Market power and forward prices

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Abstract

We construct a model of strategic behavior in sequential markets which exhibits a persistent forward price premium. On the spot market, producers wield market power while purchasers are price takers. Producers with forward commitments have less incentive to raise prices on the spot market. Purchasers are thus willing to pay a premium to producers for forward contracts. We argue that this type of forward premium is not susceptible to arbitrage by speculators on the forward market, since purchasers prefer forward contracts backed by producers. (*JEL* D43, G13, L12, L13, Q41)

Keywords: forward pricing; electricity markets; market power; arbitrage.

1 Introduction

We consider the pricing of forward contracts for a commodity whose production in a spot-market is concentrated among a small number of firms, who exercise market power. Wholesale electricity is such a commodity. Forward premia in electricity prices are often observed in market data (see, for instance Longstaff and Wang [2004], Bowden et al. [2009], Ballester et al. [2016]). Explanations for the forward premium typically invoke risk aversion (see e.g. Powell [1993], Bunn and Chen [2013]). Exceptions can be found in the work of Anderson and Hu [2008] and Ito and Reguant [2016], who argue that even in a risk-neutral setting the market power of producers can result in price premia in equilibrium. We provide a simple explanation of this phenomenon using a Cournot equilibrium model, which illustrates the strategic incentives for electricity retailers to pay a forward premium. We further argue that such a premium may not be susceptible to arbitrage by speculators trading on the forward market.

We model forward trading either by over-the-counter trade between consumers and producers or through a futures exchange in which speculators may also participate. Our assumptions are similar to those in Allaz and Vila [1993]: risk-neutral agents trade forward in order to improve their strategic positions. Whereas Allaz and Vila assume that forward prices are equal to spot prices by a no-arbitrage condition, we derive a forward demand curve from the strategic value of contracting to large consumers. In electricity wholesale markets, a retailer or load-serving entity has no discretion in the amount it must purchase and hence no market power on the spot market — even if its purchases make up a large share of the total. We find that such consumers are willing to pay a premium for over-the-counter forward contracts because increasing producers' contract cover has the effect of lowering the spot price which is paid for the uncontracted part of demand. Since this premium derives from the spot market power of producers, it does not leave an arbitrage opportunity for speculators who lack spot market power.

2 The spot market

Consumers, who lack market power, demand a total quantity x, which is totally inelastic in price. A competitive fringe (made up of small suppliers lacking in market power) supplies at marginal cost

$$C_F'(q_F) = \frac{q_F}{a}.$$

Together, the demand and the offers of the competitive fringe give a linear demand curve

$$D(p) = x - ap,$$

against which m producers (who have market power) offer quantities q_i, $i = 1, \dots m$. Each producer i has zero cost of production and sells forward a quantity s_i to the consumers. Moreover, each producer is a Cournot agent in the spot market, so they choose their spot offer quantity to solve

$$\begin{aligned} \max_{q_i, p} \ \Pi_G(s_i, p, q_i) &= p(q_i - s_i) \\ \text{subject to} \quad & q_i + q_{-i} = x - ap, \end{aligned}$$

where $q_{-i} = \sum_{j \neq i} q_j$. This gives optimum price and quantities

$$p = \frac{x - q_{-i} - s_i}{2a}, \quad \text{and} \quad q_i = \frac{x - q_{-i} + s_i}{2}, \quad i = 1, \dots m.$$

Let $g = \sum_{i=1}^{m} s_i$ be the total contract cover. When each producer offers optimally given the offer of the others, we obtain the Cournot-Nash equilibrium price and quantities

$$p = \frac{x - g}{(m+1)a}, \quad q_i = s_i + \frac{x - g}{m+1} \quad i = 1, \dots m \tag{1}$$

which are the same as those derived by Allaz and Vila [1993]. The fringe produces a quantity

$$q_F = \frac{x - g}{m+1}.$$

The output quantities and spot price p are functions of the forward positions of the producers. It is on the basis of these functions that agents derive the marginal strategic value of forward contracts.

