Pricing and Capacity Provision in Electricity Markets: An experimental Study

Chloé Le Coq (SITE, Stockholm School of Economics)

Henrik Orzen (University of Nottingham)

STOCKHOLM SCHOOL OF ECONOMICS

SITE STOCKHOLM INSTITUTE OF TRANSITION ECONOMICS

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Operating reliability and Price cap

- General concerns about *operating* reliability in the electricity sector
  - rolling blackouts, voltage reductions and public appeals for emergency conservation in California, Ontario, Chile, New Zealand and Brazil, the network collapses in the Eastern and Western U.S., Italy and elsewhere (Joskow, 2006)

- A problem for market designers: remunerating generators for the provision of peak load electricity
  - Peak capacity levels required only for very short time periods.
  - Profit-maximizing generators will avoid unnecessary excess capacities.
  - When capacities and peak demand come into close proximity, price spikes are likely to occur.

- Price cap in California
  - 9 July 2002: CAISO cut its price cap by nearly 40% : $57.14 per MWh
  - 11 July 2002: FERC returned to the region-wide cap $91.87 per MWh

"the caps could cause severe supply disruptions…We act now because we cannot expose customers in California and other Western states to the *risks of a low price cap*." FERC, 2002

This talk

How price caps affect *operating* reliability in electricity markets?

— *operating reliability*: supply and demand are balanced in real time *given* the existing physical capacity

Focus: price cap levels and efficiency of the uniform-price auction

Fabra et al. (2006, Rand and 2008)

1. Underinvestment : offer less than the *existing* physical capacity
2. Higher cap reduces underinvestment

Our experimental results with different cap levels

the cap matters for types of inefficiency

- Underinvestment with low cap but overinvestment with high cap
- Price between MC and cap with (small) excess capacity in HighCap

=> failure of the minimization of the variable costs

Experimental design, overview

Subjects in the role of firms; 4 firms per market

Capacity choice: up to 9 units

- Cost function:
  - Fixed cost for each unit: 7
  - Increasing MC: 1 unit costs 1.00; 2 units cost 2.00 etc.

Two cap levels: 30 *(HighCap)* and 15 *(LowCap)*

Timing-one round

Stage 1: simultaneous **capacity choices (up to 9 units)** under demand uncertainty

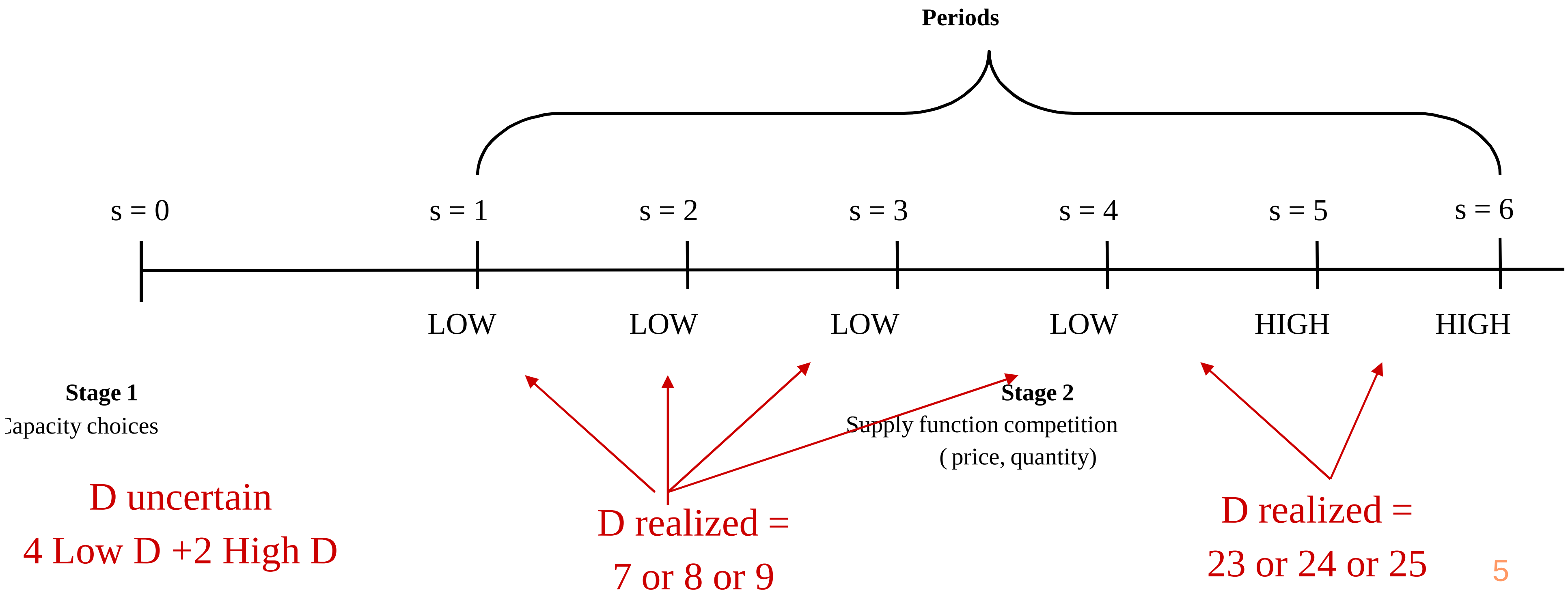
— Capacity choices are publicly observed

