CBS DEPARTMENT OF ECONOMICS
COPENHAGEN BUSINESS SCHOOL

CSEI | Copenhagen School of Energy Infrastructure

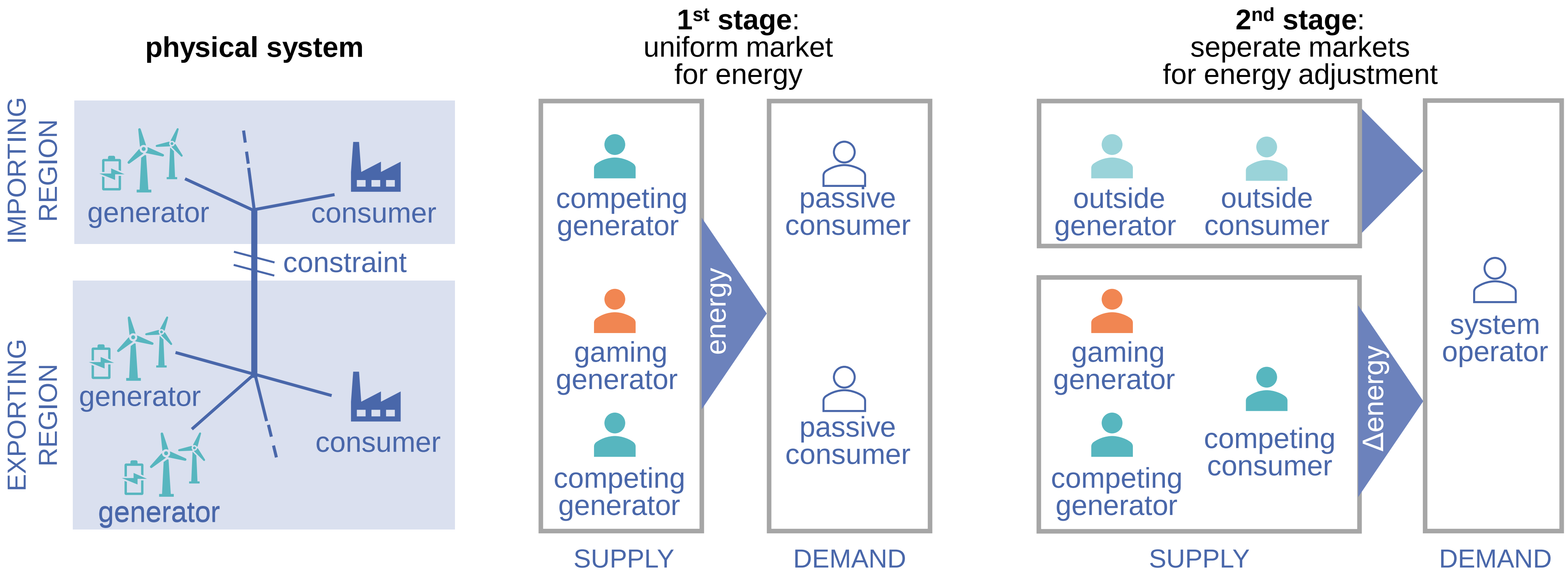
RISKS AND INCENTIVES FOR GAMING IN ELECTRICITY REDISPATCH MARKETS

Christine Brandstätt
joint work with Anna Pechan, Gert Brunekreeft & Martin Palovic

