A Forward Contract to Manage Market Power: the case of Italy

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Outline

• Aim of the paper
• Role of derivatives contracts
• The Italian electricity market
• The model
• Some preliminary results
Aim of the paper

- To verify if the introduction of a derivative electricity contract may stimulate and control the underlying spot market;
- To use the closed form solution (Dong & Liu ’05) to define the optimal forward contract features;
- To simulate the possible effect of this contract on the Italian market.
Electricity Market Deregulation

Centrally owned and operated system

Market based Decentralized system

Criteria for successful liberalisation

“deliver the lowest possible sustainable prices to all customers, for a supply that is reliable in the short and long run”

⇒ minimise entry and exit barriers

⇒ minimise transaction costs and avoidable risks

⇒ charges should be cost-reflective and paid by those causing cost
Power Market

- Unstorable commodity: perfect matching of generation and consumption
- Delivery of a specific amount of energy units during a certain period of time
- Electricity Supply quite flexible for low levels of demand and very rigid for high levels
- Electricity demand highly inelastic, and sensitive to economic cycles.
Derivative Instruments

- Accurate risk management on energy prices
- Pre-setting of cost or selling price of electricity
- Risk hedging is a cause for the existence of bilateral supply contracts;
- An equilibrium forward contract reduces commodity price risk for at least one party.
- Futures contracts may play a key role
A Forward Contract?

- Bilateral contracts in electricity markets are frequently used even when spot markets are liquid and available to both suppliers and buyers.
- Contract terms can also be set to extract forecast information (Tsay ‘99, Cachon and Lariviere ‘01) and sales effort (Taylor ‘02).
- In the presence of a spot market the introduction of a forward contract may be due to risk reduction and not to profit generation.
- Risk reduction requires financial and operational hedging: a forward contract can be viewed as a financial instrument and an operational instrument.
Pricing Forward

Pricing derivatives on non storable commodities.

No-arbitrage argument cannot be applied:

Assuming derivative markets are **perfectly** competitive

- Kawai, ‘83
- Bessembinder and Lemmon, ’02;

Assuming derivative markets are **imperfectly** competitive:

- Green and Newbery, ’92;
- Newbery ’95;
- Wolfram ’99;
- Eydeland and Geman, ‘99,
- Pirrong and Jermaykyan, ’99;
- Krapels ’00.
- Dong & Liu ‘05
Italian Electricity Market

- 1999: Deregulation started and creation of the GRTN (National Grid Network), GME (Italian Power Exchange).
- GME is responsible for the organisation and management of the Electricity Market, an electronic marketplace where electricity demand and supply meet and where quantities and prices are determined.
- The Electricity Market is also a physical market, where the schedules of electricity injections into and withdrawals from the grid are defined under the economic merit order criterion.

It consists of:
- **Day-Ahead Market** - MGP;
- **Adjustment Market** - MA;
- **Ancillary Services Market** - MSD.
Italian Electricity Market (2)

1. A forward contract in an imperfectly competitive market how should be set?

2. What kind of relation between the forward and the spot?

3. Does forward market increases the activity on the spot?
Electricity price in the scandinavian Market

Electricity prices in the italian market

London, January 18th '07
The Italian Electricity Market

Electricity Demand: Monthly Hour average
Italian Electricity Market

Total outstanding volume for the 2005, 2004

London, January 18th '07
**Demand Composition**

<table>
<thead>
<tr>
<th>Demand Composition on the IPEX and OFF-IPEX. 2005</th>
<th>MWh</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Buyer</td>
<td>139.179.880,00</td>
<td>69%</td>
</tr>
<tr>
<td>Other operators</td>
<td>47.682.936,00</td>
<td>23%</td>
</tr>
<tr>
<td>Pumping</td>
<td>8.087.174,00</td>
<td>4%</td>
</tr>
<tr>
<td>Foreign zones</td>
<td>2.773.208,00</td>
<td>1%</td>
</tr>
<tr>
<td>Additional bids</td>
<td>5.262.767,00</td>
<td>3%</td>
</tr>
<tr>
<td><strong>IPEX</strong></td>
<td>202.985.965,00</td>
<td>100%</td>
</tr>
<tr>
<td>Foreign Bilateral</td>
<td>1.143.298,00</td>
<td>1%</td>
</tr>
<tr>
<td>National bilateral (Single Buyer)</td>
<td>25.153.421,00</td>
<td>21%</td>
</tr>
<tr>
<td>National bilateral (Others)</td>
<td>93.902.066,00</td>
<td>78%</td>
</tr>
<tr>
<td><strong>OFF IPEX</strong></td>
<td>120.198.785,00</td>
<td>100%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>323.184.750,00</td>
<td></td>
</tr>
</tbody>
</table>
Electricity Prices

Prezzi Daily  Peakload

Italia
Germania

London, January 18th '07
The model

Following Dong and Liu (‘05) we use the unique equilibrium forward price and quantity to assess the possible impact of a forward contract on the Italian spot market activity.

