5^{th} Atlantic Workshop on Energy and Environmental Economics

Design of Electricity Markets with Renewables

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Two ways of presenting this paper

- Polite (but boring), restricting the analysis to renewables
  - Motivate with current challenges
  - Frame as a problem of market design
  - Formalize & solve the mechanism design problem
- Broad view (provocative, but more interesting):
  - Criticism of the standard framework / design for electricity markets
  - Offer a "mechanism design framework" – formulation, design, advantages and differences

Current challenges to the design of electricity markets

- Desire for cleaner power generation
  - retiring dirty coal plans
  - increasing penetration of renewables
- Problems
  - How to induce this transformation through the design of electricity markets?
  - Even if these changes are implemented somehow, is the *standard market design* suitable for large penetration of renewables?

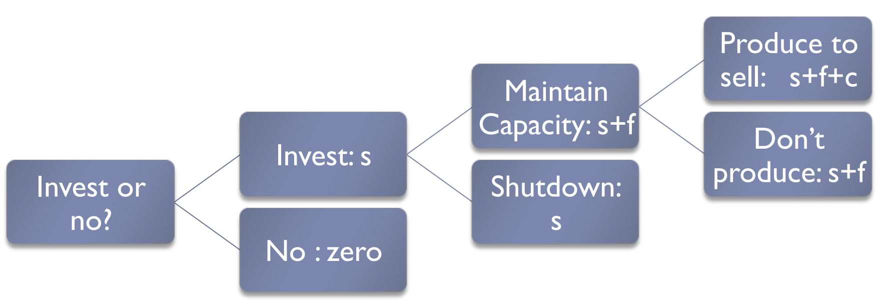
Problems with the standard market design

- In this talk: "standard market design" mean a spot **uniform-price**, energy only market
- Marginal cost of renewables are in general very low (close to zero)
- With higher penetration, renewables are likely to reduce spot prices
- This accentuates the "missing money" problem – investments are not paid – perhaps we don't have enough new investments

Criticism of the standard framework

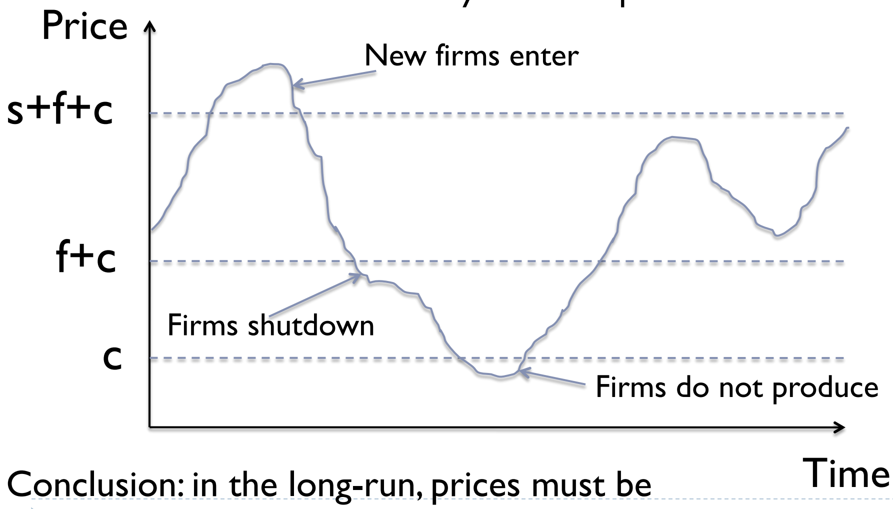
- Review of the standard "competitive / spot market" framework
- Why this framework leads to problems
- Example of inefficiencies caused by this market

