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.

- NZEM: The Wolak Controversial Report.

- 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.

- Hedge as a response to corporate frictions (tax rules, transaction costs of bankruptcy and agency costs). Stulz (1990), Bessembinder (1991) and Froot, Scharfstein, and Stein (1993).

- Hedge as a reaction to market friction (illiquidity). Mello and Parsons (2000) and Boyle and Guthrie (2006).

- 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

- Most of the literature takes forward contracts and forward prices as given when analysing their impact on market power. Allaz and Villa (1993), Newbery (1998), Green (1999), Ferreira (2003), Mahenc and Salanie (2004), Liski and Montero (2006), Green and Le Coq (2006) and Bushnell (2007).

- Few paper endogenize forward contracts in an economic set-up but assume competitive markets. Bessembinder and Lemmon (2002) and Porchet et al. (2009).

- 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:
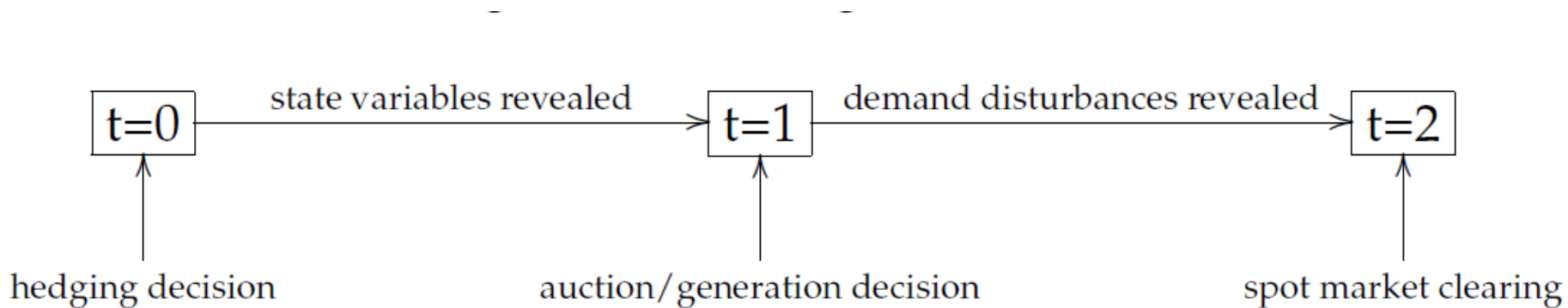
- Problem is solved recursively.

- 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:

$$\max_{\hat{S}_{it}(p)} E[U_i[\hat{S}_{it}(p)p - C_{it}(\hat{S}_{it}(p), \vec{W_t}) + m_i(p_t^R - p)D_t(p^R, \vec{W_t}) + (PC_{it} - p)QC_{it}]]$$

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.

$$\frac{p_t - MC_{it}}{p_t} = \frac{1}{\varepsilon_{it}(q_{it})}$$ $\longrightarrow$ 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.

Second step: optimal hedging decision

- 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…

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

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

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

Market Power

- Forward market clearing condition:

$$\sum_{i=1}^{N} QC_i^*(PC^*) = 0$$

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

$$E(p^c - MC_i) = \frac{b}{(K-2)} \left(\frac{E(\tilde{D})}{K} - \frac{cov(p^c, \Upsilon^*) - \frac{\lambda_R}{\lambda_G} \frac{COV(p^c, (P^R - p^c)\tilde{D})}{R}}{\sigma^2 \left(1 + \frac{K}{R}\frac{\lambda_R}{\lambda_G}\right)} \right)$$

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 spot price series (NZD/MWh). Source: Electricity Commission website.

