Equilibrium Forward Premium and Optimal Hedging in Electricity Markets with Green and Brown Producers

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Electricity Forward Premium

- Importance
  - Electricity cannot be economically stored yet;
  - Forward markets, as well as wholesale markets are critical for managing risks;
- Challenges
  - Traditional pricing approaches not working due to non-storability;
  - Markets are not perfect: asymmetrical information, market power, constraints from regulations as well as market design etc.

B&L (2002) Model

- Bessembinder and Lemmon (2002)
  - An equilibrium model, risk-averse identical generators and retailers, competitive markets;
  - The bias of forward prices is induced by the net hedge pressure in the market which depends on the distribution of the expected spot prices:
    1. Variance has negative impact; retailers have higher hedge pressure;
    2. Skewness has positive impact; producers have higher hedge pressure

Our Proposal

- Our equilibrium model: why mixed evidences on B&L(2002)?
  - Based on B&L (2002);
  - Consider the impact of policies dealing with climate change, such as promotion of green production;
  - Introduce both brown and green producers: Jonsson et al (2013), Acemoglu et al (2017), Ito and Reguant (2016) etc.;
    1. Different cost structure;
    2. Asymmetrical competition.

Key Results

- The forward premium is negatively (positively) related to the variance of spot prices, and positively (negatively) related to the skewness of spot prices <u>when the expected demand is low (high)</u>;

- The forward premium is negatively related to the kurtosis of spot prices;

- The forward premium is positively related to the uncertainty risk of green production;

- The forward premium is negatively related to the production share of renewable generations.

Model Setup—Players

	Conventional Producers	Renewable Producers	Retailers
Cost Function	$\frac{dTC_{B_i}}{dQ_{B_i}} = a\left(Q_{B_i}\right)^{c-1}$	$\frac{dTC_{G_j}}{dQ_{G_j}} = \frac{Q_{G_j}}{b_{t_j}}$	$\frac{dTC_{R_n}}{dQ_{R_n}} = P$
Comment	Convex MC; $c > 2$	Constant MC; b_{t_j} is the slope of supply curve at time t; uncertainty is measured by $b_{1_j} - b_{2_j}$	

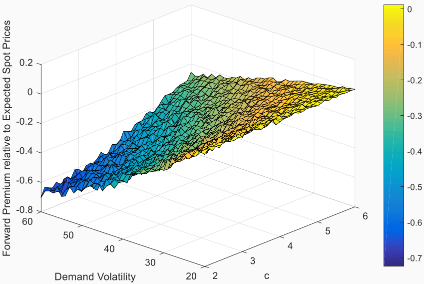
Model Setup

- In the Spot Market:
  - Asymmetrical competition: the brown producers face residual demand; the green producers are price-takers;
  - The brown producers solve their problems by maximizing their profit functions by choosing the spot price, P_W.
- In the Forward Market:
  - The players have objective function that is linear in expectations and variances, see Hirshleifer and Subramanyam (1993);

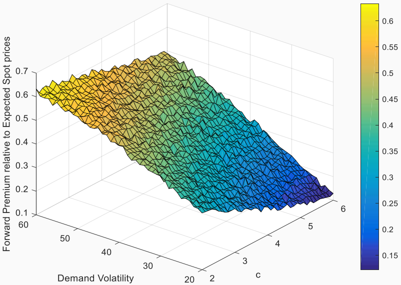
$$P_F = \beta_1 E(P_W) + \beta_2 VAR(P_W) + \beta_3 SKEWNESS(P_W) + \beta_4 KURTOSIS(P_W)$$

Model Implications—The Coefficient of Variance and Skewness

Low Demand



High Demand



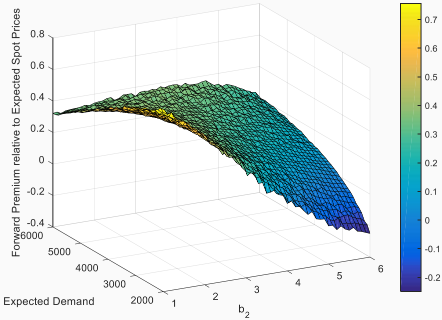
- When demand is low, higher variance of spot prices increases the hedge pressure of brown producers; higher skewness concern more to retailers;

- When demand is high, higher variance worries the retailers; higher skewness disturbs the brown producers.

