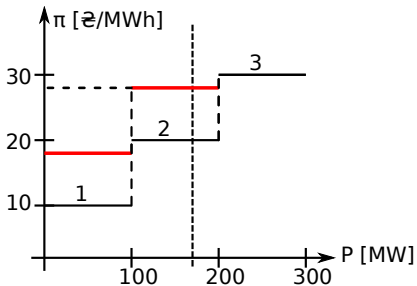
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(1822-1900)

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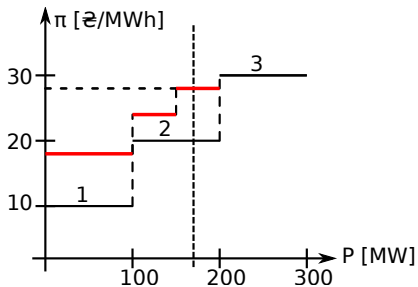
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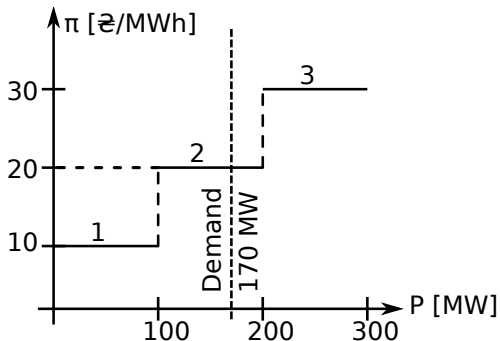
Bertrand strategy: Increase bid price above marginal cost

Hybrid strategies: Both, split bid,

...

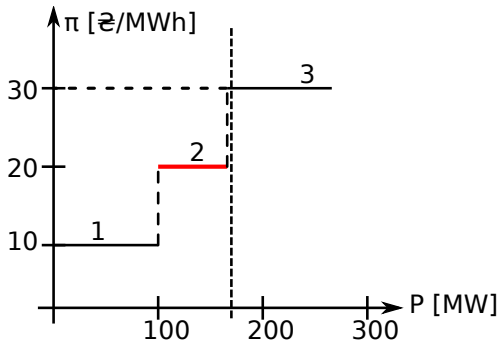


Example: 3 producers and Cournot strategy



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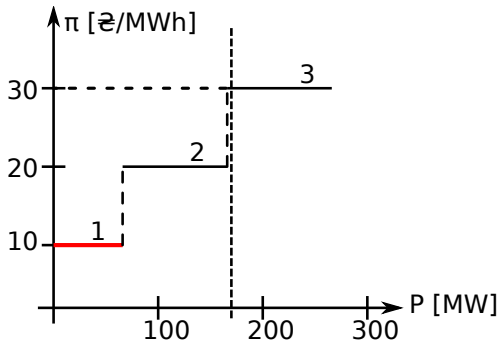
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Profit of 1: 1000 \rightarrow 2000
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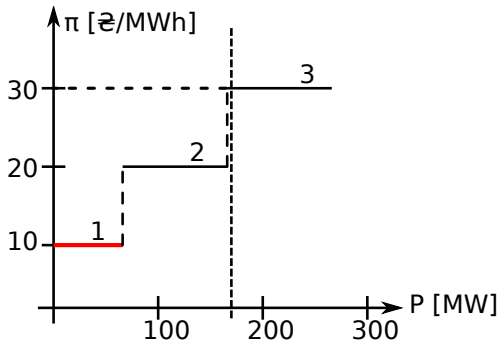
(2) $P_1 \rightarrow 69$ MW.
Profit of 1: 1000 \rightarrow 1380
Profit of 2: 0 \rightarrow 1000



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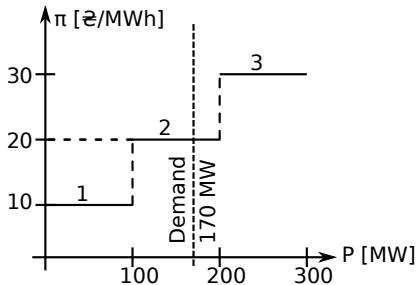
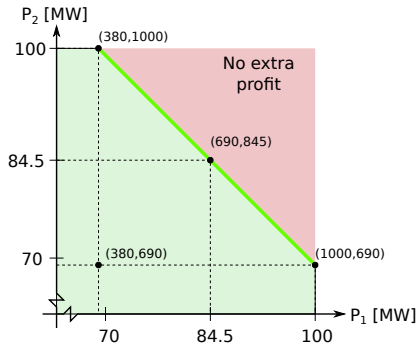
Both possibilities are equilibrium strategies!

