Do Big New Zealand Hydro Generators Bid Strategically into the Electricity Market?

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Geoffrey Bertram and Michael Webb
School of Economics and Finance
Victoria University of Wellington
P.O. Box 600, Wellington
New Zealand

- There is growing evidence that generators in deregulated electricity markets have successfully used their market power to raise prices and profits
- Wolfram's pioneering study of the UK market brought the issue to the fore
- Wolak, Bushnell, Borenstein and others have analysed market power in the California context
- The New Zealand market is more exposed than those cases to gaming by generators
  - almost complete absence of regulation
  - policy decision in 1999 to allow generators to integrate vertically with retailers
- The vertically-integrated generators successfully drove the last surviving independent retailer to the wall in 2001

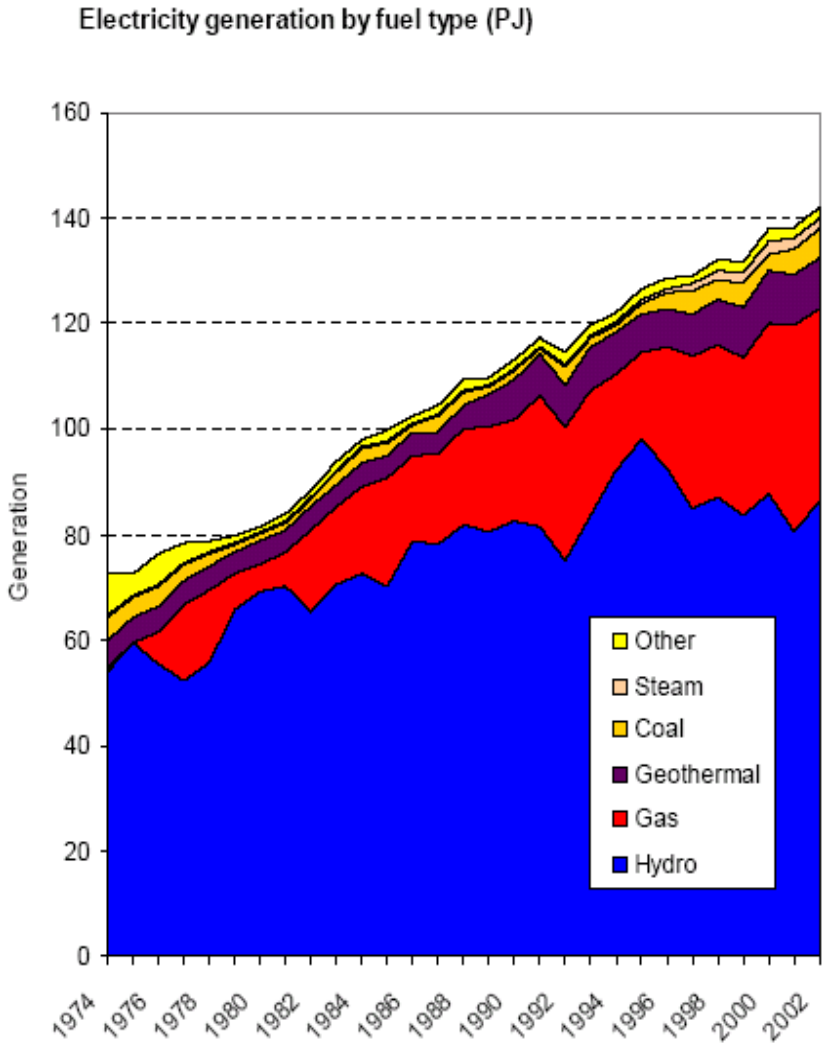
- This paper presents a report on research in progress into bidding behaviour by the two largest generators who between them control
  - 56% of installed capacity and a much higher share of hydro capacity
  - 60% of the market volume

- To begin with, I shall briefly describe the current market structure

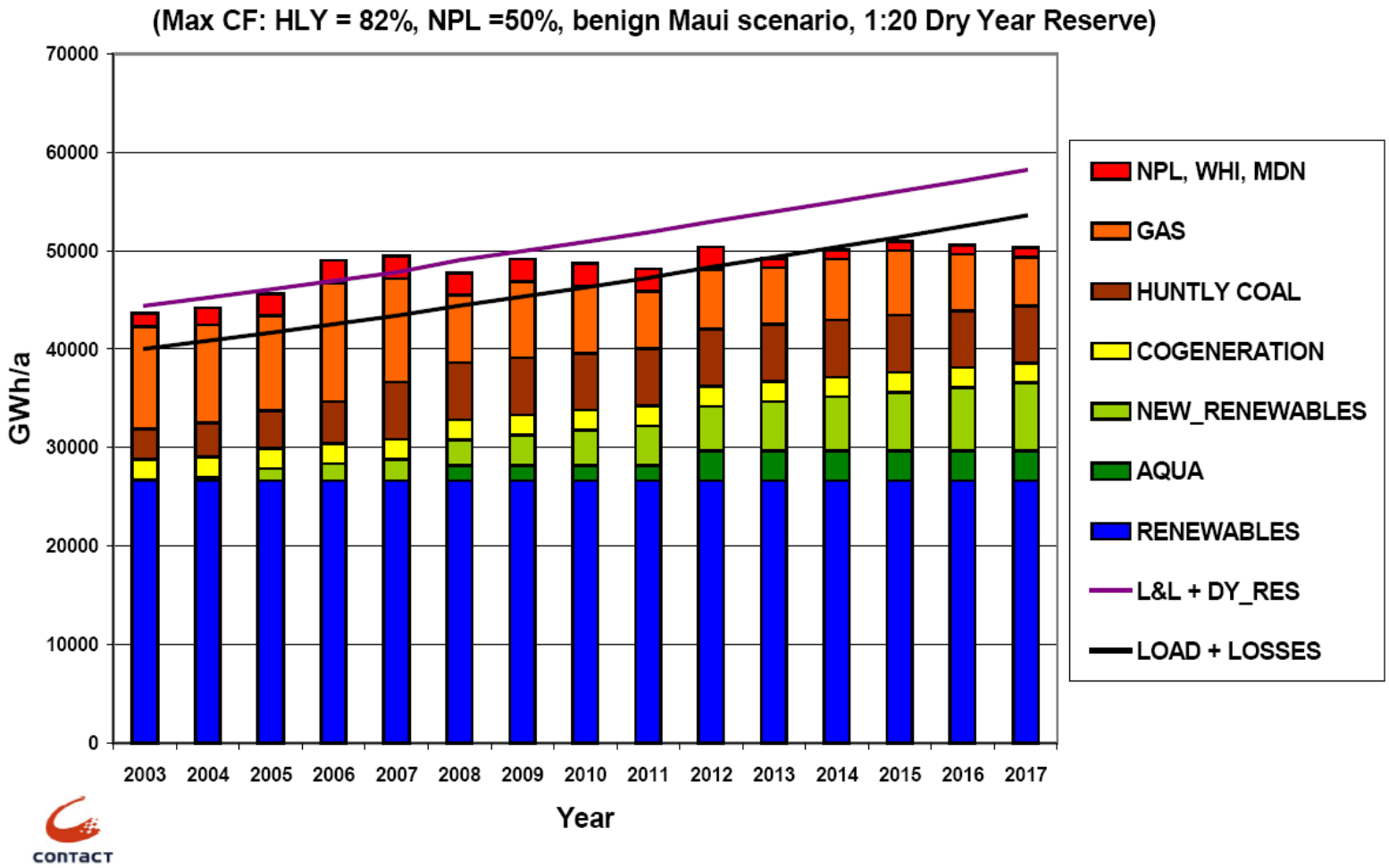
Rising electricity demand has historically been met by new hydro generation and growth in gas-fired generation

Electricity supply

- NZ electricity supply has been growing at ~2.5% p.a.
- Hydro contributes 60-70% of supply
- Growth in supply has come mainly from gas-fired generation

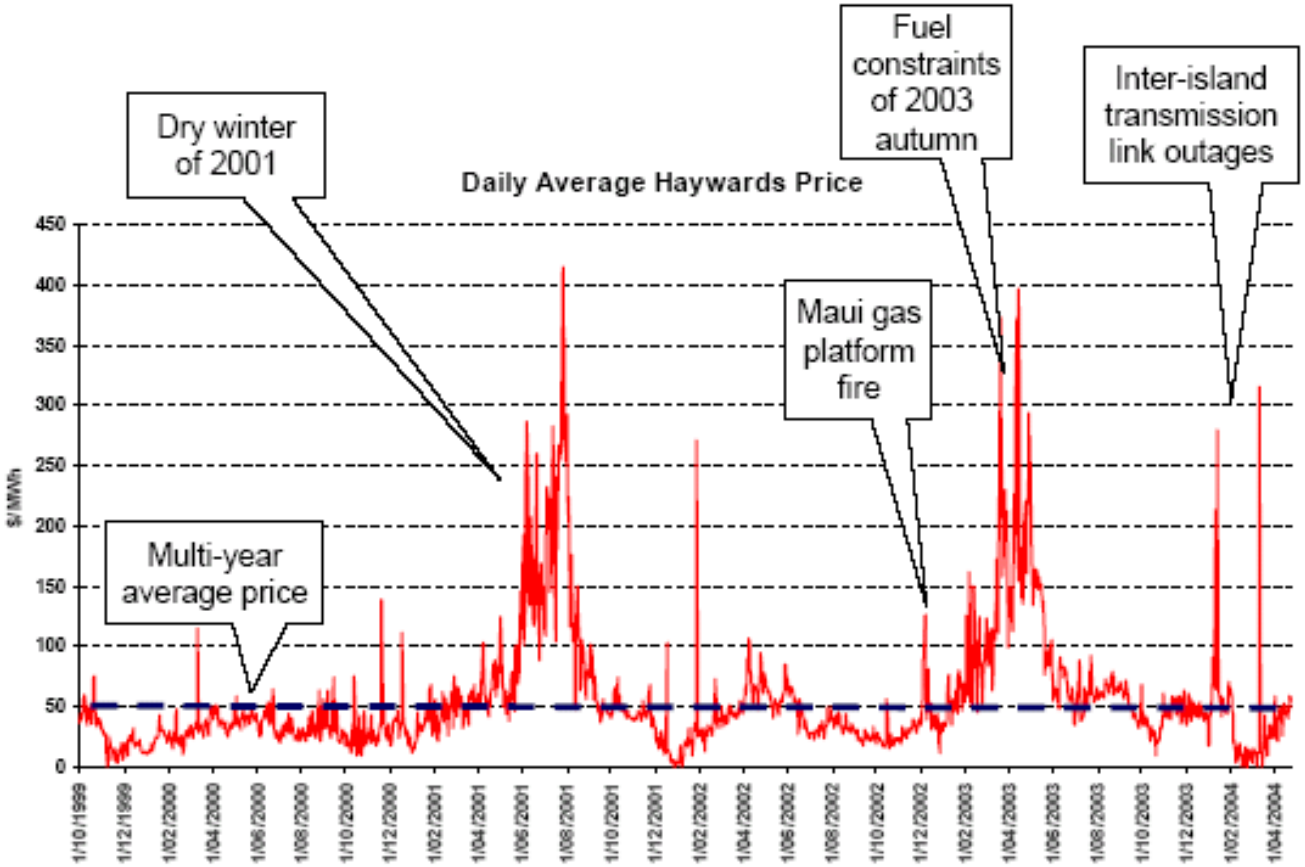


Electricity Supply and Demand projections



Management of trading risk is vital - New Zealand electricity market characterised by extended periods of high prices - induced by hydrology or key plant outages