Stage 2: price competition for 6 periods Uniform-price auction:

— Demand is realized

— subjects bid independently and simultaneously

— Uniform price auction: price equals to highest accepted bid



First best and potential inefficiencies

First Best:

(i) no rationing at all demand levels => total capacity = 25

(ii) Minimization of variable costs (MC equalization across units)

Potential inefficiencies

(i) Allocative inefficiency

- demand may be rationed too often due to underinvestment in capacity

(ii) Productive inefficiencies

- Over investment in capacity: some capacities are never used
- Due to market power, MC equalization across firms may fail

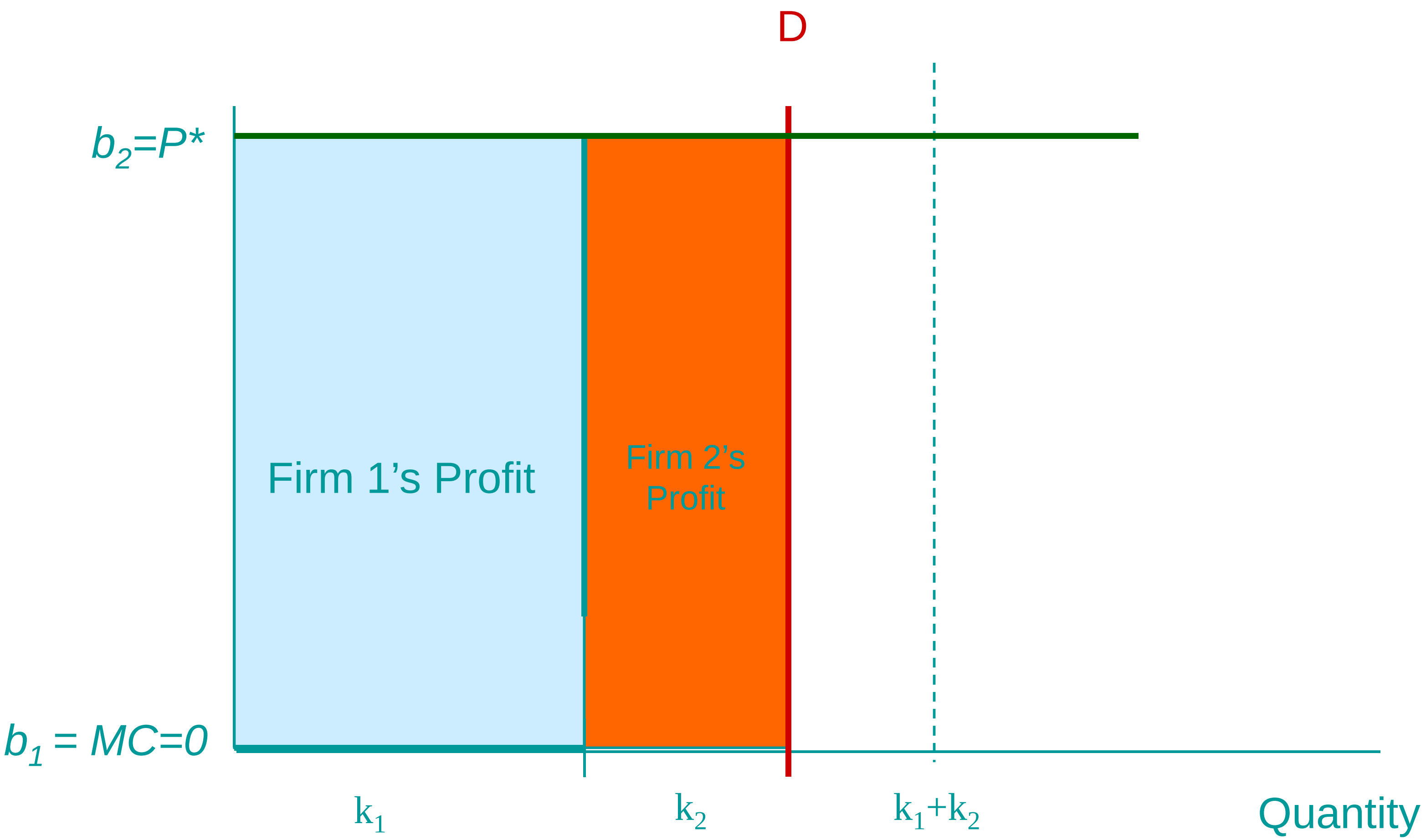
  => variable costs may not be minimized

Equilibrium in uniform-price auction

Example (small excess capacity): $D < k_1 + k_2$

Simplifying assumption: $MC_1 = MC_2 = 0$

Firm 1 bids b_1 and Firm 2 bids b_2 => price = P*



Pure Strategy Equilibrium in price subgame

Large excess capacity

Ex: Total capacity = 6+6+6+5 = 23 > 9 = Demand

=> MC-pricing (as in Bertrand)

Demand rationing or Small excess capacity

Ex 1: Total capacity = 6+6+6+5 = 23 < 25 = Demand

All firms bid the price cap for all their units

Market price = price cap

Ex 2: Total capacity = 6+6+6+7= 25 > 23 = Demand

3 firms with 6 units bid MC and firm with 7 units bids the cap

Market price = price cap

Pure strategy equilibria in capacities

Low price cap (=15)

