The role of uncertainty on hedging and electricity spot market power

Gabriel Fiuza de Bragança

School of Economics and Finance/ ISCR
Victoria University of Wellington – New Zealand
Background

- Electricity is a complex, idiosyncratic and volatile commodity.
  - Non-storable: supply must meet demand at every instant. Ubiquitous: any aspect that affect the interconnection affects all players.

- Forward/Future markets provide certainty for consumption and investments but regular forward pricing models are troublesome when applied to electricity.
  - Electricity non-storability implies that usual commodity pricing literature (and arbitrage/ cost of carry arguments) do not hold.

- Electricity markets frequently present additional complications.
  - Oligopoly, auctions and vertical integration.

  - Wolak papers assume hedging as exogenous. In this thesis we address the determinants of hedging and its relationship with market power.
Thesis Outline

1) Introduction

2) Basic Model

3) Vertical Integration

4) Concentration and Forward Prices.

5) Investing in Vertical Integration

6) Market power and hedging decision

7) Conclusion
Why hedging?

- In a frictionless world with complete markets, hedge would not add value to firms.


- Electricity markets present an additional problem: incompleteness. Preferences/risk aversion matter and also work as proxies for frictions. In this case, market structure should be expected to be relevant as well.
Context


- This chapter combines these issues in a realistic electricity market set-up. It examines the question of how forward contract is determined and how its choice is affected by market power. Numerical simulations are conducted using NZEM data.
Basic Model

- Timing framework:

  \[ t=0 \rightarrow \text{state variables revealed} \rightarrow t=1 \rightarrow \text{demand disturbances revealed} \rightarrow t=2 \]

  - hedging decision
  - auction/generation decision
  - spot market clearing

- Problem is solved recursively.

- Taking into account preferences and uncertainty about demand at \( t=2 \), Generators chose optimal supply schedule given revealed state variables and quantity contracted (\( t=1 \)). Spot market is cleared and clearing spot prices are determined.

- Generators and retailers take into account uncertainty about state variables and demand disturbances and choose optimal hedging given optimal supply (\( t=0 \)). Forward market is cleared and clearing forward prices are determined.
First step: optimal schedule decision

- Generator/Gentailer i’s maximization problem:

\[
\max_{\hat{S}_{it}(p)} \mathbb{E}[U_i(\hat{S}_{it}(p)p - C_{it}(\hat{S}_{it}(p), \hat{W}_t) + m_i(p^R_t - p)D_t(p^R, \hat{W}_t) + (PC_{it} - p)QC_{it} ]
\]
Optimal supply schedule

- If we assume that supply strategy is additively separable, we are able to considerably simplify the problem.

- Generators/Gentailers behave like monopolists with respect to the residual net demand.

\[
\frac{p_t - MC_{it}}{p_t} = \frac{1}{\varepsilon_{it}(q_{it})} \quad \text{elasticity of net residual demand}
\]

- …but we have multiple equilibria.
Equilibrium spot market outcomes

- If we further assume that i) supply strategies are linear, ii) K>2 and iii) marginal costs and demand can be approximated by linear functions.

- We able to derive optimal supply schedules: $S_{it}^*$

- Clearing the spot market, we derive a linear equilibrium relationship between spot prices and state variables/ quantities contracted given by market parameters: $p_t^c$

- This is a particular equilibrium (not unique) consistent with usual linearity approximations that make the hedging analysis tractable.
Due to the incompleteness of electricity markets, we assume a utility maximization framework. In fact, we assume that managers’ utility can be approximated by a mean-variance function:

$$\max_{QC_i^*} E[\pi_i^*] - \frac{\lambda_i}{2} Var[\pi_i^*]$$

Firstly, assume symmetric and vertically separated generators…

$$\Upsilon^* = p^c S^*(p^c) - C(S^*(p^c))$$

$$QC^{*G} = \frac{PC - E(p^c)}{\lambda_G \sigma^2} + \frac{\text{cov}(p^c, \Upsilon^*)}{\sigma^2}$$

$$QC^{*R} = \frac{PC - E(p^c)}{\lambda_R \sigma^2} + m_i \frac{\text{cov}(p^c, (p^R - p^c)\tilde{D})}{\sigma^2}$$
Market Power

- Forward market clearing condition:

\[ \sum_{i=1}^{N} QC_i^*(PC_i^*) = 0 \]

- In equilibrium, the incentive to exercise market power is ultimately driven by risk aversion and risk exposure.

\[
E(p^c - MC_i) = \frac{b}{(K - 2)} \left( \frac{E(\tilde{D})}{K} - \frac{\text{cov}(p^c, \gamma^*) - \frac{\lambda_R}{\lambda_G} \frac{\text{cov}(p^c, (P^R - p^c)\tilde{D})}{R}}{\sigma^2 \left( 1 + \frac{K \lambda_R}{R \lambda_G} \right)} \right)
\]
Numerical Exercise

Simplifications:

- Vertical Separation (relaxed later).
- Symmetry.
- Generators and retailers have same risk aversion.
- Two state variables (cost and demand shifters) that follows a multivariate normal distribution.
Data

- State variables: demand (national daily average offtake in GWh) and daily average hydro inflows (m3). Source: Electricity Commission website.


