

A long-term power market model

Matthias Silbernagl



Technische Universität München

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- 1 Motivation
- 2 Time series models
- 3 Game theoretical models
 - Market rules
 - Algorithm

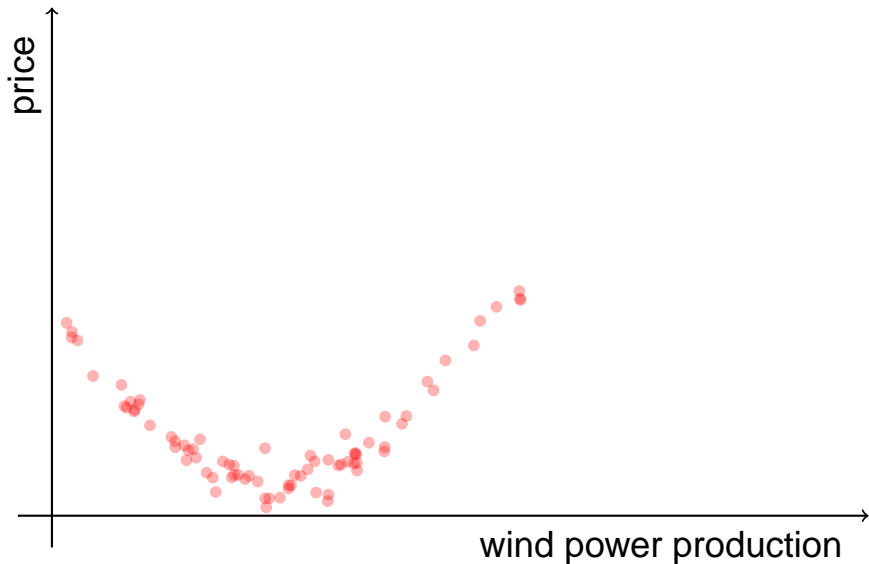
Who uses power market models?

- Government: Consequences of market rules
 - Energy-intensive industry (e.g. metal industry)
 - Energy companies (electricity & other):
 - Short-term pricing on markets
 - Long-term contracts
 - Evaluation of investments
- Cooperation with Statoil

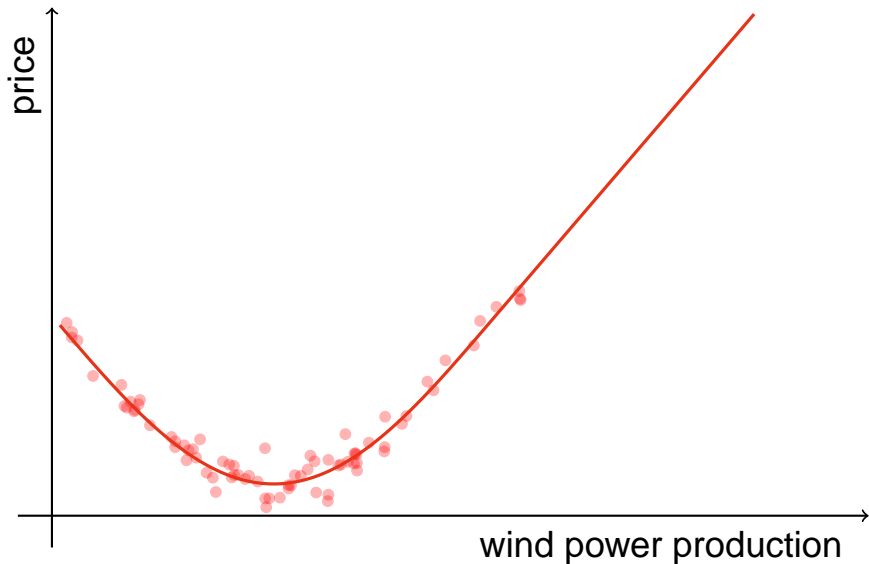
Why are time series models popular?

- Uses **historic data** to predict future
→ Extrapolation in the widest sense
- + Historic market rules & characteristics encoded in data
→ High detail without explicit model
- + Prediction “inside” (or “near”) cloud of data points: very good
- ? Prediction outside of data cloud?

