# Forward Trading and Collusion in Supply Functions

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About

This paper models

- The effect of forward trading
- in repeated oligopoly
- where the spot market clears in supply functions.

Main findings:

- Ambiguous effect of forward sales on critical discount factor for collusion.
- Colluding firms optimally do *not* sell forward.
- Transparency matters.
- Uncertainty about demand does not hinder collusion.
- Physical and financial forwards are strategically equivalent.

Motivation: Electricity markets

Electricity trades before delivery:

- Forward markets (month and years ahead)
- **Day-Ahead-Markets** (underlying of forward contracts)
- Short term balancing (low volumes, no reference prices)

**Characteristics** of Day-Ahead-Markets:

- Bids are made in form of supply (demand) *functions*
- Market power is an issue (inelastic demand)
- Frequent interaction of a small number of players.

## Literature

| | |
|---|---|
| Forwards & oligopoly | Allaz & Vila, '93, Mahenc & Salanie, 2004 |
| Forwards & Supply Functions | Newbery, RAND, 1998, **Green, JIE, 1999**<br>**Holmberg, EnJ, 2011**,<br>Holmberg & Willems, JET, 2015 |
| Forwards & Collusion | **Liski & Montero, JET, 2006**,<br>Green & Le Coq, IJIO, 2010 |
| Collusion in Supply Functions | Sweeting, EJ, 2007<br>**Ciarreta & Gutierrez-Hita, IJIO, 2006** |

$\rightarrow$ **This paper: Collusion in supply functions with forward trading**

"*Forwards and Collusion in Oligopoly*"

Liski & Montero (2006)

- Forwards can stabilise collusion, both in Bertrand & Cournot oligopoly.
- Effect of forwards depends on type of spot market:

  Cournot $\rightarrow$ colluding firms **should not** contract forward..

  Bertrand $\rightarrow$ colluding firms **should** contract forward..

  ...to decrease the critical discount factor.

Supply function equilibrium is between Bertrand and Cournot.

**What effect of forwards on collusion?**

## The one shot - two stage game

I. Forward Market:

- Firms $i$, $j$ decide to offer amount $x_i$, $x_j$ of (financial) forward contracts.
- $N > 2$ competitive speculators observe $x_i$, $x_j$, and bid for the offered contracts.

$\rightarrow$ No arbitrage condition: forward price equals expected spot price $f = E(p)$

II. Spot Market:

1. Firms $i$, $j$ bid linear supply functions $q_i(p) = \alpha_i + \beta_i p$
2. Random demand realisation: $D(p) = A - bp + \varepsilon \gg 0$
3. Auctioneer determines market clearing price $p^*$
4. Firms produce quantities $q_i(p^*)$, $q_j(p^*)$, each at cost $C(q) = c_1 q + \frac{c_2}{2} q^2$.

Total profit of firm $i$:

$$\pi_i = (f - p^*)x_i + p^* q_i(p^*) - C(q_i(p^*))$$

Outcome of the one shot game:

- surprising result: In the linear model, firms won't sell forward at all.
- Newbery ('98) & Green ('99) use conjectural variations
- $\rightarrow$ Forward positions can be calibrated.

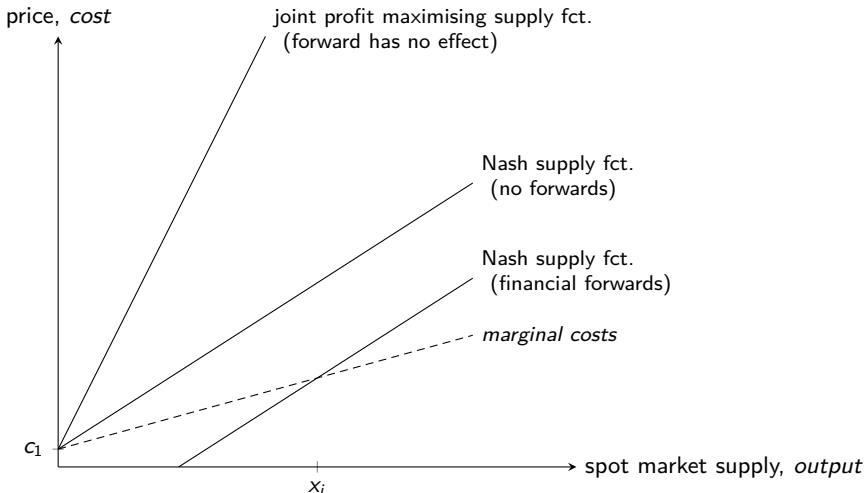$\rightarrow$ Here: first take forward positions as exogenous, then discuss generalisation.

Repeated game

1.a Forward market for the first spot period opens.

1.b Spot market clears, payments and production takes place.

2.a Forward market for the next spot period opens.

2.b Next spot market clears ...

