Save it For a Sunny Day

The Value of Water Storage

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Motivation

• Many previous studies have calculated the value of water
  – e.g. 2002 study of value of water in Manawatu-Wanganui region: hydropower $473m, agriculture $145m

• But what about the value of a water right?
  i.e. an individual water user’s right (resource consent) to use water over a period of time
  – water is often an input into a production process
  – water rights are tradeable, but may be too few transactions to determine their value
Motivation (cont.)

• Focus on value of a water right for storage

• Why?
  – Storage is a large part of NZs existing water system via hydro-generation
  – Storage has the potential to address water shortages

• Value of a storage right depends on the features of the right
  – will present a conceptual framework for valuing a right
  – will determine what features affect this value
The basic approach

• What is the value of a storage right to (say) a hydro-generator?

• Two-period example: generator has right to use 1m³ of water to generate electricity in each period, and gets $P for every m³ of water used

Value of storage right = NPV =

\[ P_0 + \frac{E[P_1]}{(1 + r)} \]
The basic approach (cont.)

- But what about storage? Gives the generator the ability to wait

- Example: store 1 m$^3$ of water in period 0, and release it in period 1 + generate from the additional 1 m$^3$ of water in period 1

  Value of storage right = \( NPV = \frac{2E[P_1]}{(1 + r)} \)

- Generator has options and these options have value
A simple model

• Split storage and generating roles of hydro-generator, focus only on storage

• Storage firm holds a perpetual storage right and has a storage lake of max. capacity 1m³

• If firm wants to store water, pay $P_t$ (e.g. compensates downstream users for the lost revenue)

• If firm wants to release water, receives $P_t$ (e.g. downstream users buy the water off the firm)
A simple model (cont.)

- In any time period \( t \), enough water always flows down a river for the lake to be filled (i.e. no variability in river flows)

- Firm also incurs some fixed cost \( c \), from storage and release

- The lake is either completely full or completely empty

- If lake is currently empty, the firm has an “option to store”
  If lake is currently full, the firm has an “option to release”
Optimal timing to store or release

- At what price will the firm choose to exercise its options i.e. store water in an empty lake or release water from a full lake?

- Empty lake: if price is high, firm is better off waiting until price drops before storing. Will be some threshold $P_S$ – if price drops below it firm will store

- Full lake: if price is low, firm is better off waiting until price rises before release. Will be some threshold $P_R$ – if price rises above it firm will release
# Valuing the storage right

<table>
<thead>
<tr>
<th>Time period</th>
<th>Price</th>
<th>Lake empty or full?</th>
<th>Payoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>$P_0$</td>
<td>Empty lake</td>
<td>0</td>
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<td>...</td>
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<td></td>
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</tr>
<tr>
<td>$T_1$</td>
<td>$P_{T_1} &lt; P_S$</td>
<td>Exercises option to store: Full lake</td>
<td>$-P_{T_1}$</td>
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<td>...</td>
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<tr>
<td>$T_2$</td>
<td>$P_{T_2} &gt; P_R$</td>
<td>Exercises option to release: Empty lake</td>
<td>$P_{T_2} - c$</td>
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Value of the storage right = discounted sum
Getting results from the model

- Model prices as mean-reverting

- Prices are log-normally distributed with:
  long-run mean = 37
  long-run variance = 0.125

- Half-life: time taken for price to revert to half the distance between current price and mean = 8.3 months
The value of the storage right
Empty lake

$26

Store, Wait

Value of storage right, $

Water price, $

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The value of the storage right

Full lake

$47

Value of storage right, $  

Wait        Release

Water price, $
Hysteresis in storage

- Difference in threshold prices results from firm’s ability to buy low and sell high
- Difference in threshold prices leads to “economic hysteresis”
- Hysteresis: a temporary cause leaves a permanent effect
- Economic hysteresis: a decision is not reversed even when the underlying cause is reversed
Hysteresis in storage (cont.)

- Wait if empty
- Release if full

Water price, $:
- 47
- 26

$50 E
$40 F
$40 E
$40 E
$20 F
$40 F

Store if empty
Wait if full
Wait if full

Time

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Uncertain river flows

- Regime Switching model - introduce two regimes (or states): wet and dry

- Wet state – flows are high enough to fill the lake if it is empty

- Dry state – flows are too low: lake cannot be filled if it is empty. Firm has to wait till flows switch to the wet state

- Introduce two new parameters:
  \[ w = \text{average rate of switching per year from wet to dry state} \]
  \[ d = \text{average rate of switching per year from dry to wet state} \]
**Stochastic inflows** (cont.)

<table>
<thead>
<tr>
<th>Time period</th>
<th>Price</th>
<th>Wet or dry?</th>
<th>Empty or full?</th>
<th>Payoff</th>
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<td>Wet</td>
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<tr>
<td>$T_2$</td>
<td>$P_{T_2} &gt; P_R$</td>
<td>Wet / Dry</td>
<td>Empty</td>
<td>$P_{T_2}$</td>
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Value of the storage right = discounted sum
The value of the storage right
Full lake in dry state

$47$ $49

\[ \rho_w = 2 \quad \rho_d = 365 \]
\[ \rho_w = 365 \quad \rho_d = 2 \]
The value of the storage right
Empty lake in dry state

$26 \quad $32
The option value of water?
Full lake - Empty lake
Implications

• Provides a tool for valuing a water storage right

• Shows that the value of a water storage right depends on:
  – current lake level, current spot price, current river flows

• Determines the optimal timing of storage or release

• Suggests economic hysteresis may be present in water storage
  – may make it difficult to create incentives for particular behaviour in the short-term

• Water itself has option value
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