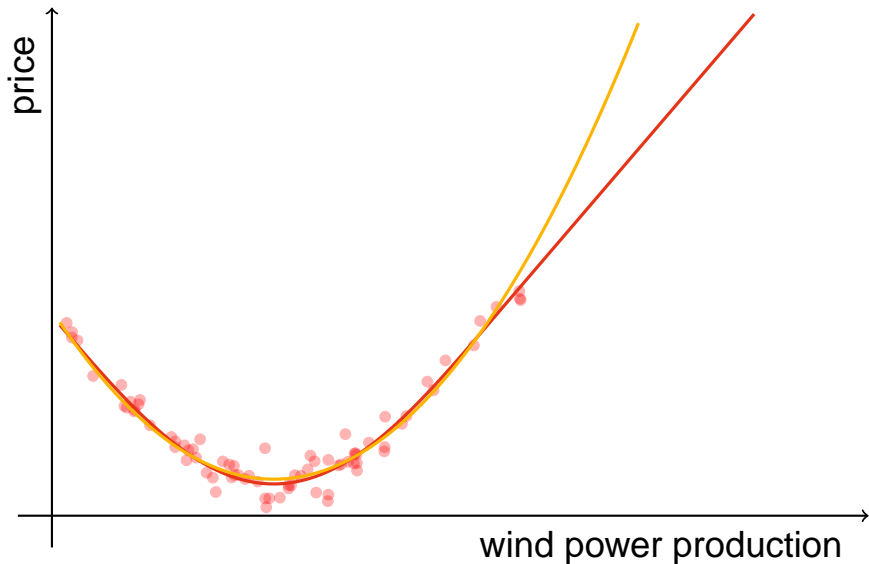
The problem with extrapolation



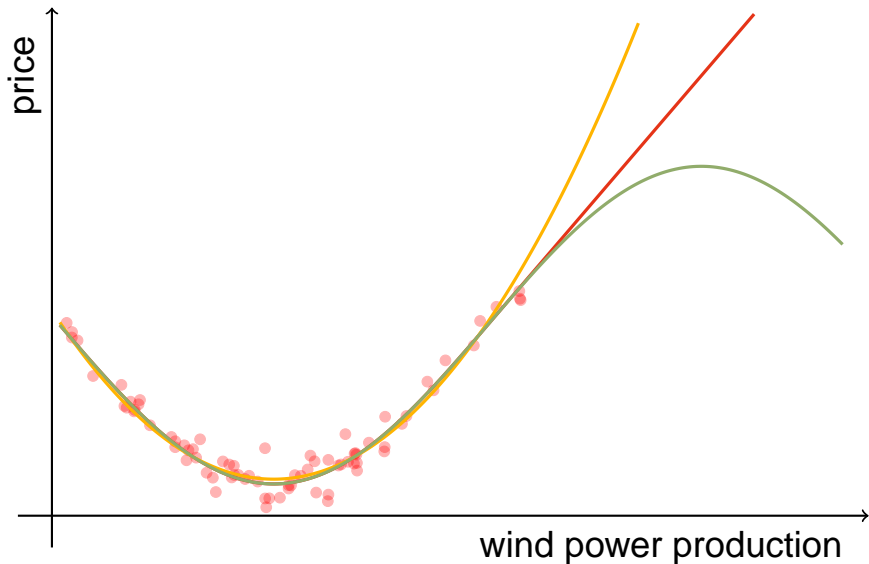
The problem with extrapolation



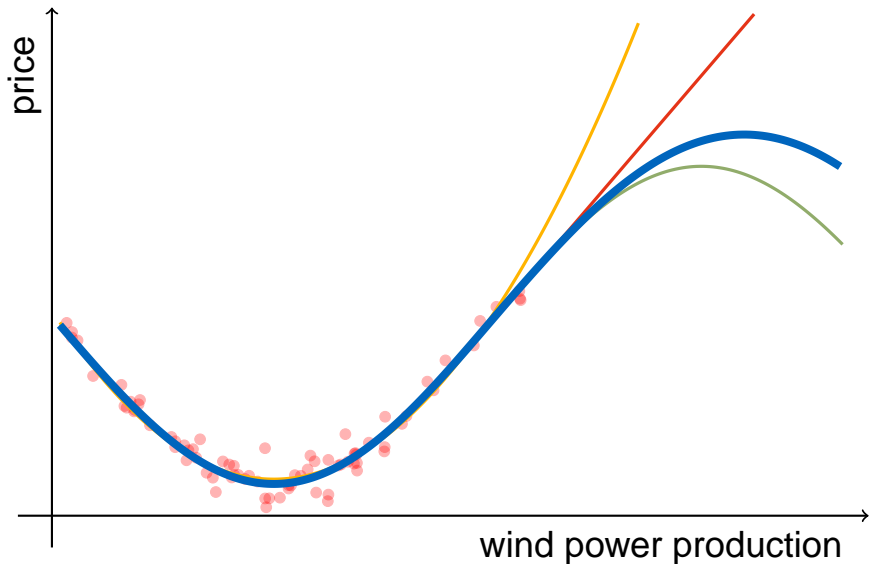
The problem with extrapolation



The problem with extrapolation



The problem with extrapolation



Why we don't use time series models

- Prediction outside data cloud: not good
- Time series models use **hidden assumption**:
“The market situation will stay similar”
- But the market already changes!
