HOW WELL CAN ONE MEASURE MARKET POWER IN RESTRUCTURED ELECTRICITY SYSTEMS ?[1]

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1. Introduction

1.1. Context

- ***Long term:***
  - General: debate on ex ante vs. ex post measures
  - More specific: the unsatisfactory (European) electricity market
- ***Immediate:***
  - Investigation of market power in the electricity sector by European competition authorities
  - Model based assessments of structural remedies (e.g. Newbery et al. (2003), London Economics (2004))

1.2. Question: how goods are our tools ?

- For measuring the exercise of market power
- For proposing ex ante structural remedies to regulators (as suggested by the reformed EU competition policy)
- Considerations inspired by Bushnell et al (2005) "abstract away from the detailed market rules and regulations ...", vs. the multi market character of restructured electricity systems (Wilson (2002) and his four submarkets).

2. Scope of the analysis

2.1. Restricted to

- Stacking/economic equilibrium models
- Perfect competition/Nash Cournot models
- Extensively used (among others Bushnell et al. (2005) relying on BBW (2002) and other papers, Newbery et al. (2003) and Hobbs et al. (2004) in Europe)
- With some remarks specific to Europe

2.2. Implications

- From a competition point of view
  - One does not consider pro-collusive effects of the repeated games type (e.g. Harrington et al. (2005))
- From the point of view of market architecture
  - One does not consider supply function equilibrim (Green and Newbery (1992))
  - And hence the recent work of Baldick and Hogan (2004) and Wilson (2005)
- But
  - Our considerations would apply to that work

3. Themes

- ***Claim 1:*** Unit commitment idiosyncracies cannot be inserted in market equilibrium models whether for perfect or imperfect competition (well discussed in the literature).

  (Structural remedies and renewable enhance the importance of unit commitment issues.)

- ***Claim 2:*** The multimarket aspect can be inserted in the pure competition models with different degree of feasibility (transmission/balancing reliability), but much remains to be done.

- ***Claim 3:*** The multimarket aspect can only be inserted in the oligopolistic models at the cost of
  - more or less arbitrary assumptions
  - significant computational difficulties

  Multiregional reliability add to that complexity

- ***Conclusion:*** Can one really "abstract away from the detailed market rules and regulations" when assessing structural remedies on the energy market ?

4. Methodology

4.1. Economic paradigms

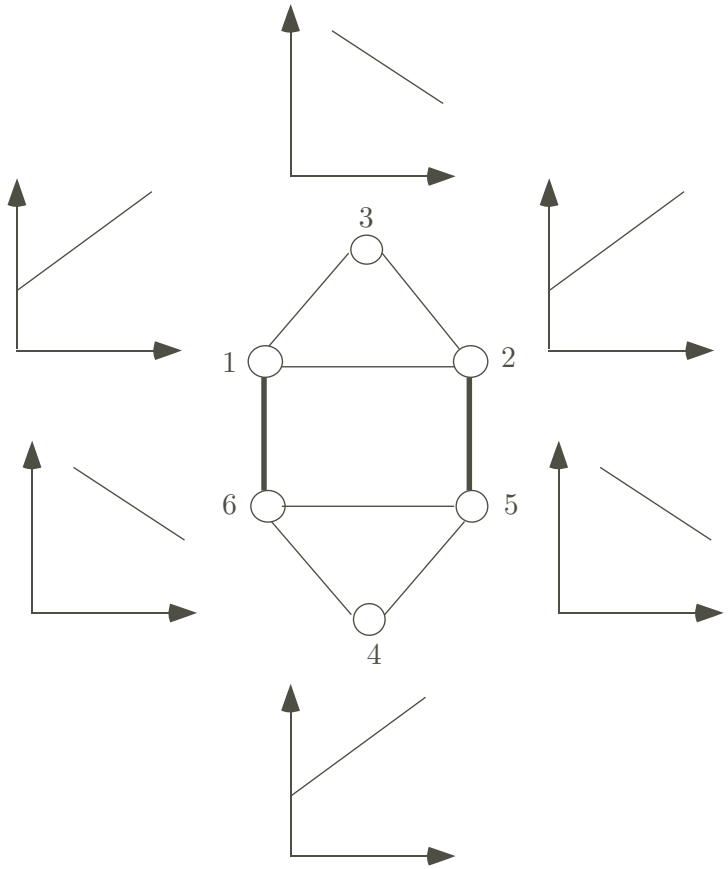
- Perfect competition
- Nash Cournot
- Complete and incomplete markets
- Subgame perfect equilibrium/EPEC