Model Implications—The Coefficient of Kurtosis

- The Sign of Kurtosis is negative, suggesting that fat tails of spot prices lead to lower forward premium
  - Spot prices could be negatively skewed when demand is low and renewable supply is high even $c \geq 2$;
  - More extreme low prices put the revenue of the brown producers at risk;
  - A net selling pressure in the forward market.

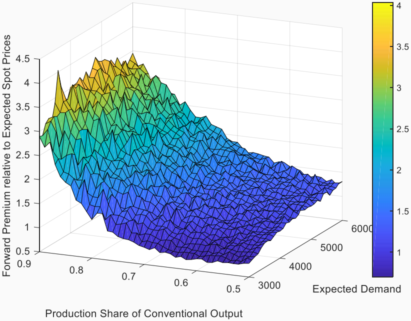
Model Implications—The impact from Uncertainty risk



- Measured by $b_1 - b_2$; the higher the uncertainty risk, the higher the forward premium;

- The higher the demand level, the lower this positive effect

Model Implications—The impact from RES shares



- The higher the production share of RES, the lower the forward premium;
- Net hedge pressure from the brown producers' side.

Empirical Results—Regression

$$\begin{aligned} Forward\ Premium_{th} &= constant + \Phi_1 variance_{th} * Lowdemand \\ &+ \Phi_2 variance_{th} * Highdemand + \Phi_3 skewness_{th} \\ &* Lowdemand + \Phi_4 skewness_{th} * Highdemand \\ &+ \Phi_5 kurtosis_{th} + \Phi_6 renewableshare_{th} \\ &+ \Phi_7 renewableuncertainty_{th} + controls + FE + \mu_{th} \end{aligned}$$

- Panel data from the Spanish electricity markets: day-ahead market and the intraday market;
- Panel fixed effect, cross-section SUR for weights and (Newey-West robust) covariance matrix;
- Variance, skewness, kurtosis are computed using moving average of 15 days, and we also computed using historical measures as robustness check;

Empirical Results—Regression

Variable	Expected sign	Moving Average Measure		Historical Measure	
		Coefficient	Coefficient	Coefficient	Coefficie
Constant		26.77***	26.57***	26.24***	26.26***
		(26.04)	(25.55)	(25.49)	(25.45)
Variance		-0.03***		0.0004	
		(-5.74)		(1.09)	
Variance*Highdemand50	+		0.02***		0.0003
			(5.29)		(1.34)
Variance*Lowdemand01	-		-0.09***		-0.002**
			(-4.11)		(-2.36)
Skewness		-0.05		-0.11	
		(-0.85)		(-1.50)	
Skewness*Highdemand95	-		0.02		-0.45**
			(0.13)		(-2.48)
Skewness*Lowdemand01	+		0.49		1.48***
			(1.49)		(3.42)
Kurtosis	-	-0.07***	-0.06***	-0.04	-0.03
		(-2.90)	(-2.92)	(-1.10)	(-1.06)
RES share	-	-24.30***	-24.94***	-25.04***	-25.16***
		(-17.52)	(-17.69)	(-18.07)	(-18.00)
Green uncertainty	+	0.06***	0.06***	0.07***	0.07***
		(11.10)	(10.17)	(12.48)	(12.77)
Controls		Yes	Yes	Yes	Yes
Fixed Effect		Yes	Yes	Yes	Yes
Observations		8400	8400	8683	8688
R-squared		0.385	0.378	0.386	0.39

Contributions

- We reconcile the mixed evidence found in the literature about the impact of the volatility and skewness of spot prices on the forward premium;
- We shed light on the relationship between the forward premium and the percentage of RES production, which provides insight on the climate change policies' impact on the electricity markets;
- We propose a measure on the uncertainty risk of RES, and discuss the influence of renewable sources on the forward premium from another perspective.

Thank you!