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A single actor investigation

Bidding Formats for Short-Term Electricity Markets

Dr. Jörn Richstein (DIW Berlin), Dr. Casimir Lorenz (TU Berlin) und Prof. Dr. Karsten Neuhoff (DIW Berlin)

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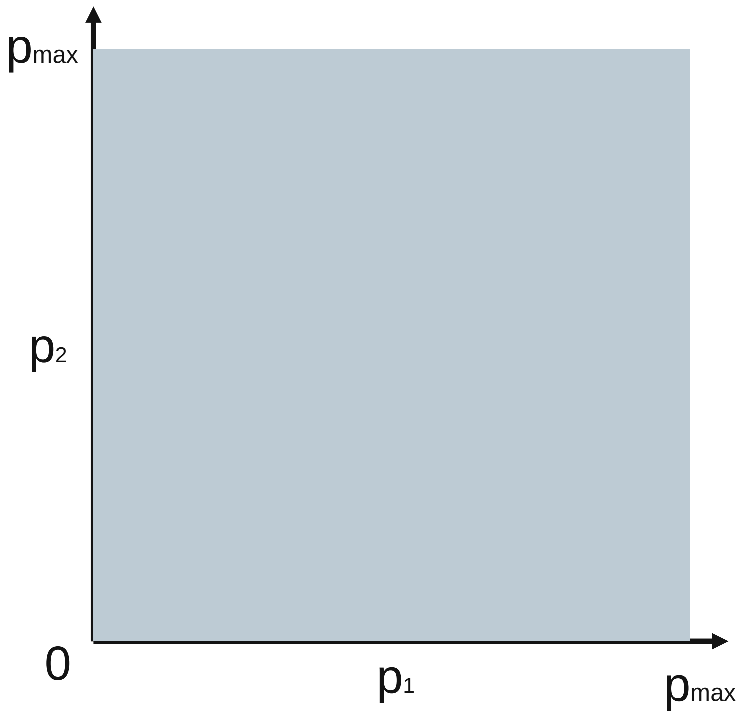
Introduction

- Short-term electricity markets have the goal to efficiently match generation and demand of electricity
- One key challenge: accounting for inter-temporal linkages between time periods:
  - Start-up costs
  - Ramping constraints
  - Remaining electricity in a battery
- Electricity in different time-periods are often not fully independent products: complementarity (or substitutability) of sales in consecutive hours
- Various market designs:
  - Simply bidding (individual hours)
  - Block bidding (blocks of hours)
  - Multi-part bidding (financial and technical parameters, sometimes referred to as complex bidding)
- If there exists some price uncertainty regarding prices in consecutive hours there is an ex-post risk of suboptimal market outcomes