Trading risk - spot prices



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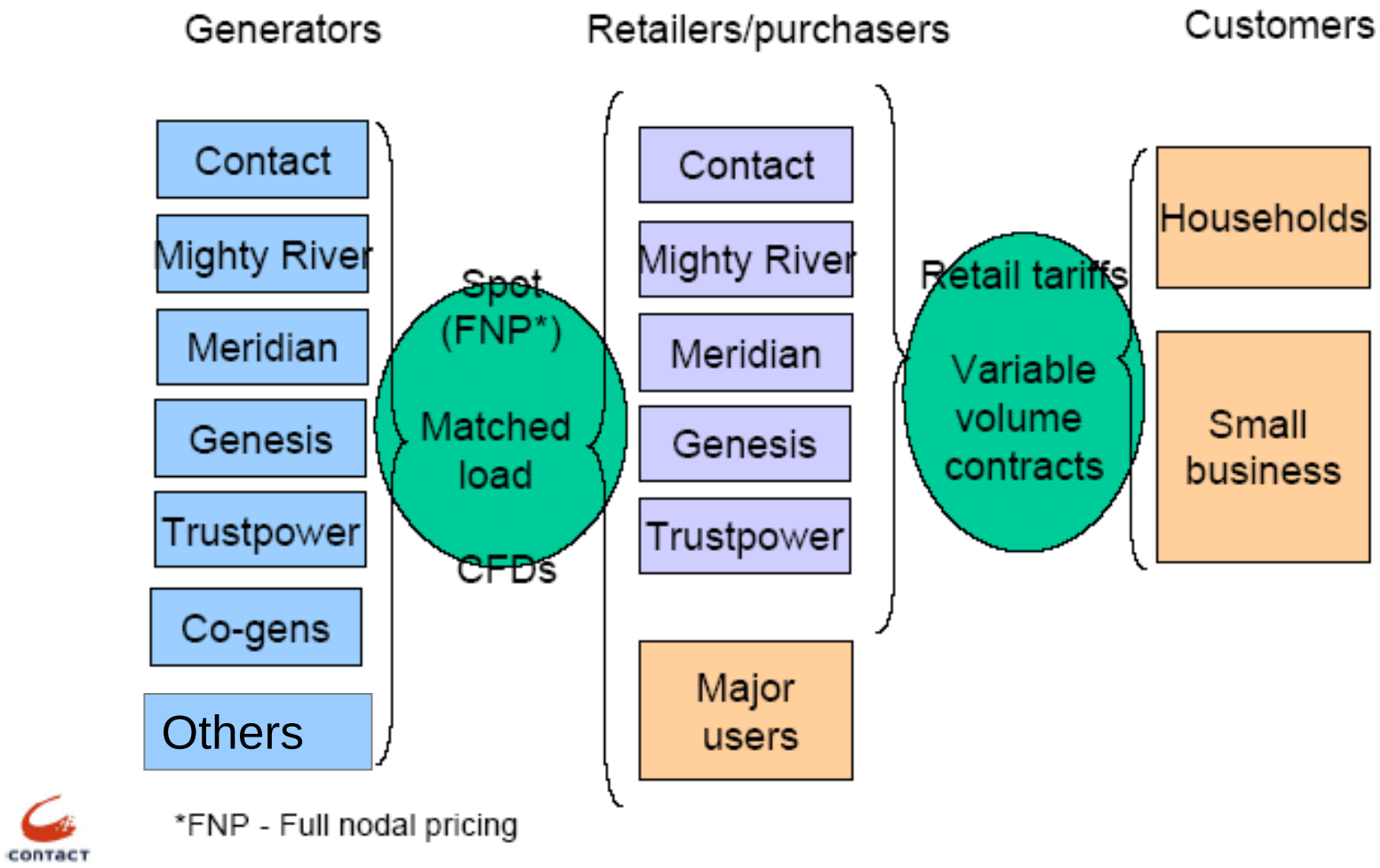

Generators
Retailers/purchasers
Customers
Contact
Mighty River
Meridian
Genesis
Trustpower
Co-gens
Others
Spot
(FNP*)
Matched
load
CFDs
Contact
Mighty River
Meridian
Genesis
Trustpower
Major
users
Retail tariffs
Variable
volume
contracts
Households
Small
business
*FNP - Full nodal pricing

Generator capacities

Firm	Capacity MW	Capacity with NGC reallocated[1]	% of total generation capacity with NGC reallocated
NGC	399		
Contact	1,940	2,294	28
Genesis	1,596	1,596	19
Mighty River	1,213	1,213	15
Meridian	2,323	2,323	28
Trustpower	423	455	6
Todd	132	145	2
Others	205	205	2
Total	**8,230**	**8,230**	**100**

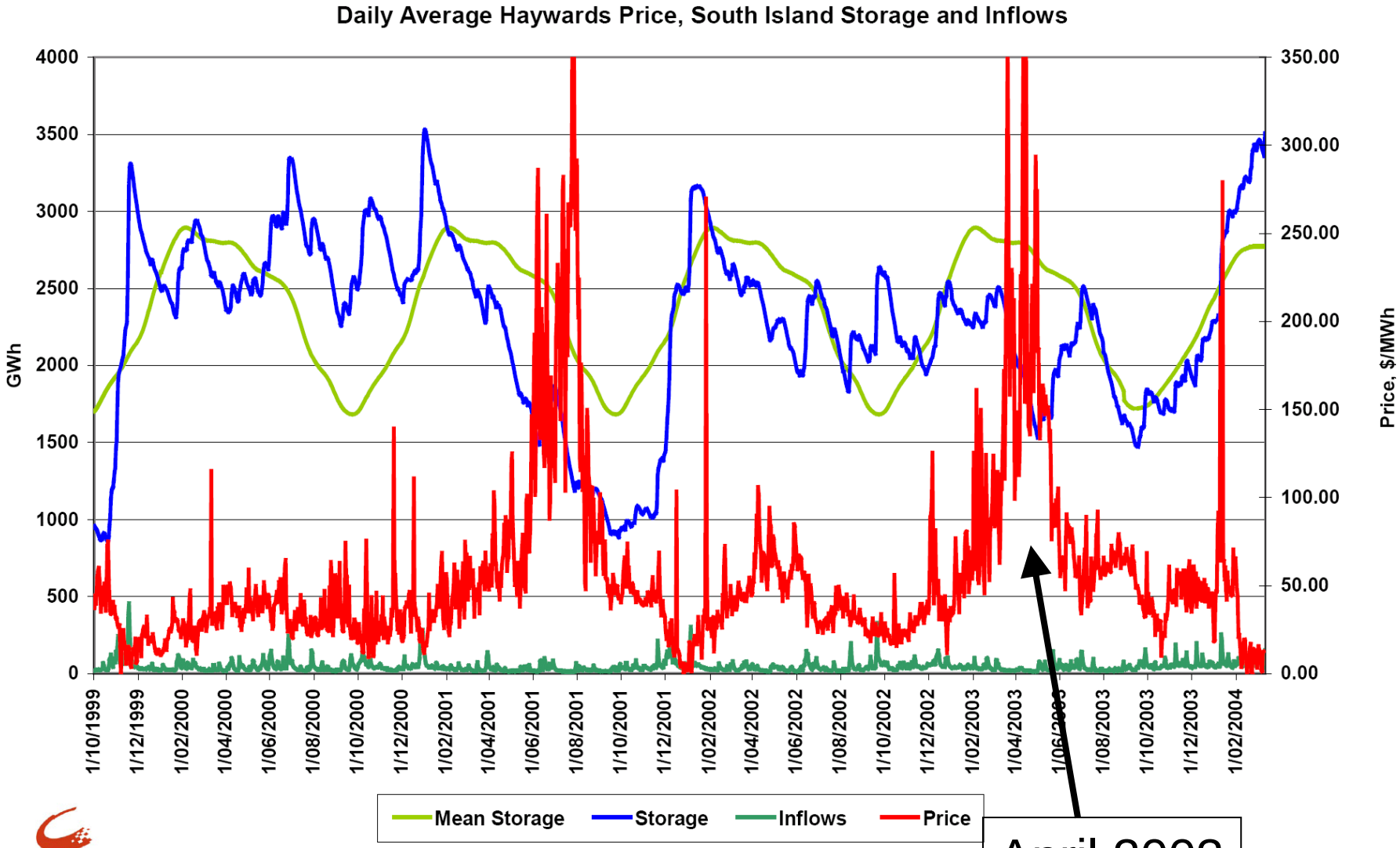
The New Zealand market has had recurrent supply "crises" since deregulation

- In 1991, 2001 and 2003 prices spiked very high during dry winters (hydro storage below normal).
- There is clearly truth in the claim that the high prices were related to low hydro storage
- But this leaves open the question of whether strategic behaviour by generators might have exacerbated the crises, or even caused them
- Particularly in 2003, the storage situation was arguably not sufficiently serious to justify prices above $350 per MWh