3 Forward trading

When a consumer buys forward from a producer they change not only their forward position, but also that of the producer from whom they buy. By accounting for the influence of producers' forward positions on spot output and prices, we can derive the marginal value of forward sales for producers and consumers who trade over the counter.

3.1 A producer's value of a forward position

Suppose that producer i sells contracts to cover s_i units of its output in the spot market. Given a spot price p, the *cost* (negative value) incurred by this producer is $(s_i - q_i)\,p$, where q_i is the amount that they produce in the spot market. In order to determine the marginal cost of its contract cover, this producer must anticipate the effect that changing contract sales has on both their equilibrium spot market output and the spot price; in an imperfectly competitive spot market, both q_i and p are functions of s_i, so the cost of contracting s_i is

$$G\,(s_i) = (s_i - q_i(s_i))\,p(s_i). \tag{2}$$

The marginal cost of contract cover for producer i is therefore

$$\frac{dG}{ds_i} = p - \frac{\partial q_i}{\partial s_i} p - (q_i - s_i)\,\frac{\partial p}{\partial s_i}. \tag{3}$$

If a producer can sell an extra unit forward at a price $\pi > \frac{dG}{ds_i}$, then the sale is profitable. The term $\frac{\partial q_i}{\partial s_i} p$ represents the marginal profit from extra market share from selling forward, while the term $(q_i - s_i)\,\frac{\partial p}{\partial s_i}$ represents the change in profit from a change in the spot price. The desire to trade forward, as in Allaz and Vila [1993], comes about because the gain from increased market share outweighs the loss from a drop in the spot price; producers who can sell part of their output forward at, or above, the anticipated spot price will find it profitable to do so, as long as $q_i > s_i$.

3.2 A consumer's value of a forward position

A consumer has a utility function U for their consumption x. They purchase a forward position b and the remainder $(x - b)$ on the spot market. The *value* to a consumer of holding a forward position b (ignoring its price), given the spot price p is

$$V = U(x) - (x - b)\,p.$$

The consumer's marginal value of contracts is given by the total derivative of this value function with respect to the contract position:

$$\frac{dV}{db} = p - (x - b)\,\frac{dp}{db}. \tag{4}$$

Producers have market power on the spot market, and when the consumer buys forward this increases the contract cover of producers by the same amount. This results in a decrease in spot prices, so $\frac{dp}{db} < 0$. For a consumer who is less than fully contracted, $x - b > 0$, so the marginal value (4) is greater than the anticipated spot price p. When producers succeed in exploiting this willingness to pay, there will be a forward premium.

3.3 Cournot equilibrium on the forward market

The forward price π and spot price p are determined in equilibrium by a two-stage Cournot game. Suppose there are n identical large consumers in the market. The marginal value of contracts to a consumer with demand x/n and contract cover b_i is then given by

$$V_i'(b_i) = p - (x/n - b_i)\frac{dp}{db_i}.$$

When the total forward sales are g, then each consumer will have contracted for g/n. If each consumer takes the others' contract positions to be fixed when calculating the marginal value, then we have

$$\frac{dp}{db_i} = \frac{dp}{dg}.$$

The inverse forward demand function at the contracting level g is thus

$$\begin{aligned} F(g) = V_i'(g/n) &= p + \frac{x - g}{n}\frac{dp}{dg} \\ &= p\left(1 + \frac{1}{n}\right), \end{aligned} \tag{5}$$

so the premium paid equals the spot price divided by the number of consumers.