- Haywards (month ahead) forward contracts (to build forward premium). Source: EnergyHedge company website (last accessed in 01/2011).

Calibrated parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a$</td>
<td>97.27</td>
</tr>
<tr>
<td>$b$</td>
<td>2.46</td>
</tr>
<tr>
<td>$\text{corr}(w_2, \tilde{D})$</td>
<td>-0.2515</td>
</tr>
<tr>
<td>$\bar{w}_2$</td>
<td>1422.86</td>
</tr>
<tr>
<td>$\bar{D}$</td>
<td>102.62</td>
</tr>
<tr>
<td>$K$</td>
<td>5</td>
</tr>
<tr>
<td>$\rho$</td>
<td>-0.06</td>
</tr>
<tr>
<td>$\lambda_G$</td>
<td>0.00045</td>
</tr>
<tr>
<td>$\lambda_R$</td>
<td>0.00045</td>
</tr>
<tr>
<td>$\sigma_D$</td>
<td>6.60</td>
</tr>
<tr>
<td>$\sigma_2$</td>
<td>353.83</td>
</tr>
<tr>
<td>$R$</td>
<td>5</td>
</tr>
</tbody>
</table>
Forward Premium
Hedge Ratio

(times) hydro inflow volatility

(times) demand volatility
Market Power
## Vertical Integration

<table>
<thead>
<tr>
<th>Company</th>
<th>2008</th>
<th>2008 adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact Energy</td>
<td>27%</td>
<td>29%</td>
</tr>
<tr>
<td>Genesis Energy</td>
<td>25%</td>
<td>27%</td>
</tr>
<tr>
<td>Meridian Energy</td>
<td>12%</td>
<td>12%</td>
</tr>
<tr>
<td>Mighty River Power / Mercury Energy</td>
<td>19%</td>
<td>20%</td>
</tr>
<tr>
<td>Trust Power</td>
<td>11%</td>
<td>12%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>94%</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>
What changes under VI assumption

- Close substitute for forward contracts.

- As far as we have large net retailers and net wholesalers, forward markets can coexist with high level of vertical integration.

- However, in this case, the size of the forward market seems to be less sensitive to risk.

- We should extend the model to endogenize VI and have an integrated view of hedging.

- This substitution between forward hedging and vertical integration means…
Market Power under VI
Conclusion

- Supply and hedging decisions are intrinsic to the market.

- In equilibrium, the incentive to exercise market power is ultimately driven by risk aversion and risk exposure. Market power measurements should be controlled for risk.

- Outcomes of spot and forward markets can be differently affected by supply-side and demand-side volatilities.

- Vertical integration is also a hedge instrument (price and quantity risks) and should be analyzed as an intrinsic component of the market as well.
Thank you!

Gabriel Fiuza de Bragança

gabrielfiuza@gmail.com

School of Economics and Finance/ ISCR
Victoria University of Wellington – New Zealand
Some definitions

- There are $N$ firms ($K$ generators and $R$ retailers). Firms can participate in both markets ($I = K + R - N$ gentailers).

- State variables: $\vec{W}_t = \{w_{1t}, w_{2t}, \ldots, w_{Lt}\}$

- The consumers’ $\sum_{i=1}^{R} m_i D_t(p_t^R, \vec{W}_t) = D_t$

- Generator i’s cost function: $C_{it}(S_{it}, \vec{W}_t)$

- Contracts: $QC_{it}, PC_{it}$

- Retail market share: $m_i$
Equilibrium forward market outcomes

\[ PC^* = E(p^c) - \frac{K \text{ cov}(p^c, \gamma^*) + \text{ cov}(p^c, (P^R - p^c) \tilde{D})}{\frac{R}{\lambda_R} + \frac{K}{\lambda_G}} \]

\[ QC^{*G} = \frac{\text{ cov}(p^c, \gamma^*) - \frac{\lambda_R}{\lambda_G} \text{ cov}(p^c, (P^R - p^c) \tilde{D})}{\sigma^2 \left(1 + \frac{K}{R} \frac{\lambda_R}{\lambda_G}\right)} > 0 \]

\[ QC^{*R}_{i} = -\frac{\frac{K}{R} \text{ cov}(p^c, \gamma^*) + \left(\frac{1}{R} - m_i \left(\frac{\lambda_R}{\lambda_G} + \frac{K}{R}\right)\right) \text{ cov}(p^c, (p^R - p^c) \tilde{D})}{\sigma^2 \left(\frac{\lambda_R}{\lambda_G} + \frac{K}{R}\right)} \]
Numerical Exercises

\[ p^c = \hat{a} + \hat{\rho} \hat{\nu}_{2t} + \hat{\beta} (\tilde{D}_t - \frac{QC^{*G}}{K - 1}) \]

\[ QC^{*G} = \frac{c\text{ov}(p^c, \Upsilon^*) - \frac{c\text{ov}(p^c, (P^R - p^c)\tilde{D})}{R}}{\sigma^2 \left(1 + \frac{K}{R}\right)} \]

\[ \hat{P}C - E(p^c) = -\hat{\lambda} \frac{K \ c\text{ov}(p^c, \Upsilon^*) + c\text{ov}(p^c, (P^R - p^c)\tilde{D})}{R + K} \]
Spot Price

NZD/MWh (CPI adjusted)