(Increase your bid \rightarrow benefits vanish, decrease \rightarrow less profit)

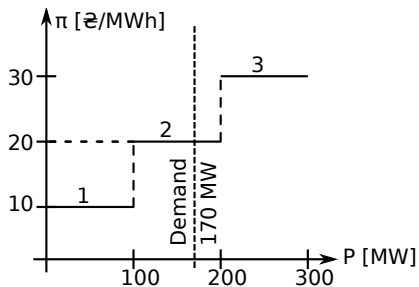
Q: Which one will occur in practice?

Example: 3 producers.

We can draw the profit of producers 1 and 2 as a function of their production.



This example was simplified. How?

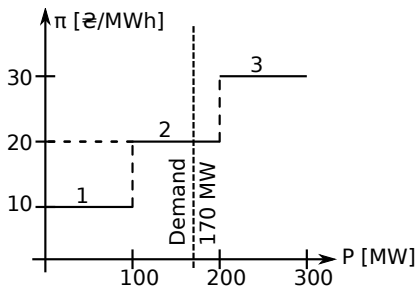


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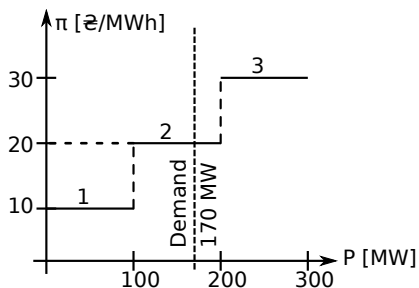
- Full knowledge
- Sharp cost curve + small size
- No uncertainty of production/load/wind

All of these make gaming harder in real life.

Many avenues of research!
(And real money to be made...)

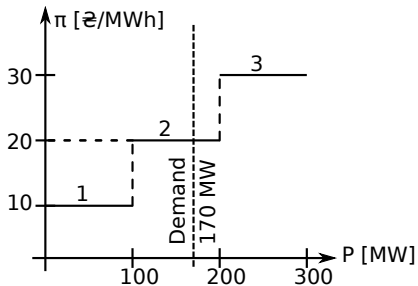


Thus far, markets have had uniform pricing.
Merit order, last bid sets price for everyone.
But this is not the only type of pricing!



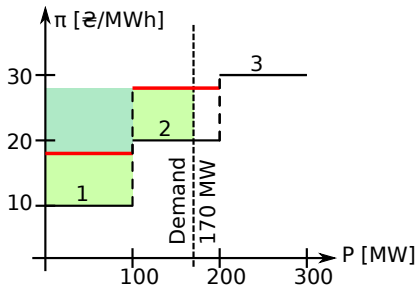
Why not pay-as-bid?

In a pay-as-bid market you are paid at your bid price.
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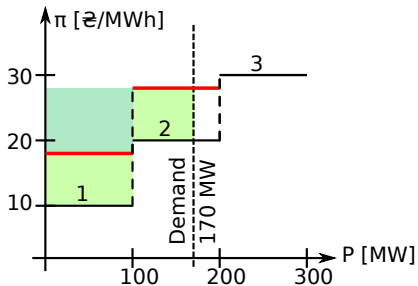


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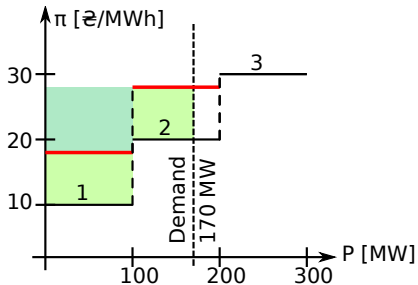
Let's try it out!

Go to bit.ly/elmacourse2 and get bidding!



Pay-as-bid in practice

A player's maximum profit is obtained by correctly guessing the marginal price.
Huge loss if they guess slightly too high.



Can lead to market power for big producers with a diverse portfolio.
But costs to consumers are more stable!

Summary

- In equilibrium, no single player wants to change their strategy
- The equilibrium strategy is not necessarily the one that will emerge in practice
- Market players game using price and quantity
- Pay-as-bid leads to stable prices at the cost of profit risk

Further resources

Some good search terms Public Good Game, Cournot vs. Bertrand competition, Braess' Paradox, Mixed Nash Equilibrium, Market Power

<https://www.youtube.com/watch?v=nM3rTU927io> Yale lecture series; Thorough, practical introduction to game theory. Many good examples!

https://www.youtube.com/watch?v=TM_QFmQU_VA Stanford lecture series: Designing policies knowing that gaming will occur. More advanced and in depth.

<http://www.iro.umontreal.ca/~marcotte/ARTIPS/AOR2007.pdf>
For the OR-interested; using bilevel programs to model competition.