Dong & Liu derive a solution for a forward contract in a non perfectly competitive market.

Basic assumptions:
1. the input commodity is nonstorable;
2. the supplier and the manufacturer have significant market power;
3. negotiation of the forward contract is described by a Nash bargaining process:
...The model

- The supplier and the manufacturer have mean variance preferences over their own risky profits.
- The supplier and the manufacturer incur fixed negotiation costs, $F_s$, $F_m$.
- The supply contract is in the form of a forward contract $(f, Q)$, $Q > 0$, $f > 0$.
- The supplier and the manufacturer can also trade in the spot market for the electricity.
- The final product demand, $D$, the final sale price, $s$, the non storable commodity price, $p$, are all random variables with bounded supports and with certain means and variances:

$$
\left(\mu_D, \sigma^2_D\right), \left(\mu_s, \sigma^2_s\right), \left(\mu_p, \sigma_p^2\right),
$$
The model

- The manufacturer and the supplier choose optimal production levels to maximize their profits at time 1.
- They have mean-variance preferences over their own time $T$ risky profits. $\pi_m, \pi_s$. $\lambda_m$ and $\lambda_s$ are the respective risk aversion coefficients:

\[
U_m(\pi_m) = E\pi_m - \lambda_m \text{var } \pi_m
\]

\[
U_s(\pi_s) = E\pi_s - \lambda_s \text{var } \pi_s
\]

\[
\lambda_j < \frac{1}{\pi_j}
\]

Utility functions increasing in profits
...The model

The manufacturer’s utility

\[
U_m(Q, f) = E_t [\pi_m(Q, f, D, p, s)] - \lambda_m \text{var} [\pi_m(Q, f, D, p, s)]
\]

where

\[
\pi_m(Q, f, D, p, s) = \max_{q \geq 0} \left\{ s \min(q, D) - fQ - p(q - Q) - g(D - q)^+ \right\} - F_m 1_{\{Q \neq 0\}}
\]

The supplier’s utility

\[
\tilde{U}_s(Q, f) = U_s(f, Q) - U_{s0} = (f - \mu_p)Q - F_s 1_{\{Q \neq 0\}} - \lambda_s \Delta \text{var}_s
\]

\[
\Delta \text{var}_s = \left(1 - \rho^2 \right) \left[ \sigma^2_p Q^2 - 2Q \frac{\text{Cov}_s + \text{Cov}_i \rho \sigma_p / \sigma_p}{1 - \rho^2} \right]
\]

Corr between the final product price and the input spot price

the cov between the production profit and the financial profit
The model

*The forward market is imperfectly competitive.*

Market power shows the level of competitiveness in each sector. The *Nash bargaining process* describes the contract negotiation process:

\[
\max_{(f, Q)} \hat{U}_m(f, Q)^\theta \hat{U}_s(f, Q)^{1-\theta} \quad \theta \in [0,1]
\]

s.t.

\[
\hat{U}_m(f, Q) \geq 0, \quad \hat{U}_s(f, Q) \geq 0
\]

Relative bargaining power
The equilibrium solution

Dong and Liu (‘05) find a unique equilibrium:

\[ Q^* = \begin{cases} 
\frac{\lambda_m \text{cov}_m + \lambda_s (\text{cov}_s + \text{cov}_i \rho \sigma_p / \sigma_{p_i})}{(\lambda_m + \lambda_s (1-\rho^2))\sigma_p^2}, & \text{if} \\
0, & \text{otherwise} 
\end{cases} \]

\[ \lambda_m \text{cov}_m + \lambda_s (\text{cov}_s + \text{cov}_i \rho \sigma_p / \sigma_{p_i}) > \sqrt{(\lambda_m + \lambda_s (1-\rho^2))\sigma_p^2 (F_m + F_s)} \]

\[ f^* = (1-\theta)\left[\mu_p - \lambda_m \left(\sigma_p^2 Q^* - 2 \text{cov}_m\right) - \frac{F_m}{Q^*}\right] + \theta \left[\mu_p + \lambda_s \left((1-\rho^2)\sigma_p^2 Q^* - 2(\text{cov}_s + \text{cov}_i \rho \sigma_p / \sigma_{p_i})\right) + \frac{F_s}{Q^*}\right] \]
Empirical Analysis

• Italian market data

• To estimate the forward price using spot prices information

• To simulate the effect of the forward contract on the underlying market.
Empirical Analysis

We have to choose a model to describe spot price dynamic.