(6,6,6,6) => total capacity = 24

Remarks:

1. Demand rationing when D = 25
2. Coordination problem in price game when D = 23
3. Variable costs minimized for all demand levels even when price = cap

High price cap (=30)

(6,6,6,7) => total capacity = 25

Remarks:

1. Coordination problem in capacity choices
2. Coordination problem in price game when D = 23 and (possibly when) D=24.
3. Variable costs need not be minimized when price = cap

Difference in aggregate capacity between LowCap and HighCap:

larger mark-up with 25th unit in *HighCap* when price = cap and demand is high

=> higher cap motivates fixed cost of extra unit

Capacity choice and Av. Spot Market Prices

	Low Demand	High Demand
CAPACITY CHOICE		
LowCap	21.8	
HighCap	26.2	
PRICE CHOICE		
LowCap Rounds 3-10 [Rounds 1-2]	2.85 [3.06]	13.23 < 15 [7.2]
HighCap Rounds 3-10 [Rounds 1-2}	2.91 [3.12]	24.3 < 30 [7.21]

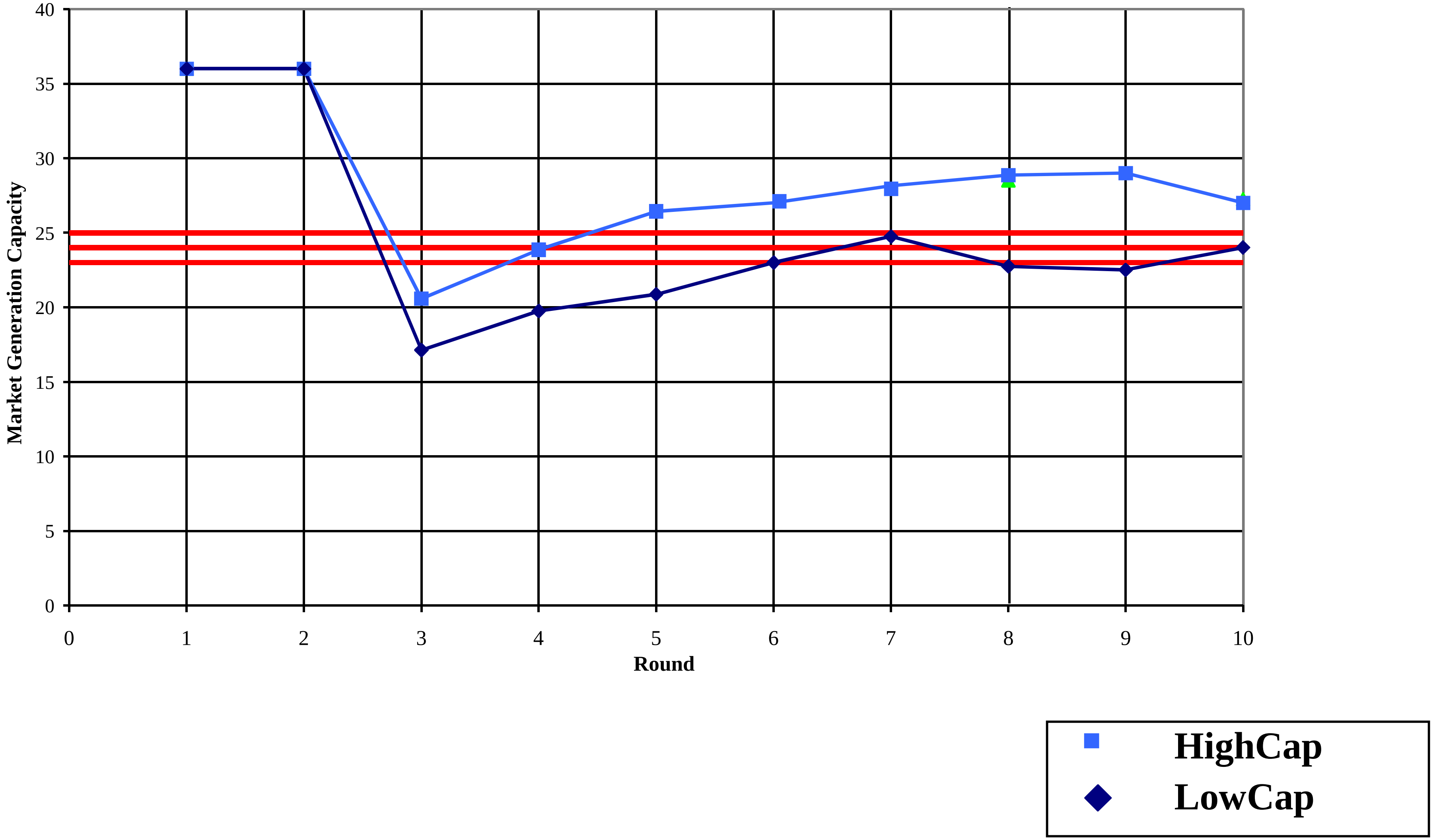
H1: Underinvestment for LowCap (24) and efficient investment for HighCap (=25)

