Climate and the NZ Electricity Spot Market

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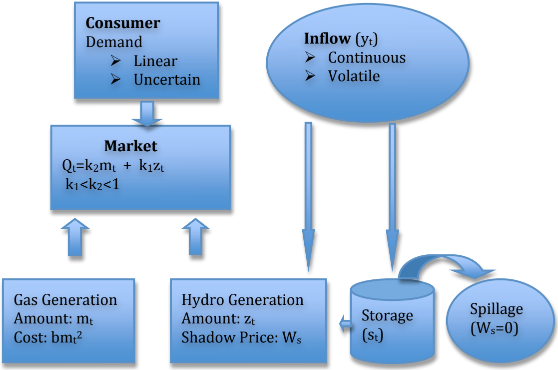
Draws on work of Lewis Evans, Graeme Guthrie, Andrea Lu and John Nash

Outline

The Spot Market

The Market



New Zealand Electricity Market Calibration

- Quantity: q is TWh
- Demand curve: $P(q) = 185 - 3.47q$ [plus price shocks for a given quantity]
  elasticity of demand = 0.4 (Borenstein and Bushnell, 1998)
- $k_1 = 0.956$ (Otahuhu-Benmore)
  $k_2 = 0.984$ (Otahuhu-Hayward)
- Generation Capacity $\bar{z} = 47$ and $\bar{m} = 35$ TWh/y
- Lake Capacity $\bar{s} = 4.44$ TWh
- The risk-free interest rate $r = 0.04$
- Cost of gas: $C(m) = 0.7112m^2$
  - Marginal cost of generating the total quantity of non-hydro electricity generated in 2007 plus transmission costs equals the market price in 2007.

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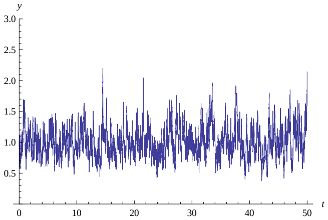
50 Years of Daily Inflows

- stationary diffusion process: with mean = 1
- increment in inflow =mean reversion*(1-inflow) + shock (affected by variance and inflow level)
- $dy_t = 6.9448(1 - y_t)dt + 0.9056\sqrt{y_t}d\epsilon_t$



Social Planner Objectives I

- Given m_t and z_t, the flow of net social benefit at date t is

$$NSB(z_t, m_t, y_t) = \underbrace{\int_0^{k_2 m_t + k_1 z_t} p(q)dq}_{\text{area under demand curve}} - \underbrace{c(m_t)}_{\text{gas generation}}$$

- No other use for water and reservoir fixed cost, so no water cost in flow of net social benefit
- Social planner's ultimate interest is in maximizing the *expected present value* of net social benefit

$$W(s, y) = E_0 \left[\int_0^{\infty} e^{-rt} NSB(z_t, m_t) dt \right]$$

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- <1-> Given generation policy (m, z), total welfare W must satisfy

$$\underbrace{rW}_{\text{``required return''}} = \underbrace{\underbrace{NSB(m,z,y)}_{\text{Net Social Benefit}} + \underbrace{(y-z)\frac{\partial W}{\partial s} + \nu\frac{\partial W}{\partial y} + \frac{1}{2}\phi^2\frac{\partial^2 W}{\partial y^2}}_{\text{expected social ``capital gain''}}}_{\text{expected ``total return''}}$$

- Planner chooses generation (m, z) to maximize RHS: that is, maximise the social planner's "short-run" objective function

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Solving: Find Gas (m*) and Hydro Generation (z*) and hence change in storage (s*) for which

- price = marginal cost of gas adjusted for transmission
- price = shadow price of water adjusted for transmission
- <3-> there is inter temporal consistency: ie the shadow price of stored water and generation (and consequent change in storage) satisfy at each instant in time (given the inflow and storage at that time)

$$\text{"}\textit{required return}\text{"} = \textit{Net Social Benefit} + \textit{expected} \text{"}\textit{capital gain}\text{"}$$

- subject to a) reservoir constraints and b) generation constraints.
- solve iteratively A) construct a file (cube) of consistent inflows, demand shocks and the shadow price of water. B) let inflows, demand evolve over time ensuring storage and generation are consistent.