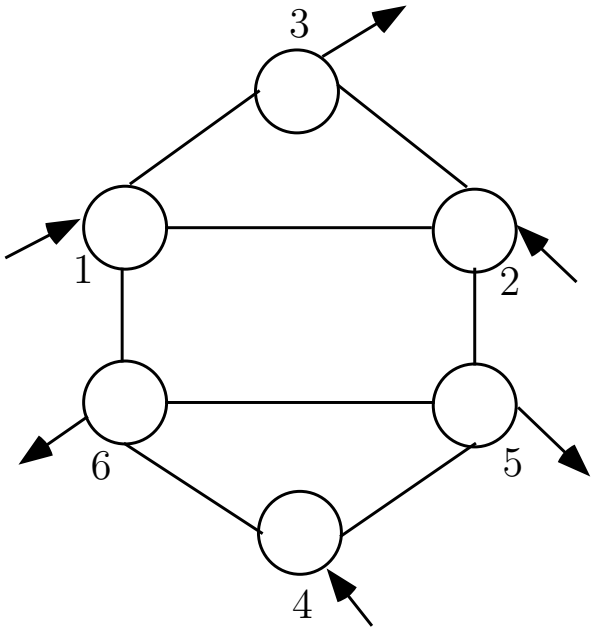
4.2. Multimarket models

- Energy only
- Energy and balancing
- Energy and forward markets
- Energy and transmission
- Energy and reliability
- Each of them taken one at the time

5. Illustration

Chao and Peck (1998) six node model





Assume two firms

$f = 1$ plants located in 1 and 2 $C_i(g_i)$ is the plant variable cost in i

$f = 2$ plant located in 4

Demand located in 3,5,6 $P_j(s_j)$ is the net inverted demand in j

6. Complementarity formulations

6.1. Complete markets (Model A)

- Energy only

$$0 \leq q + Mx \perp x \geq 0$$

$$(0 \leq a \perp b \geq 0;\ a_i \geq 0;\ b_i \geq 0;\ a_i b_i = 0)$$

x: quantities (injection, withdrawals) and prices.

M: M^p, M^c (perfect, Cournot competition and variations thereof).

- Energy and transmission/reliability

$$0 \leq q + M^p x + Ry \perp x \geq 0$$

$$0 \leq r + Nx \perp y \geq 0$$

$r + Nx$: (linearized version of) transmission feasibility, reliability criterion.

6.2. Incomplete markets (Model B)

What if y does not exist ? (reliability and/or transmission unpriced).

- Generalized Nash equilibrium (the old Oren/Stoft debate).
- There are multiple prices for each constraint (one per agent).
- Infinite number of solutions that we do not know how to characterize (as long as one does not complete the market).

6.3. Market Power and transmission/reliability models

- Single stage model (Model C)

$$0 \leq q + M^c x + Ry \perp x \geq 0$$

$$0 \leq r + Nx \perp y \geq 0$$

+ (if thought desirable) arbitrage conditions linking x and y (e.g. energy and transmission prices).

y: price of transmission/reliability taken as such by the agents.

