Stochastic programming in deregulated energy markets

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Main messages

- Directly on modeling
  - When we make market assumptions, do we change the models accordingly?
  - How will certain well-known models change if producers are price-takers in functioning markets?
- For stochastic programming
  - Distributed decision-making – are we ready?

Warning !

- The purpose is not to say that this is how all models ought to be in light of deregulation, but to point at some modeling issues.

- Our market is not like that …

Background

- OMEGA – a fifth-framework EU program on electricity markets
  - SINTEF: Asgeir Tomasgard, Matthias Nowak, Thor Bjørkvoll

Deregulation, competition …

- De- /reregulation: something has changed in the regulation
- Free competition: “not very much regulation”
- Perfect competition: All players are small / all players are price-takers
- Monopoly: Only one player
- Oligopoly: A few players who are aware of each other.

Spot market

- Day-ahead forward market: promises to buy or sell certain volumes at certain prices the next day
- Regulatory market: Continuous-time market that clears the supply and demand on the spot.

Unit commitment

- Several units, some thermal
- Minimal up and down-time
- Minimal and maximal production rate
- Reserve constraints
- Goal: schedule units to meet the demand (load)

But what if demand changes?

- Flexibility becomes an issue.
- Are units producing such that we can meet sudden changes up and down?
  - Römisch, Nowak
- A interesting question: How to set up pools so as to facilitate the characteristics of thermal units?
  - Elmaghraby and Oren (1999), Contreras et al (2001)

What if all producers are price-takers?

- Micro-economic theory says: Price is determined by setting supply equal to demand,
- in a context where no single producer can affect the price,
- i.e. all producers take the price for given, knowing they cannot change it themselves.

Is demand (load) still uncertain when all producers are price-takers?

- Yes, (of course),
- but is that relevant for a price-taker? Should he care?
- Two cases:
  - before bidding in the forward (“spot”) market
  - after bidding

- Before bidding:
  - There is not really a unit commitment problem
- After bidding
  - We have promised to deliver (we have a contract)

What if we ...

- have several thermal units
- are price-takers in functioning markets
- have delivery contracts
  - to the pool or
  - bilaterally

and we choose to ...

- schedule our units subject to
  - contracts
  - properties of the units
  - the uncertain spot price (to take into account over/under production)

income from contracts
\+ net sales from production above contracts
\- net buys when production below contracts

What if we forget about the contracts in the scheduling?

- Income from contracts is known
- Cost of fulfillment = cost of buying the volume in the spot market.
  - Which is stochastic
- Income from production equals the spot value of our production.
  - Which is stochastic

What is the profit from our production and contracts in this case?

income from contracts

\+ net sales from production above contracts

\- net buys when production below contracts

Contracts do not need to be taken into account while scheduling if we only care about expected values!

- So we can as well schedule our units subject to
  - properties of the units
  - the uncertain spot price
- and take into account that the income is affected by contracts in a predictable way.
- Is this a good problem?

The units are de-coupled!