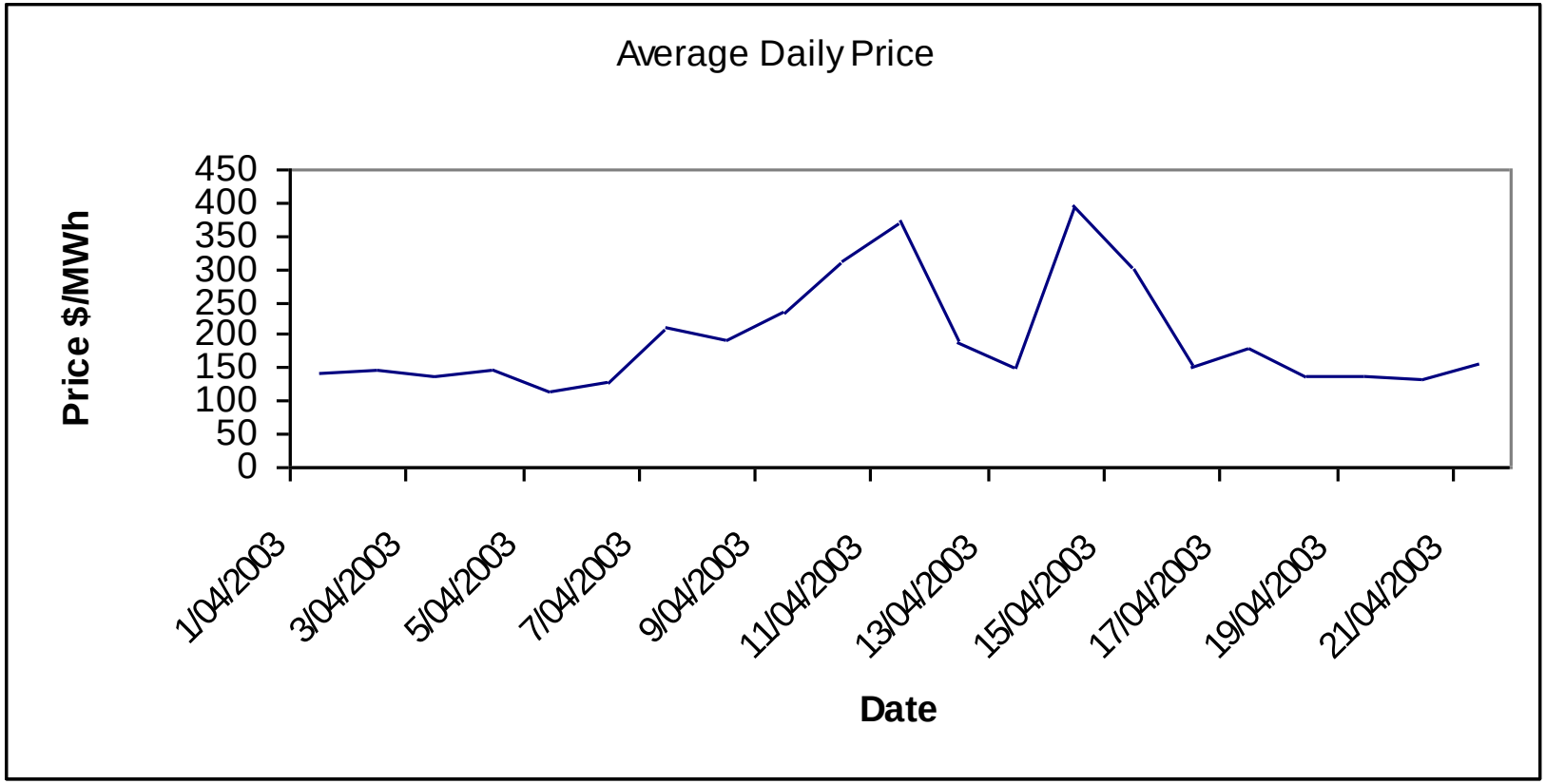
It is nevertheless true that April 2003 followed an unusually dry early autumn

- Inflows into the major storage lakes during March were 70% of the average level
- On 5 April Contact's storage lake, Hawea, was at 77% of the usual level for that time of year
- In the week to 20 April, inflows were 47% of normal
- Six of nine hydro catchments nationwide were at or below 35% of capacity

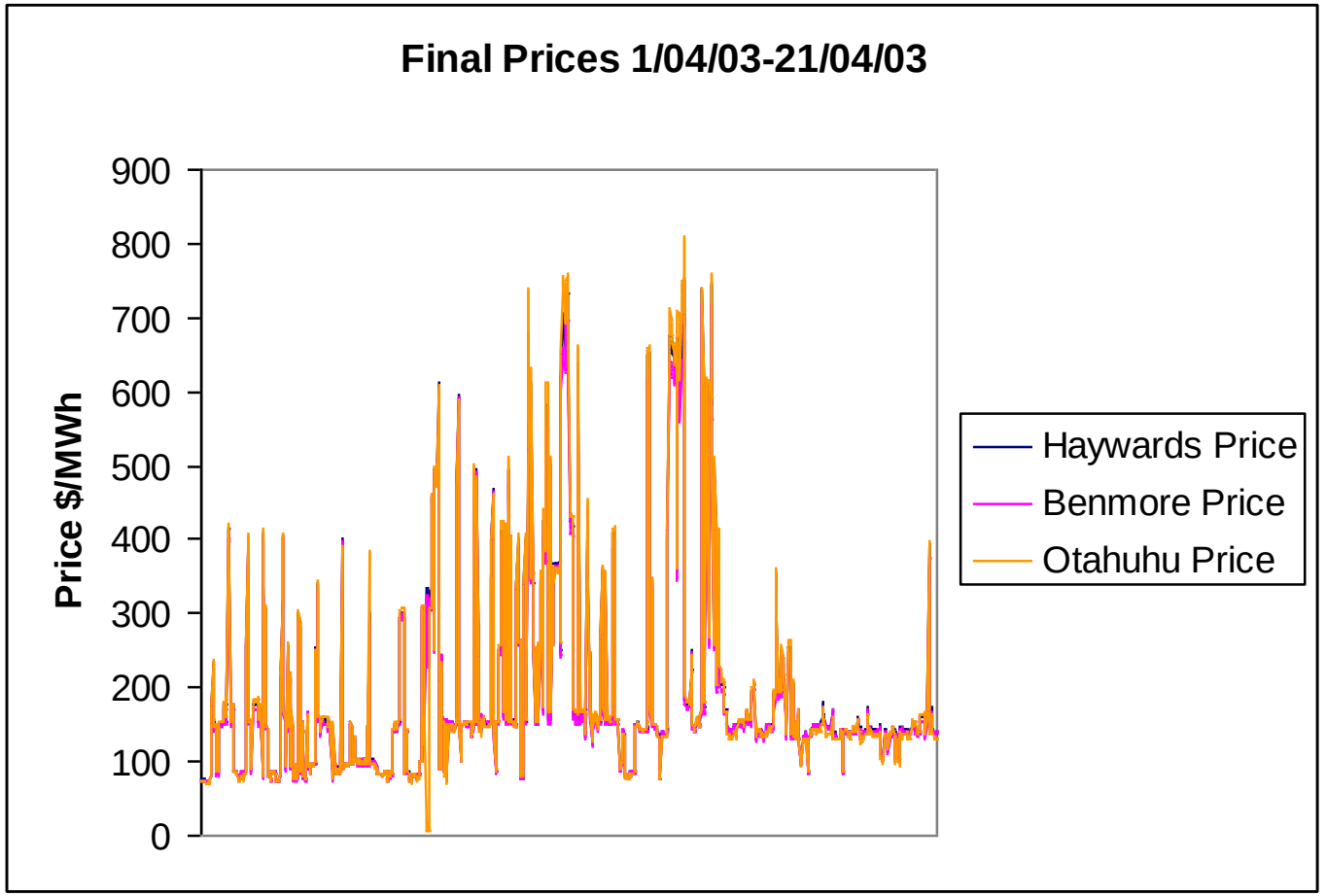
Wholesale Prices and Storage



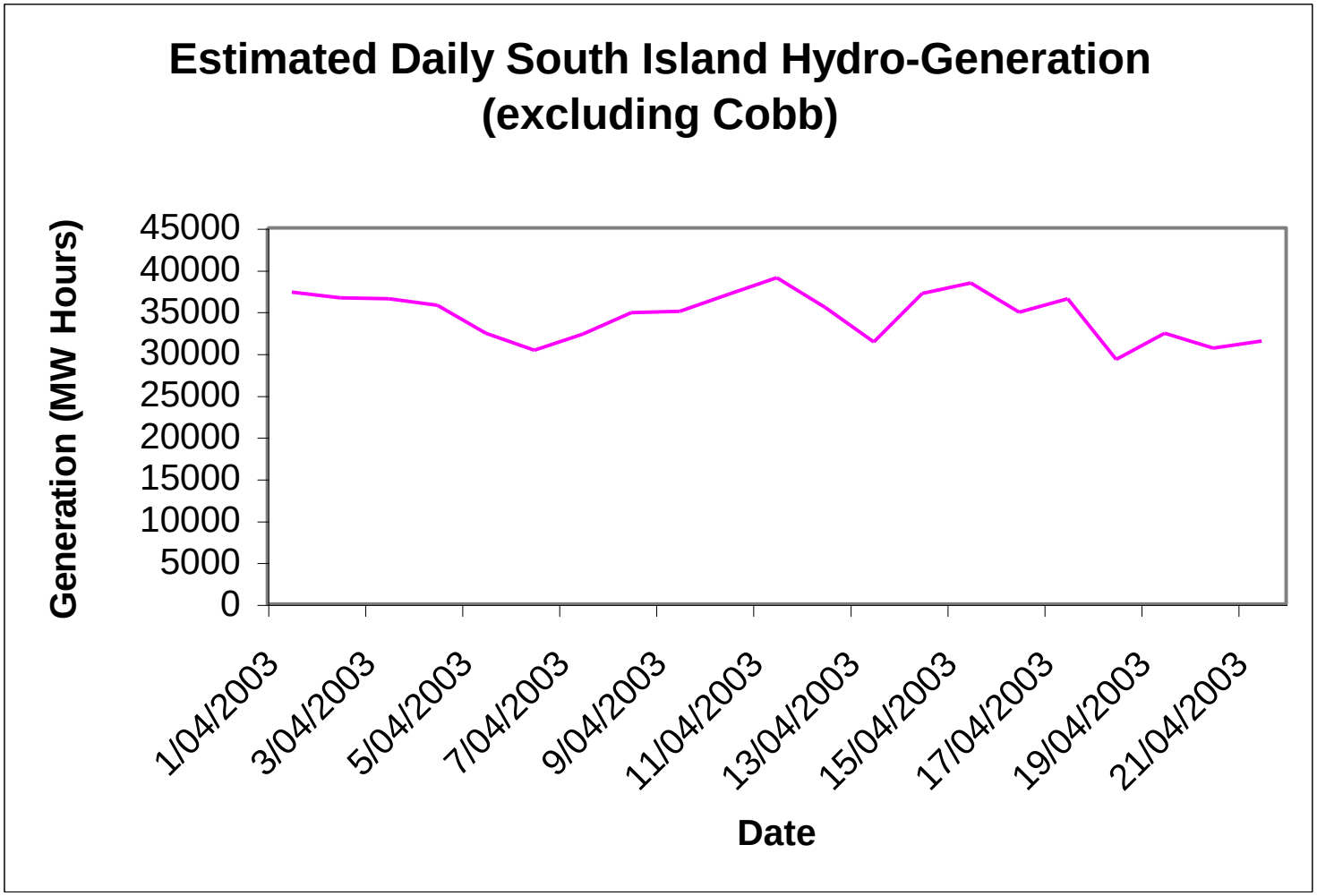
The April 2003 events seemed to provide a good test case for exercise of market power by generators. Prices rose:



In a large number of half-hourly periods prices spiked to $500-800 per MW



But our estimate of total day-by-day generation by the two big South Island hydro generators showed no sign of capacity withholding :



Thermal outages certainly contributed to the high prices

- Two major thermal stations in the North Island were partly or fully shut down for maintenance during April.