Single solution but

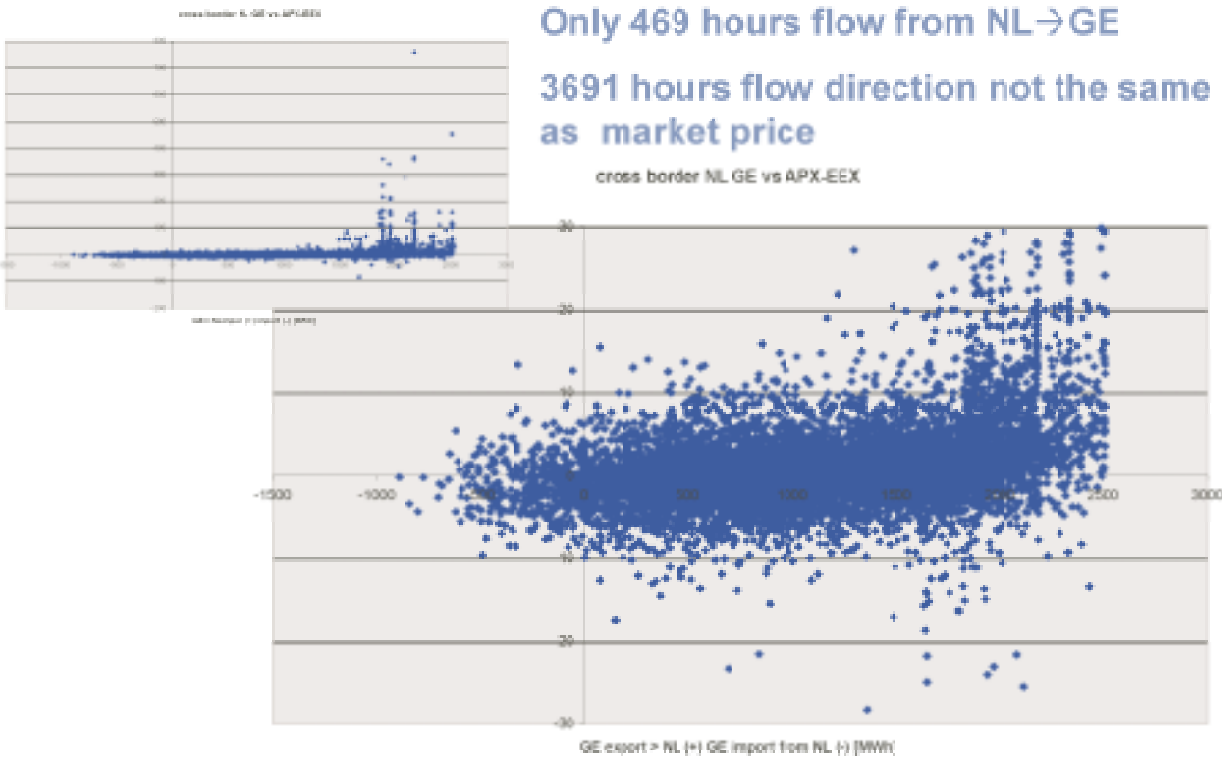
– Asymmetric assumption of competition in energy and other markets

– To what extent is arbitrage really taking place ?

Explicit Auctions may result in wrong border flows

Only 469 hours flow from NL→GE

3691 hours flow direction not the same as market price



- Two stage models (Model D)

$$0 \leq q + M^c x + Ry + Pz \perp x \geq 0$$

$$0 \leq r + Nx \perp y \geq 0 \qquad z = (z_1, z_2 \text{ dual variables})$$

$$\begin{pmatrix} 0 \leq r + Nx & z_1 \\ 0 \leq y & z_2 \end{pmatrix}$$

y (price of transmission/reliability) is manipulated; "$\frac{\partial y}{\partial x}$" is accounted for by z_2.

$r + Nx$ (tightness of system) is manipulated; "$\frac{\partial (r+Nx)}{\partial x}$" is accounted for by z_1.

(Recall again Oren/Stoft debate.)

- the problem is (well known) non convex with possibly no equilibrium or multiple equilibria
- again a generalized Nash game but we do not know how to complete the market
- but (may be less known) it may not have isolated equilibria (multiplicity of dual variables z).

6.5. Discussion

- Model A (complete/energy only/perfect and imperfect competition)

$$\begin{aligned} 0 &\leq q + Mx \perp x \geq 0 \\ M &= M^p, M^c \end{aligned}$$

  is what is found in many studies (Bushnell et al. (2005), Newbery et al. (2003)).

- Model B (incomplete market/perfect and imperfect competition)

$$\begin{aligned} 0 &\leq q + Mx \perp x \geq 0 \\ 0 &\leq r + Nx \quad \text{not priced} \end{aligned}$$

  is probably best to describe the current European system (with "market based" pricing of transmission, and no pricing of balancing and reliability).

