Do Firms Sell Forward for Strategic Reasons?
An Application to the Wholesale Market for Natural Gas

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Introduction

→ Energy markets undergone liberalization process worldwide

→ Vertical structure monopolized

→ Long-lasting bilateral contracts standard of trade

→ Liberalization aims at developing *markets* for the commodity.
Spot markets for electricity and gas
  - electricity: the Pool, ISO, real-time PJM market, ERCOT, EPEXSPOT
  - natural gas: NBP, The Henry Hub, Zeebrugge, TTF

Risk and market power perceived to exist and persist

At the heart of the 2000-2001 electricity crisis in California (Bushnell, 2007)

Widely held spot markets must be complemented with forward markets (Ausubel & Cramton, 2010)
Facilitating forward transactions can deliver social benefits on two accounts.

- Forward markets address the need of a firm to *hedge risks* (Baron, 1970; Holthausen, 1979).
- Forward markets activate strategic commitment and this create a prisoners’ dilemma-like situation where aggregate output is increased (Allaz, 1992; Allaz & Vila, 1993).
Policies in various fronts.

- Platforms are created where property rights can more easily be transferred among the participants well ahead of or on delivery.

- Sponsor directly the creation of futures markets.
  - electricity forward markets: CALPX, EEX Power Derivatives
  - natural gas: ENDEX

- Impose forward obligations (vesting contracts, gas release programs, asset divestments, VPPs)
Whether the forward market institution delivers social benefits by itself on these two accounts is not yet well-known.

- One reason: many restructured markets have been subject to transitional arrangements that include the forced selling of forward contracts.
- A second reason: disentangling the various incentives behind the contract cover of a firm is, at least, challenging.
- A third reason is probably lack of data regarding forward and spot positions, as well as the fraction of speculative trades.
Objective

- This paper proposes an empirical strategy to find out whether firms use forward contracts for strategic motives, for risk-hedging or for both

→ We apply our method to the Dutch wholesale market for natural gas.

→ This is a market where forward contracts have been motivated by market forces.
Empirical strategy builds on the ideas that:

- risk-hedging relevant if price is volatile and firms are risk-averse
- commitment has value only if it is (imperfectly) observable
Model

$n$ asymmetric firms supply a homogeneous good in the spot and forward markets

- firms differ in mg. cost $c_i$
- and in risk aversion $\rho_i$

$q_i$: firm $i$’s total production; part sold forward ($x_i$), rest sold spot ($s_i = q_i - x_i$)

Demand is random:

$$p = a - bQ + \epsilon,$$

with $\epsilon \sim N(0, \sigma^2)$, $Q = \sum_{i=1}^{n} q_i$
Model (cont.)

SPOT MARKET

\[ \mapsto \text{uncertainty } \epsilon \text{ resolved at spot market stage} \]

\[ \mapsto \text{firms choose } s_i \text{ to maximize } \pi_i^s = (p - c_i)s_i \]

FORWARD MARKET

\[ \mapsto \text{total (forward & spot) profits of firm given by:} \]

\[ \pi_i = (p - c_i)s_i + (f - c_i)x_i \]

where \( f \) denotes the forward price.

\[ \mapsto \text{risk-averse firms pick } x_i \text{ to maximize expected utility} \]

\[ E[u(\pi_i)] = \int -e^{-\rho_i \pi_i} dF(\pi_i) \]

(2)
Model (cont.)

SPOT MARKET

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TRANSPARENCY.

→ Forward positions become observable with probability $\gamma$. Various interpretations valid for the parameter $\gamma$.

Objective of paper is to identify and quantify $\gamma$.

SPECULATORS.

→ Fringe of competitive speculators, no transmission capacity rights, offset positions before delivery takes place.

→ In all cases, for the moment, assume pure financial traders observe positions, so we have an efficient forward market, so $f = E(p)$.
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Model (cont.)

→ Timing:
  ▶ Stage 1: Firms offer forward contracts
  ▶ Stage 2: Forward positions become observable or not
  ▶ Stage 3: Demand uncertainty is resolved
  ▶ Stage 4: Firms compete in quantities in the spot market and delivery of total output (forward + spot) takes place
Analysis

**SPOT MARKET**

Let $I$ be a Bernoulli variable with parameter $\gamma$.