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

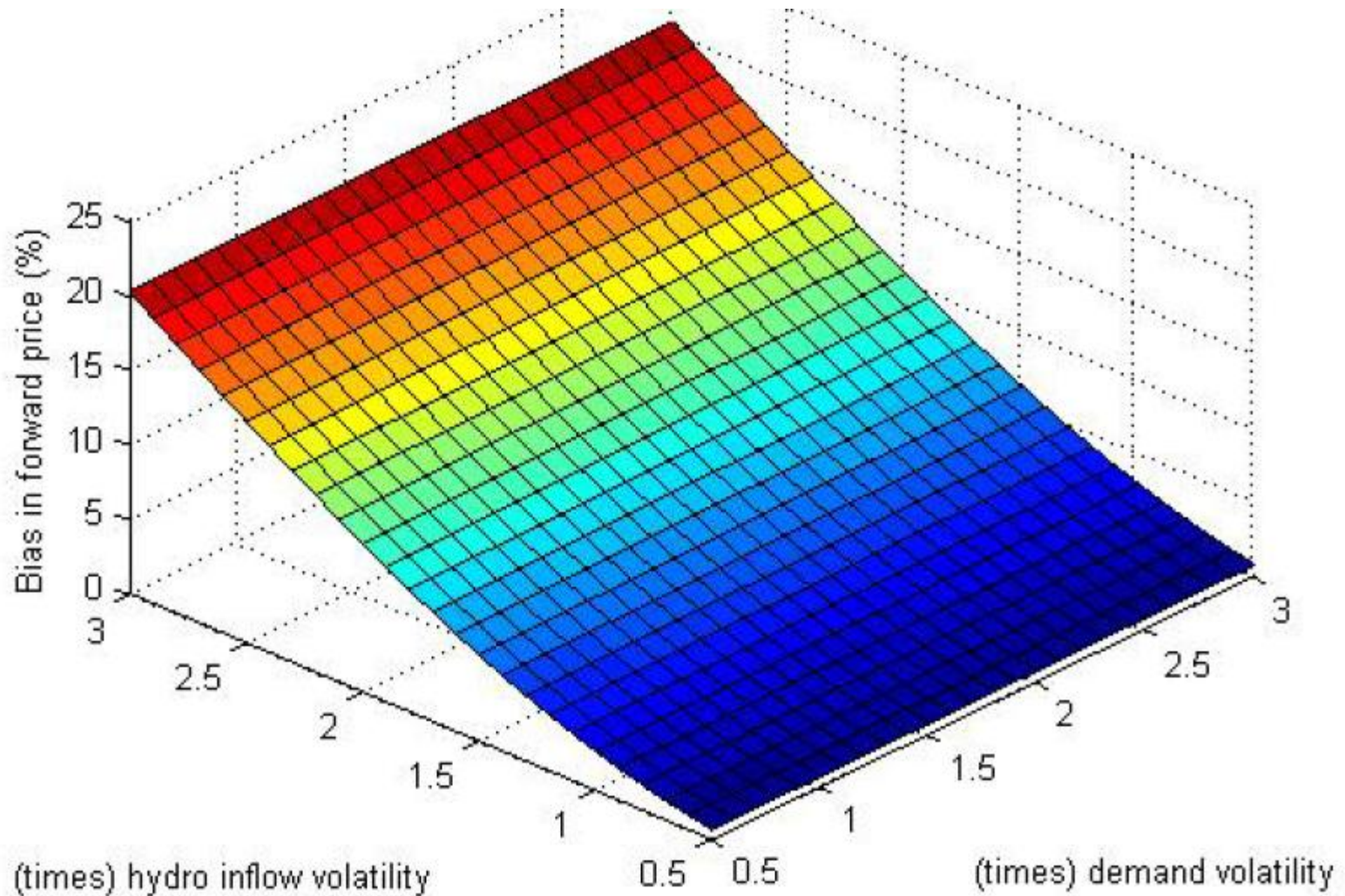