- Model D

$$0 \leq q + Mx + Ry + Pz, x \geq 0$$

$$0 \leq r + Nx, y \geq 0$$

  because it

  – may not have a solution

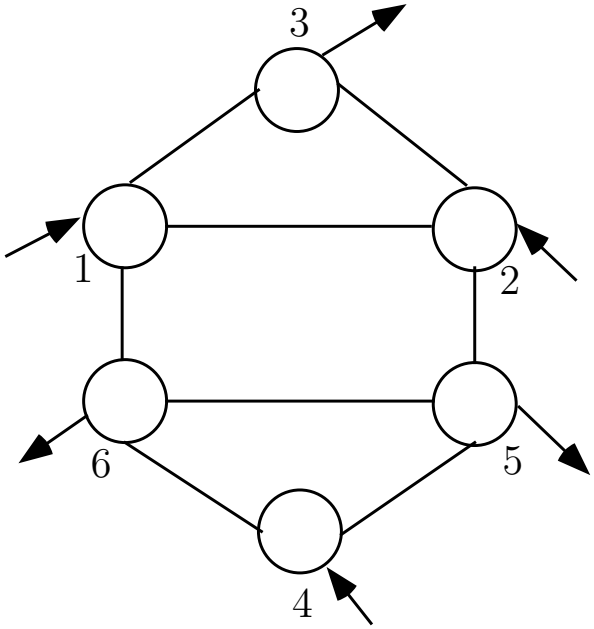
  – may have an infinite number of solutions

  – has been replaced by the notion of conjectured supply curve (Day et al. (2000))

    to avoid numerical problem (but does not solve the economic ambiguity)

7. Energy only models
(Model A: complete, perfect/imperfect competition)

7.1. The reference model (the standard model)



Assume two firms

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- ***Single stage, single period deterministic model are readily formulated***

  – Perfect competition

$$0 \le C_i' + \nu_i - \eta \perp g_i \ge 0; \qquad f = 1, i = 1, 2;\ f = 2,\ i = 4$$

$$0 \le \eta - P_j \perp s_{fj} \ge 0; \qquad f = 1, 2;\ j = 3, 5, 6$$

$$0 \le G_i - g_i \perp \nu_i \ge 0; \qquad i = 1, 2, 4$$

$$0 \le \sum_{i=1,2} g_i - \sum_{j=3,5,6} s_{1j} \perp \eta_1 \ge 0$$

$$0 \le g_4 - \sum_{j=3,5,6} s_{2j} \perp \eta_2 \ge 0$$

– Cournot competition

$$0 \leq C_i' + \nu_i - \eta_f \perp g_i \geq 0; \qquad f = 1,\ i = 1, 2;\ f = 2; i = 4$$

$$0 \leq \eta_f - P_j - P_j' s_{fj} \perp s_{fj} \geq 0; \qquad f = 1, 2;\ j = 3, 5, 6$$

$$0 \leq G_i - g_i \perp \nu_i \geq 0; \qquad i = 1, 2, 4.$$

$$0 \leq \sum_{i=1,2} g_i - \sum_{j=3,5,6} s_{1j} \perp \eta_1 \geq 0$$

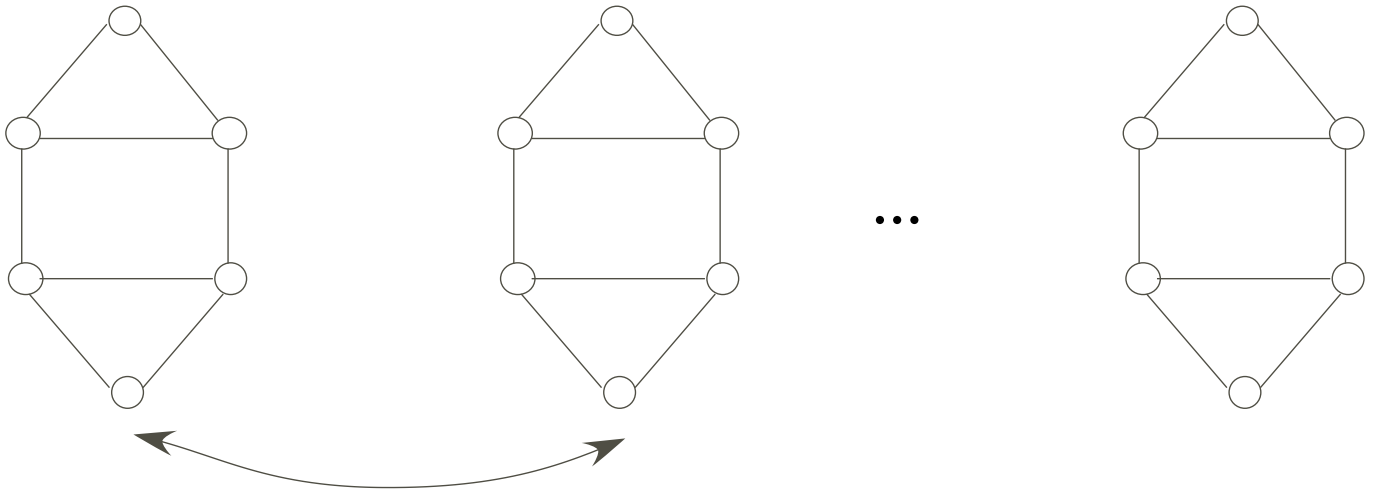
$$0 \leq g_4 - \sum_{j=3,5,6} s_{2j} \perp \eta_2 \geq 0$$