- One of these, Huntly, halved the output from one of its four 250MW turbine on 11 April, as the price began to rise, and closed the unit down completely on 17 April (after the price had come down again)

- A second Huntly turbine was taken out for maintenance between 11 and 14 April (the period when prices fell back).

- These dates seem to rule out strategic behaviour by Huntly's owner, Genesis Power, although the partial outage of Turbine 3 from 11 April probably strengthened the hand of other generators in bidding high

More significant was probably the shutting-down of Contact's 354MW combined cycle plant at Stratford

- This plant was withdrawn on the evening of 10 April (just as the price started to rise) and returned to service on 15 April
- This may have contributed to the price spike of 11-13 April, which raised the profitability of Contact's hydro stations through the crisis
- However Stratford was online throughout the second price excursion of 14-16 April

The Minister of Energy, Hon. Pete Hodgson, attributed the price rise to failure of coordination rather than collusive behaviour

"On Friday ... spot prices sat at 20c, half an hour later they were at 70c, an hour later they were at 20c and then back up again. We had a problem of not high prices, but extreme volatility. How can this be?

"Well, at first guess ... Huntly had to take a machine out. The machine went back in at 6.30pm on Monday night. By the time I watched the machine come on at Huntly, then the price went up again.

"It seems to me a logical explanation that all five companies happened by coincidence -- because they are not able to talk to each other -- to bid nothing in between 25 and 65. The moment all the 25c power was used, the spot price went to 65c. You couldn't call that a functional market."

An alternative view could be that with no need to collude, the two largest generators may have been bidding strategically to benefit from exercising their market power

- We have already seen that over the course of the month, South Island hydro output stayed pretty much on track with no withholding day by day
- This may well reflect upper and lower constraints on hydro flows: the rivers have to continue to flow below the dams, and spilling of water is strongly discouraged and sanctioned by Government
- But within the course of each day there may be evidence of exercise of market power

Bushnell has recently proposed a model of within-day strategic shifting of water flows by generators

- The paper appeared in *Operations Research* 51(1) Jan-Feb 2003
- Bushnell suggests that large hydro generators with market power will run their plants hard during the night-time off-peak period in order to have less water available for daytime peaks
- The rationale is that fringe generators will be scheduled anyway during the daytime high-price peak but can be forced off the scheduling list at night
- Hence the large hydro firms can readily dispose of a large amount of their daily water use at night, leaving a smaller amount of residual water to be used during the peak.
- This will accentuate price volatility and may be an effective way of driving daytime prices up high enough to give the maximum possible profit on the 24-hour water flow

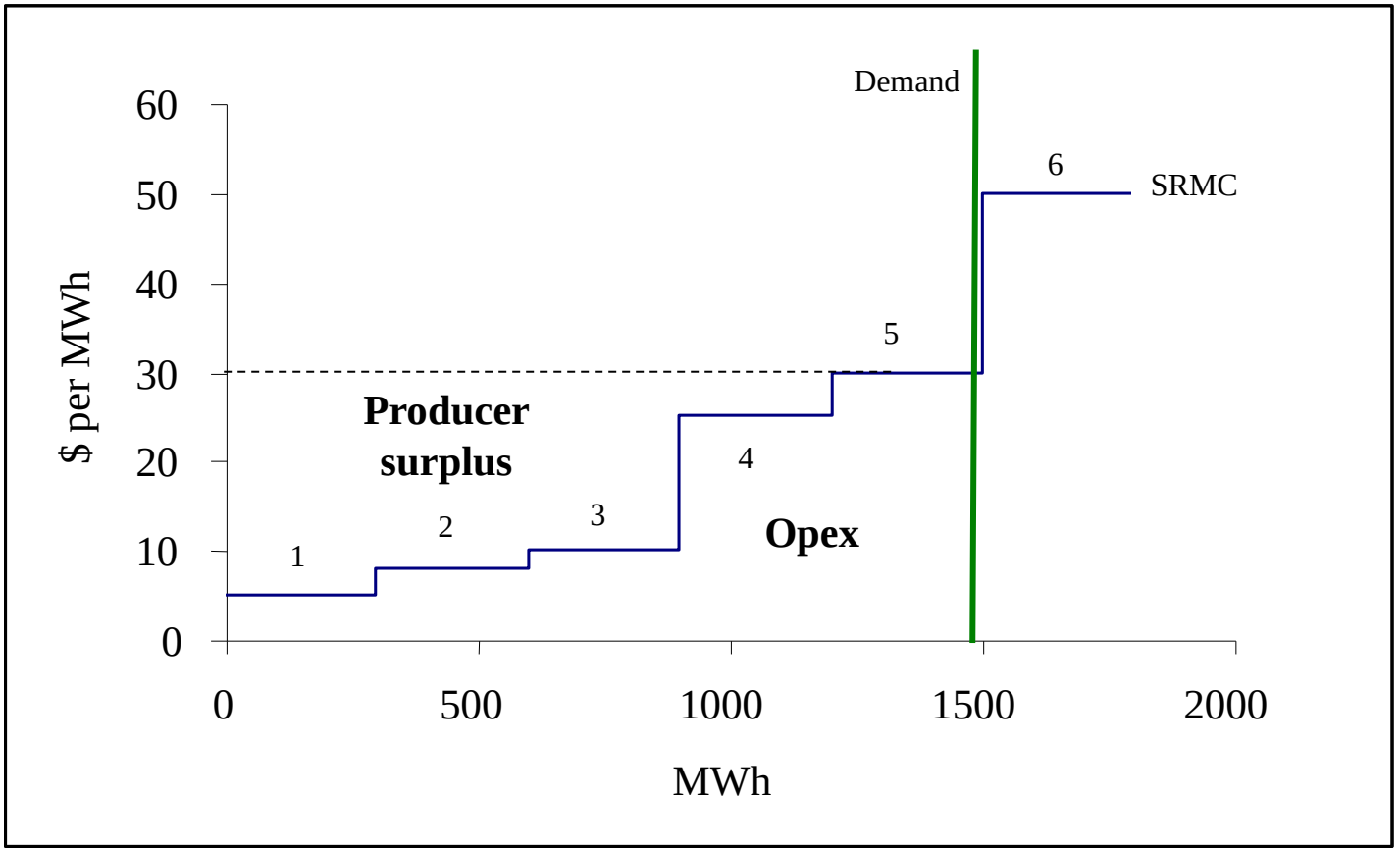
- This potentially yields a testable hypothesis that actual bidding behaviour by large hydro plants will depart significantly from perfectly-competitive behaviour

- This was what we set out to model.

- The core idea is that perfectly-competitive bidding and scheduling of hydro capacity would have significantly reduced the size of the price spikes compared with what was observed

- Our main problem turned out to be establishing what the perfectly-competitive benchmark should look like

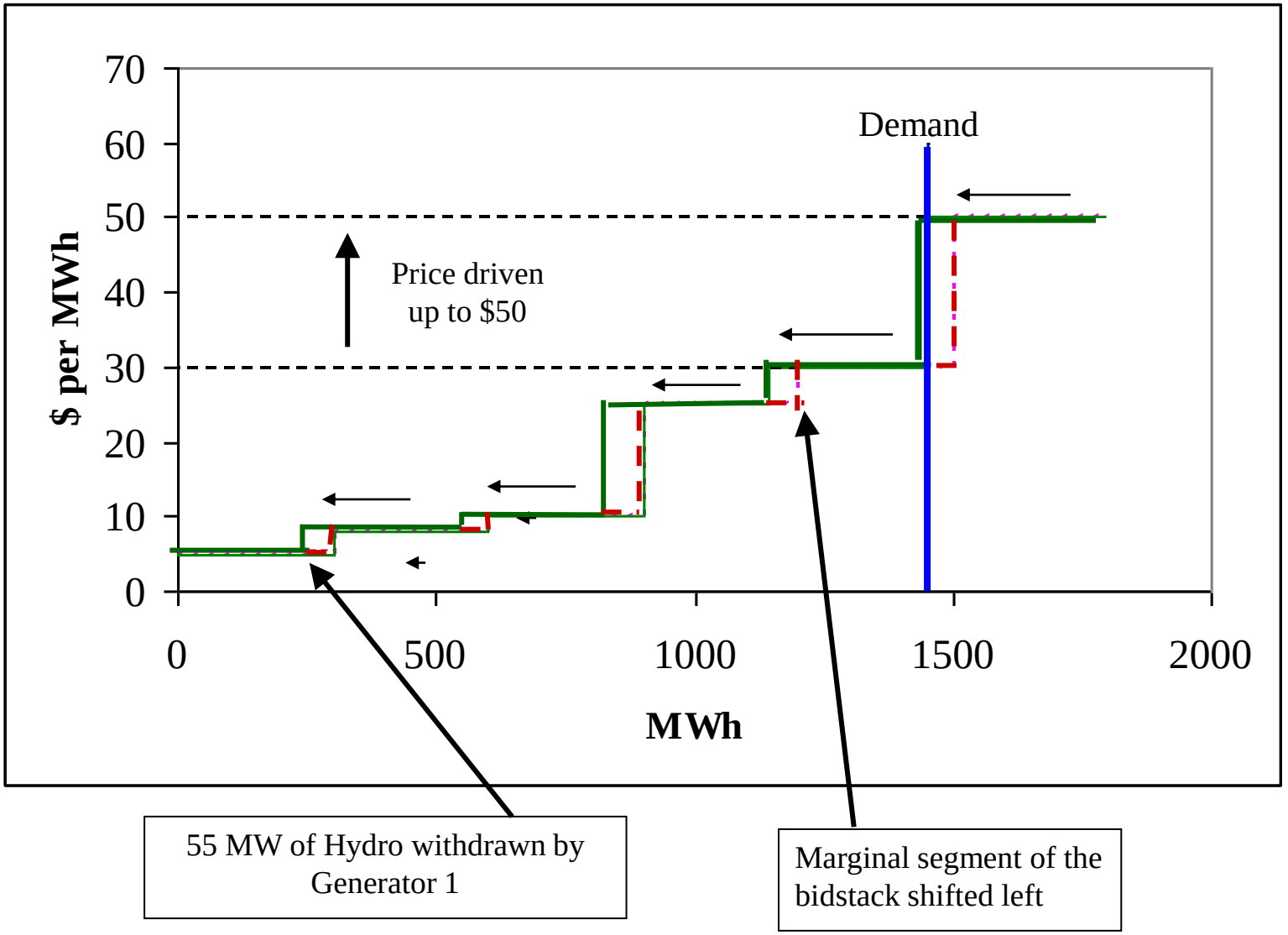
Take a hypothetical bidstack with six plants owned by three firms. Each firm owns one low-cost hydro and one higher-cost thermal plant, and all plant is bid into the pool at SRMC