If $I = 0$, firm $i$’s spot market strategy is

$$s_{i}^{I=0} = a + \epsilon + \sum_{j \neq i} c_{j} + b(n - 1)\hat{x}_{i}/2 - nc_{i} - b(n + 1)x_{i}/2 - b\sum_{j \neq i} \hat{x}_{j}$$

where $\hat{x}_{j}$ denotes $j$’s conjectured forward position with conditional profits

$$\pi_{i}^{I=0} = b(s_{i}^{I=0})^2 + (f - c_{i})x_{i}.$$
Analysis (cont.)

SPOT MARKET (cont.)

If \( I = 1 \)

\[
\frac{s_{i}^{I=1}}{b(n + 1)} = \frac{a + \epsilon + \sum_{j \neq i}^{n} c_j - nc_i - bx_i - b \sum_{j \neq i}^{n} x_j}{b(n + 1)}
\]

with conditional profits

\[
\pi_{i}^{I=1} = b(s_{i}^{I=1})^2 + (f - c_i)x_i.
\]
FORWARD MARKET

\[ \rightarrow \text{At the forward stage, firm } i \text{ chooses the amount of forward sales that maximizes expected utility:} \]

\[ E[u(\pi_i)] = -\gamma \int e^{-\rho_i \pi_i^{l=1}} f(\epsilon) d\epsilon - (1 - \gamma) \int e^{-\rho_i \pi_i^{l=0}} f(\epsilon) d\epsilon \]

\[ \rightarrow \text{The optimal level of forward contracting solves:} \]

\[ E \left( u'(\cdot) \frac{d\pi_i}{dx_i} \right) = 0 \]
Taking the FOC, and using $\hat{x}_i = x_i$ for all $i$ so that $\pi_i^1 = \pi_i^0 = \pi_i$, we have

$$\int \rho_i e^{-\rho_i \pi_i} \left( \frac{\partial \pi_i}{\partial x_i} + (1 - \gamma) \frac{\partial \pi_i}{\partial s_i} \frac{\partial s_i}{\partial x_i} + \gamma \sum_j \frac{\partial \pi_i}{\partial s_j} \frac{\partial s_j}{\partial x_i} \right) f(\epsilon) d\epsilon = 0$$
Analysis (cont.)

FORWARD MARKET (cont.)

Or

\[
\int e^{-\rho_i \pi_i} \left( -\frac{bx_i}{2} - \frac{\epsilon}{n+1} + \frac{\gamma b(n-1)(x_i + s_0)}{2(n+1)} + \frac{\gamma(n-1)\epsilon}{(n+1)^2} \right) f(\epsilon)d\epsilon = 0
\]

where

\[
s_0 = \frac{a + \sum_{j \neq i} c_j - nc_i - bx_i + b \sum_{j \neq i} x_j}{b(n+1)}
\]

price effect, strategic effect and risk-hedging
Consider the case of a fully obscure market \((\gamma = 0)\)

\[
\int e^{-\rho_i \pi_i} \left( -\frac{b x_i}{2} - \frac{\epsilon}{n+1} \right) f(\epsilon) d\epsilon = 0
\]

price effect: fixed component \((-1 + \frac{1}{2}) b x_i\)

risk-hedging: random component \((-\frac{\epsilon}{n+1})\)

\(\triangleright\) \(f = p - \frac{\epsilon}{n+1}\); Mg. profit negatively correlated with \(\epsilon\)

\(\triangleright\) Mg. utility too because of risk aversion, so they co-vary with \(\epsilon\)
FORWARD MARKET (cont.)

When market is more transparent $(0 < \gamma \leq 1)$

\[
\int e^{-\rho \pi} \left( -\frac{bx_i}{2} - \frac{\epsilon}{n+1} + \frac{\gamma b(n-1)(x_i + s_0)}{2(n+1)} + \frac{\gamma(n-1)\epsilon}{(n+1)^2} \right) f(\epsilon) d\epsilon = 0
\]

where

\[
s_0 = a + \sum_{j \neq i} c_j - n c_i - bx_i + b \sum_{j \neq i} x_j
\]

new strategic effect:

- fixed component \( \frac{\gamma b(n-1)(x_i + s_0)}{2(n+1)} \)
- random component \( \frac{\gamma(n-1)\epsilon}{(n+1)^2} \)
Results

Proposition

The average inverse hedge (total-to-forward-sales) ratio of a firm $i$ is

$$\Gamma_i \equiv \frac{(n + 1)^2(1 + n + (n - 1)\gamma) + 2(3 + \gamma + (3 - \gamma)n)\frac{\rho_i\sigma^2}{b}}{2(n + 1)((n^2 - 1)\gamma + 2\frac{\rho_i\sigma^2}{b})}. \quad (3)$$

The average inverse hedge ratio $\Gamma_i$ satisfies the following properties:

(i) It is independent of $a$ and $c_i$
(ii) It decreases in $\rho_i$ and $\sigma^2$ but increases in $b$
(iii) It decreases in $\gamma$
(iv) There exists $\tilde{\gamma}$ such that $\Gamma_i$ increases (decreases) in the number of firms $n$ for all $\gamma \leq (\geq)\tilde{\gamma}$
Results (cont.)