- ***Discussion***
  - Complementarity conditions introduce
    - Non linearities with respect to parameters (0K)
    - Non convexities with respect to parameters !
  - The move from perfect to Cournot competition (or variations thereof) is trivial and does not cause numerical difficulty
  - These models are used to analyze markets and suggest ex ante structural remedies

Are they realistic ?

7.2. The dynamics of power operations

7.2.1. Ramping rate, start up cost and minimal down time constraints



7.2.2. Ramping rate constraints

- Linking the above perfect competition models

  Introduces

  – Additional constraints

  – prices of these constraints and modifications of the equilibrium conditions

  Methodology done, or in the process of being done (Friez et al. (2005)).

- Linking the above Cournot models is not a really difficulty as long as one does not introduce too demanding rationality assumptions.

7.2.3. Start up costs and minimal downtime constraints

- Departure from the complementarity formulation
- We do not know how to handle these constraints in the perfect competition, let alone market power paradigms.
- Mansur (2003), Wolak (2003, 2004)
- Work on this by O' Neill et al. (2004) and Bjørndal and Jörnsten (2005)

Discussion in the literature (Harvey and Hogan (2002)): the computation of marginal cost is difficult; in any case that computation in the standard model is misleading.

7.2.4. Are these important

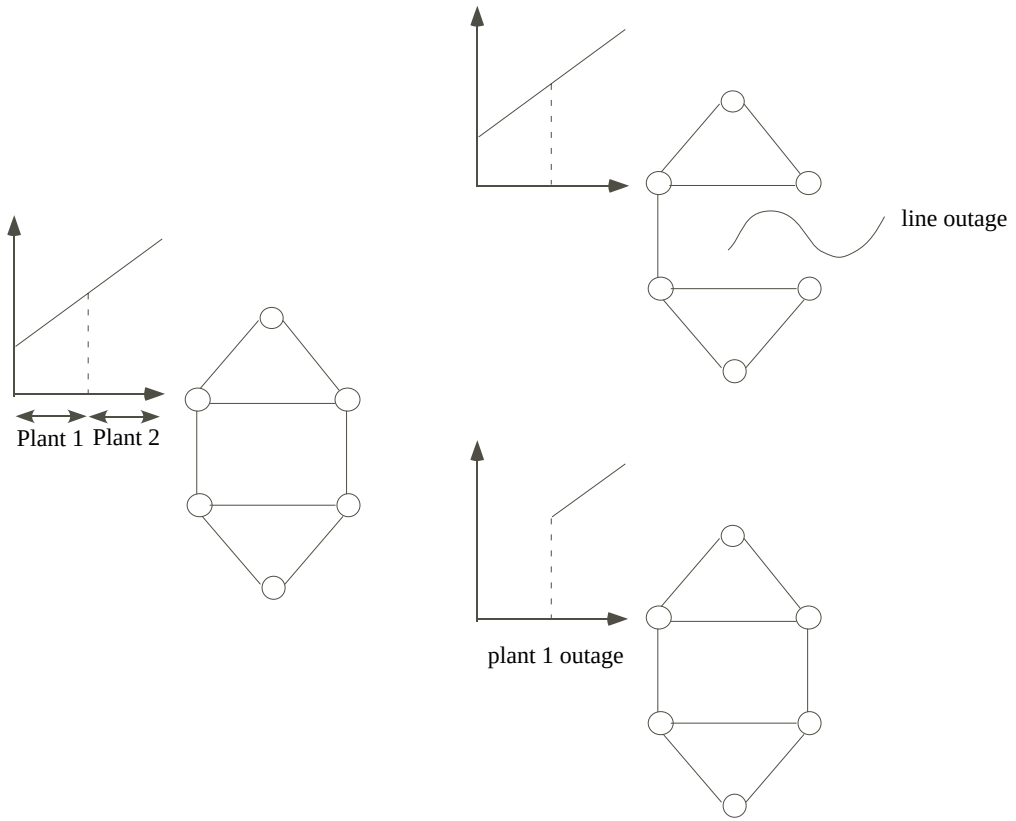
- "These features are internalized in the bids" : yes, but not in the standard model
- In practice: expanding size in PJM has proved useful for mitigating these difficulties (easier unit commitment and accommodation of wind power)
- Structural remedies, by reducing the size would enhance these difficulties (e.g. discussion on flexibility in recent movement in Elsam/Vattenfal)