Hp:

\[ x(t) = y(t) + p(t) \]

Were \( p(t) \) is the random component of the prices and according to Lucia & Schwartz ('02) can be described:

\[ dp_t = (\mu - \alpha_1 p_t)dt + \sigma dz_t \]

\( y(t) \) is a highly predictable component accounting for the seasonality effects

\[ y(t) = \mu + \beta_1 D_1(t) + \beta_2 D_2(t) \]
Empirical Analysis

According to the assumption spot prices are lognormally distributed so:

\[
E[p_t | \mathcal{F}_0] = E[e^{-\eta t} \log(p_0) + (1 - e^{-\eta t})(\mu + \frac{\sigma^2}{4\eta})]
\]

\[
\text{var}[p_t | \mathcal{F}_0] = E[2e^{-\eta t} \log(p_0) + (1 - e^{-\eta t})(\mu + \frac{\sigma^2}{2\eta})]E\left[\frac{\sigma^2}{2\eta} \left(1 - e^{-\eta t}\right) - 1\right]
\]
**Empirical analysis**

We estimate the spot price parameters for the different seasons

<table>
<thead>
<tr>
<th>Estimation results (winter)</th>
<th>Estimation results (spring)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_w$</td>
<td>$\alpha_s$</td>
</tr>
<tr>
<td>0.31</td>
<td>0.21</td>
</tr>
<tr>
<td>(0.022)</td>
<td>(0.032)</td>
</tr>
<tr>
<td>$\sigma_w$</td>
<td>$\sigma_s$</td>
</tr>
<tr>
<td>0.21</td>
<td>0.19</td>
</tr>
<tr>
<td>(0.002)</td>
<td>(0.012)</td>
</tr>
<tr>
<td>$\mu_w$</td>
<td>$\mu_s$</td>
</tr>
<tr>
<td>2.984</td>
<td>3.184</td>
</tr>
<tr>
<td>(0.019)</td>
<td>(0.019)</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>$\beta_1$</td>
</tr>
<tr>
<td>0.27</td>
<td>0.17</td>
</tr>
<tr>
<td>(0.021)</td>
<td>(0.019)</td>
</tr>
<tr>
<td>$\beta_2$</td>
<td>$\beta_2$</td>
</tr>
<tr>
<td>-0.498</td>
<td>-0.698</td>
</tr>
<tr>
<td>(0.12)</td>
<td>(0.12)</td>
</tr>
<tr>
<td>LL</td>
<td>LL</td>
</tr>
<tr>
<td>73.44</td>
<td>89.45</td>
</tr>
<tr>
<td>SC</td>
<td>SC</td>
</tr>
<tr>
<td>110.78</td>
<td>134.78</td>
</tr>
</tbody>
</table>

London, January 18th '07
Empirical Analysis

• We analyze the daily hourly demand;
• We assume the final product cost is proportional to the commodity price (simplifying assumption)

A forward may help a participant both to improve profitability (*speculative benefit*) and to reduce profit risk (*hedging benefit*)

A forward market increases both the production of the commodity and the trading volume in the spot market.
Empirical Analysis

We estimate the parameters required to get the equilibrium forward price and quantity:

<table>
<thead>
<tr>
<th>Parameter Estimates</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu_D$</td>
<td>27,5</td>
<td>20,12</td>
<td>30,12</td>
<td>24,24</td>
</tr>
<tr>
<td>$\sigma_D$</td>
<td>8,12</td>
<td>9,51</td>
<td>3,14</td>
<td>6,12</td>
</tr>
<tr>
<td>$\mu_s$</td>
<td>40,1</td>
<td>38,12</td>
<td>41,12</td>
<td>36,4</td>
</tr>
<tr>
<td>$\sigma_s$</td>
<td>6,45</td>
<td>5,68</td>
<td>6,01</td>
<td>5,35</td>
</tr>
<tr>
<td>$\rho_{PD}$</td>
<td>-0,23</td>
<td>-0,32</td>
<td>-0,56</td>
<td>-0,61</td>
</tr>
<tr>
<td>$\rho_{Ps}$</td>
<td>0,9</td>
<td>0,87</td>
<td>0,89</td>
<td>0,92</td>
</tr>
<tr>
<td>$\rho_{SD}$</td>
<td>-0,4</td>
<td>-0,45</td>
<td>-0,55</td>
<td>-0,54</td>
</tr>
<tr>
<td>$\theta$</td>
<td>0,65</td>
<td>0,8</td>
<td>0,4</td>
<td>0,7</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>0,6</td>
<td>0,6</td>
<td>0,6</td>
<td>0,6</td>
</tr>
</tbody>
</table>
Some Results

- Changes in spot may affect forward differently in the 4 seasons.
- When p is small the effect on speculation dominates so forward doesn’t show relevant changes.
- When p increases the effect on hedging becomes more relevant.

Forward price as function of spot price
Some Results

• As the spot price risk increases the forward price for all seasons increases.
• It makes more valuable to use a forward to hedge against the price risk
Preliminary Conclusion

• The presence of a forward contract may increase the trading on the spot market.

• The forward price can be a downward or an upward biased predictor of the spot price depending on the market power and on the convenience yield.

Work in progress

• Introducing jumps in the spot price dynamic

• Estimating the market power using different assumptions

• Adapt the model to the bilateral contracts and estimate endogenously the implied market power