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Assessing the performance of Electricity Markets: Part II

Prepared for the CEEM and ISCR Workshop on

Electricity Restructuring

UNSW 19 & 20 April 2007

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Real options created by storage can explain high electricity prices

with Graeme Guthrie

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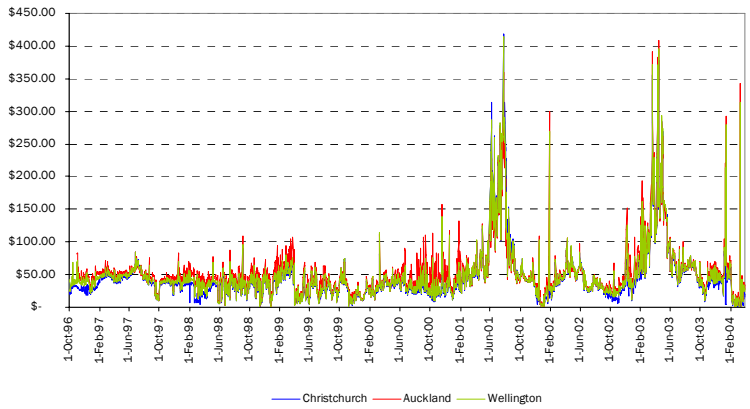
Pricing and Storage: management of scarcity or market power



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Introduction

- We explain the role ("convenience") of storage of water and gas in optimal generator bids when there is no market power, and extend explanations of "convenience" in commodity markets.
- Electricity spot markets have high-price episodes that would benefit from explanations that allocate outcomes between market power and desirable management of scarce resources
- Studies of market power in California and the UK have not properly incorporated "convenience";
- Most (e.g. Borenstein, Bushnell, and Wolak/Joskow & Kahn).conclude that the 2000-2001 episode was largely due to market power on the part of generators: but Cicchetti, Dubin and Long (CDL) assess electricity prices as reasonable given demand and supply (fundamental) factors of the period.
- We find optionality of storage to be more important than marginal generation cost: offering a plausible basis for CDL's conclusion

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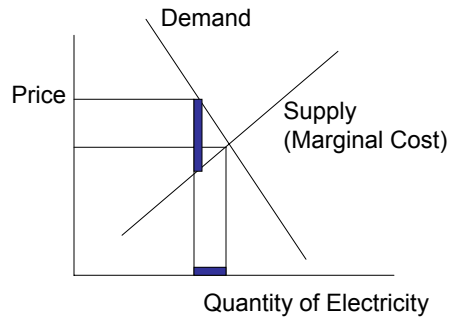
Studies of Market Power: UK and CA

Treat
Supply as mechanistically supplied
Rank in order of unit cost depending largely on the price of fuel

Issues
Funding fixed costs, capacity constraints etc

Uncertainty
Outages are "handled"
Fuel availability is not "handled"



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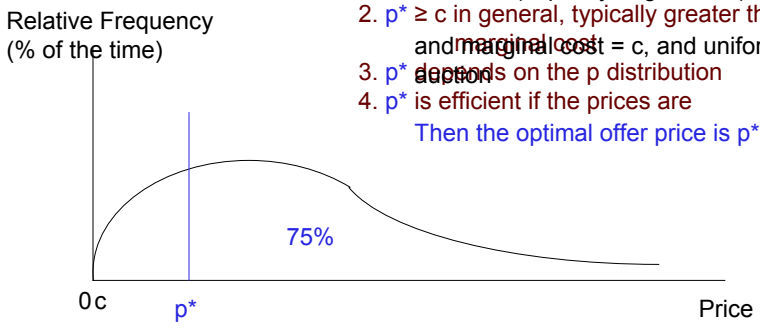
Hydro-generator Offers with Storage, No Market Power, Price Volatility

Notes:
1. Storage imparts a valuable delay option: shift generation through time
2. p* ≥ c in general, typically greater than marginal cost
3. p* depends on the p distribution
4. p* is efficient if the prices are

Suppose (Fuel Capacity) / (capacity to generate) = .75
and marginal cost = c, and uniform-price auction
Then the optimal offer price is p*