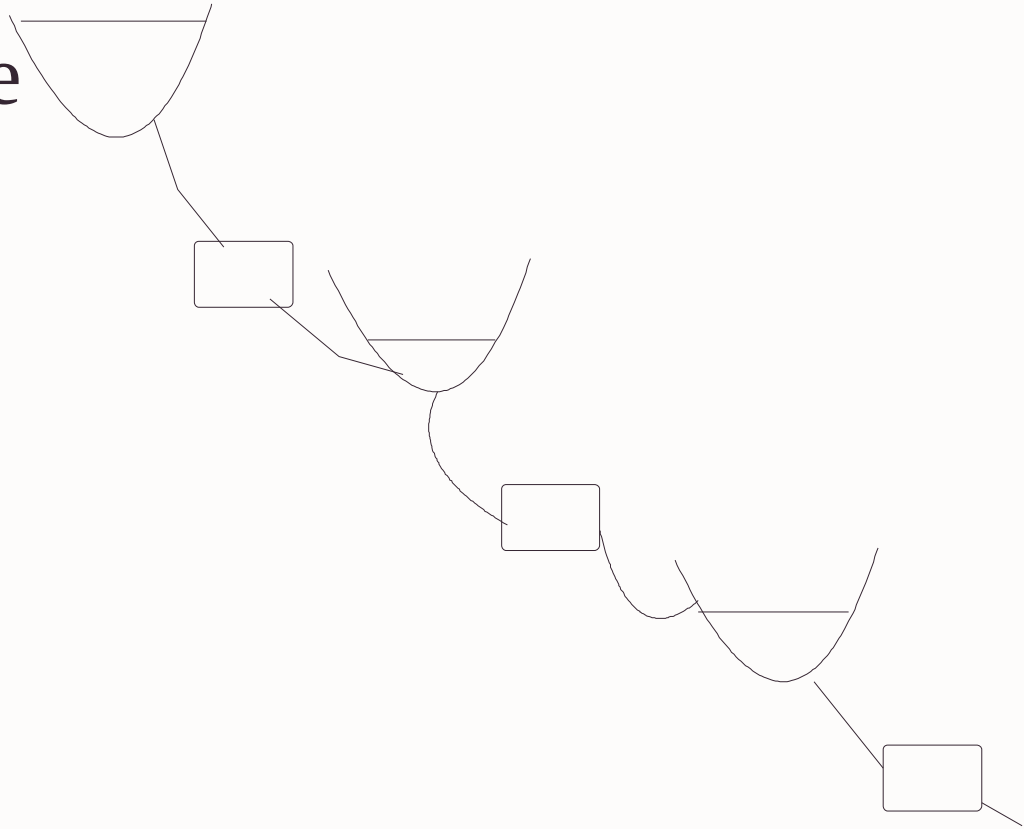
- We can as well schedule one unit at a time or ...
- schedule units decentralized

Where did all the contracts go?

- Do they not matter at all?
- Risk!

Hydro scheduling

- Same situation if we have several units ?
- Yes, if there are no cascades
- If not, contracts can still be disregarded, but we must look at one cascade at a time.



Transportation

- But what if there are zones with different prices (and there will be) and we produce in one zone and have a contract to deliver in another?
  - Enough transfer capacity between the zones
  - Not enough capacity

Enough transfer capacity

- The higher price will equal the lower price plus fees and value of losses.
- Assume they did not ….
- So we can as well satisfy the contracts by buying in spot and then maximize the value of our production.

Not enough transfer capacity.

- There will still be losses.
- Owners of transfer lines can raise price until there is enough capacity given the price.

An equilibrium will be reached where, as before:

price in low
price zone
+
losses and fees
=
price in high
price zone

So what if we …

- made a model for operating all our units in all zones, and made sure we bought enough transfer capacity to satisfy our customers?
- A tough model to solve.

Drop the contracts

- What if we just satisfied all contracts in the spot marked of the relevant zones and then maximized the value of our production?
- Just as before: contracts enter the objective function but need not enter the constraints.

Sell in other zones

- Should we consider selling electricity in a zone with a higher spot price than where we are?
- No, because …

Contracts = risk attitude

- Contracts do not need to be included in the scheduling
- But they matter !
  - if we are risk averse
- The distribution of our total income is a function of contracts and production

