Does Wholesale Market Power Extend to Fixed-Price Forward Prices in Electricity Markets?

Seamus Hogan

Department of Economics
University of Canterbury
seamus.hogan@canterbury.ac.nz
(03) 364-2524

Abstract:

The wholesale electricity market in New Zealand has a Cournot-like structure in which generators have an incentive to withhold supply from the market in order to raise the market-clearing price. This incentive, however, is reduced or eliminated if generators are either buyers in the wholesale market as a result of vertical integration between generation and retailing, or if they pre-contract to sell at fixed prices in a forward market.

This paper addresses whether the market power that firms would have in the absence of forward contracting or vertical integration will be automatically priced into forward-contracts or retail prices.

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1. Introduction.

The wholesale market for electricity in New Zealand is a computer-based auction market in which suppliers simultaneously submit a supply schedule of quantities (willingness to supply at a range of prices), from which the market price is calculated by equating the demand to the submitted supply. Each supplier produces the quantity it offered to supply at that price, and receives the price for every unit produced.

This market resembles a Cournot quantity-setting game. Suppliers have an incentive to withhold quantities by overstating their supply curves in order to generate a higher equilibrium price, and the perfectly competitive outcome of price equalling marginal cost only arises in the limiting case as the number of firms tends to infinity. It is well-known, however, that when generators have fixed-price forward obligations, the incentive to exercise market power is reduced, for the simple reason that the benefits from inflating the wholesale price are reduced to the extent that one has a contractual obligation to buy at that price.[1]

Fixed-price forward obligations can arise either through generators having sold forward cover to final users, or, more importantly in the New Zealand case, through vertical integration in which generators have a retail branch purchasing in the wholesale market and then on-selling the power to retail customers at a pre-determined price.

The extent of market power in the New Zealand wholesale market was the subject of the analysis conducted by Frank Wolak in a report prepared for the *Commerce Commission* (Wolak, 2009). This report acknowledges the mitigating effect that fixed-price forward obligations can have, in theory, on the incentive for firms to exercise unilateral market power, and derives measures of the incentives New Zealand firms had to exercise market power based on this theory.

The report also notes, however, that the "high degree of vertical integration with no formal price regulation" is one of a "number of dimensions along which the New Zealand market differs from …other wholesale markets [which] only increase the likelihood that suppliers in New Zealand have the ability and incentive to exercise unilateral market power" (Wolak, 2009, paragraph 8).

These two viewpoints can perhaps be reconciled by a third statement in the report—namely that

> *During a period of significant unilateral market power in the short-term market, retail customers could limit the incentive of suppliers to exercise such marketpower by increasing their purchases of fixed-price forward market*

[1] See, for example, Hogan and Meade (2007) or Mansur (2003).

> *obligations from the suppliers that are long in the short-term market. …However, these forward-market purchases would not come without a cost because the suppliers selling them know that they would be giving up the opportunity to exercise substantial unilateral market power in the short-term market, and would therefore only be willing to do so if the forward market price compensated them for the short-term power they expected to be able to exercise over the duration of the fixed-price long-term contract.*
>
> (Wolak, 2009, paragraph 201)

The idea here seems to be that the presence of fixed-price forward commitments, either through forward contracts or vertical integration, may, while having the mitigating effect on wholesale prices predicted by the theory, simply be passing on to a different point in the supply chain the point at which wholesale market power is converted into high final-user prices.

In this paper, we analyse this idea. We build a model of wholesale competition and consider both the effect that fixed-price forward contracts have on the wholesale price, and whether one would expect the resulting loss of market power to be priced into the forward contracts.

In the next section, we briefly describe the New Zealand wholesale electricity market, and the abstractions we make from the reality in order to produce a tractable model. Sections 3 and 4 then consider the impact on market power of forward contracting and vertical integration, respectively. Section 5 offers some concluding remarks.