- In a **long-term** model, we're really interested in situations far away from the data cloud

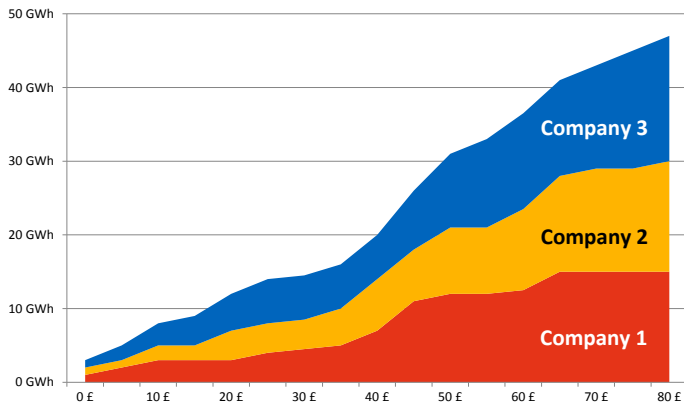
What do game theoretical models offer?

- + Do not need historic data
- Use **market principles** to predict the future
- + Single major assumption:

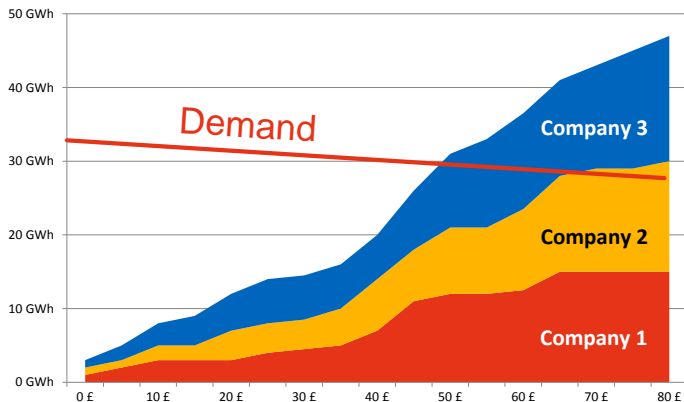
“All players act rationally with the goal of maximizing their profit.”

- +/_ Market rules and situation modeled explicitly
 - + We can model arbitrary market situations
 - + We can analyze different market scenarios