- Allocative efficiency requires dispatch of the five plants whose SRMC is below or equal to the market-clearing price of $30

- Hence under perfectly-competitive conditions plants 1-5 will be scheduled and the marginal plant will recover only its variable operating cost

- However if any of the firms withholds from the relevant half-hour some part of its low-cost capacity, the leftward shift of the bidstack that results will drive the price up to $50, which yields a sharp increase in producer surplus for all inframarginal, and some marginal, plant:


70
60
50
40
30
20
10
0
$ per MWh
Demand
Price driven
up to $50
0
500
1000
1500
2000
MWh
55 MW of Hydro withdrawn by Generator 1
Marginal segment of the bidstack shifted left

	Bertrand				Strategic			
	Vol-ume MWh	Rev-enue @ P=$30 /MWh	Opex	Surp-lus	Volu me MWh	Rev-enue @ $50/ MWh	Opex	Surp-lus
Hydro 1	100	3,000	500	2,500	100	5,000	500	4,500
Hydro 2	100	3,000	800	2,200	100	5,000	800	4,200
Hydro 3	100	3,000	1,000	2,000	100	5,000	1,000	4,000
Thermal 1	100	3,000	2,500	500	45	2,250	1,125	1,125
Thermal 2	50	1,500	1,500	0	100	5,000	3,000	2,000
Thermal 3		0	0	0	small	small	small	0
Total	**450**	**13,500**	**6,300**	**7,200**	**445**	**22,250**	**6,425**	**15,825**

Surplus doubles

- In Bushnell's model, the problem for the hydro generator is how to achieve this profitable withholding during peak price periods without violating the minimum-flow constraint for the day

- His suggestion is that water is "dumped" at night, earning no (or very low) profit directly, but raising the opportunity value of the remaining water which is to be bid during the day

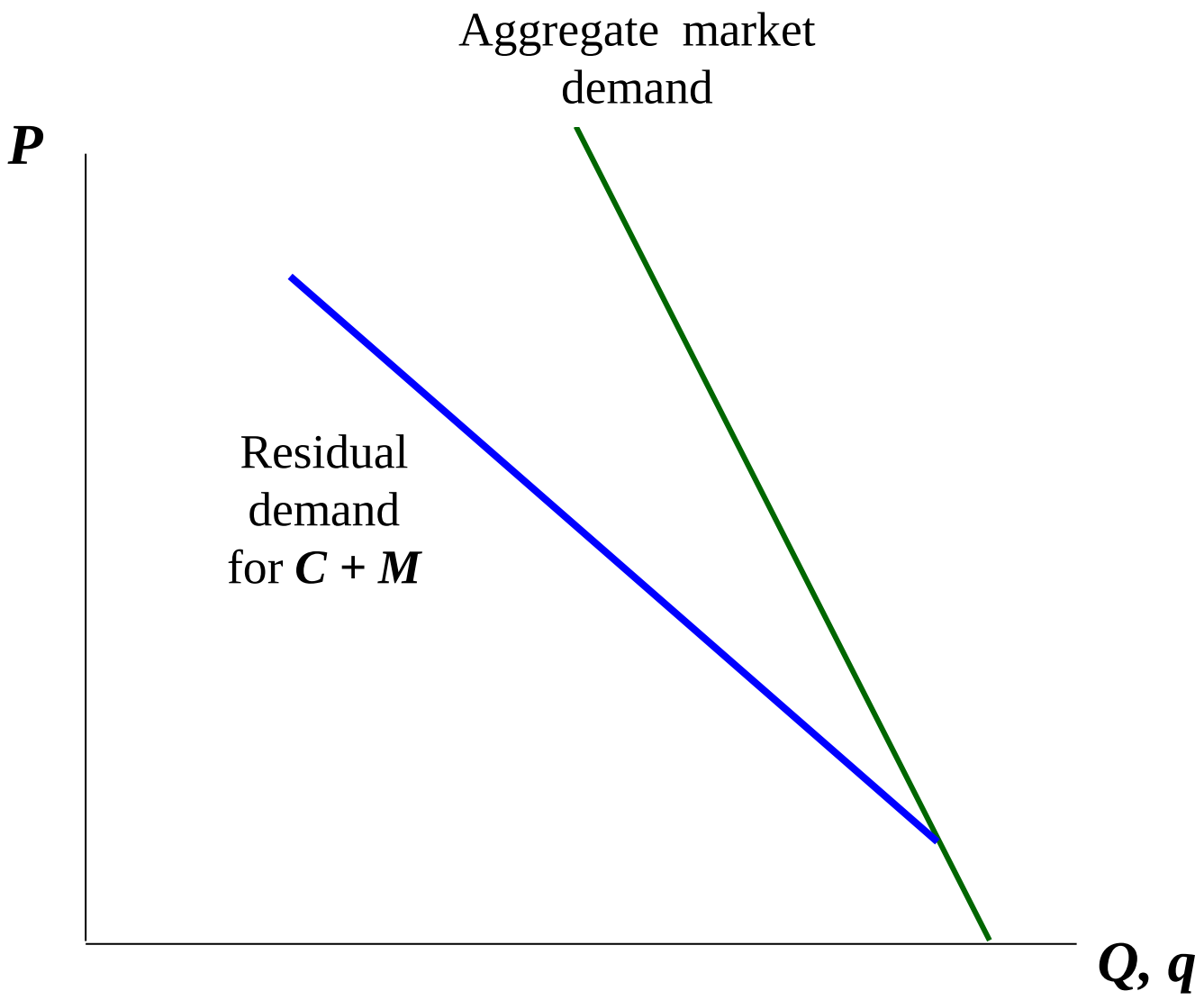
The Model

- Demand $p = a - bQ$ where $Q = \sum_i q_i$

- Two groups of firms: fringe pricetakers f and two large hydro generators C and M which play a Cournot or Stackelberg-type game subject to their joint residual demand curve

$$q_{(C+M)} = Q - q_f$$

- C and M have variable costs of zero and an opportunity value of water, σ, which reflects the fact that water not used in the present period can be used to earn revenue in a future period


Aggregate market demand
P
Residual demand for C + M
Q, q

We estimated the residual demand curve for each period using market bids and fringe supply curves

- All demand-side bids into the pool were aggregated nationwide to give an approximate demand curve
- All generation bids by fringe players that lay below the dispatch price for each period were aggregated and subtracted from demand to give the residual demand curve each period
- We then treated Contact as a price-responsive "follower" of Meridian's Stackelberg leadership. Hence Contact's bid-stack was subtracted from residual demand to give Meridian's residual demand
- From we estimated Meridian's marginal revenue curve

Each hydro generator $i=C,M$ has a maximum-capacity hydro output:

$$q_{it}^{h} \leq q_{i\,max}^{h}$$

and a minimum-flow constraint:

$$q_{it}^{h} \geq q_{i\,min}^{h}$$

and a long-run constraint that over time, total output cannot exceed inflows to the reservoir:

$$\sum_{t} q_{it}^{h} = \bar{q}_{i}^{h}$$

Each of these three constraints implies a Lagrange multiplier (shadow price) derived from the first-order conditions for profit maximisation:

$$\gamma_{it}\left(q^{h}_{i\,min} - q^{h}_{it}\right) = 0$$

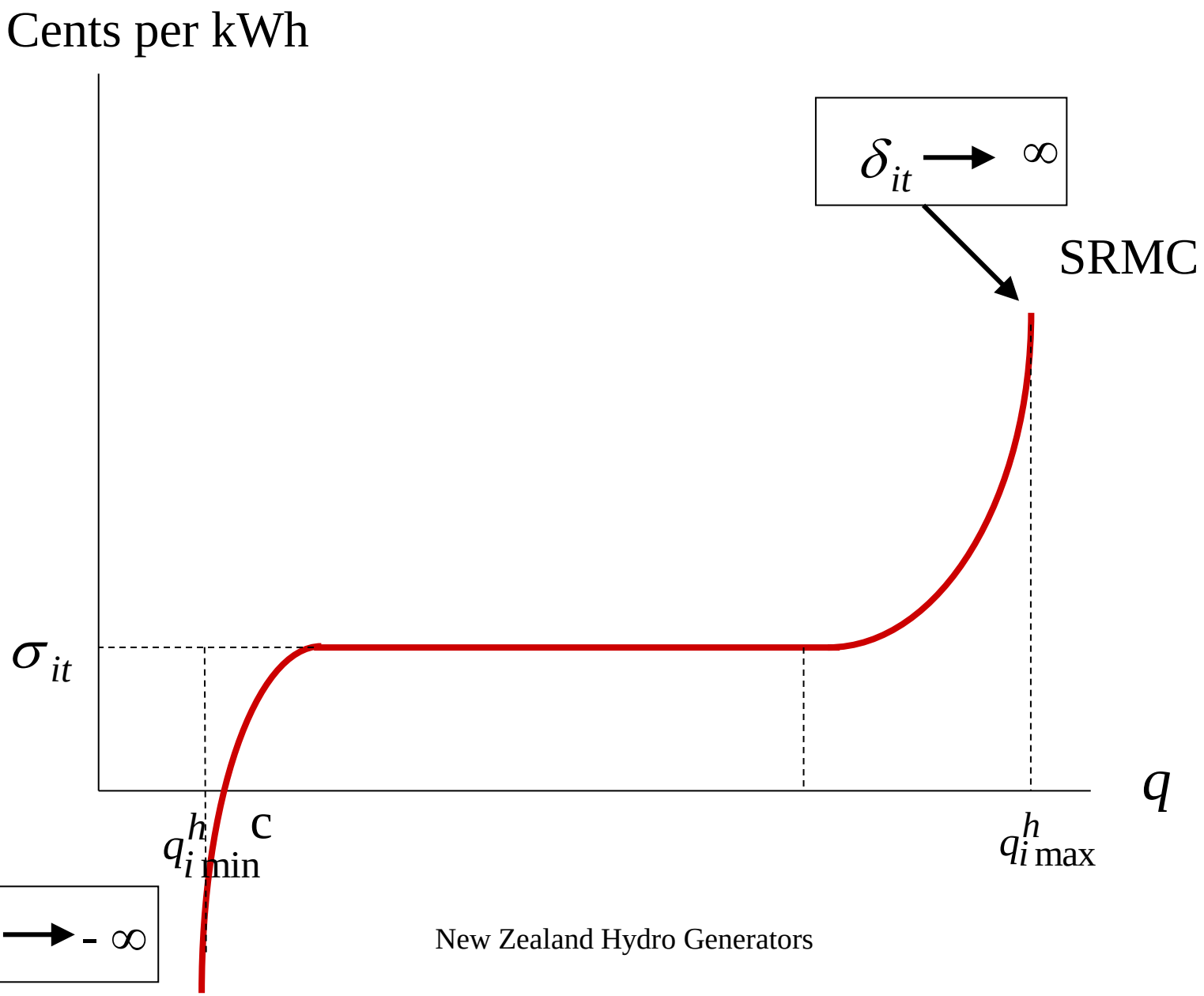
$$\delta_{it}\left(q^{h}_{it} - q^{h}_{i\,max}\right) = 0$$