Link between costs and decision problems



Dynamics of prices and investment in new capacity

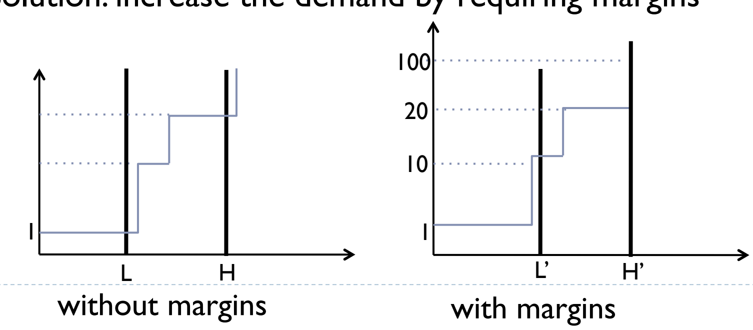
- Dynamics of prices vs. decisions



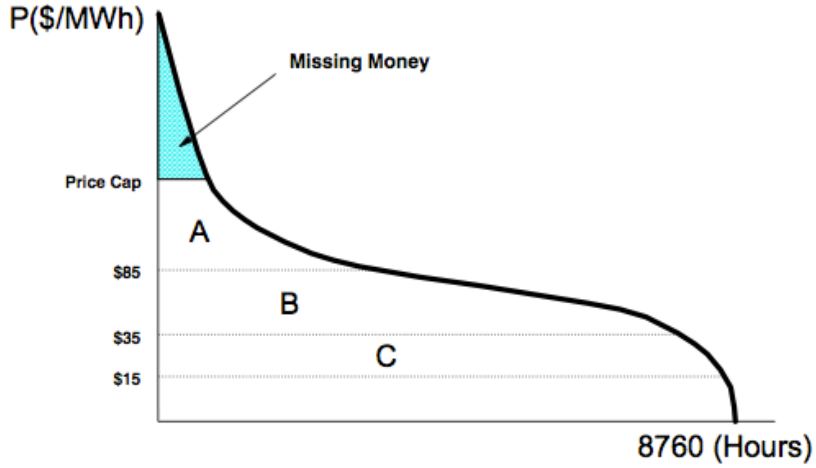
Conclusion: in the long-run, prices must be between S+F+m and F+m

This works fine in theory, but…

- When does price goes much above marginal costs (>S+F+m)?
  - When demand is greater than capacity
  - This corresponds to Blackouts – which society strongly dislikes
  - High prices during peak hours
- Solution: increase the demand by requiring margins



Missing money problem

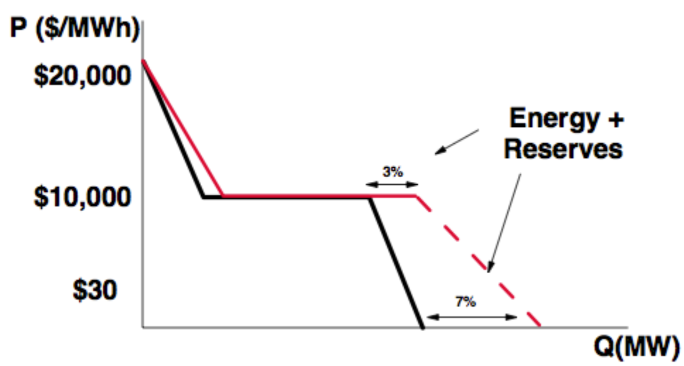


Solution: increase the demand by requiring margins (that would rise normal prices) (Hogan, 2005)

10

Correction: margins added to the demand

Illustrative Energy + Reserve Demand



Energy plus reserve demand defines the demand for generation operating capacity.

11

Source: Hogan (2005)

Comparison of different market designs

	Reliability Targeting	Replace Missing Money	Years new unit covered	Contract Type	Price-Based Performance Incentives	Hedge Extent & Type*
Energy-Only Design Track						
Wolak: contract adequacy	None	No	0	Financial	Weak	Approx.
Oren: call options	None	No	0	Physical	Weak	Approx.
Chao-Wilson: call options	None	No	Yrs. > 0	Physical	Weak	Approx.
Hogan / MISO: energy-only	Price	Yes	0	Financial	Yes	Approx.
Convergent Design Track						
Singh: combined option ICAP	Q / P	Partial	0	Physical	Weak	L. Follow
ISO-NE's LICAP / CPUC	Quantity	Yes	0	Physical	Yes	Over
Bidwell-Henney: call options	Quantity	Yes	4	Physical	Weak	Over
Cramton-Stoft FCM	Quantity	Yes	4—5	Physical	Yes	L. Follow
ICAP Design Track						
Current Northeast ICAPs	Quantity	Yes	0	Physical	No	No
CRAM / PJM Proposal	Quantity	Yes	3	Physical	No	No

* "L. Follow" refers to a load-following hedge. "Approx." means not all load is hedged, but sometimes it is over-hedged. "Over" means that more than peak load is hedged at all times.