8. Sequence of energy markets
(energy and balancing: energy and forward markets)

8.1. Energy and balancing

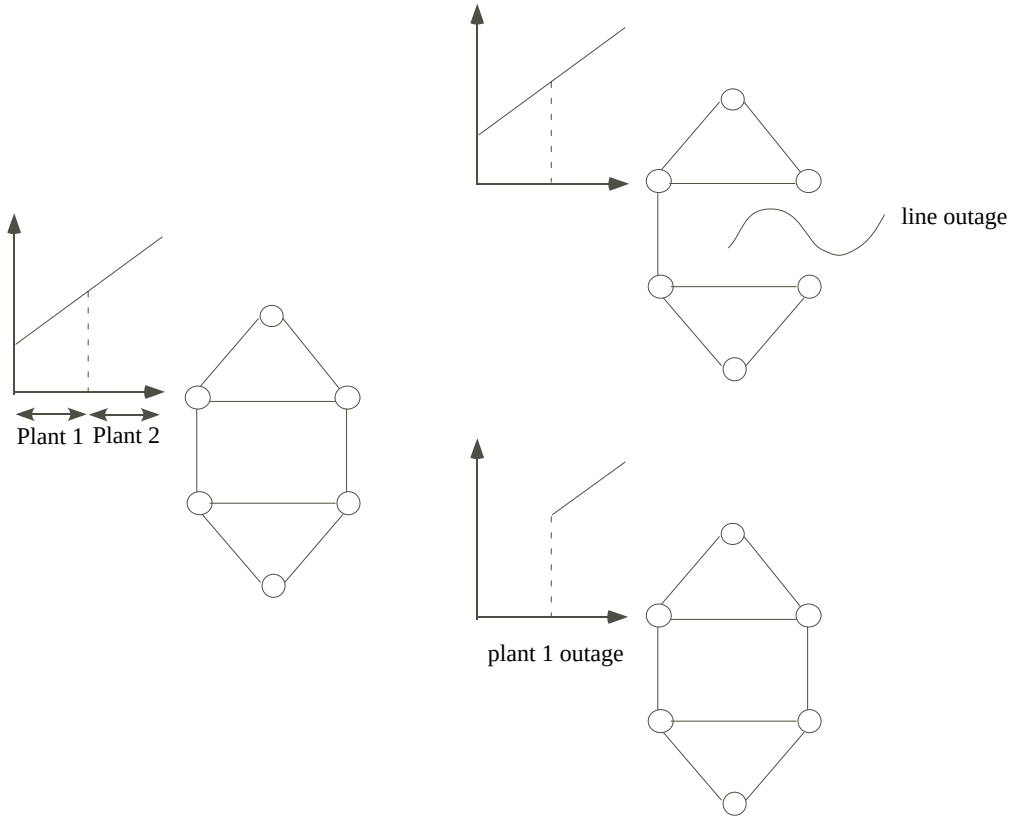
- ***Where is the spot market ?***
  - In the US, the balancing market (in practice (the Pools of the East Coast) and in theory (Wilson (2002))
  - In Europe, the day-ahead market (Nordpool and the national markets)
- ***Where are the forward markets ?***
  - ahead of the spot market
    - day-ahead and before in the US
    - before day-ahead in Europe

- ***Two stage models: day-ahead and balancing***



day ahead market balancing market

- ***Two stage models: forward and day-ahead***



forward market

day ahead market

8.2. Day-ahead and balancing

- ***The perfect competition paradigm***
  - well understood when agents are risk neutral and have identical probabilities of occurrence of a given set of contingencies
  - not really explored otherwise: (e.g. risk averse agents)
  - Little numerical experience with theses models
- ***Market power***
  - Extension to market power ?
  - Existence, uniqueness, computability of sub-game perfect equilibrium
  - Arbitrage (Kamat And Oren (2004)) ?