$$\sigma_{it}\left(\sum_{t} q^{h}_{it} - \bar{q}^{h}_{i}\right) = 0$$

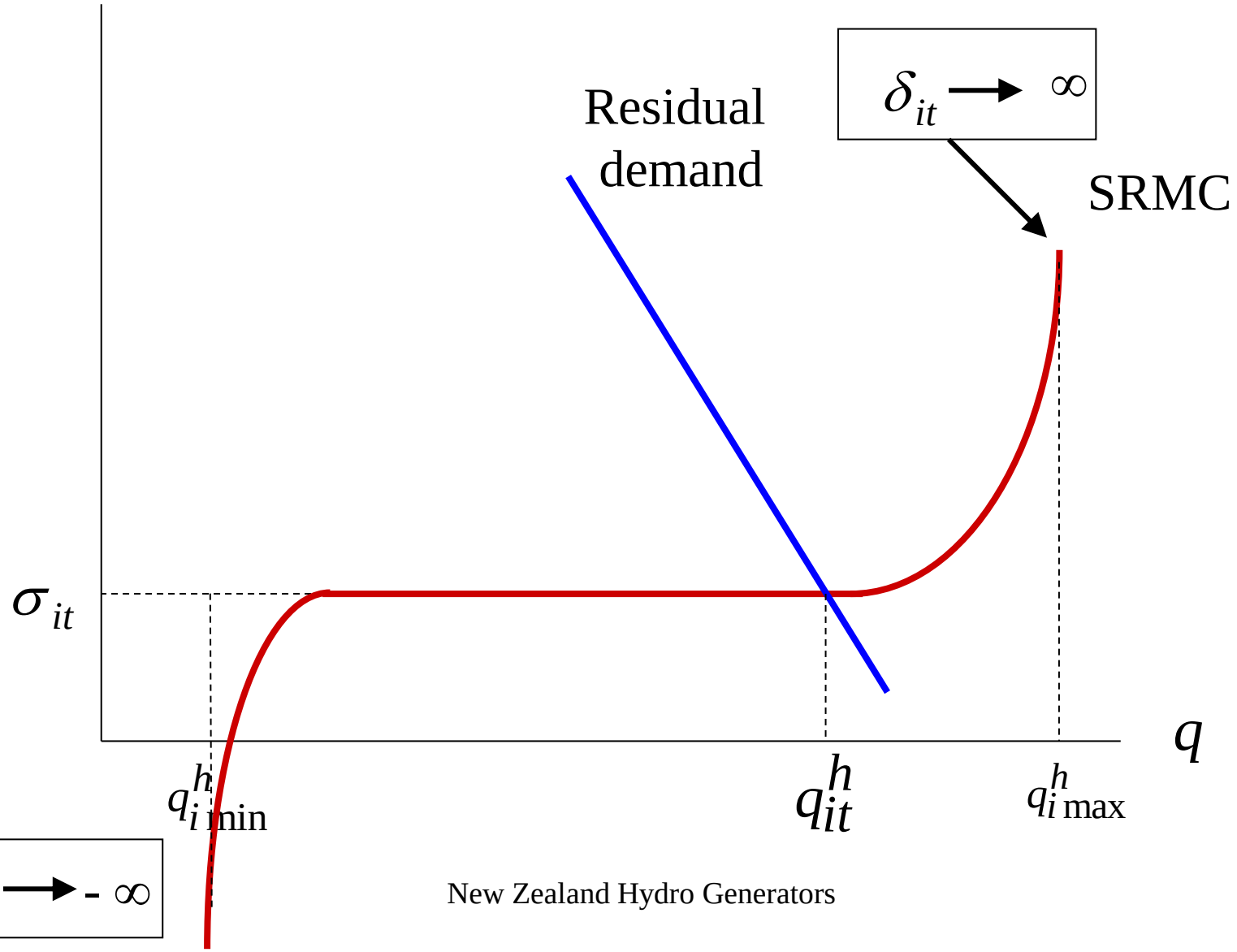
Whence the marginal cost is $MC^{h}_{i} = \delta_{it} + \sigma_{it} - \gamma_{it}$

- Thus in using a unit of water the firm
  - sacrifices the opportunity to use that water in some future period: σ_{it}
  - incurs the cost of moving closer to its maximum capacity output: δ_{it}
  - secures the gain of moving further above its minimum-flow constraint: γ_{it}

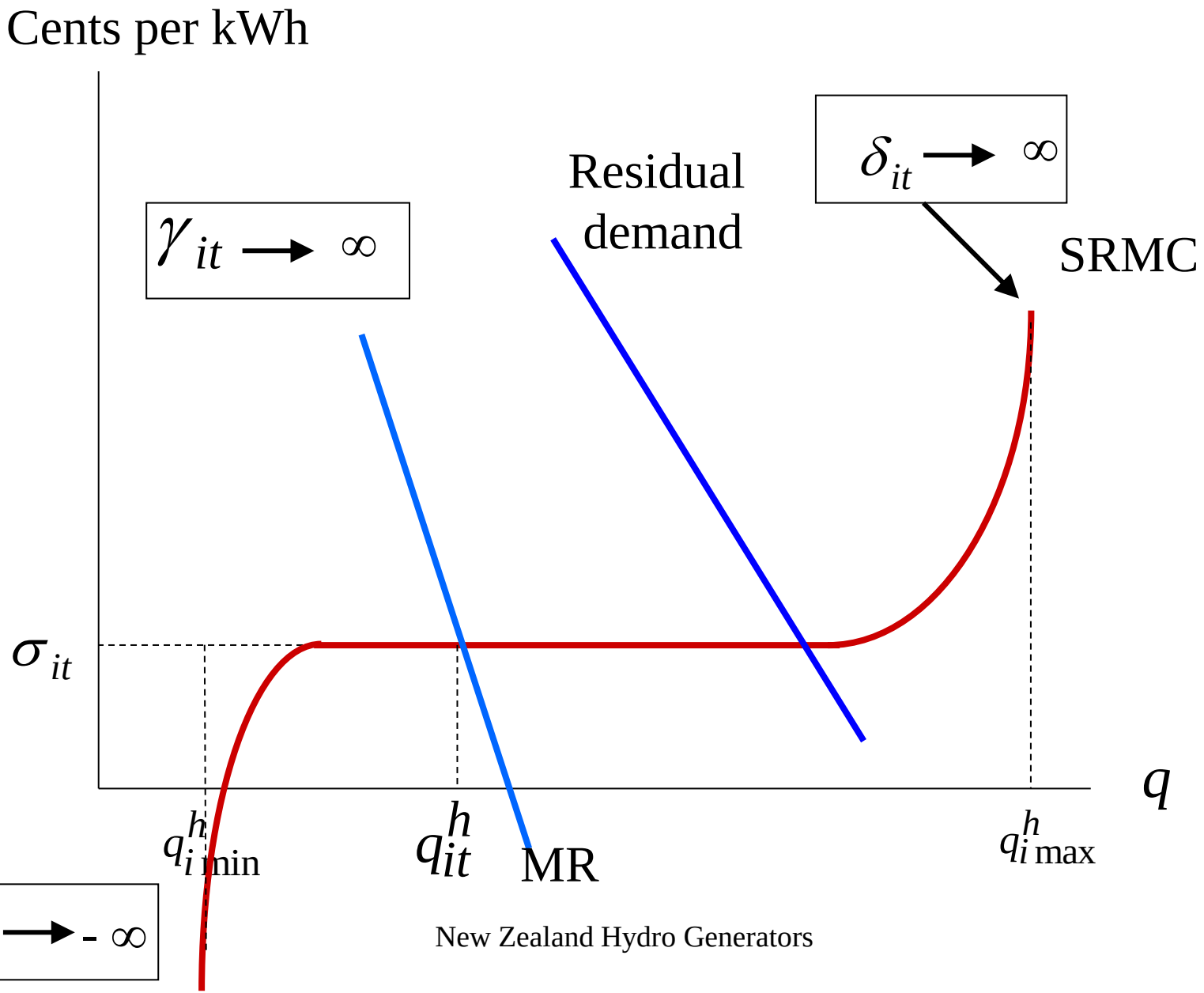
- Hence we expect the marginal cost curve to be:


Cents per kWh
$\delta_{it} \rightarrow \infty$
SRMC
σ_{it}
q
$q_{i\,\min}^{h}$
c
$q_{i\,\max}^{h}$
$\gamma_{it} \rightarrow -\infty$

The price-taking firm equates MC to residual demand:



The strategic firm equates MC to marginal revenue:



- Because strategic output in each period would be less than the price-taker's output, there will be a tendency to use less water than is provided by inflows

- The surplus water is dumped in the period when the loss from doing so is least, namely the middle of the night when price is very low anyway

- By bidding in at a must-run price at that time, the strategic generator undercuts the entire residual demand curve

- We hypothesized that a price-taking large hydro firm would vary its period-by-period volume offers in such a way as to meet residual demand at the average price for the day.