- Source: Cramton and Stoft (2006): "The convergence of market designs for adequate generating capacity"

12

An example

- Main reason for using auctions: private information
- Suppose that:
  - Demand is 1 (for sure)
  - Wind generator: fixed and marginal cost: 0; produces 1 with probability q < 1
  - Two standard generators: (private information) cost is c_i
- They face uncertain demand with probability q it will be 0 unit and with probability 1-q it will be 1 units
- Optimal solution: build one unit if $q\,E[c_i] + F_i < (1\text{-}q)V$
- Generators observe private information and decide (independently) to enter or not – let E_i be the event of entering and assume that $Pr(E_i) > 0$
- With positive probability $Pr(E_1E_2)=Pr(E_1)Pr(E_2)>0$, two enter

16

New way of thinking about the problem

- Alternative framework – mechanism design
- Focus: resource adequacy (contract expansion of electricity production to meet increase in demand)
- Problem – decide what projects should be built
- Auction of long-term contracts with two-part payments – fixed payments + marginal costs (like an option)
- Bids: Fixed costs (sunk+fixed) and marginal costs
- *Market Competition* among future producers (no market power) for the contracts
- Efficient allocation

Problem: how to contract for new supply

- private **fixed cost of building of** F_i (sunk plus fixed),
- private per-unit **marginal cost** $\tilde{c}_i$,
- per technology **environmental cost** e_i,
- private per-unit **adjusted production cost** $c_i = \tilde{c}_i + e_i$,
- known **probability of supply** of p_i,
- known **total capacity** K_i,
- known unit **value of lost load** v.

Case with no standard technologies

- Let W be set of producers with $p_i < 1$ and C: $p_i = 1$
- If all producers are in W, choose $x_i = 0$ or 1 to solve:

$$\min \sum_{i \in W} F_i x_i + \sum_{i \in W} p_i c_i x_i + v(D - \sum_{i \in W} p_i x_i)$$

- Easy solution: set $x_i = 1$ as long as:

$$F_i + p_i c_i - v p_i \leq 0 \Rightarrow \frac{F_i}{p_i} + c_i \leq v$$

20

Problem for the standard producers

- For producer i and demand j:

$$b_{ij} = F_i + c_i Pr(d \geq j) = F_i + c_i [1 - F_K(j-1)]$$

Fix the set $K \subseteq W$ and consider

$$h(K) = \min \sum_{i \in C} \sum_{j=1}^{D} b_{ij} x_{ij}$$

$$\text{s.t.} \sum_{j=1}^{D} x_{ij} \leq 1 \ \forall i \in C$$

$$\sum_{i \in C} x_{ij} = 1 \ \forall 1 \leq j \leq D$$

$$x_{ij} \in \{0, 1\}$$

21

Solution

- This optimization problem is a polymatroid and can be solved by the greedy algorithm (fast algorithm)
- Implementable by Vickrey auction
- Solution is efficient
- Truthful bidding is dominant strategy
- This is a situation where the criticisms to Vickrey auction do not apply
  - No complementarities
  - Outcome is in the core
- No risks for investors – important reduction in premium for price risks, translated into lower costs
- Opportunity costs and profits are property of the "load"

22

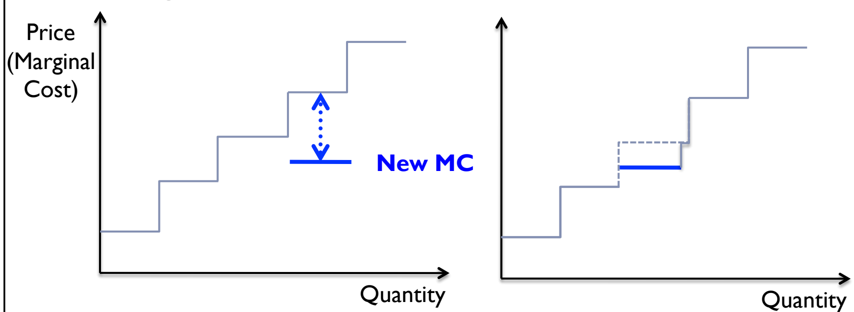
Additional comments

- Note that there is no uniformity of prices
- Economists have argued for the uniformity of prices and spot prices
  - Cramton and Stoft (2007): "Why We Need to Stick with Uniform-Price Auctions in Electricity Markets", The Electricity Journal
- What about existing producers?
  - Long-term contracts
  - This is not very different from some current markets
- "This is a communist solution"
  - Energy-only spot market + "fixes": administrative margins, subsidies for renewables, price floors, etc. And law to create a "market for carbon"
  - Our proposal administrative need: prevision of future need (demand increase), environment cost of each technology

23

There is still a function for the “spot” market

- There are incentives for cost reduction – leads to profit
- If the cost reduction is substantial, a producer may want to improve the probability of being dispatched
- Renegotiation of contracts



Future aspects to incorporate

- Ramp-up costs
- Energy efficiency