- ***European idiosyncrasies***
  - Balancing charge is a penalty and not a price
  - The penalty is sometimes determined on the basis (after some transformation) of the day-ahead market or of another market
  - No existing model of that effect
  - We know at least one thing: a penalty in real time increases the opportunity cost in the day-ahead market (with increasing "finding" of market power)
  - This effect is real (NETA)
- ***Implication***

  Measure of market power in the day-ahead market when balancing is a penalty !

8.3. Forward and day-ahead markets

- ***General***
  - Forward contracts (taken exogenously) reduce market power (many authors)
  - But European competition authorities see long term contracts by dominant operators as foreclosing the market
- ***Perfect competition models***
  - Easy: long-term contracts can be neglected (in deterministic models)
- ***Market power***
  - Two stage models
  - For which we have the same methodological difficulties as with day ahead and balancing models
- ***Implication***

Assessment of the endogenous development of forward contracts after structural remedies !

9. Energy and transmission

9.1. The reference paradigm: nodal prices

- Extensively discussed in the literature
- Successful in practice
- Apparently politically incorrect in Europe
- Does not need any reminder

9.2. Discussion

- Current situation in continental Europe: postage stamp in individual countries, Italy and Austria excepted (market splitting)
- Set of more or less ad hoc processes for access to international interconnections
- What if one does not price transmission or does not price it properly (as in the case in several interconnections) ?
- Incomplete market with an infinite set of solutions
- Cournot models in incomplete markets?

9.3. Suppose one prices transmission

- Perfect competition paradigm with nodal pricing is well understood
- But does not extend unambiguously to market power?
- Single and two stage models correspond to different assumptions of rationality of the agents
- It is difficult to choose among these assumptions
- But the results depend on the choice (Ehrenmann and Neuhoff (2005), Neuhoff et al. (2005))

9.4. What about other paradigms ?

- In the US: the nodal price paradigm is expanding
- In Europe: something trying to replicate Nordpool (market coupling) is announced for 2006 in France/Benelux.
- The current situation is too ad hoc to be modelled
- The same can be said of some reliability recommendations of UCTE operations handbook.

9.5. Impact

- The simplest problem is not solved: impact of different organisations of transmission on the relevant market (e.g. application of the SSNIP test).
- More complicated: structural remedies in a market that one cannot model except by assuming it to be entirely national).

10. Energy and reliability

10.1. With exogenous capacities

- A paradigm: the former pool of E & W
  - Reliability is commonly recognized as a public good (even if some see a dual public and private character to reliability)
  - Pricing of reliability was regulated in the pool
  - And E& W was seen as a single node (which makes computation feasible)
  - Perfect competition, energy only models, can readily be extended to accommodate reliability along these lines

- Principle
  - Energy sales must pay for decreasing reliability
  - (Endogenous) available capacities are remunerated for increasing reliability
  - The charge/remuneration is a given multiple of the marginal expected unserved energy (Loss of Load probability)
  - The coefficient is exogenous when the price of reliability is regulated
  - The coefficient is endogenous when the reliability target is regulated.
  - The latter gives a capacity market with smooth demand for capacity.
  - A reserve rate gives a discontinuous demand for capacity.

- Discussion
  - The perfect competition paradigm does not caused any interpretation or computational difficulty for a single node system (computation of a single node Expected unserved energy is easy)
  - The same cannot probably be said in a multi-region (computation of multi area expected unserved energy is a combinatorial problem)
  - What if one does not price reliability?
  - Incomplete markets with an infinite set of solutions
- Market power:the computable version of Creti and Fabra (2004)
  - A two-stage equilibrium model with its usual interpretation and computational difficulties

10.2. With endogenous capacities

- Reliability and capacity expansion
  - Capacity expansion and the distinction between short and long run marginal cost in optimised generation systems
  - Short run marginal cost requires a careful evaluation of the scarcity rent
  - Capacity expansion models of the past included reliability criterion (or expected unserved energy) that added a component to the capacity and operation costs
  - The perfect competition paradigm of capacity expansion can be defined without any difficulty
  - But its market power version is just beginning to be explored (Oren et al (2005), Ehrenmann and Smeers (2005)) and encounters all the same difficulties as two (or more) multistage models

11. Conclusion
(with a focus on Europe)

- Lack of integration enhances market power
- Technically, we know how to integrate the market
- Politically, we do not know how to integrate the market: this integration requires too much harmonisation
- Technically, we are probably unable to assess structural remedies
- Politically, we can implement structural remedies because they can be left to national law; assessment will come ex post

"we have to do something" ... this is something ... so, let us do it"

(R. Green)