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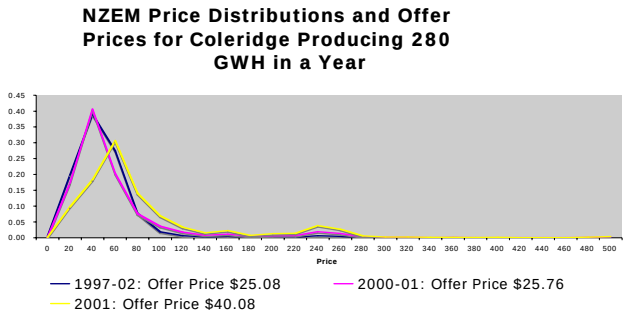
Offer Price under Storage Correlated with the Market Price Process



- Offers positively correlated with the general price level
- Offer depends on the (expected) distribution of prices: mean and volatility

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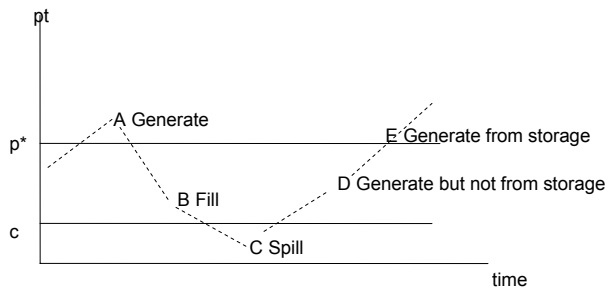
Volatile Price *and* Uncertain Fuel Availability Water Arrival Starting with an Empty Lake



Continuity of the price process implies use of pay-as-bid prices

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Volatile Price *and* Uncertain Fuel Availability

No Market Power

- Electricity price uncertainty

$$dp = 29(62 - p)dt + 10p^{1/2}d\xi$$ (CA 2004/5) Katrina

$$dp = 47(74 - p)dt + 30p^{1/2}d\xi$$ (CA 2005/6)

[Prices : day-ahead pay-as-bid]

- Fuel availability uncertainty where water arrives in 1 unit lots with probability πdt in each dt: i.e. on average every 1/π years, and
- can store 1 unit (in a lake)

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Derivation of The Value of Stored Water [G(p)]:

- A value function for stored water is the expected return G(p) that should satisfy (1) - (3) if a full lake remains full :

a. Spill yields zero profit so $G(p) \geq 0$ (1)

b. Could generate so $G(p) \geq p - c$ (2)

c. Retain water so expect gain G(p+dp) minus *expected* opportunity cost of water arriving at a full lake ≥ 0: (3)

- G(p) is solved for using (1)-(3) the spot price process and probability of water arrival πdt

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Note on the source of the opportunity cost of stored water

Retain water so expect gain
G(p+dp) minus *expected* opportunity cost of water
arriving at a full lake ≥ 0: (3)

The expected opportunity cost being

π [pay-off to an empty lake - pay-off to a full lake (equivalently no lake)]dt

π [max {0,G(p),p-c} - max {0,p-c}]dt = π [G(p) - max {0,p-c}]dt

because if it is desirable to lake keep full then G(p) > max{0,p-c}

Thus $G(p) \geq e^{-rdt}E[G(p+dp) - \pi (G(p)-\max\{0,p-c\})dt$ is (3)

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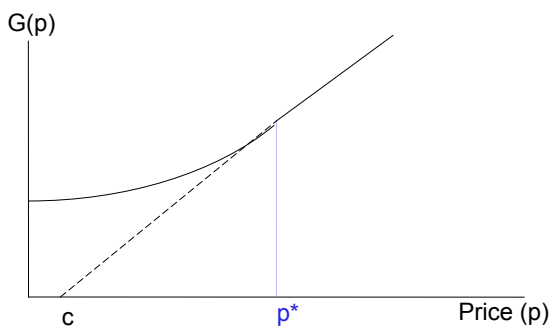
The Value of Stored Water: Characteristics