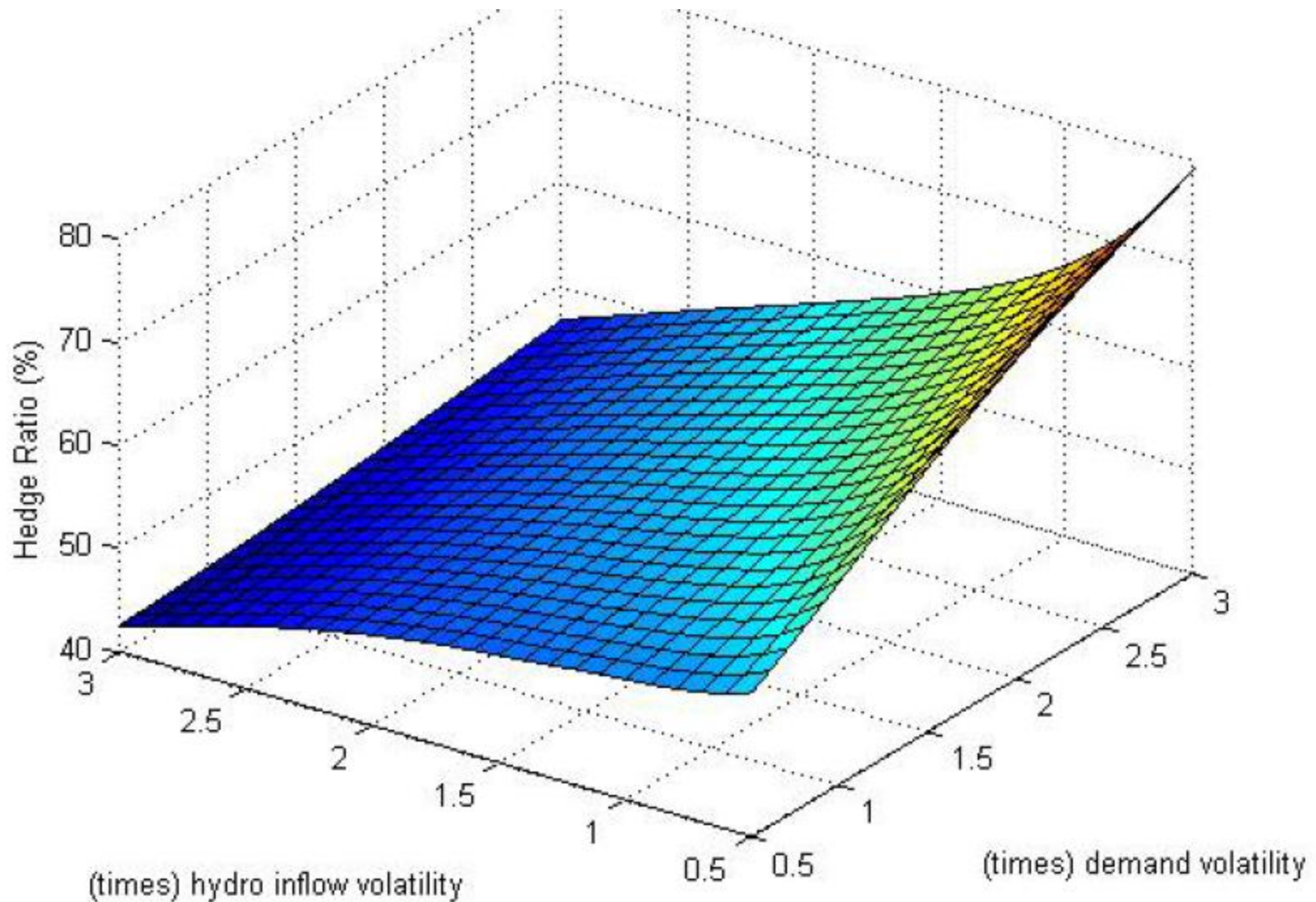- monthly series from 04/2004 to 06/2010.