available at https://bremen-energy-research.de/wp-content/bewp/bewp43.pdf

IAEE European Conference, 25th July 2023, Milan

Background: Electricity markets & congestion



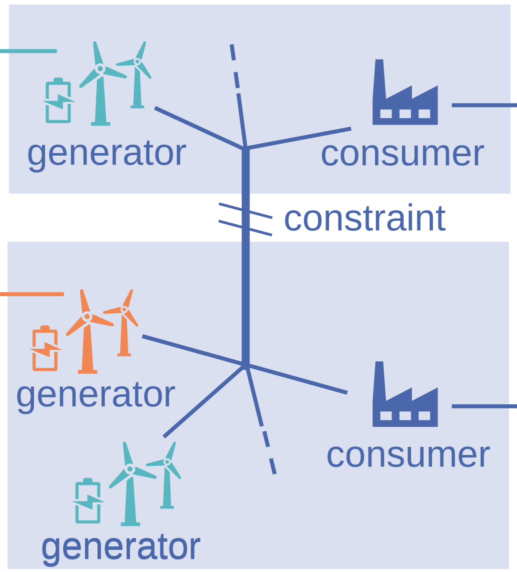
Research Question: Gaming strategies

Δ: more electricity, i.e. ++ generation, -- consumption, → remuneration from system operator

1st stage:
high bid & foregone dispatch
2nd stage:
high remuneration & ramp up

1st stage:
high bid & unprofitable dispatch
2nd stage:
high remuneration & ramp down

IMPORTING REGION



EXPORTING REGION

1st stage:
low bid & unprofitable dispatch
2nd stage:
low payment & ramp down

1st stage:
low bid & forgone dispatch
2nd stage:
low payment & ramp up

Δ: less electricity, i.e. -- generation, ++ consumption, → payment from system operator

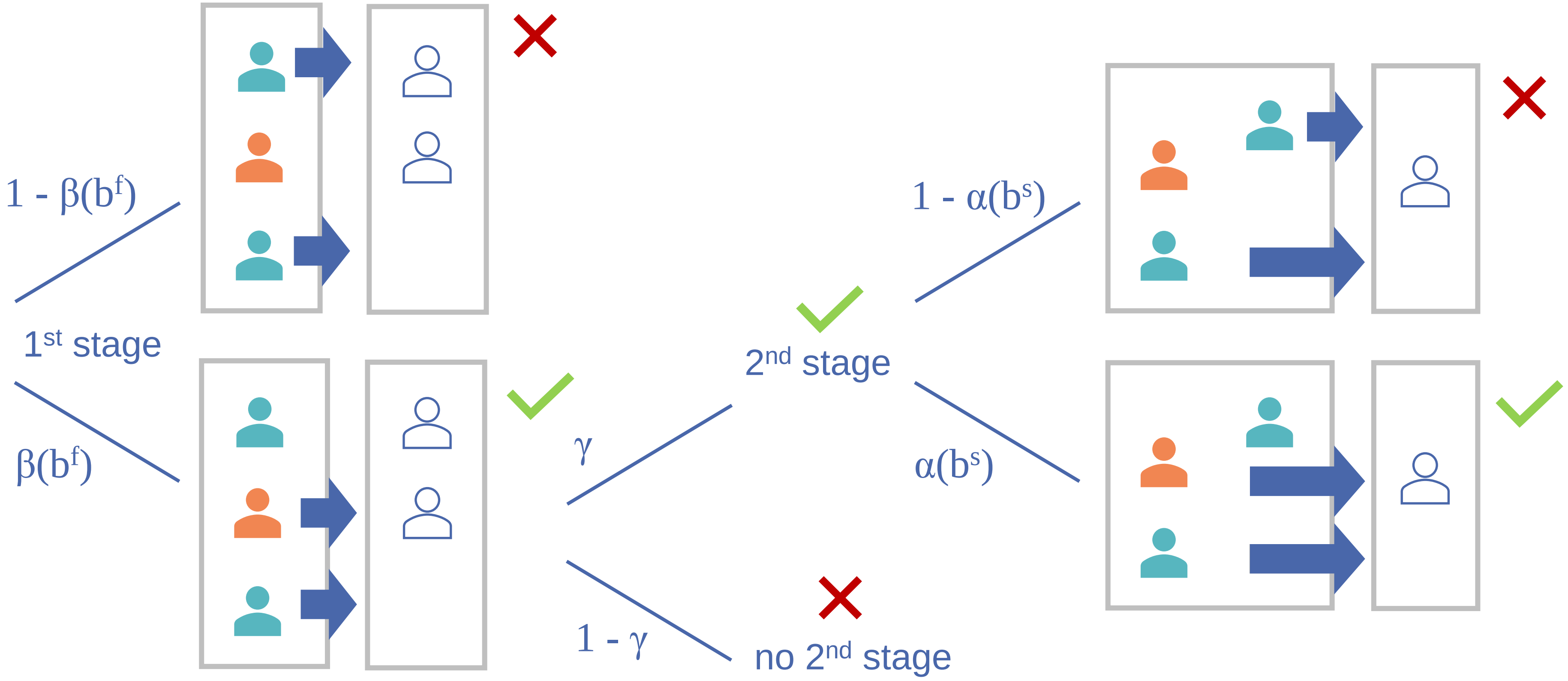
- Is there a risk of gaming ‚per se‘? And if not, what limits it?
  What are precisely the incentives? What is the effect of competition and market regulation?