=> Hypothesis 1 rejected in HighCap

H2: MC pricing when demand is low (= 7,8 or 9) => Hypothesis 2 confirmed

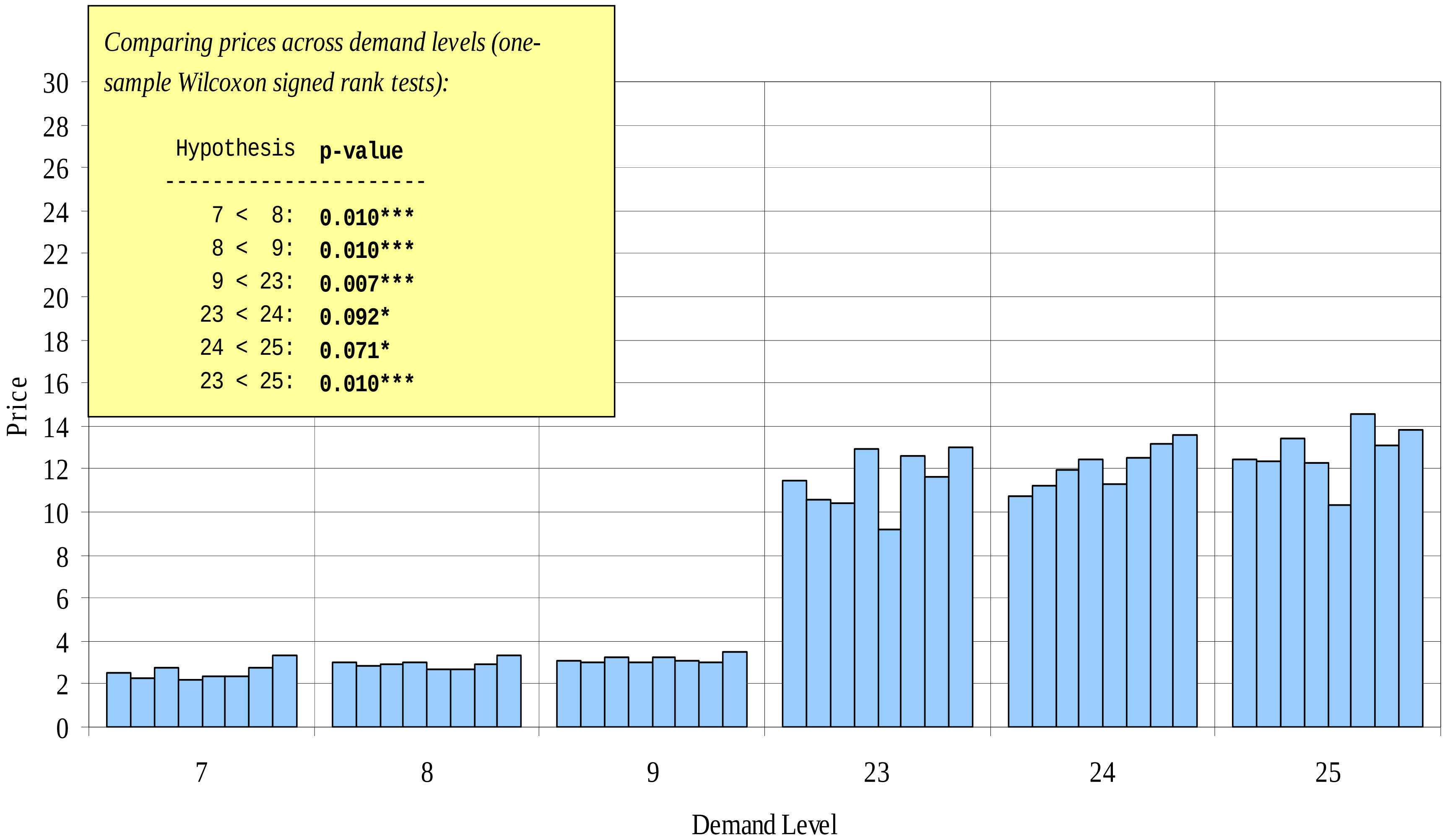
H3: Price = Cap when demand is high (= 23,24 or 25) => Hypothesis 3 rejected