Figure: Inverse hedge ratio and the number of firms
\((\rho_i = 4, \sigma^2 = 1, b = 1)\)
Empirical application

OBJECTIVE

→ We seek to answer the question whether oligopolistic firms use forward contracts for risk-hedging, strategic reasons or for both.

→ Use data from the Dutch gas natural wholesale market (TTF).

→ TTF is a virtual market place where gas can be sold spot and forward.

→ TTF is supplemented by spot (APX) and forward (ENDEX) exchanges.

→ We analyze the period running from April ’03 until June ’08.
DATA

Obtained from ICIS Heren and from GTS (Dutch TSO)

Data contains spot, forward and speculative trades.

Data comes from centralized and decentralized market places (bilateral and brokered transactions)

GTS provides us with critical data: churn rates and number of wholesalers operating in the market.

... still data could have been better :) - : )
Empirical application (cont.)

DATA (some descriptive statistics)

<table>
<thead>
<tr>
<th>Year</th>
<th>Variable</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>Std. Dev.</th>
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</thead>
<tbody>
<tr>
<td>2006</td>
<td>Wholesalers</td>
<td>21</td>
<td>24</td>
<td>22.42</td>
<td>1.24</td>
</tr>
<tr>
<td></td>
<td>Wholesalers 80%</td>
<td>10</td>
<td>11</td>
<td>10.25</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>Spot (MWh)</td>
<td>621,600</td>
<td>2,397,683</td>
<td>1,022,418</td>
<td>487,182</td>
</tr>
<tr>
<td></td>
<td>Forward (MWh)</td>
<td>13,030,152</td>
<td>19,472,208</td>
<td>15,788,766</td>
<td>2,150,126</td>
</tr>
<tr>
<td></td>
<td>Churn rate</td>
<td>2.83</td>
<td>4.23</td>
<td>3.29</td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td>Net forward (MWh)</td>
<td>4,166,793</td>
<td>5,615,750</td>
<td>4,805,133</td>
<td>471,609</td>
</tr>
<tr>
<td></td>
<td>Inv. hedge ratio</td>
<td>1.14</td>
<td>1.43</td>
<td>1.21</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Table: Descriptive Statistics

An interesting remark is that while sales have grown enormously (by a factor of 20):

- $\Gamma$’s more or less constant
- standard deviation of $\Gamma$ has fallen
Empirical application (cont.)

Figure: Forward sales and spot sales
Empirical application (cont.)

INFORMAL EVIDENCE

Figure: Empirical relation between the number of wholesalers and the inverse hedge ratio
Empirical application (cont.)

STRATEGY

Inverse hedge ratios have random generating processes given by:

\[
\frac{q_i^*}{x_i^*} = \frac{b(n + 1)^2(1 + n + (n - 1) \gamma) + 2(3 + \gamma + (3 - \gamma)n) \rho_i \sigma^2}{2(n + 1)(b(n^2 - 1) \gamma + 2 \rho_i \sigma^2)} + \frac{1}{b(n + 1)x_i^*} \epsilon
\]

Rewrite as:

\[
(n + 1)q_i^* = \frac{(n + 1)^2(1 + n + (n - 1) \gamma) + 2(3 + \gamma + (3 - \gamma)n) \frac{\rho_i \sigma^2}{b}}{2((n^2 - 1) \gamma + 2 \frac{\rho_i \sigma^2}{b})} x_i^* + \frac{1}{b} \epsilon
\]

Using individual firm level data on \(q_i^*\), \(x_i^*\) and \(n\), this forms a system of equations that can be fit by NLS.
STRATEGY (cont.)

Unfortunately, lack individual firm information.