1. ----- value of water without storage
   G(p) and hence p* are increasing in
2. 0 < dG(p)/dp ≤ 1 and G(p) = p - c if p ≥ p*= min{p; p = c + G(p)}
   - the volatility of prices and
3. Generate from a full lake if full cost covered i.e. whenever p ≥ p*
   - scarcity (reduced probability of inflows)

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Optimal Hydro Bid Prices in CA: 2004/5 and 2005/6

Days to Refill Average	2004/5 mc = 1;	10	2005/6 mc = 1
infinite	93	94	181
365	84	84	144
36.5	74	74	114
3.7	67	67	91
0.0	1	10	1

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Storable Resources with Alternative Uses (Spot Market): e.g. Gas

(no market power)

- Stored gas may
  - used for electricity generation or
  - sold on the gas spot market: at price g
  - take time to re-fill and there may be prospective unavoidable shortages
- We model the value of stored gas G(p,g) with
  - the probability of arrival re-interpreted as delays in delivery and re-filling,
  - stochastic processes for electricity (p) and gas prices (g): possibly correlated.
  - one unit of gas producing h units of electricity where 1/h is the heat rate.
- We illustrate the characteristics of G(p,g) numerically, given that we have not found a closed form expression for it.

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The Gas Price (g) Process

electricity as before

$$dg = 36(6-g)dt + 3g^{1/2}d\varsigma$$

(CA 2004/5)
Katrina

$$dg = 13(7-g)dt + 4p^{1/2}d\varsigma$$

(CA 2005/6)

[Prices : pay-as-bid]

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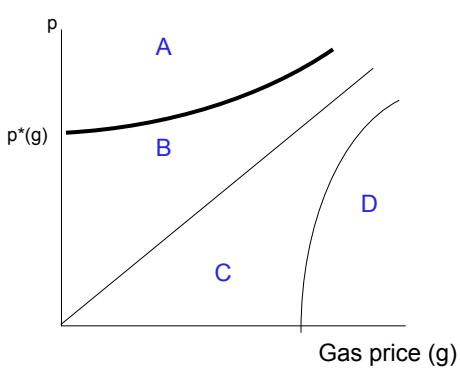
Optimal Bid Prices for Gas Plants



Calibration settings
CA 2004/5 price processes
c = 0
Refill average 36.5 days
r = 0.04
1/h 6.8 MMBtu

Optimal Bid Price p*(g) is p given g such that

ph = c + max{g, G(p,g)}

For {p,g} in area:

A use stored gas to generate electricity

B don't generate with stored gas: but purchase un-stored available gas and generate

C don't generate with stored or un-stored available gas

D sell stored gas into the spot market

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Optimal Gas Generator Bid Prices in CA: 2004/5 and 2005/6

Generation Offer Price p*(g)

Days to Refill Average	2004/5 gas price (g) 6.30	2005/6 gas price (g) 7.32
infinite	91	176
365	81	141
36.5	72	113
3.7	64	90
0.0	43*	50*

Calibration

Price processes: estimated
Gas price: estimated long run levels
Low heat rate: prices higher for less efficient plant
***Marginal cost**: where gas used at LR spot price
Interest rate r = 0.04

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Backwardation and the Convenience Yield Literature

- Argue that forward price = spot price + the cost of carry
- Observe "backwardation" where:

  spot price > forward price + cost of carry and storage occurring

  => argument that there is some "convenience yield"
- There has to be a reason (economic calculus) for the "convenience".
- Backwardation can arise
  - in a certain world as a result of storage and transport costs (Brennan et al, 1997)
  - in an uncertain world where there are frictions
  - in hydro-generation where uncertain inflows *and* prices are present

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Final Comment

- The NZ electricity market provides a residual value for water and manages water scarcity across regions, time, relative to other fuels and (potentially) other uses such as irrigation.
- Inter-temporal substitution made possible by storage desirably manages fuel volatility utilising the full opportunity cost of delay
- This opportunity cost is sensitive to the (expected) price process and fuel delivery uncertainty
- Implies assessing market power in markets with storage should consider the options provided by storage.
- Rational expectations models are implied

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