Model I – risks and expected profit

probability 1: gaming bid selected in 1st stage

probability 2: 2nd stage market opened (congestion occurs)

probability 3: gaming bid selected in 2nd stage



$$E\Pi_j\left(b_j^f, b_j^s\right) = \beta\left(b_j^f\right)\cdot\left(b_j^f - C_j\right)\cdot q_j + \beta\left(b_j^f\right)\cdot\gamma\cdot\alpha\left(b_j^s\right)\cdot\left(C_j - b_j^s\right)\cdot q_j$$

Model II – reference bid

- $\alpha(b_j^s) = Pr(b_{ref}^s \leq b_j^s) = \Phi\left(\frac{b_j^s - \mu_{b_{ref}^s}}{\sigma_{b_{ref}^s}}\right)$

➢ $\max_{b_j^s} E\Pi_j$

- $\frac{dE\Pi_j}{db_j^s} = \beta\left(b_j^f\right) \cdot \gamma \cdot q_j \cdot \left[\frac{d\alpha\left(b_j^s\right)}{db_j^s} \cdot \left(C_j - b_j^s\right) - \alpha\left(b_j^s\right)\right] = 0$

- $b_j^{s^*} = C_j - \frac{\alpha\left(b_j^{s^*}\right)}{\alpha'\left(b_j^{s^*}\right)}$

- selection probabilities (α, β) are
  - endogenous (influenced by own strategic bids) and normally distributed
  - depend on (mean and variation of) the reference bid in the market
- congestion probability (γ) is exogenous, reflecting the likelihood at a specific link in a specific instant

- first order condition: expected market outcome marked-down according to selection probability (bid shading in discriminatory pricing)

- marginal cost as upper limit to optimal bid
- expected reference bid as lower limit $b_{ref}^s \leq b_j^{s^*}$

Dicussion : competitive environments

Case 1: no reference bidder

- no competing offers for redispatch
- $\alpha = 1$
- any loss from first stage can be compensated
  → essentially market power

➢ strong incentives for gaming (moderated only by probability of first-stage selection and congestion i.e. β and γ)

Case 2: weak reference bidder

- offers relatively low payment
- $b^{s}_{ref} << b^{f}_{ref}$
- loss of outbidding b^{f}_{ref} in first stage may be compensated

➢ incentives for gaming (moderated by δ and other remaining risks)

Case 3: strong reference bidder

- offers relatively high payment
- $b^{s}_{ref} \approx b^{f}_{ref}$
- no margin for high enough b^{s}_{j} in second stage to compensate loss of outbidding b^{f}_{ref} in first stage