Aggregate Capacity per round

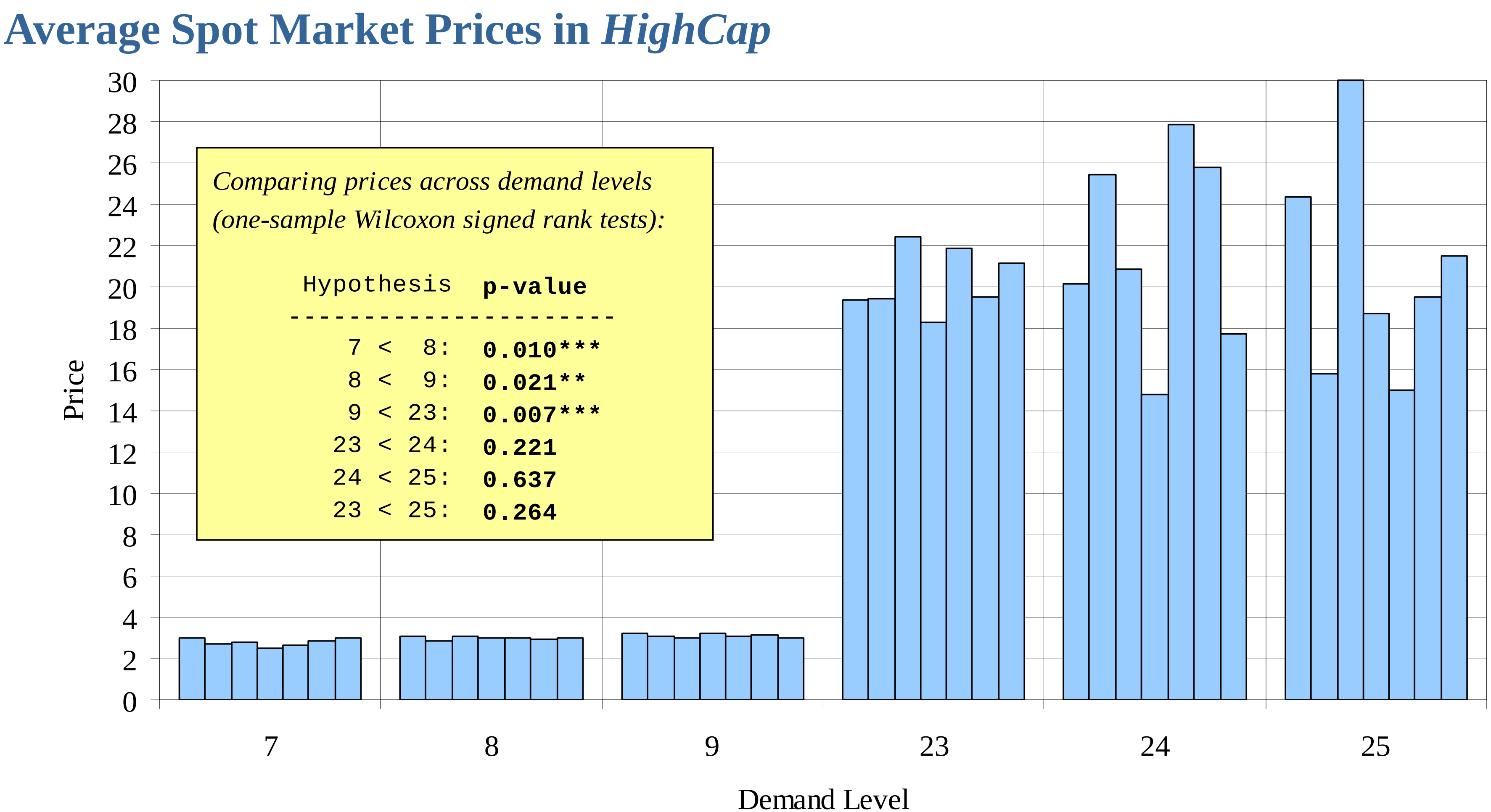


Price variability when D is high

Average Spot Market Prices in *LowCap*



Price variability when D is high, even more so in HighCap



Variable cost minimization fails when demand is high

H4: Variable costs

(i) are minimized in *LowCap*

(ii) need not to be minimized in *HighCap*

In LowCap:

Demand rationing with asymmetric capacities => no MC equalization

In HighCap:

(Small) Excess capacities => High price volatility => no MC equalization

Main results on price cap effect

Focus: price cap effect on the uniform-price auction outcome

Main Results: Price cap level matters in types of inefficiencies

- Underinvestment in LowCap and Overinvestment in HighCap
- MC equalization fails when demand is high for different reasons
  - — D rationing in *LowCap*
  - — Small excess capacities in *HighCap*

More treatments to explore

1. Demand side*:* effect of an elastic demand
2. Capacity payment with *LowCap* : compensation for providing units
3. Students and Practitioners

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Energy-only approach vs Explicit capacity payments