Market

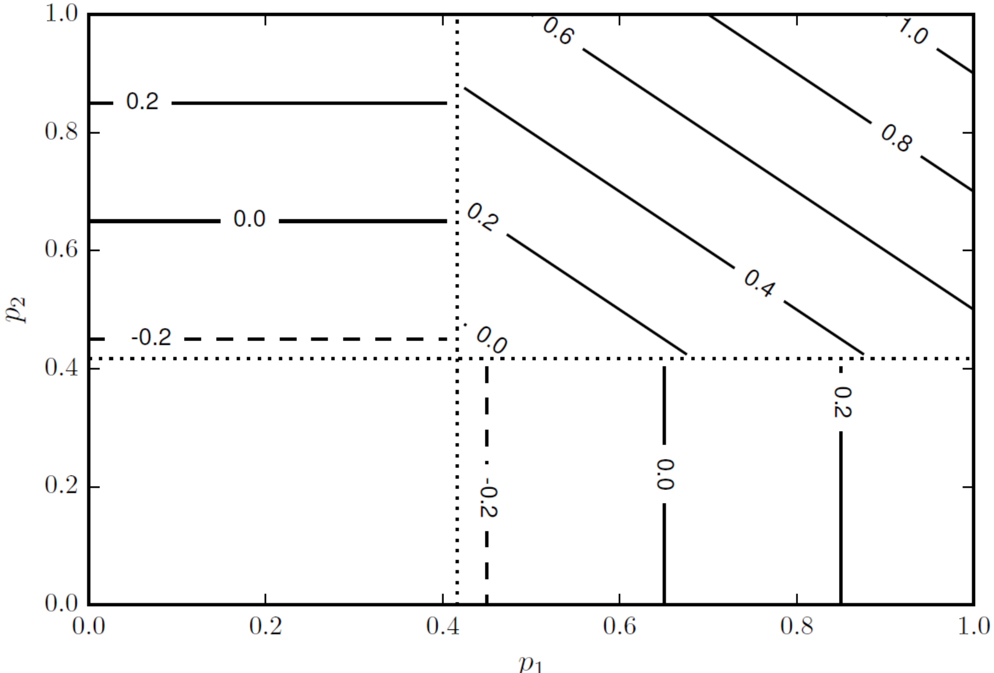


- Two time periods with independent price distributions $U(0, p_{max})$
- Uniform pricing

Actor

- Owns a power plant
  - With variable costs c_v
  - Start-up costs c_s
- Tries to maximize the expected profit by bidding under different bidding schemes:
  - Simply bidding (b_1 and b_2)
  - Block bidding (b)
  - Multi-part bidding (b_v and b_s)
- Solved analytically

Simple Bidding



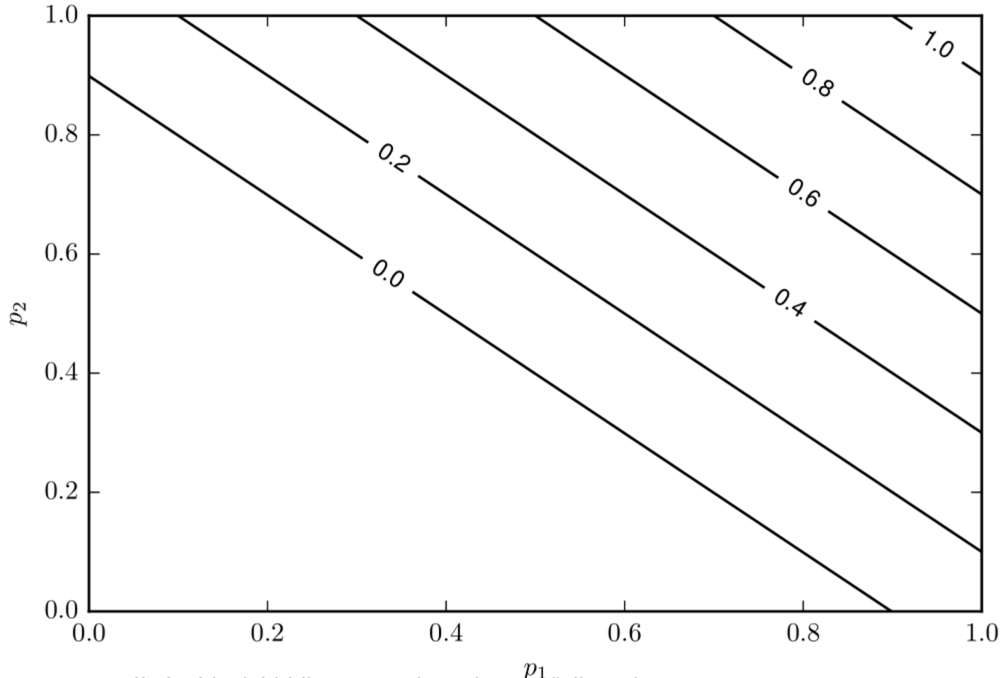
Payoffs for simple bidding example as iso-profit lines (p max = 1 ,cv = 0.25, cs = 0.4,b = 0.417)

$$b^* = \begin{cases} \frac{c_v P_{max}}{P_{max} - c_s} & \text{for } c_s + c_v < P_{max} \\ P_{max} & \text{otherwise} \end{cases}$$

$$\mathbb{E}[\pi^*_{Simple}] = \begin{cases} \frac{(P_{max} - c_s - c_v)^2}{P_{max} - c_s} & \text{for } c_s + c_v < P_{max} \\ 0 & \text{otherwise} \end{cases}$$