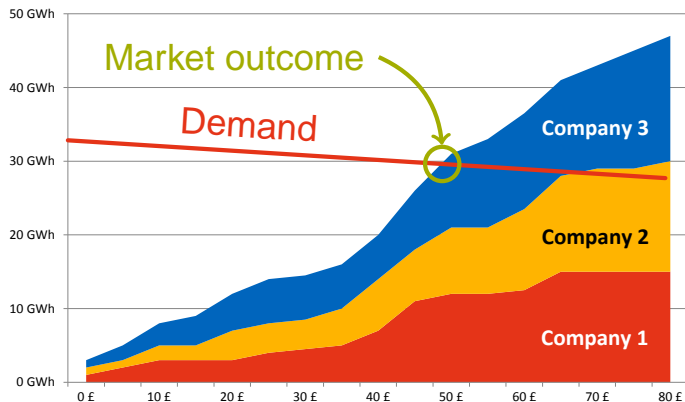
Supply & Demand model



Supply & Demand model

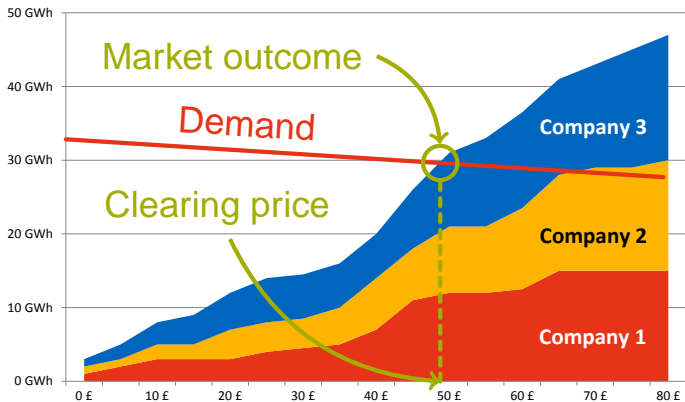


Supply & Demand model



Market outcome at intersection
of supply & demand

Supply & Demand model

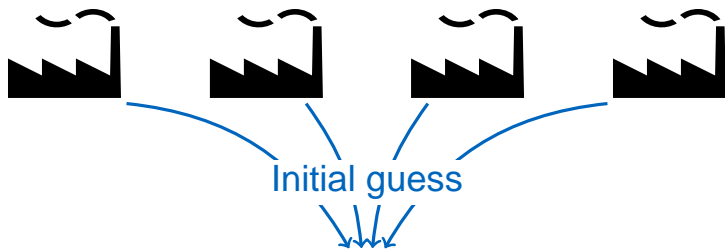


Market outcome at intersection
of supply & demand

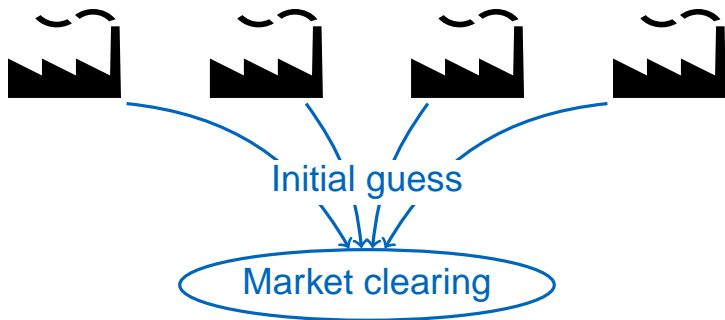
How do companies find their strategy?



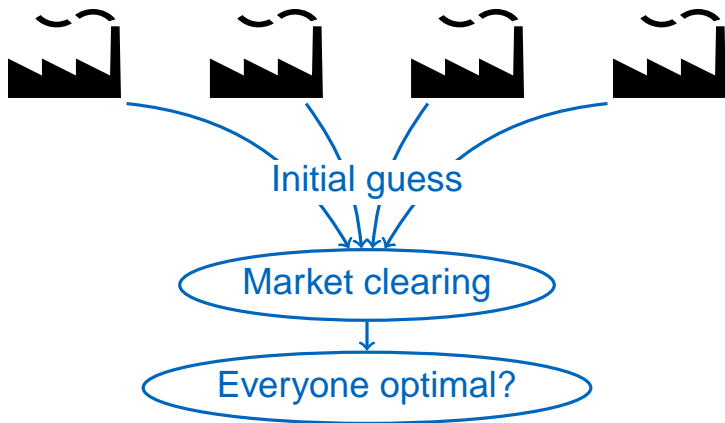
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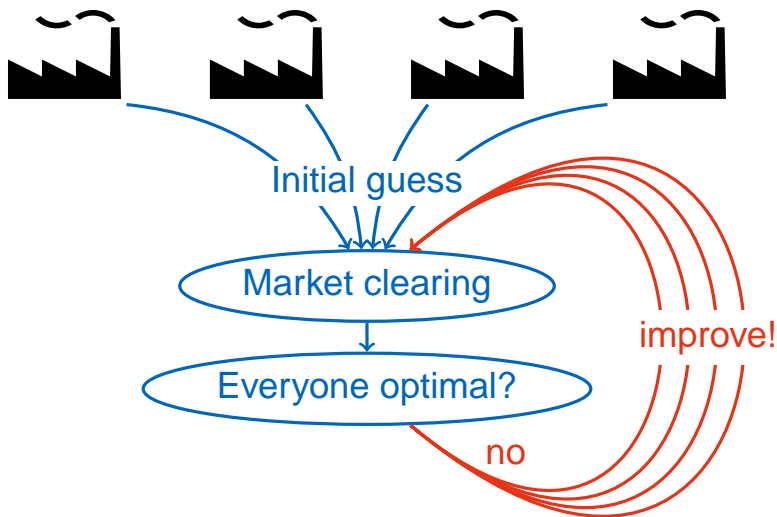
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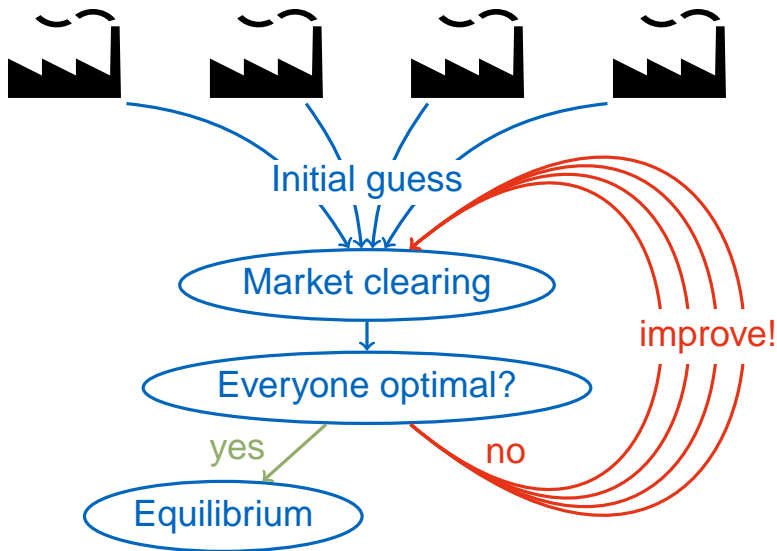
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How do companies find their strategy?