- This is obviously a crude assumption, fully justifiable only when the actual price is smoothed by the operation of the large hydro producers such that volatility in price is eliminated completely.

- For the first round of modelling, it gave us a counterfactual benchmark

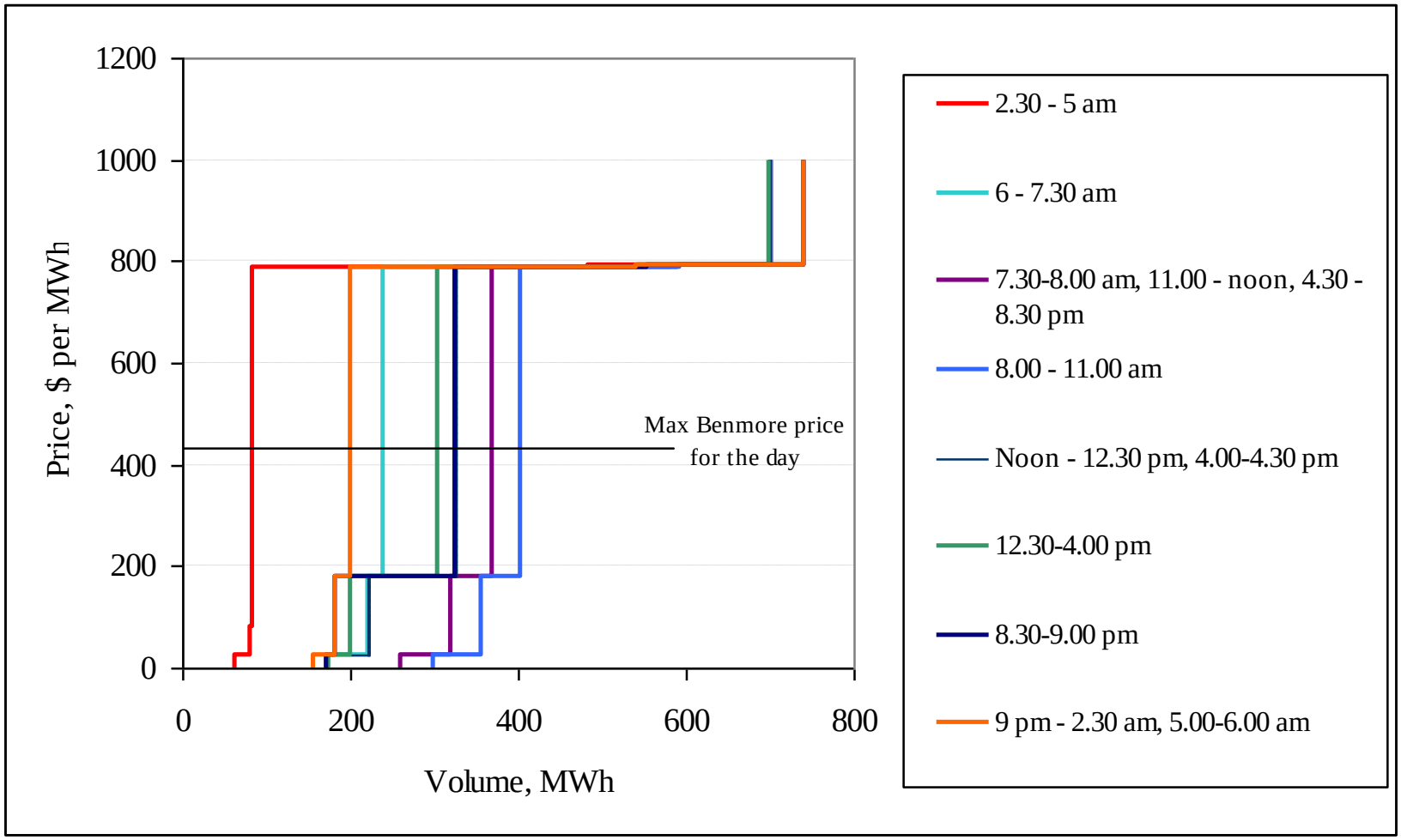
New Zealand market data

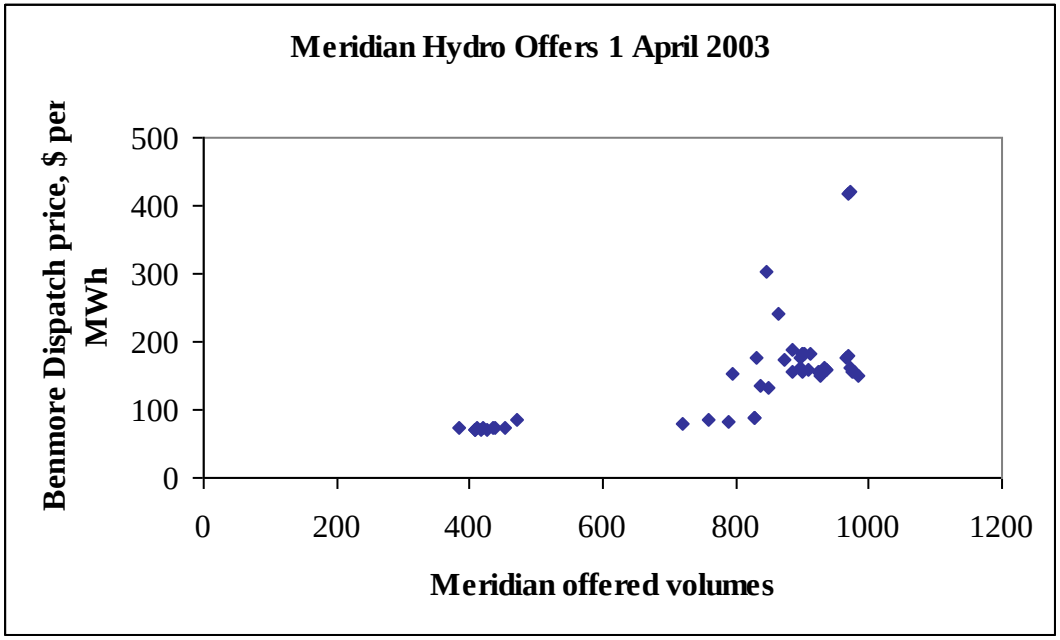
- We do not have information on the marginal cost of generating sets, but we do have half-hourly data on the bids from both the supply side and demand side of the wholesale electricity market, by grid node and company.

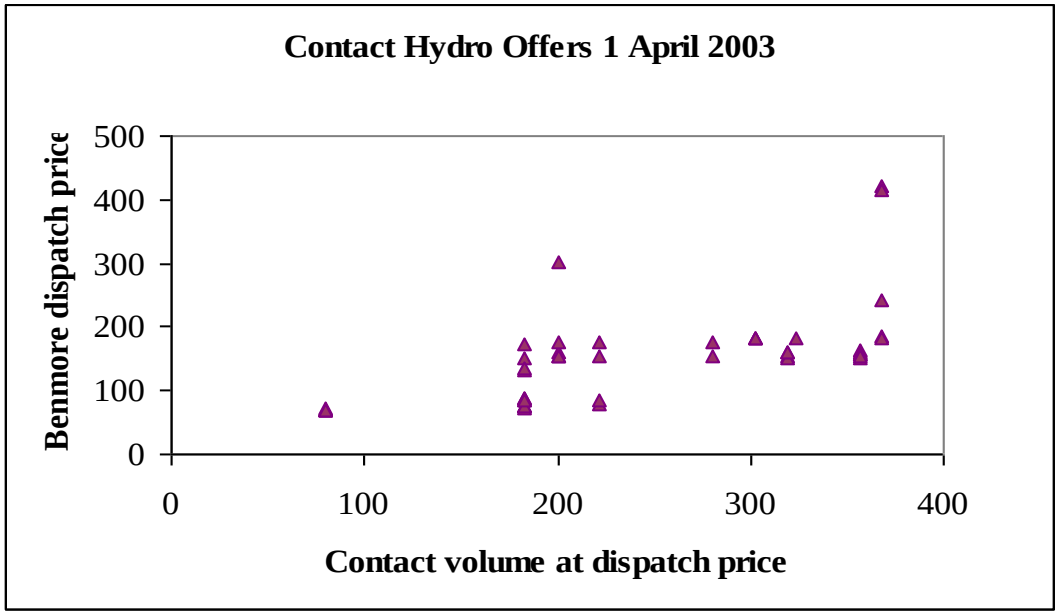
- Bids can be presumed to be above marginal cost, but our focus is on the shape of the bidstack

- Both our two large hydro firms offered varying volumes over the day, as a price taker would do, and both presented upward-sloping supply curves

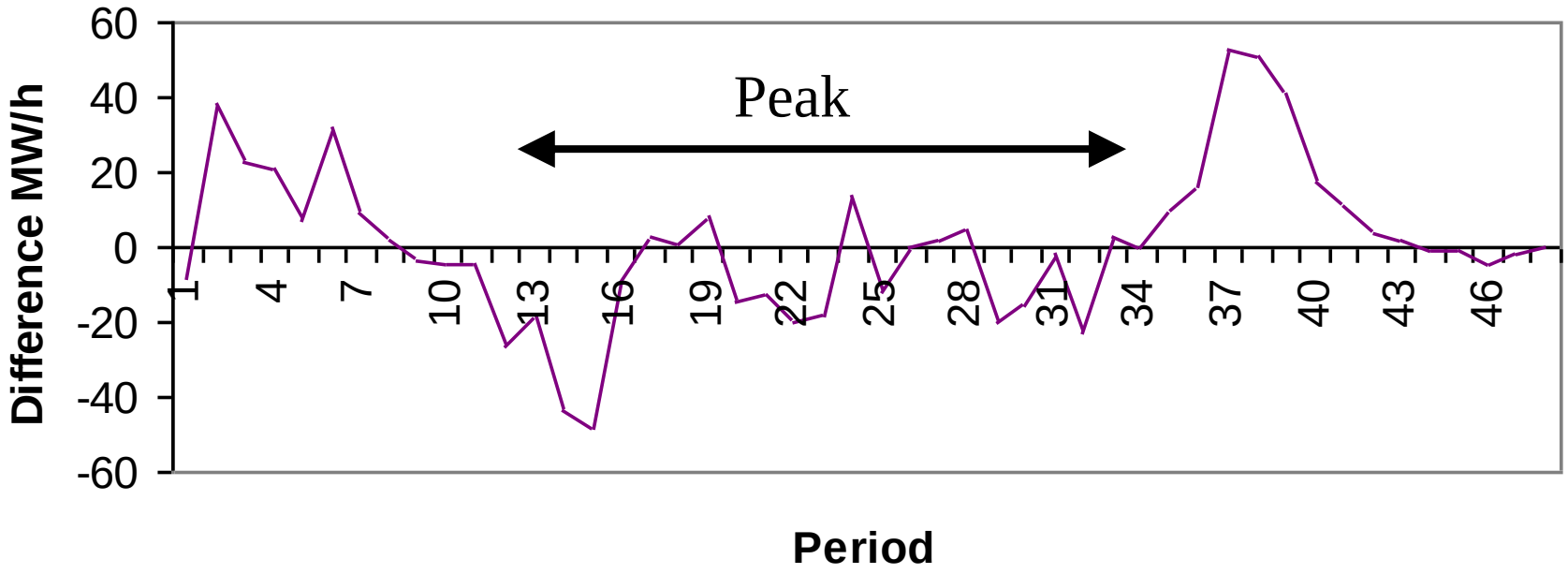
Contact and Meridian bidding on 21 April 2003