➢ no incentives for gaming

Implications for Regulation

- several measures to influence risk and incentives for gaming

- facilitating entry
- long-term contracts
- boasting μ and σ thus shifting from case 2 to 3 or from 1 to 2

reversing 1st stage payment
- $b_s = b_f + m$ only selected with very weak or no competition

$$E\Pi_j\left(b_j^f, b_j^s\right) = \beta(b_j^f) \cdot q_j \cdot \left[(b_j^f - C_j) + \gamma \cdot \Phi\left(\frac{b_j^s - \mu_{b_{ref}^s}}{\sigma_{b_{ref}^s}}\right) \cdot \left(C_j - b_j^s\right)\right]$$

monitoring & penalty
- eliminating $E\Pi$

grid reinforcement
- reducing γ

- system-owned flexibility
- occasional random allocation
- increasing σ and reducing α

Conclusions

- ➢ Incentives for gaming are limited in competition and market regulation can actively decrease the incentives for gaming
- ➢ Market-based approach remains relevant to reduce redispatch cost & enable efficient local flexibility markets

- Market-based redispatch is feasible in many (most?) circumstances, especially as
  - demand-side and distributed actors strengthen competition in the redispatch market
  - storage and grid-enhancing technologies diversify redispatch options

- System operators can reduce the profitability of gaming by use of
  - own flexibility
  - long-term contracts
  - occasional random allocations

- Remainder of cases likely falls under market manipulation
  and can be left to legislation, e.g., REMIT.

Thank you for your time and attention!

Christine Brandstätt
Assistant Professor

Copenhagen School of Energy Infrastructure
Copenhagen Business School

cbr.eco@cbs.dk

csei@cbs.dk

www.csei.eu

Discussion around market-based redispatch

Motivation & Background:

- Electricity allocation in Europe occurs in (at least) two stages with different advance time and of varying geographical scope
- EU: market-based resdispatch – unless the expected level of competition is insufficient
  (Art. 13, EU 2019/943)
- ACER, ENTSO-E, BMWi: risk of gaming?!
  i.e. bidders make infeasible bids in the spot market, betting on being scheduled for redispatch to relieve congestion

Research Question:

Is there a risk of gaming ‚per se'? And if not, what limits it?

- What are precisely the incentives for gaming in market-based redispatch?
- What is the effect of competition and market regulation on the profitability of the strategy?

Literature

- strategies in sequential electricity market (of identical geographical scope)
  - Ito & Reguant (2016) for Spain, Borenstein et al. (2008) for California
- incentives for market power abuse in locationally differentiated (but not sequential) electricity markets
  - Hogan (1997), Borenstein et al. (2000), Joskow and Tirole (2000)
- influence of redispatch on the first stage market
  - Dijk & Willems (2011): focus on first stage bidding
  - Holmberg & Lazarczyk (2015): effects on bidding and investment
  - Sarfati et al. (2019, 2020): simulated effect on production efficiency and network cost
- case studies of gaming in electricity markets:
  - Graf et al. (2020) empirical analysis of redispatch in Italy
  - Perino & Schnaars (2021) simulation for Germany in administrative setting, Hirth & Schlecht (2020) for market-based future
  - Palovic et al. (2022) qualitative analysis of cases in California, UK and Denmark

➢ **here: detailed analysis of the incentives, including different probabilities and competition**