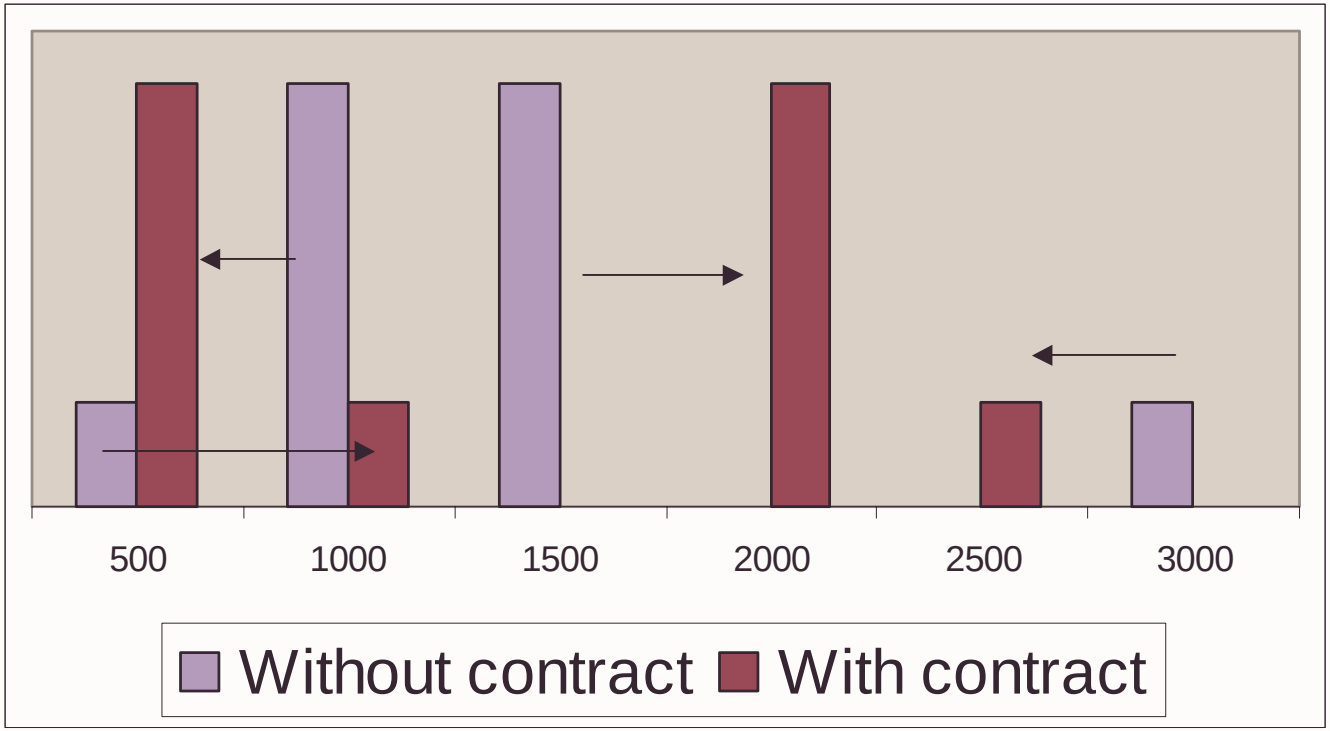
Three possible profit levels from production

Contract: Sell 50% at price 100 in forward market

Production	50	150	50	150	
Price	10	10	20	20	
Probability	10%	40%	40%	10%	Exp
					1350
Profit	500	1500	1000	3000	
New profit	1000	2000	500	2500	