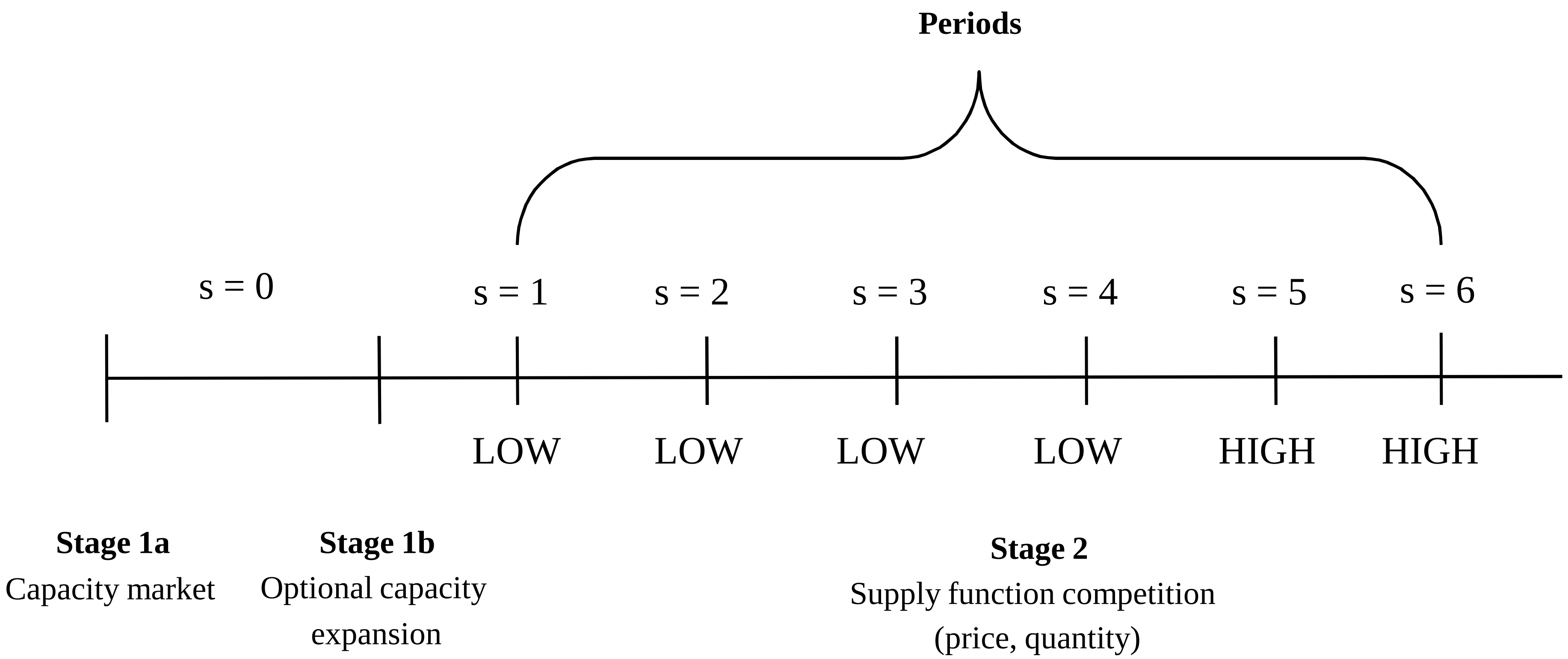
- Energy-only approach with price cap
  - — Selling electricity itself is the only source of revenue.
  - — From this generators have to cover their current variable/marginal costs as well as their earlier capacity investment costs.
  - — Price spikes in times of peak demand are necessary and reflect a return of capacity investment, “concentrated” into a very short time period, and contain scarcity information.
- Explicit capacity payments
  - — e.g., administratively determined direct capacity payments
  - — e.g., capacity market with obligation to contract expected demand

Different rules for remunerating generators

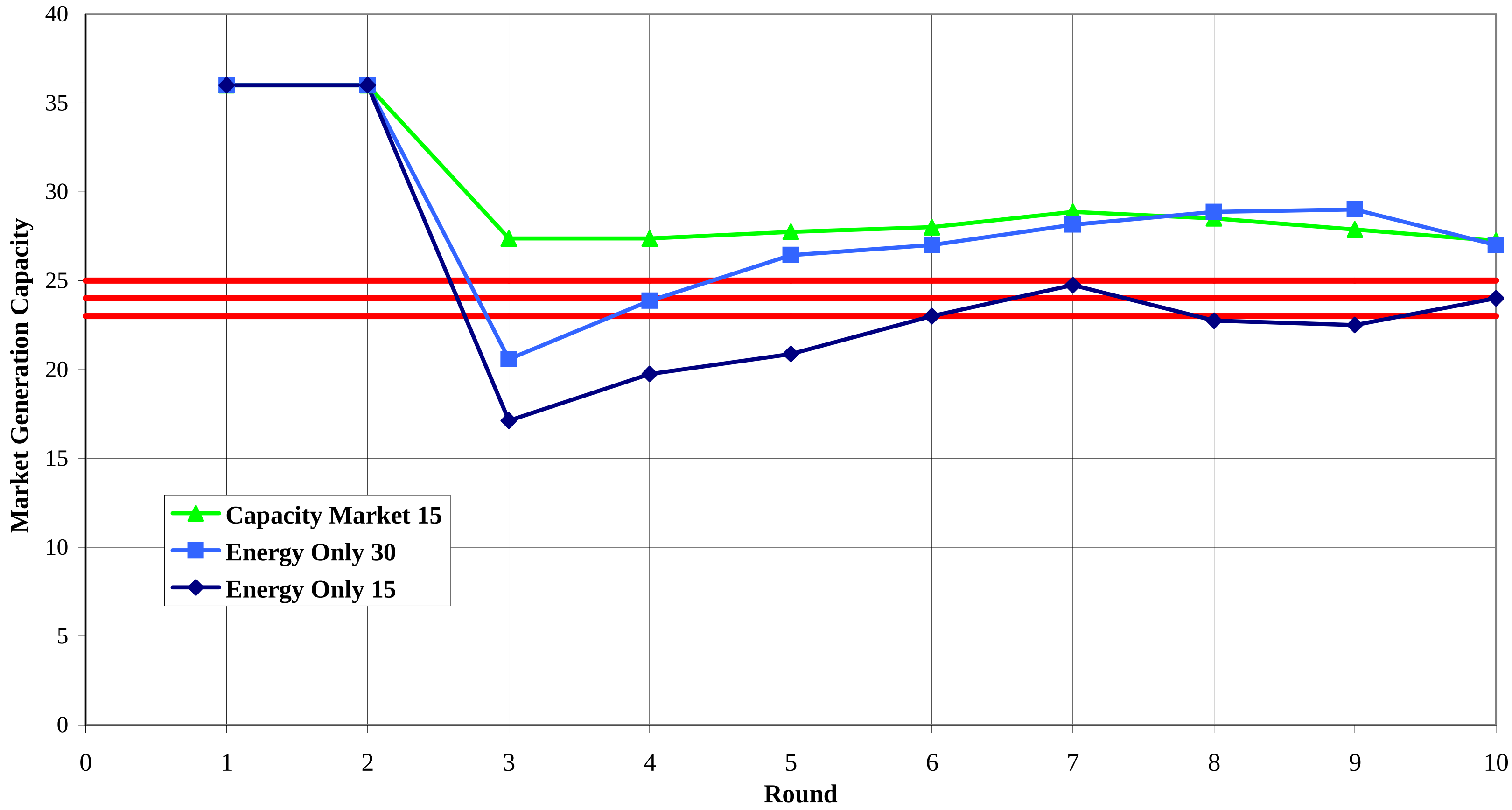
Market structure	Countries
No explicit price	Australia, California, Scandinavia (in the beginning)
Direct compensation	Argentina, Colombia, Spain UK (until 2001)
Capacity market	Pennsylvania, New England, New York, Norway and Sweden (since 2001)