2. The New Zealand Wholesale Electricity Market.

Prices in the New Zealand wholesale market are determined through a computer-based auction market. Firms submit supply offers every half hour (essentially an increasing schedule of prices at which they would be prepared to supply a specified quantities of power) for their willingness to supply to specified points on the national grid called “grid injection points” (GIPs). Buyers do not submit bids, but simply draw as much power as is desired from “grid exit points” (GXPs). The computer-based market maker then determines a price at each GIP and GXP after the half-hour period in order to both equate demand to the total supply inferred from the individual supply offers, and to maximise efficient use of the grid, taking into account transmission loss and payments to the grid operator, *Transpower*, for use of the grid.

The prices at these nodes fluctuate considerably over the course of a year, due to a combination of demand fluctuations—time-of-day, day-of-week, and seasonal effects—supply fluctuation—due to both fluctuations in rainfall in the catchments for hydro-electric generation and fluctuations in the price of fuel for thermal generation—and congestion constraints on the national grid.

Only a small percentage of the quantity of power purchased at GXPs is by final users. The vast majority is purchased by retail companies who sell to final users, typically at a fixed price rather than a floating price that varies with the wholesale price. There is a high degree of vertical integration, with each of the four major generating firms also having a large presence in the retail market. There is also a small amount of forward contracting between generators and other purchasers in the wholesale market.

The model in this paper strips away most of this structure to focus on the essence of a wholesale market with market power that can be mitigated through fixed-price forward contracting. We consider a simple Cournot quantity-setting market in which there exists the possibility for sellers to sell fixed-price forward obligations, either through a futures market or through vertical integration. In using this structure, we have abstracted away from three major aspects of the actual New Zealand electricity market.

First, we consider a single-node system. That is, rather than having separate injection and exit points, with prices at each, our model is applicable to a situation where supply and demand occur at a single node with a common supply and demand price at that point.

Second, the model has no supply or demand fluctuations, and hence no uncertainty, so forward contracting and vertical integration only have an effect through their impact on the exercise of market power, and do not serve any insurance role.

Finally, the Cournot market that we model has firms choosing a fixed quantity to sell with market power constrained in part by a demand curve with non-zero elasticity. In contrast, the actual wholesale electricity market is characterised by a form of uniform-price auction in which firms choose entire supply schedules but short-run demand is perfectly inelastic. The incentive to exercise market power, however, is similar in the two types of market. In both types, market power exists by firms having an incentive to withhold quantity at any given price in order to push up the resulting wholesale price; and in both types, there is a price sensitivity that limits the extent to which firms can exercise market power, with the key difference being that that sensitivity derives from a non-zero elasticity of demand in the Cournot model, and from a non-zero elasticity of supply in the uniform-price auction.

The reason for choosing to use a Cournot model in the analysis is that it has a much simpler structure than one in which each firm's decision variable is an entire function, and so it is a cleaner vehicle for highlighting the intuition underlying the results. It is left for future work to extend the results to the kind of uniform-price auction used in the New Zealand market.

3. Fixed-Price Forward Obligations in a Simple Cournot Model.

Let there be *n* firms in a market, and let each firm *i* choose a quantity to produce, q_i. Let the total quantity produced be $Q = \sum_i q_i$, and let the inverse demand function in the market be $p(Q)$.

Since the purpose of using a Cournot model is transparency rather than generality, we will assume that the market demand curve is linear, and that all firms have a common constant marginal cost of production with no fixed costs. This will result in the equilbiria having simple closed-form solutions. Without further loss of generality, we can set the marginal cost at zero (in effect, interpreting all prices as the difference between price and the common marginal cost), and, choose the units of measurement of price and quantity so that the inverse demand curve can be written as

$$p(Q) = 1 - Q. \tag{1}$$

This model produces the well-known equilibrium values

$$q_i^* = \frac{1}{n+1}, \tag{2}$$

$$p^* = \frac{1}{n+1}, \text{ and} \tag{3}$$

$$\pi_i^* = \frac{1}{(n+1)^2}. \tag{4}$$

with the perfectly-competitive result of price equalling marginal cost only arising the in the limiting case where the number of firms tends to infinity.

Now let us imagine that each firm, *i*, negotiates fixed-price contracts with buyers to purchase a quantity, x_i, at an average price per unit of p_i. Exactly how this will affect the wholesale-market equilibrium depends on the demand function of the buyers now purchasing on fixed-price contracts rather than directly from the wholesale market. There are two canonical approaches we could take.