Sell 100 at price 15 in forward market

Variance has increased



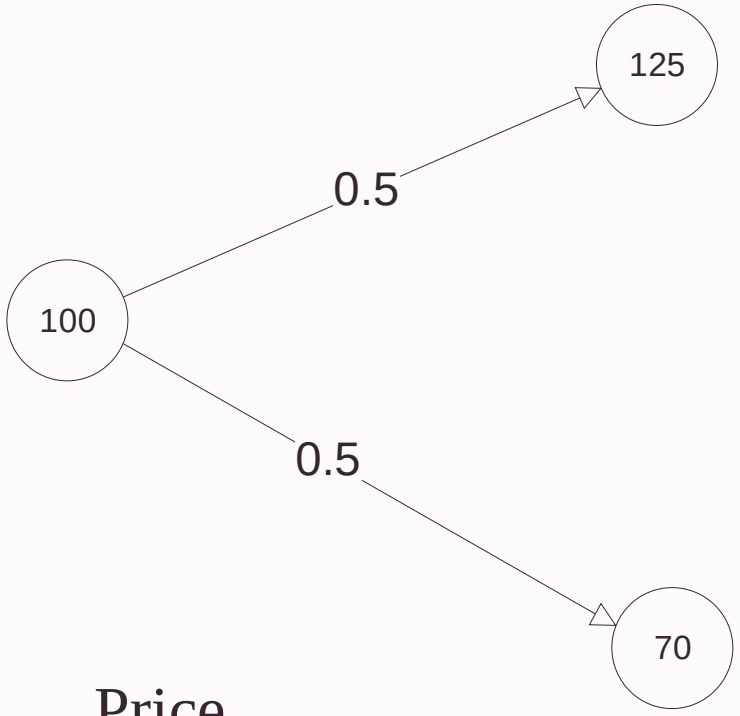
Model setup

- Schedule units (or cascades) distributed. Maximize the expected value of the production
- Have a central unit for contracts (i.e. risk management)

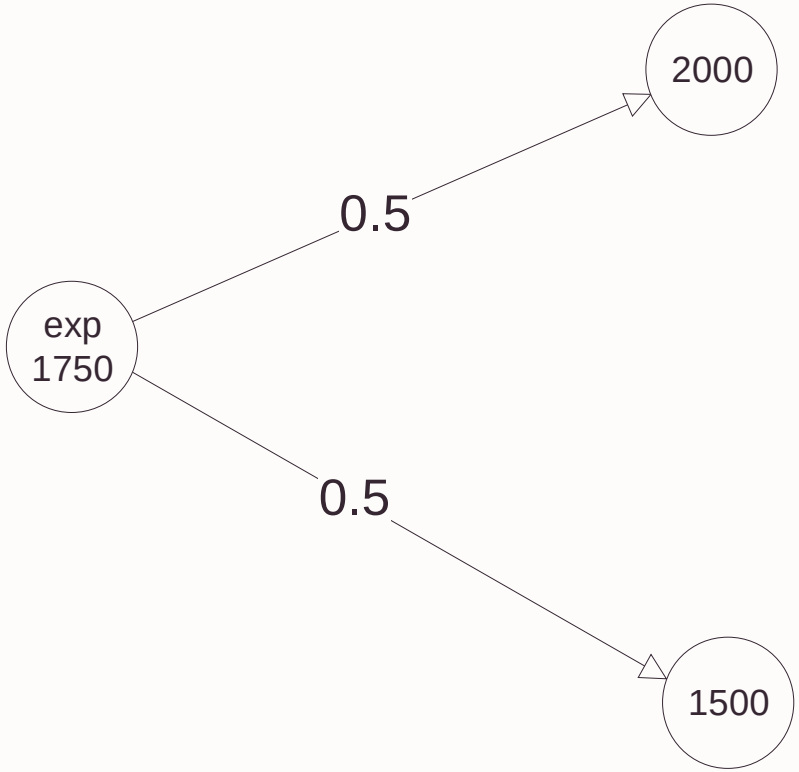
Confused ?

- Good, you should be …
- What about the flexibility inherent in the hydro system … save water for later ?
- Practical answer
  - Has been disregarded
  - Cost of organization
  - And then …