Capacity market treatment

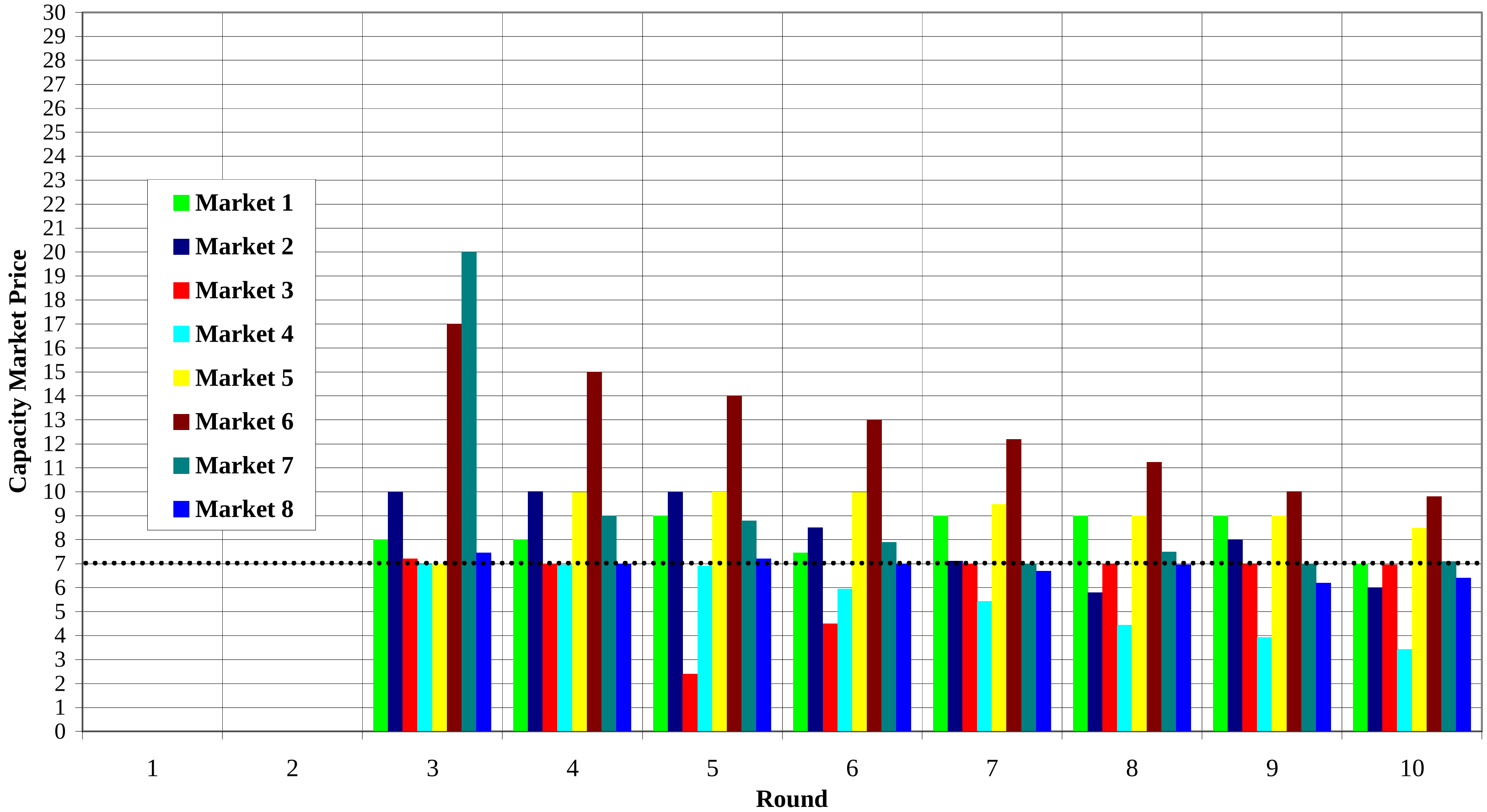
Capacity market: Regulator “buys” 25 units of capacity. There is a spot market price cap of 15.00 and a capacity market price cap of 30.00