In the first, we imagine that the market demand curve arises from a continuum of consumers demanding a fixed quantity of the good, with declining reservation prices, and that it is only the consumers with the highest reservation prices that purchase forward cover. The residual inverse demand curve in the wholesale market, then, is just a leftward shift of the original curve. In the second approach, we imagine that the market consists of a continuum of identical buyers, whose individual demand curves sum to get the market demand curve described above. In this case, the residual demand curve of customers purchasing in the wholesale market is found by pivoting the market demand curve around its price-axis intercept.

In this paper, we take the first approach, as the leftward-shift of the demand curve closest in spirit to capturing the effect of fixed-price contracting in a uniform-price auction in which demand is in fact perfectly inelastic and the elasticity that constrains the exercising of market power derives from the supply side. For completeness, we include an appendix that redoes the analysis of Section 3 for the second canonical case.

Let q_i continue to represent the total production of firm *i*. Firm *i*'s profit function and resulting first-order conditions are now

$$\pi_i(q_i) = (1-Q)(q_i - x_i) + p_i x_i, \text{ and}$$
$$\pi_i'(q_i) = (1-Q) - q_i + x_i = 0.$$

From this we have

$$q_i^* = (1-Q) + x_i.$$

$$\Rightarrow \quad Q^* = \sum_i q_i^* = n(1-Q^*) + X,$$

$$\Rightarrow \quad Q^* = \frac{n+X}{n+1}, \text{ so that}$$

$$q_i^* = \frac{1-X}{n+1} + x_i, \tag{5}$$

$$p^* = \frac{1-X}{n+1}, \text{ and} \tag{6}$$

$$\pi_i(q_i^*) = \left(\frac{1-X}{n+1}\right)^2 + p_i x_i. \tag{7}$$

Now consider the incentives facing a firm seeking to expand its quantity of fixed-price forward contracts, x_i, by inducing some buyers to purchase such contracts rather than buying from the wholesale market. The following result is automatic:

Theorem 1:

If n>1, it will always be profit increasing for a single firm to sell fixed-price contracts at a price equal to the wholesale price, taking the stock of other firms' fixed-price contracts as given.

Proof:

From Equation (7), we have

$$\frac{\partial \pi_i(q_i^*)}{\partial x_i} = p_i - \frac{2p}{n+1}.$$

This shows that, it is profit increasing for a firm to sell fixed-price contracts at any price, p_i, such that $p_i > 2p/(n+1) < p$. This is despite the fact that any expansion of fixed-price contracts will result in a reduction in the wholesale price.

□

The intuition for this result is that the withholding of supply by a firm in a Cournot game confers a positive pecuniary externality on other firms, since all firms benefit from the higher price when any one firm withholds output, but only that firm bears the cost of withholding. As a result, when a firm is considering at what prices it would be prepared to sell forward contracts, it only needs to capture in the forward price the lost benefit to itself from having less incentive to exercise market power; it does not need to capture the lost external benefits to other firms.

We have not modelled a market for fixed-price contracts to determine an equilibrium price for such contracts. As it stands, however, Theorem 1 shows that individual firms can sell forward contracts at less than the wholesale price and still be profit maximising, while conscious of the fact that those forward contracts would reduce the amount of market power implicit in the Cournot structure. In other words, the intuition suggested by the quote from the Wolak report given in the introduction is not borne out in this model.

It would not be in any single firm's interest to sell sufficient forward contracts to drive the equilibrium wholesale price down to marginal cost and hence eliminate fully the market power. The following result, however, suggests that perfect competition would be the natural outcome of a competitive market in forward contracts.

Theorem 2:

At any positive price, it is always profit increasing for a firm to increase its supply of forward contracts if it can do so by increasing its market share of a fixed set of contracts.

Proof:

This can be seen clearly from Equation (7). If firm *i* is competing for a fixed stock of forward contracts, we have

$$\frac{\partial X}{\partial x_i} = 0,$$

and so we have

$$\frac{\partial \pi_i}{\partial x_i} = p_i.$$

□

In effect, when a firm can take market share in the forward market away from another firm, it transfers some of the responsibility of withholding supply in order to maintain price above marginal cost to that other firm.