A producer i chooses contracting level s_i to maximize the value of their contracting position in a Cournot game against this forward demand, given the anticipated spot market costs, $G(s_i)$, defined by (2). This producer's problem is to maximize

$$\begin{aligned} &\max_{s_i,\pi} && \pi s_i - G(s_i) \\ &\text{subject to} && \pi = F\left(\sum_i s_i\right). \end{aligned} \tag{6}$$

The producer's forward marginal cost function, holding s_{-i} constant, is calculated from (3):

$$\frac{dG}{ds_i} = \frac{2\left(x - s_i - s_{-i}\right)}{\left(m+1\right)^2 a} = \frac{2}{m+1}p. \tag{7}$$

This marginal cost function is a little unconventional, being downward-sloping — as producers sell more contracts, they require less for them at the margin. Notwithstanding, the purchaser's marginal value of contracts $F\left(g\right)$ is decreasing at an even faster rate than $\frac{dG}{ds_i}$, so the objective in (6) is concave, and there is a unique equilibrium in forward contracts.

With the forward demand and cost functions (5) and (7), we can solve for the producer contracting levels in equilibrium, giving

$$s_i^* = \frac{\left(m+1\right)\left(n+1\right) - 2n}{\left(m+1\right)^2 + n\left(m^2+1\right)}x. \tag{8}$$

The contract level is decreasing in the number of consumers. This is because with more consumers, the forward premium is reduced, and so producers gain less from selling forward.

3.3.1 Example

Suppose there are $m = 2$ producers and only $n = 1$ consumer trading on the forward market. Without contracting, it is easily verified from (1) that the spot equilibrium is

$$q_1^* = q_2^* = \frac{x}{3},\ p = \frac{x}{3a}.$$

In our own model, the equilibrium forward sales from (8) are

$$s_1^* = s_2^* = \frac{2x}{7}.$$

With this volume of forward sales, the spot market clears with each producer selling

$$q_1 = q_2 = \frac{3x}{7},$$

and the competitive fringe supplying the remaining $\frac{1}{7}x$. The forward price is

$$\pi = \frac{2x}{7a}$$

and the spot price is

$$p = \frac{x}{7a}.$$

If instead the number of consumers becomes very large, the forward premium tends to zero, and we approach the Allaz and Vila equilibrium. This is

$$s_1^* = s_2^* = \frac{x}{5},\ q_1^* = q_2^* = \frac{2x}{5},\ p = \frac{x}{5a}.$$

We summarize the prices and outputs in Table 1, along with the equilibrium welfare for producers

$$q_i p + s_i^* (\pi - p)$$

and consumers

$$U(x) - px - (\pi - p)\, b.$$

	No contract	Allaz-Vila	Our model
s_i^*	0	$\frac{x}{5}$	$\frac{2x}{7}$
π	0	$\frac{x}{5a}$	$\frac{2x}{7a}$
q_i^*	$\frac{x}{3}$	$\frac{2x}{5}$	$\frac{3x}{7}$
q_F	$\frac{x}{3}$	$\frac{x}{5}$	$\frac{x}{7}$
p	$\frac{x}{3a}$	$\frac{x}{5a}$	$\frac{x}{7a}$
Total producer welfare	$\frac{2x^2}{9a}$	$\frac{4x^2}{25a}$	$\frac{10x^2}{49a}$
Consumer welfare	$U(x) - \frac{x^2}{3a}$	$U(x) - \frac{x^2}{5a}$	$U(x) - \frac{11x^2}{49a}$
Fringe welfare	$\frac{x^2}{18a}$	$\frac{x^2}{50a}$	$\frac{x^2}{98a}$
Total welfare	$U(x) - \frac{x^2}{18a}$	$U(x) - \frac{x^2}{50a}$	$U(x) - \frac{x^2}{98a}$

Table 1: Equilibrium outcomes for example problem under varying assumptions

Observe that in both the model of Allaz and Vila [1993] and in our model, a prisoners' dilemma is observed, whereby firms have an incentive to contract, but in equilibrium, this leads to lower profits. Note that in both models consumer welfare is improved by allowing forward contracting.