Proceed by aggregating at the market level (need assumption $\rho_i = \rho$ for all $i$).

$$\frac{n+1}{n} \sum_{i=1}^{n} q_i = \frac{b(n+1)^2(1+n+(n-1)\gamma)+2(3+\gamma+(3-\gamma)n)\frac{\rho\sigma^2}{b}}{2n((n^2-1)\gamma+2\frac{\rho\sigma^2}{b})} \sum_{i=1}^{n} x_i + \frac{1}{b} \epsilon$$
RESULTS

Table: NLS Regression

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimates</th>
<th>t-Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\lambda$</td>
<td>11.975</td>
<td>0.450</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.828*</td>
<td>25.961</td>
</tr>
</tbody>
</table>

$R^2 = 0.704$

* Significant at the 1 percent significance level

Firms seem to use forward contracts as strategic instruments.

By contrast, the results do not seem to suggest risk-hedging is prevalent.
ISSUE #1: Previous results assume demand volatility constant through time

Construct a measure of demand volatility.

\[ p_t = a_t - b_t \sum_i \Gamma_{it} x_{it} + \frac{1}{(n_t + 1)} \epsilon \]  \hspace{1cm} (4)

Therefore:

\[ \sigma^2_t = (n_t + 1)^2 \sigma_{p_t}^2. \]  \hspace{1cm} (5)
RESULTS

Table: NLS Regression with demand volatility measure

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimates</th>
<th>t-Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho/b$</td>
<td>9,189.1</td>
<td>0.00</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.70*</td>
<td>30.83</td>
</tr>
</tbody>
</table>

$R^2 = 0.70$

* Significant at the 1 percent significance level
Empirical application (cont.)

Figure: Fit of the model
### ISSUE #2: LEARNING by wholesalers over time?

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>t-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho/b$</td>
<td>9967.8</td>
<td>0.00</td>
</tr>
<tr>
<td>$\gamma_{2003}$</td>
<td>0.81</td>
<td>1.19</td>
</tr>
<tr>
<td>$\gamma_{2004}$</td>
<td>0.30</td>
<td>0.99</td>
</tr>
<tr>
<td>$\gamma_{2005}$</td>
<td>0.67*</td>
<td>7.42</td>
</tr>
<tr>
<td>$\gamma_{2006}$</td>
<td>0.66*</td>
<td>13.20</td>
</tr>
<tr>
<td>$\gamma_{2007}$</td>
<td>0.71*</td>
<td>18.12</td>
</tr>
<tr>
<td>$\gamma_{2008}$</td>
<td>0.71*</td>
<td>20.76</td>
</tr>
</tbody>
</table>

$R^2 = 0.72$

**Notes:**
- $n$ equal to wholesalers 80% of market
- * Significant at the 1 percent level

**Table:** NLS regression with demand volatility measure and year dummies.
ISSUE #3: Endogeneity of the number of players?

We add a zero-profit condition:

\[(a - c)^2 \Omega(b, \gamma, \rho, \sigma^2, \mu, n)/b - F + \nu = 0, \quad \nu \sim N(0, \sigma^2_\nu) \quad (6)\]

where $F$ denotes a firm's cost of entry and $\nu$ is a random term.

Need to proxy for

- demand intercept: $a_t = a_0 + a_1 e_t$ with $e_t$: electricity price
- marginal cost: $c_t = c_0 + c_1 o_t$ with $o_t$: oil price
RESULTS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>t-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\lambda$</td>
<td>26.83</td>
<td>0.64</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.81*</td>
<td>21.83</td>
</tr>
</tbody>
</table>

$R^2 = 0.83$

Notes: $n$ equal to wholesalers 80% of market
* Significant at the 1 percent significance level

Table: NLS regression results with endogenous $n$
Empirical application (cont.)

ISSUE #4: Imperfect observability by financial traders

New Bernoulli variable with parameter $\mu$.

Forward price and spot need not coincide off-the-equilibrium

Inverse hedge ratios are increasing in $\mu$

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>t-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\lambda$</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.63</td>
<td>8.27</td>
</tr>
<tr>
<td>$\mu$</td>
<td>0.47</td>
<td>0.01</td>
</tr>
</tbody>
</table>

$R^2 = 0.71$

Notes: $n$ equal to wholesalers 80% of market
* Significant at the 1 percent significance level

Table: NLS regression results with imperfect financial traders
Conclusions

→ Paper presents structural methodology to test whether firms sell forward for strategic, hedging, or both types of reasons.

→ Build on a model of the interaction of asymmetric risk-averse firms that sell forward and spot

→ Strategic reasons requires players to "observe" forward positions.

→ Model this ability as a parameter, estimable using variation in $n$.

→ For the Dutch wholesale gas market, find:
  ▶ strategic reasons relevant
  ▶ no convincing evidence in favor of risk-hedging.