- Actor bids separately for 2 time periods
- Can be:
  - Accepted for both
  - Accepted for one
  - Not accepted
- Trade-off between profitable acceptance for 2 periods and potential losses -> risk of inefficient outcome
- Optimal bid can only be lower or equal the sum of variable and fixed costs
- … is not the same as simple “start-up cost spreading” heuristic

Block bidding



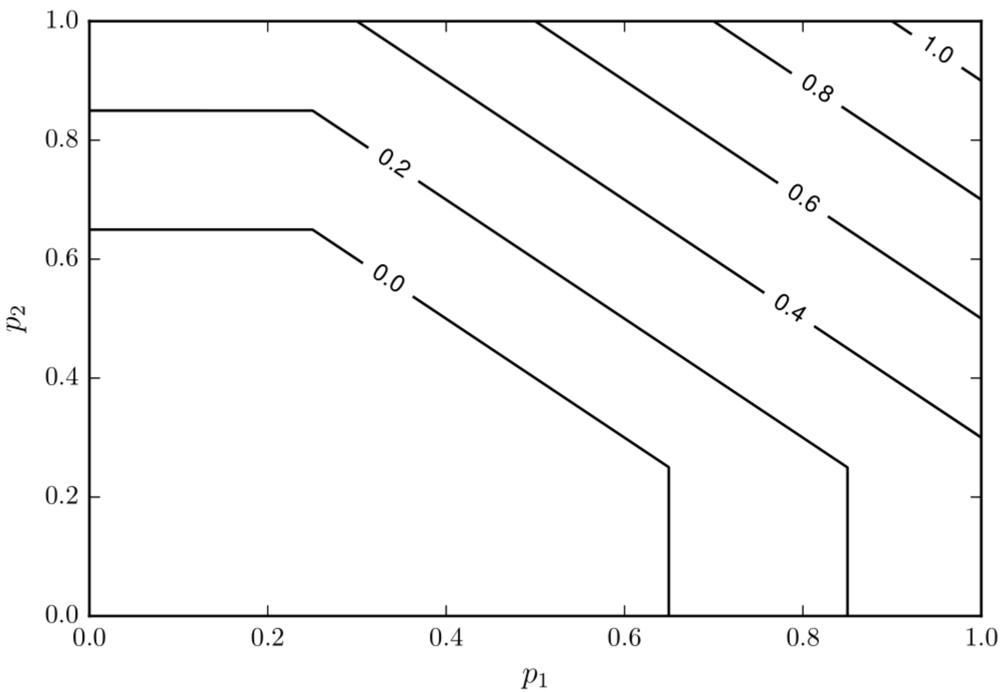
Payoffs for block bidding example as iso-profit lines (p max = 1 ,cv = 0.25, cs = 0.4,b = 0.417)

$$b_b^* = \begin{cases} c_s + 2c_v & \text{for } c_s + 2c_v < 2P_{max} \\ P_{max} & \text{otherwise} \end{cases}$$

$$\mathbb{E}[\pi^*_{Block}] = \begin{cases} P_{max} - c_s - 2c_v + \frac{(c_s+2c_v)^3}{6P_{max}^2} & \text{for } c_s + 2c_v < P_{max} \\ \frac{1}{6P_{max}^2}(2P_{max} - c_s - 2c_v)^3 & \text{for } P_{max} \leq c_s + 2c_v < 2p_{Max} \\ 0 & \text{otherwise} \end{cases}$$

- Actors bid jointly for two time periods
- Therefore best to exclude all losses
- Optimal bidding is equal to intuitive solution
- However, also here ex-post inefficient outcome are possible: acceptance in both periods although the variable cost is below the price in one period.