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Lets Now Solve

the code

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4CXjvpSHnV5zrXF8PAfF/LHxfPR5kyK3Gh5z+nvfxb3W4zkpz9Nr1RQnYJWw

Summary Interpretation:

the social planner decisions = competive market

- 1/2 hour-by 1/2 hour generation decisions are
  - static but linked to future by the shadow price of stored water
  - based upon inflows and stored fuel
  - forward looking (expectations)
  - affected by volatility in inflows and demand
- outcomes and economic welfare are affected by
  - the structure of demand and supply
    - e.g shape of demand
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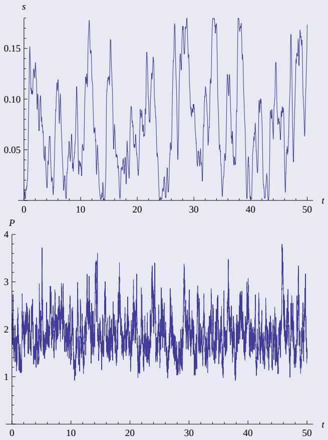
Storage and Price



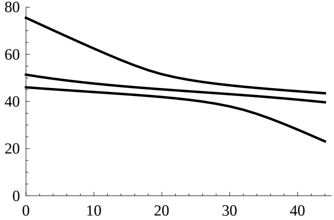
Under Competition

associations

Correlations

- shadow price with
  - storage: -0.83
  - inflows: -0.72
  - gas generation: 0.99
- Hydro generation with
  - storage: 0.78
  - inflows: 0.71
  - gas:-0.91
- inflow with
  - price: -0.18

- Shadow price by inflows: Reservoir Empty/Half full/ Full



- Need not have the shadow price of water equal to the operational marginal cost of gas

Monopoly Findings

No Volatility in Demand

Monopoly vs Competition

- Monopoly has
  - higher prices (standard)
  - higher average storage
  - much less volatile price
  - much less gas used
  - lower welfare: where volatility can be costlessly managed
- Reservoir expansion by 1 TWh

	Competition	Monopoly
Social Value	$13m	$52m
Market Value	$39m	$23m

Climate Change

Explore by

1. Varying mean (average) inflows
2. Varying forecastability (volatility of inflows
3. Carbon tax

Changes in Mean Inflows

Decrease average inflow by 30%

- NIWA argues that inflow will actually increase
- Decrease in average inflow means increased amount of low-cost fuel over any reasonable period

Relative to Base	Competition	Monopoly
Hydro G	70%	71%
Gas G	1.26%	2.83%
Social W	91%	93%
Profit	1.04	96%
Social Value Extra Capacity	31%	17%
Market Value Capacity	44%	70%

Volatility spread between competition and monopoly remains

Reduced Inflow Predictability

Decrease mean reversion parameter by 30%

Increases overall variability as well

Relative to Base	Competition	Monopoly
Hydro G	100%	98%
Gas G	100%	112%
Social W	100%	100%
Profit	99%	100%
Social Value Extra Capacity	223%	158%
Market Value Extra Capacity	174%	156%

Volatility spread between competition and monopoly remains

Big increase in the value of extra reservoir

Carbon Tax

$25/tCO2 = 25% increase in mc of gas

Price increase less than half the increase in marginal cost

Relative to Base Case	Competition	Monopoly
Hydro G	100%	100%
Gas G	90%	93%
Social W	98%	99%
Profit	109%	100%
Social Value capacity	115%	114%
Market Value capacity	113%	113%
Price	112%	1.01

What Next?

Developments

- more on random demand and correlation with inflows
- other oligopoly market structures
  - oligopoly with mixed portfolios
  - oligopoly with specialised portfolios
  - other forms of competition
- Cap and Trade would be a particular challenge

References

1. Evans, Lewis, Graeme Guthrie and Andrea Lu, *A New Zealand Electricity Market Model: Assessment of the effect of climate change on electricity production and consumption, mimeo,* New Zealand Institute for the Study of Competition and Regulation *(www.iscr.org.nz)* research paper, *July 2010, 20pp.*