Calibrated parameters

a	97.27	ρ	-0.06
b	2.46	λ_G	0.00045
$\mathrm{corr}(w_2, \tilde{D})$	-0.2515	λ_R	0.00045
$\bar{w}_2$	1422.86	σ_D	6.60
$\bar{D}$	102.62	σ_2	353.83
K	5	R	5

Forward Premium

Hedge Ratio

Market Power
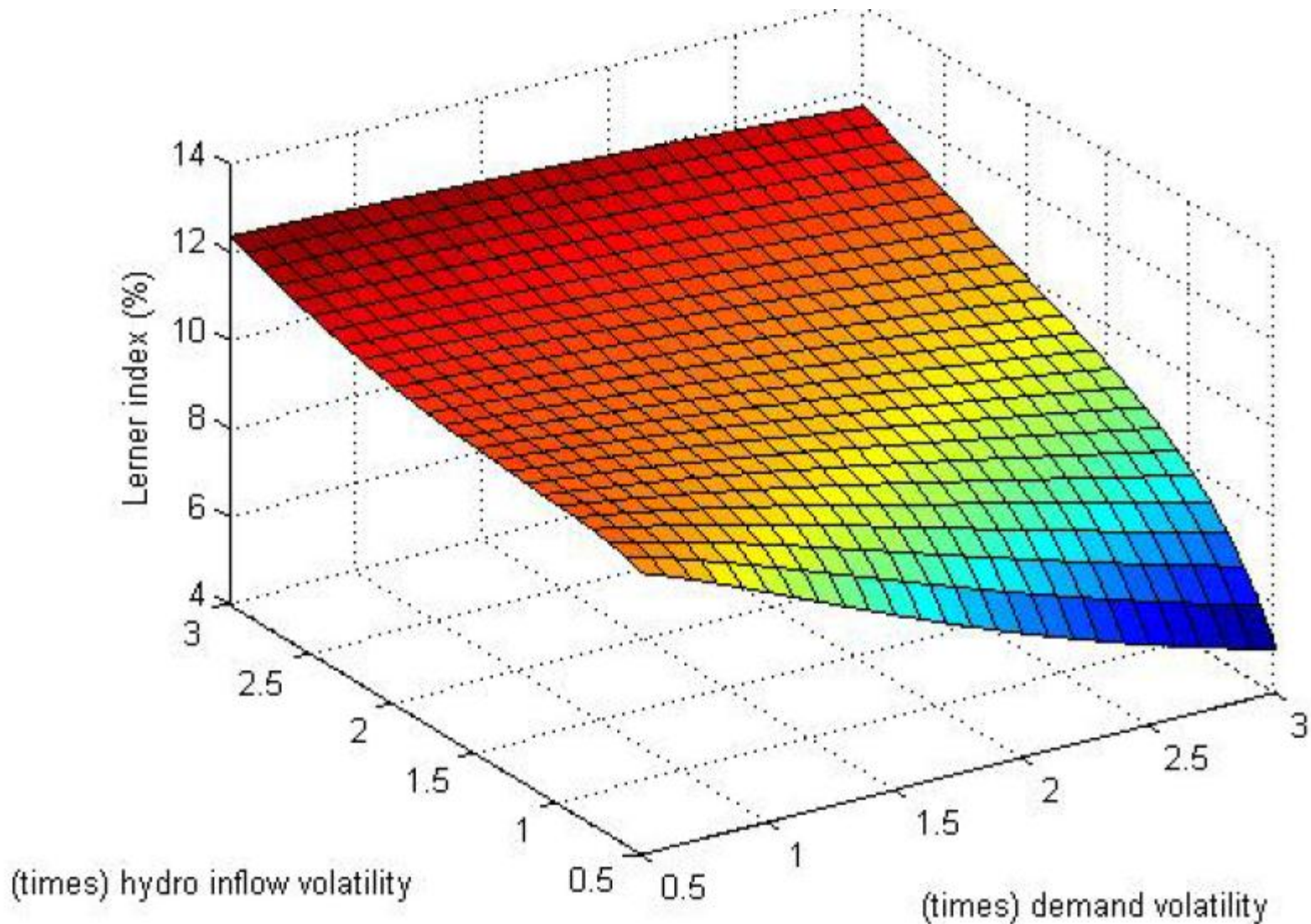
Vertical Integration

Company	2008	2008 adjusted
Contact Energy	27%	29%
Genesis Energy	25%	27%
Meridian Energy	12%	12%
Mighty River Power / Mercury Energy	19%	20%
Trust Power	11%	12%
Total	94%	100%