Statements from game theory

Game Theory predicts*

- The process converges towards an equilibrium.
- The equilibrium is unique.
I.e. the initial supply function and the nature of the improvement do not matter, as long as the goal stays the same.
- * under some simplifying but natural assumptions

How to improve strategy?

- Maximize company's profit under last market conditions
- *Unit Commitment problem*
 - Characteristics of our model
 - 1 Price dependent on company's production
 - 2 Uncertainty of wind power production
 - 3 Minimal production for every unit
 - 4 Accurate start-up costs
 - 5 Production-dependent efficiency
 - 6 Minimal up- and downtime

Profit optimization model

$$\max \sum_{k \in K} \left[\left(\text{Demand}^k - \sum_{g' \in G \setminus \{g\}} \text{Supply}_{g'}^k \right)^{-1} \left(\sum_{j \in J} p_j^k \right) \sum_{j \in J} p_j^k - \sum_{j \in J} (\text{cp}_j^k - \text{cu}_j^k - \text{cd}_j^k) \right]$$

$$v_j^k \leq t_j^k = t_j^{k-1} (1 - T_j^\downarrow) + v_j^k \cdot T_j^\downarrow + L \cdot h_j^{k-1}$$

$$\underline{p}_j v_j^k \leq p_j^k \leq \bar{p}_j v_j^k$$

$$\bar{p}_j^k \leq p_j^{k-1} + L \cdot \text{RU}_j v_j^{k-1} + \text{SU}_j (1 - v_j^{k-1}) - \min\{\text{SU}_j, \underline{p}_j + L \cdot \text{RU}_j\} \cdot (1 - v_j^k)$$

$$p_j^k \geq p_j^{k-1} - L \cdot \text{RD}_j v_j^k - \text{SD}_j (1 - v_j^k) + \min\{\text{SD}_j, \underline{p}_j + L \cdot \text{RD}_j\} \cdot (1 - v_j^{k-1})$$

$$\bar{p}_j^{k-1} \leq \bar{p}_j v_j^k + \text{SD}_j (v_j^{k-1} - v_j^k)$$

$$\text{cp}_j^k = (\text{FA}_j \cdot \text{FC}_{F_j}^k + \text{PA}_j) L \cdot p_j^k + (\text{FB}_j \cdot \text{FC}_{F_j}^k + \text{PB}_j) L \cdot v_j^k$$

$$\text{cd}_j^k \geq \text{CD}_j (v_j^{k-1} - v_j^k)$$

$$\text{cu}_j^k \geq (\text{HC}_{j,k} + \text{HF}_{j,k} \cdot \text{FC}_{F_j}^k) L \cdot t_j^k$$

...

Thank you for your attention!
Questions?