Market Capacity over Time



Price in the market price



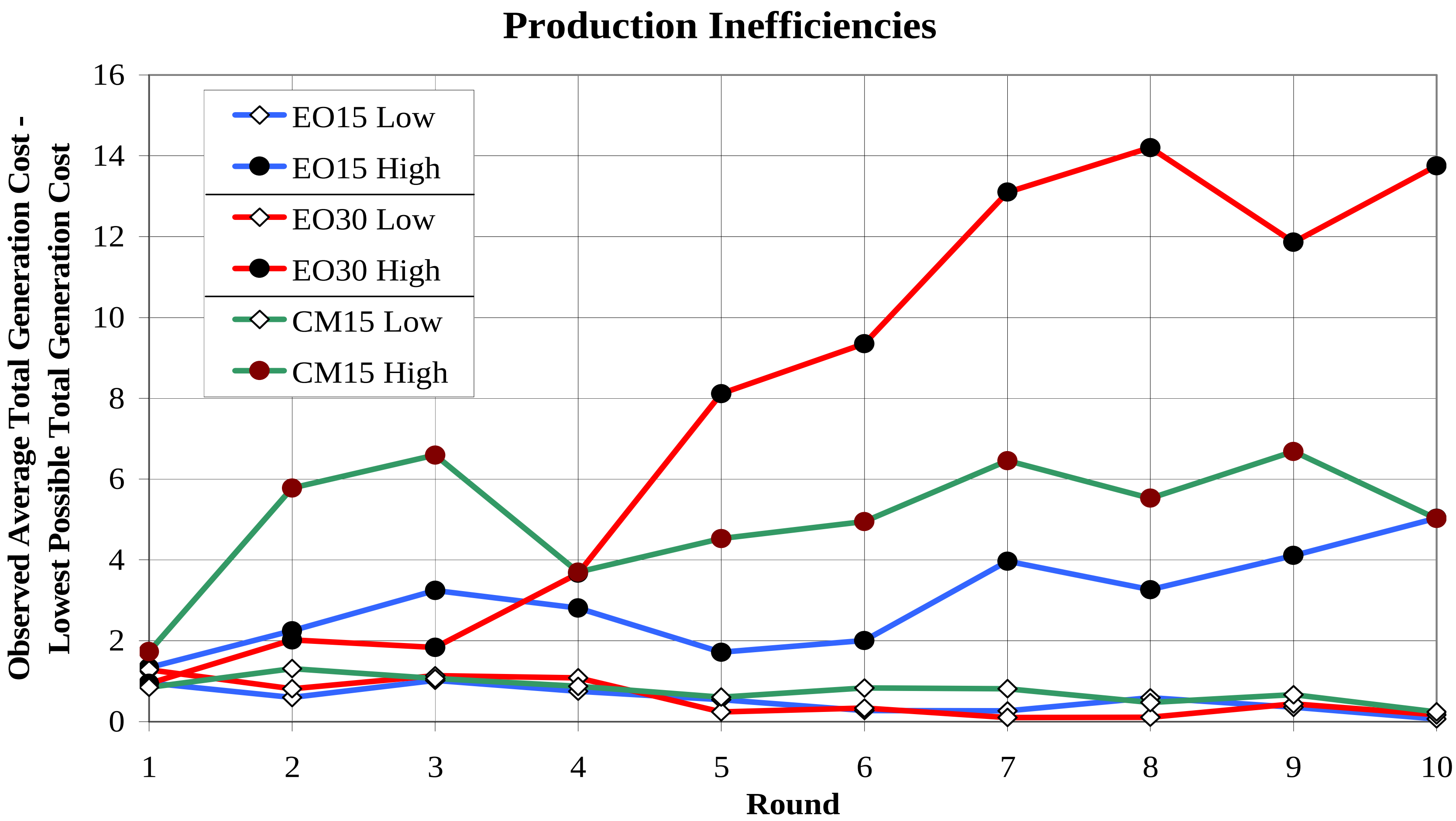
Market price

	Low D	High D
Low Cap	2.85	13.23
High Cap	2.91	24.3
Capacity Market	2.98	10.9

Market price among treatments

	Low D	High D
Low Cap	2.85	13.23
High Cap	2.91	24.3
Capacity Market	2.98	10.9
Av price of the Capacity Market:	8.27	8.27

Production Efficiency



Summary & Preliminary Conclusions

- Experiment to explore relationships between generation capacity, competition and adequacy of supply in different regulatory settings in an abstract and controlled laboratory environment
- Price spikes do have signalling function. On the other hand, they are not necessarily a manifestation of inadequate supply.
- Not clear at all that price spikes are out-of-equilibrium situations.
- What is “sufficient” capacity?
- Short run: High production capacity and competitive pricing go hand in hand.
- Long run: To some extent a trade-off between adequate supply & low prices.
- Are price caps unambiguously evil?
  - Problematic if they distort capacity investment signals
  - Perhaps necessary in electricity markets with a lacking demand response
  - Price cap works quite well in our framework when combined with capacity market (firms do not need extra profits to recover capacity costs)