References I

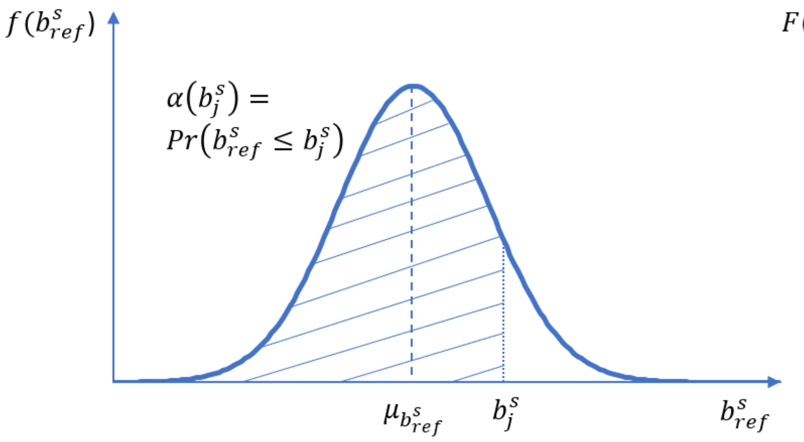
- Borenstein, S.; Bushnell, J. & Stoft, S. (2000) The Competitive Effects of Transmission Capacity in a Deregulated Electricity Industry. RAND Journal of Economics 31 (2): 294-325.
- Borenstein, S.; Bushnell, J.; Knittel, C.R. & Wolfram, C. (2008) Inefficiencies and Market Power in Financial Arbitrage: A Study of California's Electricity Markets. Journal of Industrial Economics 56 (2): 347-78.
- Dijk J & Willems B (2011). The effect of counter-trading on competition in electricity markets. Energy Policy, 39, pp. 1764-1773.
- Graf Ch, Quaglia F & Wolak F (2020). Simplified electricity market models with significant intermittent renewable capacity: Evidence from Italy. NBER Working Paper No. 27262. Available at http://www.nber.org/papers/w27262. Accessed on 02. Dec. 2022.
- Grimm V, Martin A, Sölch Ch, Weibelzahl M & Zöttl G (2020). Market-based redispatch may result in an inefficient dispatch. Available at SSRN: https://ssrn.com/abstract=3120403 or http://dx.doi.org/10.2139/ssrn.3120403
- Hirth L, Schlecht I (2020, Juli 24). Market-based redispatch in zonal electricity markets: The preconditions for and consequence of Inc-dec gaming. Working Paper. ZBW – Leibnitz Information Centre for Economics.
- Hogan, W.W. (1997) A Market Power Model with Strategic Interaction in Electricity Networks. Energy Journal 18 (4): 107-141.
- Holmberg P & Lazarczyk E (2015). Comparison of congestion management techniques: Nodal, zonal and discriminatory pricing. The Energy Journal, 36(2), pp. 145-166.

References II

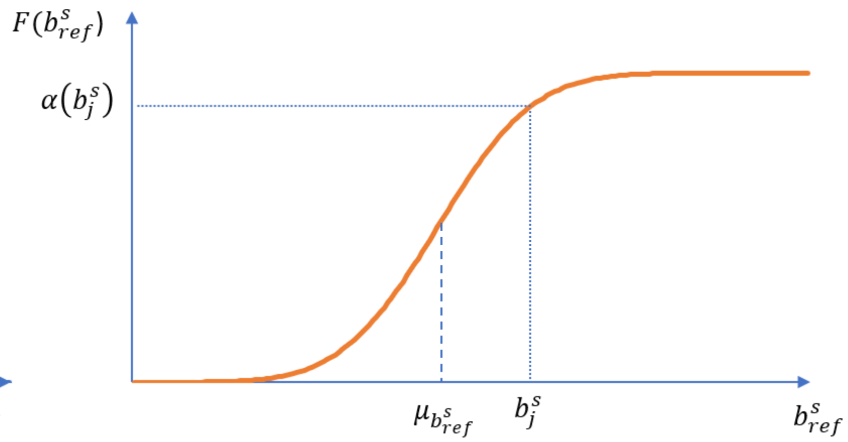
- Ito, K. & Raguant, M. (2016) Sequential Markets, Market Power, and Arbitrage. American Economic Review 106 (7): 1921-57.
- Joskow, P.L. & Tirole, J. (2000) Transmission Rights and Market Power on Electric Power Networks. RAND Journal of Economics 31 (3): 450-487.
- Palovic M, Brandstätt Ch, Brunekreeft G & Buchmann M (2022). Strategic behavior in market-based redispatch: International experience. The Electricity Journal, 35(3).
- Perino G & Schnaars P (2021). Arbitrage in cost-based redispatch: Evidence from Germany. Available at SSRN: https://ssrn.com/abstract=3890723 or http://dx.doi.org/10.2139/ssrn.3890723
- Sarfati, M. & Holmberg, P., 2020. Simulation and Evaluation of Zonal Electricity Market Designs. Electric Power Systems Research, Volume 185. https://doi.org/10.1016/j.epsr.2020.106372.
- Sarfati, M., Hesamzadeh, M. R. & Holmberg, P., 2019. Production efficiency of nodal and zonal pricing in imperfectly competitive electricity markets. Energy Strategy Reviews, Volume 24, pp. 193-206. https://doi.org/10.1016/j.esr.2019.02.004