Multi-part bidding

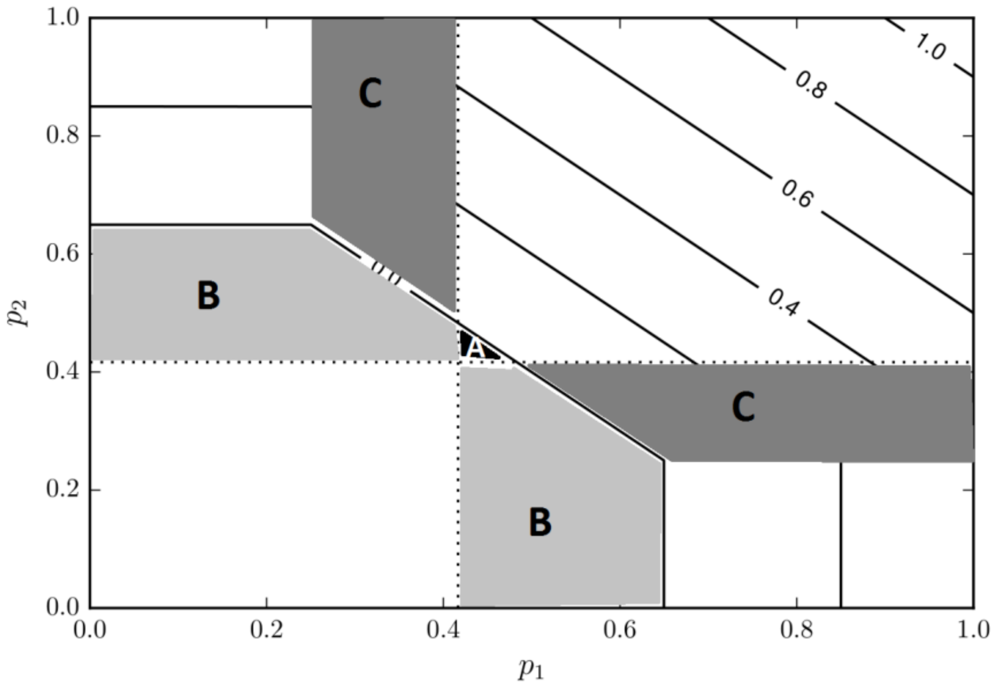


$b_s^* = c_s$ and $b_v^* = c_v$

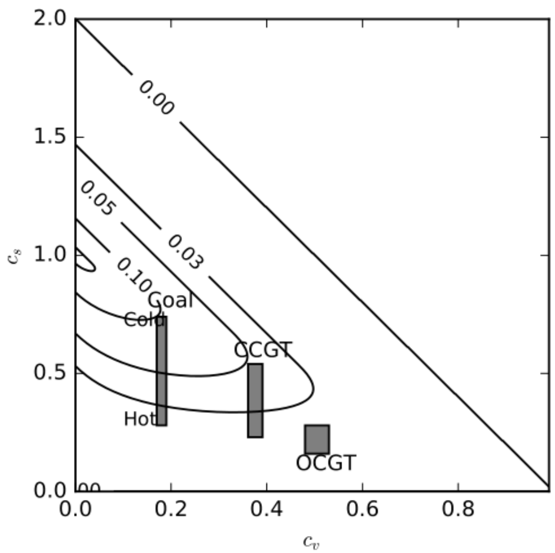
$$\mathbb{E}[\pi^*_{Multipart}] = \begin{cases} \frac{c_s^3}{6P_{max}^2} + \frac{c_s^2 c_v}{P_{max}^2} + \frac{c_s c_v^2}{P_{max}^2} - c_s + \frac{c_v^2}{P_{max}} - 2c_v + P_{max} & \text{for } c_s + c_v < P_{max} \\ -\frac{1}{6P_{max}^2}(c_s + 2c_v - 2P_{max})^3 & \text{for } P_{max} \leq c_s + 2c_v < 2P_{max} \\ 0 & \text{otherwise} \end{cases}$$