4 Arbitrage opportunities

It is often argued, as in Allaz and Vila, that any premium between forward and spot prices will be susceptible to arbitrage. To explore this we consider speculators seeking arbitrage opportunities in the forward market. These speculators may trade on the forward market, but not on the spot market; they represent 'virtual bidders' in electricity markets. A speculator would like to take advantage of the forward premium by selling forward contracts at the forward price π and paying out at the spot price $p < \pi$, to close their position at a profit.

Consider a speculator and a consumer negotiating the price of a forward contract. The speculator is unable to change the spot price, so the marginal value to the consumer of buying forward from a speculator is just the expected value of the forward contract, which is equal to the anticipated spot price. Hence the consumer is only willing to pay the anticipated spot price to the speculator. Since the consumer cannot shift the spot price either, the most a speculator would be willing to pay a consumer is also the anticipated spot price.

On the other hand, the speculator who trades forward with a producer is equivalent to a consumer who has zero real demand for the product. A speculator with a zero contract position is willing to pay no premium for forward contracts. Bona fide consumers are willing to pay a premium for forward sales and so producers prefer to trade with them. Speculators cannot sell forward to producers at prices above the anticipated spot price either, because the producers' marginal cost of contract cover is below the anticipated spot price.

Hence the speculator has no opportunity to sell forward contracts at a premium to the anticipated spot price, nor to buy them at a discount. Though there exists a price difference, speculators in the forward market fall victim to discrimination on the part of consumers, and so are unable to arbitrage away the strategic premium. From a consumer's perspective, the producer-backed and the speculator-backed forward contracts are distinct products. One has the strategic value of influencing the spot price, while the other does not.

Over-the-counter trading allows consumers to distinguish between producers and speculators, However, in some electricity markets there are also futures exchanges where forward trading is anonymous. Our model explains a preference for forward contracts backed by spot-market power, since they reduce spot market payments. As observed by Bessembinder and Lemmon [2002], the volume of trading in electricity futures exchanges is low compared with that of bilateral, over the counter trades.

References

Blaise Allaz and Jean-Luc Vila. Cournot competition, forward markets and efficiency. *Journal of Economic Theory*, 59(1):1–16, 1993. doi:10.1006/jeth.1993.1001.

Edward Anderson and Xinmin Hu. Forward contracts and market power in an electricity market. *International Journal of Industrial Organization*, 26(3): 679–694, 2008. doi:10.1016/j.ijindorg.2007.05.002.

Jose María Ballester, Francisco Climent, and Dolores Furió. Market efficiency and price discovery relationships between spot, futures and forward prices: the case of the Iberian Electricity Market (mibel). *Spanish Journal of Finance and Accounting*, 45(2):135–153, 2016. doi:10.1080/02102412.2016.1144441.

Hendrik Bessembinder and Michael Lemmon. Equilibrium pricing and optimal hedging in electricity forward markets. *The Journal of Finance*, 57(3):1347–1382, 2002. doi:10.1111/1540-6261.00463.

Nicholas Bowden, Su Hu, and James Payne. Day-ahead premiums on the midwest ISO. *The Electricity Journal*, 22(2):64–73, 2009. doi:10.1016/j.tej.2009.01.001.

Derek Bunn and Dipeng Chen. The forward premium in electricity futures. *Journal of Empirical Finance*, 23:173–186, 2013. doi:10.1016/j.jempfin.2013.06.002.

Koichiro Ito and Mar Reguant. Sequential markets, market power, and arbitrage. *American Economic Review*, 106(7):1921–57, July 2016. doi:10.1257/aer.20141529.

Francis Longstaff and Ashley Wang. Electricity forward prices: A high-frequency empirical analysis. *The Journal of Finance*, 59(4):1877–1900, 2004. ISSN 1540-6261. doi:10.1111/j.1540-6261.2004.00682.x.

Andrew Powell. Trading forward in an imperfect market: the case of electricity in Britain. *The Economic Journal*, 103(417):444–453, 1993.