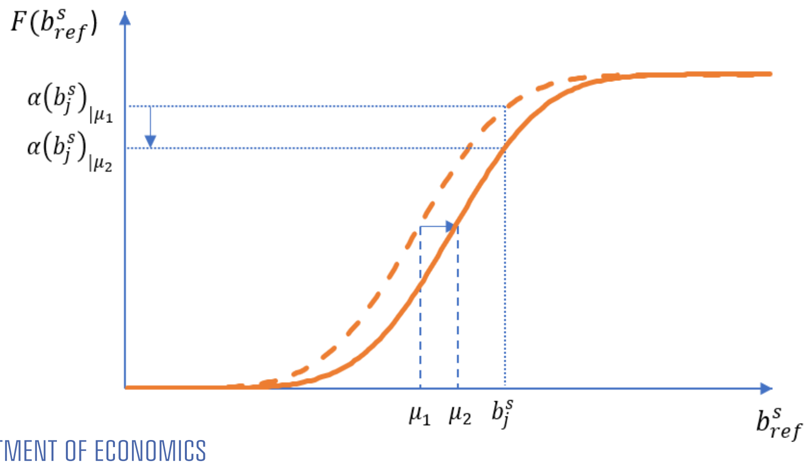
Selection Probability

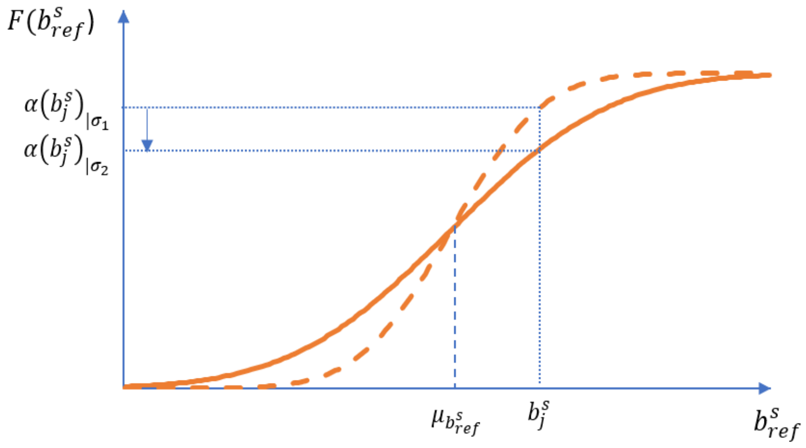
Probability density function



Cumulative distribution function







Profit from Gaming Strategy

for a generator in the exporting region (j)

- $\Pi_j = \underbrace{(b_j^f - C_j) \cdot q_j}_{\text{first stage}} + \underbrace{(C_j - b_j^s) \cdot q_j}_{\text{second stage}} = \left(b_j^f - b_j^s\right) \cdot q_j$

- $E\Pi_j\left(b_j^f, b_j^s\right) = E\Pi_j^f(b_j^f) + E\Pi_j^s(b_j^s)$
  $= \beta\left(b_j^f\right) \cdot \left(b_j^f - C_j\right) \cdot q_j \quad + \beta\left(b_j^f\right) \cdot \gamma \cdot \alpha(b_j^s) \cdot (C_j - b_j^s) \cdot q_j$