- Actors have a multi-part bid with a variable b_v and fixed b_s component
- Dispatch:
  - In one time period if price is higher $b_v + b_s$ in one period, but not higher than b_v in the other
  - Else dispatch in both periods if $p_1 + p_2 \geq b_s + 2b_v$
- Optimal bidding is equal to intuitive solution of bidding variable and start-up costs
- No risk of ex-post in-efficient outcomes

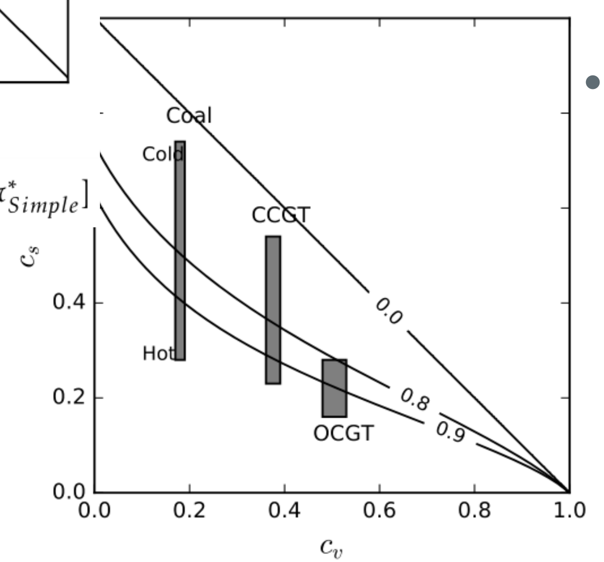
In-efficiencies in bidding



- For a single round several types of in-efficiencies:
  - A: Accepted in two instead of zero
  - B: Accepted in one instead of zero
  - C: Accepted in one instead of two
- Multi-part bidding always has higher or equal expected profit than either single or block bidding

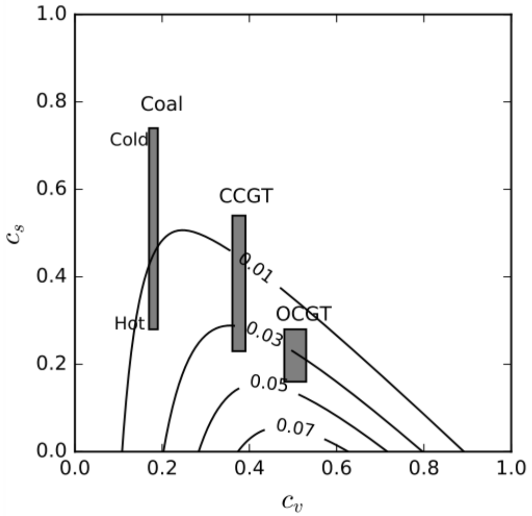


(a) Difference: $\mathbb{E}[\pi^*_{Multipart}] - \mathbb{E}[\pi^*_{Simple}]$

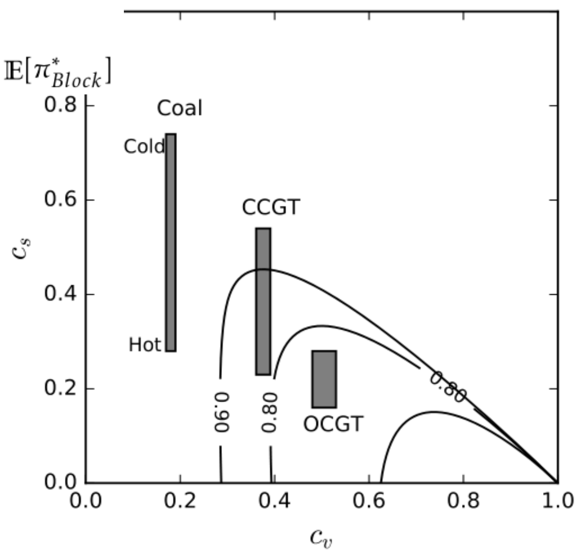


(b) Ratio: $\mathbb{E}[\pi^*_{Simple}]/\mathbb{E}[\pi^*_{Multipart}]$

- Graphs show profit difference and ratios between simple and multi-part bidding
- Profit under simple bidding is always lower than in the multi-part bidding case
- Simple bidding is relatively less worse for variable cost dominated power plants, such as OCGTs.