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
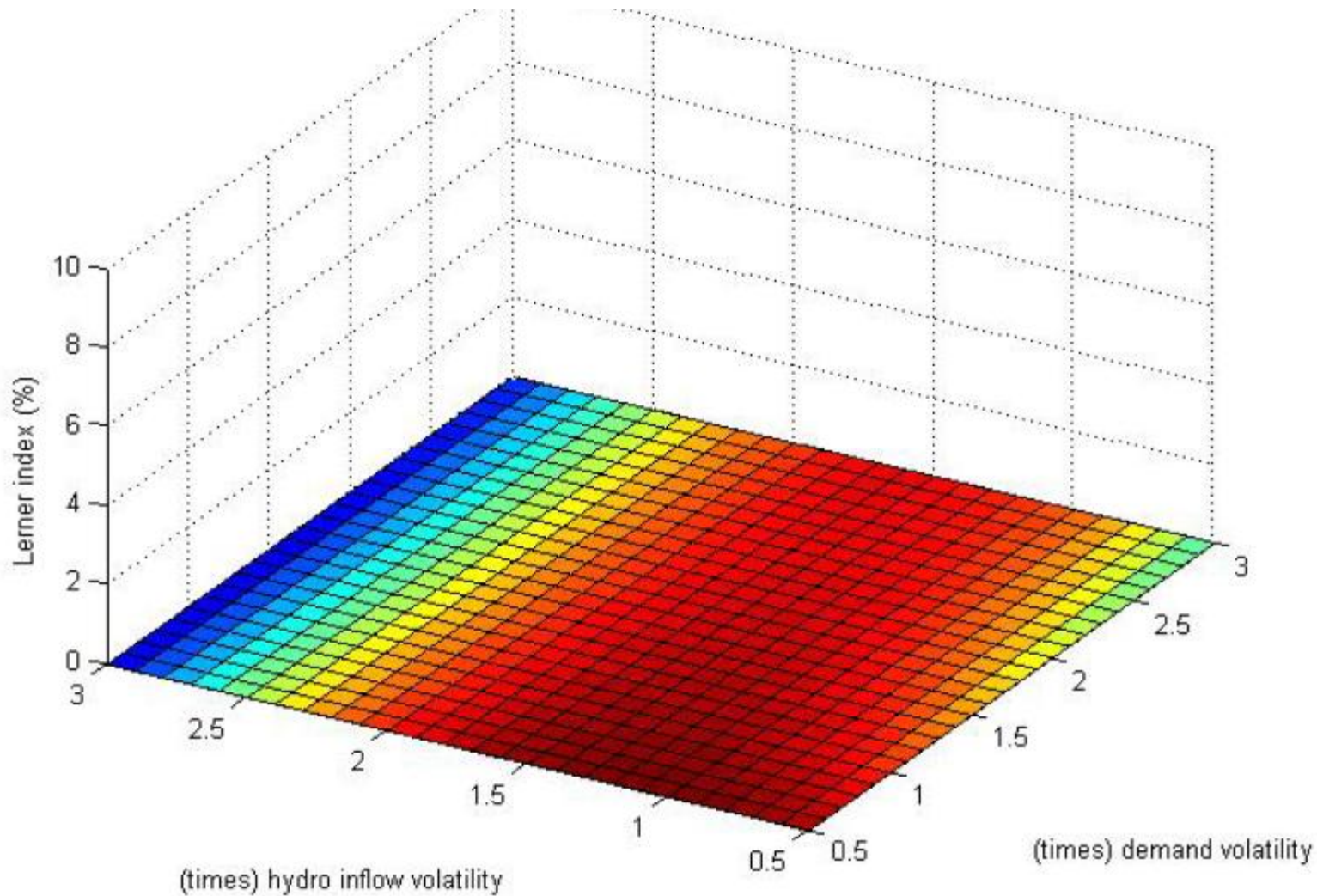
Conclusion

- 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: $QC_{it} \quad PC_{it}$

- Retail market share: m_i

Equilibrium forward market outcomes

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

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

$$QC_i^{*R} = -\frac{\frac{K}{R}cov(p^c, \Upsilon^*) + \left(\frac{1}{R} - m_i\left(\frac{\lambda_R}{\lambda_G} + \frac{K}{R}\right)\right)cov(p^c, (p^R - p^c)\tilde{D})}{\sigma^2\left(\frac{\lambda_R}{\lambda_G} + \frac{K}{R}\right)}$$

Numerical Exercises

$$p^c \;=\; \hat{a} + \hat{\rho}\tilde{w}_{2t} + \hat{\beta}\left(\tilde{D}_t - \frac{QC^{*G}}{K-1}\right)$$

$$QC^{*G} \;=\; \frac{\hat{\text{cov}}(p^c, \Upsilon^*) - \dfrac{\hat{\text{cov}}(p^c,(P^R-p^c)\tilde{D})}{R}}{\hat{\sigma}^2\left(1 + \frac{K}{R}\right)}$$

$$\hat{PC} - E(p^c) \;=\; -\hat{\lambda}\frac{K\,\hat{\text{cov}}(p^c, \Upsilon^*) + \hat{\text{cov}}(p^c,(P^R-p^c)\tilde{D})}{R + K}$$

Spot Price

NZD/MWh (CPI adjusted)