A market world

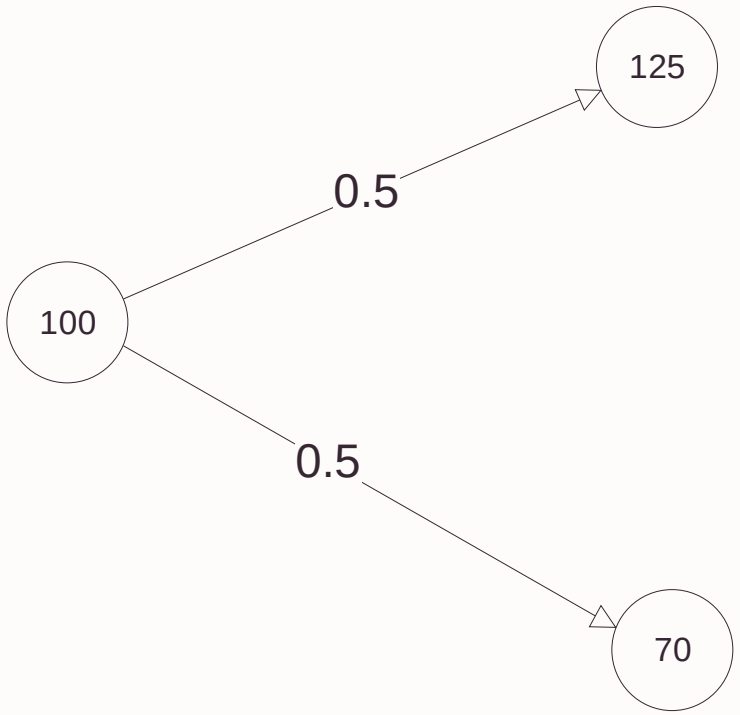


Price



Profit

State prices

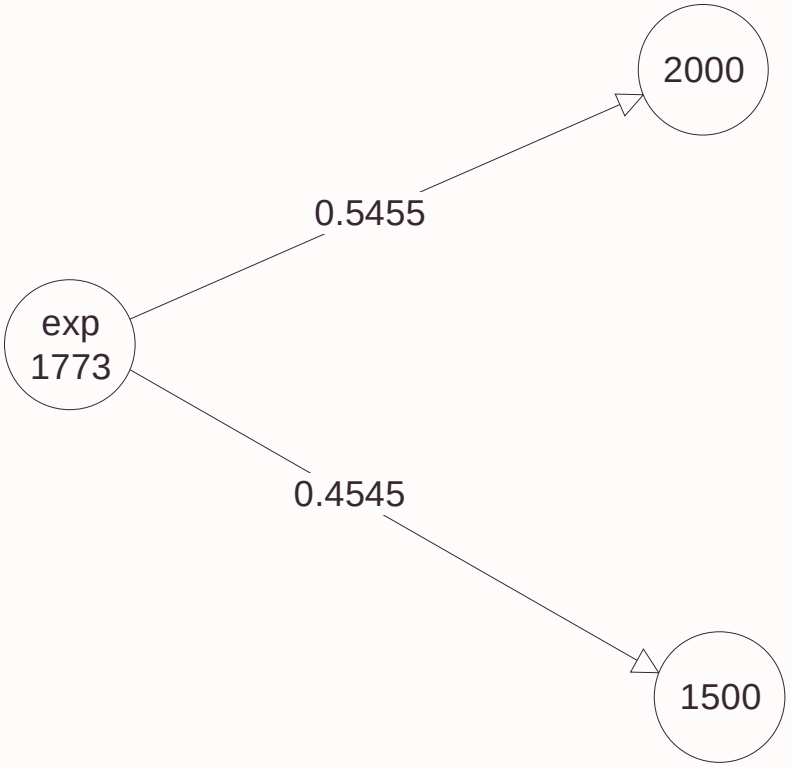


$$100 = 125\pi_1 + 70\pi_2$$

$$1 = \pi_1 + \pi_2$$

$$\pi_1 = 0.5455 \quad \pi_2 = 0.4545$$

Market value



Market value of production:

$$0.5455 * 2000 + 0.4545 * 1500 = 1773$$

Expected value was 1750

What happened ?

- The expected value was below the market value.
- Good deal:
  - Buy the production for above expected value
  - Sell it in the forward market at market price
  - Have a certain profit

$$1773$$
$$-1751$$
$$= 22$$

Markets and scheduling

- Let the decentralized units maximize the market value of their production
- Have a central unit operate in the contract market for risk control
  - Will not change the market value of the firm if the market is perfect

Financial or physical contracs – any difference?

In a perfectly functioning market there is no difference as the effect is financial in any case.

Only theory ?

- Models are always approximations.
- Tradeoff between losses due to:
  - idealized market assumptions
  - Inability to solve large involved models

Challenges

- Distributed decision-making with local or global information
- Relationship to market values when they exist.
  - Treatment of risk
  - Discounting
- Make models consistent with the assumed market form
  - Make appropriate approximations