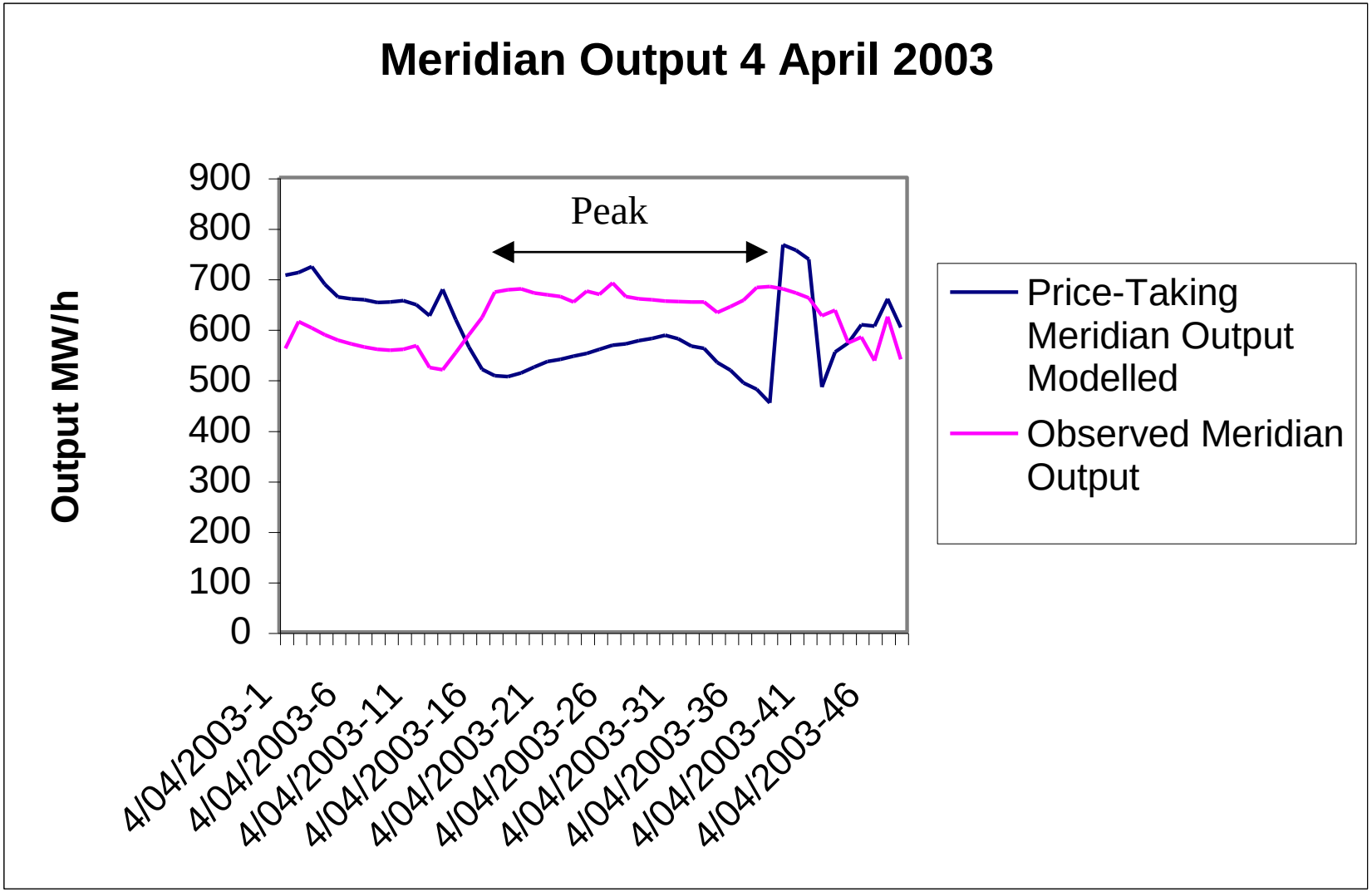

Meridian Hydro Offers 1 April 2003
Benmore Dispatch price, $ per MWh
500
400
300
200
100
0
0
200
400
600
800
1000
1200
Meridian offered volumes


Contact Hydro Offers 1 April 2003
Benmore dispatch price
500
400
300
200
100
0
0
100
200
300
400
Contact volume at dispatch price

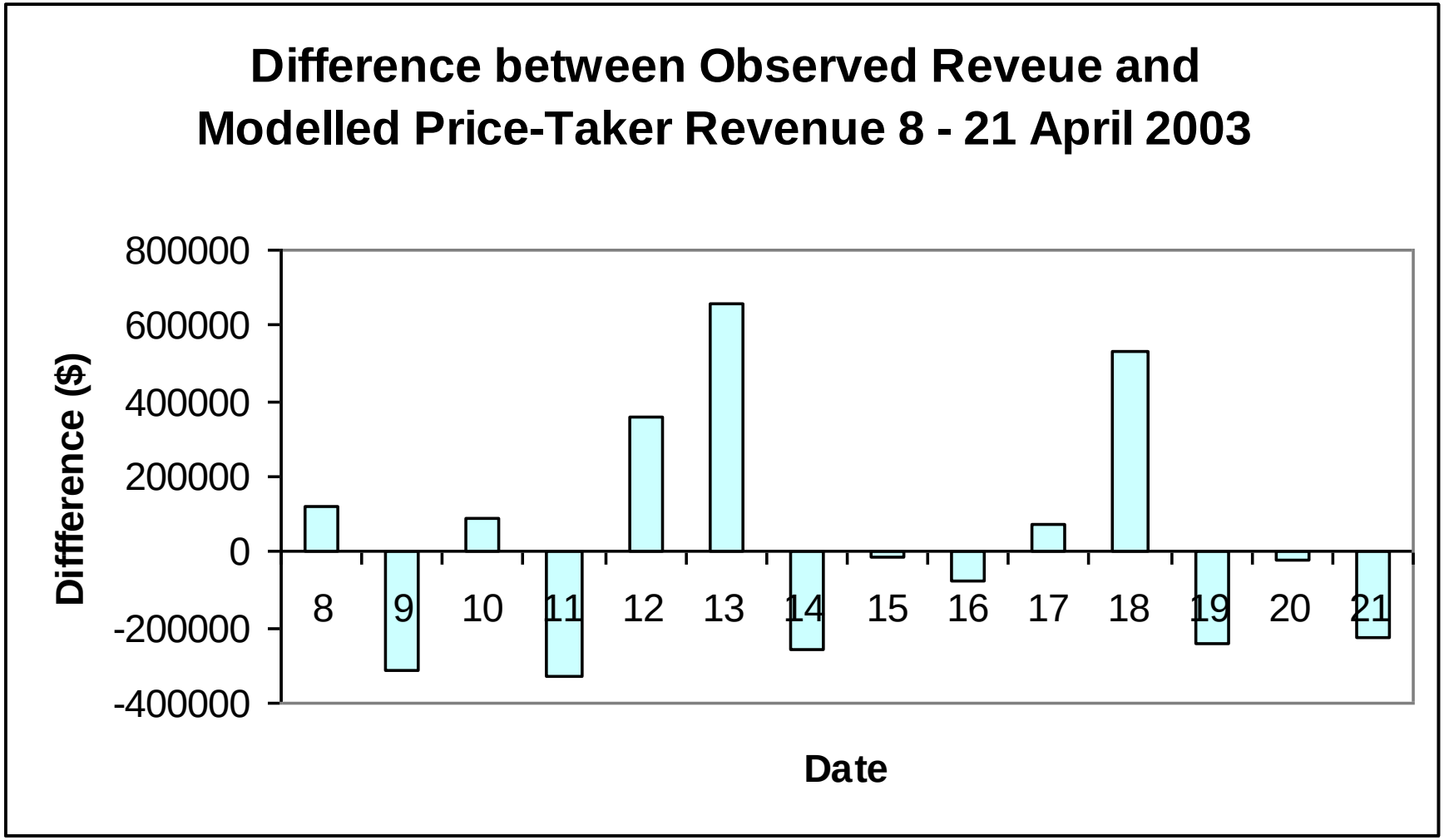
Mean Difference Between Observed Median Output and Modelled Price-Taker Output (1 - 21 April 2003)



- This is weak evidence of Bushnell-type intertemporal water shifting
- We estimate that Meridian secured $806,500 over the three weeks in excess of what our price-taker would have received
- But there were spectacular exceptions; take for example 4 April:


Meridian Output 4 April 2003
Output MW/h
900
800
700
600
500
400
300
200
100
0
Peak
4/04/2003-1
4/04/2003-6
4/04/2003-11
4/04/2003-16
4/04/2003-21
4/04/2003-26
4/04/2003-31
4/04/2003-36
4/04/2003-41
4/04/2003-46
Price-Taking Meridian Output Modelled
Observed Meridian Output

- We also ran the model for day-to-day volumes actually observed for Meridian against our hypothetical price-taker over three weeks 8-21 April:



Actual revenue exceeded price-taker revenue by $351,000

- Results so far indicate that strategic behaviour, if it exists, is more complex than Bushnell has suggested
- There is weak evidence of strategic within-day water shifting by Meridian
- But there are significant days of contrary behaviour
- It seems likely that leadership (manipulation of the market price over the course of they day) may switch between Contact and Meridian, so that in Contact-led days Meridian reverses its water-shifting to maximise the free-riding gains available
- This research project is ongoing and this paper has reported only our first-round results. Much work remains to be done