*Question:* *What are the effects of forward positions on the stability of collusion?*

(Note: standard trigger strategy, no sophisticated punishment strategies assumed)

## Strategies



price, *cost*

joint profit maximising supply fct.
(forward has no effect)

Nash supply fct.
(no forwards)

Nash supply fct.
(financial forwards)

*marginal costs*

$c_1$

$x_i$

spot market supply, *output*

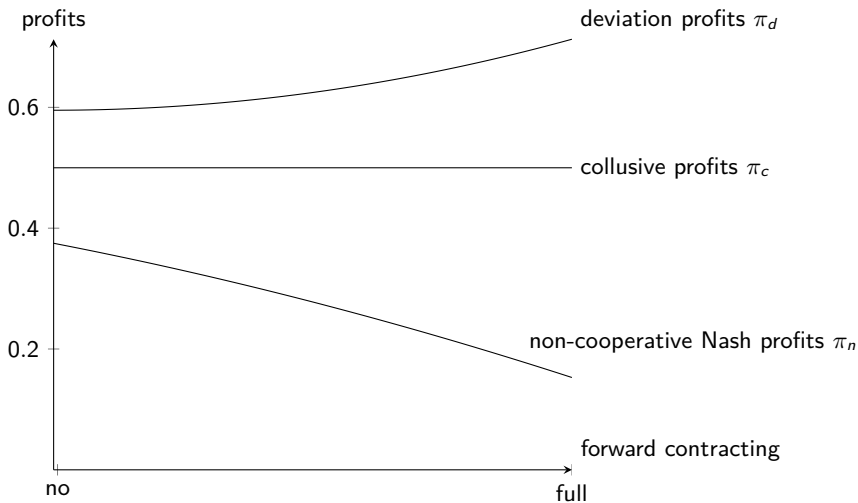<u>Deviation</u>: best-response supply function to joint-profit maximising supply fct.

Results

Lemma 1
*Selling forward increases the incentive of a firm to deviate. A collusive agreement is less easy to sustain when firms have sold forward.*
*Collusion is easier to sustain when firms expect significant forward sales during the punishment phase.*

$\rightarrow$ qualitatively equivalent to *Cournot* in Liski & Montero (2006).

## Intuition for proof of Lemma 1

Results

#### Lemma 1

*Selling forward increases the incentive of a firm to deviate. A collusive agreement is less easy to sustain when firms have sold forward.*
*Collusion is easier to sustain when firms expect significant forward sales during the punishment phase.*

#### Lemma 2

a. *When there are no forward markets, the variance of the demand shock $\sigma^2$ does not affect the level of the critical discount factor.*

b. *When firms hold contracts during collusion, deviation or Nash reversion, the effect of these forward positions on the critical discount factor is decreasing in $\sigma^2$.*

## Linear vs. non-linear supply functions

In the linear model, there are no endogenuous forward sales.

Reason: The equilibrium slope is unaffected by forward positions,
but the slope is the relevant strategy for the competitor.
$\rightarrow$ No effect of selling forward on rivals strategy.

In the **non-linear** model, slopes vary with forward positions.

Therefore, selling forward changes the rivals slope.
$\rightarrow$ With concave SFE, firms have an incentive to trade forward.
(Holmberg, 2011)

## Lemma 1: Generalisation

Same structure as before,but:
  - convex marginal costs, and
  - non-linear monotone continuous supply functions $q_i(p)$, $q_j(p)$.

*What is the sufficient condition to prove Lemma 1?*

- $\frac{d\pi_i^c}{dx_i} = 0$ Jointly maximised profits are unaffected by forwards.    ✓

- $\frac{d\pi_i^d}{dx_i} > 0$ Profits of deviation are increasing with forward sales.    ✓

- $\frac{d\pi_i^n}{dx_i} < 0$ Profits during punishment phase decrease with forward sales.    ✓

Result:

  $\rightarrow$ Lemma 1 will also hold for non-linear SFE.

   But from Holmberg (2011) we know that there will be endogenous forward contracting.

  $\rightarrow$ Forward markets can ease collusion in supply functions, equivalently to Cournot competition (Liski & Montero, 2006).

Information structure / implications for regulation

A deviating firm will try to sell forward at the collusive price.

Two cases:

A. Forward positions are observable.

- Speculators will infer if incentive constraint doesn't hold and not buy at the collusive price.
- → Forward sales are limited.

B. Forward positions are unobservable

- Speculators expect deviation and do not buy forward at the collusive price.
- → No incentive to sell forward for firms.
- → Forward trading ceases completely.

In summary:

*liquid & anonymous forward markets are a counter-indicator for collusion.*

# Conclusion

- The case of supply function bidding with forwards is strategically similar to the case of quantity setting studied by Liski & Montero (2006).

- Demand uncertainty dampens the effect of forwards on the critical discount factor.

- Considering non-linear supply functions would not substantially change the results, but yield endogenous forward contracting.

- Forwards with physical delivery are strategically equivalent to financial settlement, but reduce the volumes in the spot market (Generalisation of Green's 99 model).

Thank you very much.