- $\alpha\left(b_j^s\right) = Pr\left(b_{ref}^s \leq b_j^s\right) = \Phi\left(\frac{b_j^s - \mu_{b_{ref}^s}}{\sigma_{b_{ref}^s}}\right)$

- $\beta\left(b_j^f\right) = Pr\left(b_{ref}^f > b_j^f\right) = 1 - \Phi\left(\frac{b_j^f - \mu_{b_{ref}^f}}{\sigma_{b_{ref}^f}}\right)$

- successful gaming leverages the difference in payments between the two stage (f, s)
- simplification: uniform q_j and C_j in both stages
- expected profit reflects probabilities of selection and congestion

- selection probabilities (α, β) are
  - endogenous (influenced by own strategic bids) and normally distributed
  - depend on (mean and variation of) the reference bid in the market

- congestion probability (γ) is exogenous, reflecting the likelihood at a specific link in a specific instant

Optimal Gaming Bid

for a generator in the exporting region (j)
in a market with discriminatory pricing (pay-as-bid)

- $\max_{b_j^f\, b_j^s} E\Pi_j = \beta(b_j^f) \cdot \left[(b_j^f - C_j) \cdot q_j + \gamma \cdot \alpha(b_j^s) \cdot \left(C_j - b_j^s\right) \cdot q_j\right]$
- $\frac{dE\Pi_j}{db_j^s} = \beta\left(b_j^f\right) \cdot \gamma \cdot q_j \cdot \left[\frac{d\alpha\left(b_j^s\right)}{db_j^s} \cdot \left(C_j - b_j^s\right) - \alpha\left(b_j^s\right)\right] = 0$
- $b_j^{s^*} = C_j - \frac{\alpha\left(b_j^{s^*}\right)}{\alpha'\left(b_j^{s^*}\right)}$

- gamer maximizes expected profit by means of strategic bids (subject to $E\Pi_j > 0$)
- first order condition: expected market outcome marked-down according to selection probability (bid shading in discriminatory pricing)
- marginal cost as upper limit to optimal bid
- expected reference bid as lower limit $b_{ref}^s \leq b_j^{s^*}$

Threshold for Successful Gaming

for a generator in the exporting region (j) in a market with discriminatory pricing (pay-as-bid)

$$\frac{\partial E\Pi_j(b_j^{s*})}{\partial \mu_{b^s_{ref}}} = \beta \cdot \gamma \cdot \left(\frac{\partial \alpha(b_j^{s*})}{\partial \mu_{b^s_{ref}}} \cdot \frac{\partial b_j^{s*}}{\partial \mu_{b^s_{ref}}} \cdot \left(C_j - b_j^{s*}\right) - \alpha(b_j^{s*}) \cdot \frac{\partial b_j^{s*}}{\partial \mu_{b^s_{ref}}} \right) \cdot q_j < 0$$

- expected profit decreases monotonously with increase of the second stage reference bid (as $\frac{\partial \alpha}{\partial \mu_{b^s_{ref}}} < 0$)

$$E\Pi_j\left(b_j^f, b_j^{s^*}\right) < 0$$

$$\Leftrightarrow b_j^s > (1 - \frac{1}{\gamma \cdot \alpha(b_j^s)}) \cdot C_j + \frac{1}{\gamma \cdot \alpha(b_j^s)} \cdot b_j^f$$

- gaming becomes unattractive if potential loss from the first stage is unlikely to be compensated in the second stage

$$T\colon\ C_j - b_j^f = \gamma \cdot \alpha(b_j^{s^*}) \cdot \frac{\alpha(b_j^{s^*})}{\alpha'(b_j^{s*})}$$

- there is a threshold beyond which expected profit is negative even with optimal bidding
  - success depends on the reference bids, i.e. on competition