(a) Difference: $\mathbb{E}[\pi^*_{Multipart}] - \mathbb{E}[\pi^*_{Block}]$

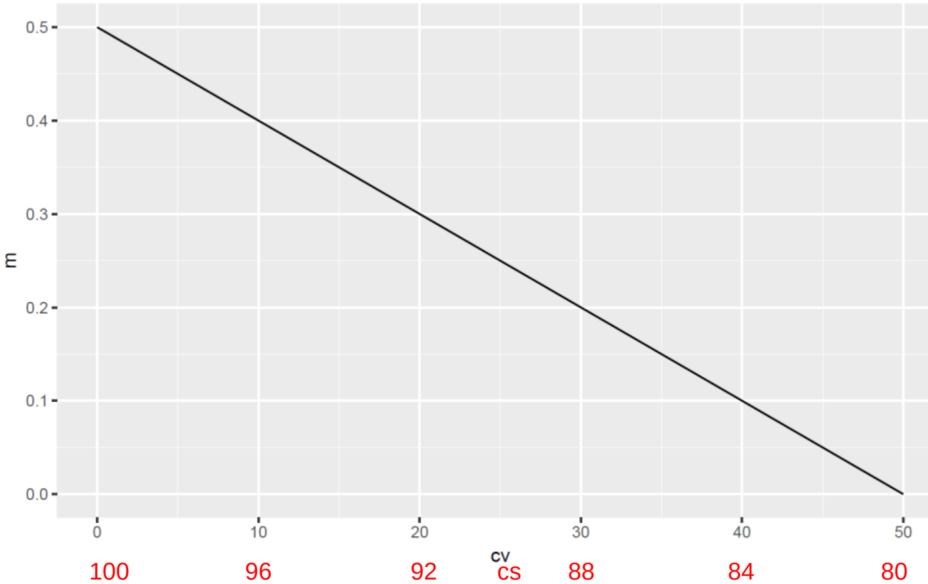


(b) Ratio: $\mathbb{E}[\pi^*_{Block}]/\mathbb{E}[\pi^*_{Multipart}]$

- Graphs show profit difference and ratios between block and multi-part bidding.
- Profit under block bidding is always worse or equal than under multi-part bidding .
- Block bidding relatively less worse for fixed cost dominated power plants, such as coal power plants.

When is the model correct, even if there's a 2nd trading round?

- A limitation of the model is that we do not consider a second (or further) trading rounds
- The model is still correct if accepting the market outcome is more profitable than re-trading.
- Assuming that consecutive markets are less liquid and trading affects the price
  - If only period is accepted the actor prefers producing himself if the additional demand would increase prices above running and start-up costs.
  - Analogue for other cases.



$$c_v * K * l + c_s * K < (p_1^{\alpha} + m_1 * K * l) * K * l$$

$$m_1 > \frac{c_v + \frac{c_s}{l} - b'}{K * l} = \frac{c_v + \frac{c_s}{l} - \frac{cv * Pmax}{Pmax - c_s/l}}{K * l}$$

With increasing variable costs and decreasing start-up costs less price elasticity m is needed for the model to be correct

Conclusions and discussion

- Price uncertainty can lead to inefficient dispatch under simple and block bidding
- This does not occur under multi-part bidding
- The effect is bigger for start-up intensive power plants for simple bidding, and for variable cost intensive power plants for block bidding
- Trading possibilities on consecutive markets mitigate the effect, depending on the price elasticity on these markets
- The closer to real time and the more uncertain the situation is, the more relevant this effect becomes → increasing relevance in high RES systems

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DIW Berlin — Deutsches Institut
für Wirtschaftsforschung e.V.
Mohrenstraße 58, 10117 Berlin
www.diw.de

Redaktion
Jörn C. Richstein, jrichstein@diw.de

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