Theorems 1 and 2 show that firms have a limited incentive to price aggressively to attract more buyers into the forward market, and a far stronger incentive to compete aggressively with other firms for market share in the existing market. In effect, the forward market brings the elements of Bertrand competition as a mitigating force against the monopolistic tendencies of a Cournot market.

This result, however, is most relevant if there is a competitive market for forward contracts. In New Zealand the forward market is quite thin, but this is likely because instead there is a very high degree of vertical integration, so that a very large percentage of the demand for wholesale electricity is by the generators themselves acting as retailers.

4. Vertical Integration and Retail Competition in the Simple Cournot Model.

We now consider a model in which some final users do not purchase directly from the wholesale market, but rather purchase from a retailer at a fixed price who purchases from the wholesale market. We continue to make the assumption that fixed-price purchasers are those whose reservation prices are in excess of the market price, so the presence of a fixed-price retail market in the absence of vertical integration will have no effect on the equilibrium wholesale price or the profits of individual firms.

Now consider the effect of vertical integration. Specifically, let firm *i* have a commitment to sell x_i units of the good in the retail market at a price of p_i. For the wholesale market, this model is formally identical to the model of forward contracts considered in the previous section: The larger is the presence of generator firms in the retail market, the lower will be the wholesale price; and, because of the negative-pecuniary externalities between firms from the fixed-price obligations, firms have an incentive to price forward contracts at prices that don't fully recover the value of the lost market power in the wholesale market, particularly when competing amongst themselves for a share of the fixed-price market.

Where the model with vertical integration differs from the model with direct forward contracting comes in the interaction between the wholesale and retail markets. Consider a market with n firms selling into the wholesale and potentially the retail markets, $i=1..n$, and an additional m retail-only firms, $i=n+1..n+m$.

Let $x_i(p_i, \boldsymbol{p}_{-i})$ be the quantity of power that firm i can sell in the retail market at a price of p_i given prices of all other firms, $\boldsymbol{p}_{-i}$. We assume imperfect competition between retailers, as would arise, for instance, by each retailer having differentiated characteristics and customers differing in the value they place on those characteristics. We continue to assume that each individual final consumer has inelastic demand, and that the total stock of customers buying at the retail rather than wholesale market is fixed. These assumptions imply that

$$\frac{\partial x_i}{\partial p_i} < 0, \qquad \frac{\partial x_j}{\partial p_i} \geq 0,\ \forall j \neq i, \qquad \sum_{i=1}^{n+m} \frac{\partial x_j}{\partial p_i} = 0.$$

For simplicity, we assume that there are not other costs to retailing other than the cost, p^*, of purchasing power on the wholesale market. The profit function of a retail-only firm is

$$\pi_i^R(p_i) = (p_i - p^*)x_i(p_i, \boldsymbol{p}_{-i}).$$

The profit of a wholesale firm is

$$\pi_i^W(p_i) = (p_i - p^*)x_i(p_i, \boldsymbol{p}_{-i}) + p^* q_i^*.$$

Now consider the first-order conditions for each category of firm:

$$\frac{\partial \pi_i^R(p_i)}{\partial p_i} = F_i(p_i) - x_i(p_i, \boldsymbol{p}_{-i}) \sum_{j=1}^{n} \frac{\partial p^*}{\partial x_j} \cdot \frac{\partial x_j}{\partial p_i} = 0, \tag{8}$$

$$\frac{\partial \pi_i^W(p_i)}{\partial p_i} = F_i(p_i) + (q_i^* - x_i(p_i, \boldsymbol{p}_{-i})) \sum_{j=1}^{n} \frac{\partial p^*}{\partial x_j} \cdot \frac{\partial x_j}{\partial p_i} + p^* \sum_{j=1}^{n} \frac{\partial q_i^*}{\partial x_j} \cdot \frac{\partial x_j}{\partial p_i} = 0, \tag{9}$$

where

$$F_i(p_i) = x_i(p_i, \boldsymbol{p}_{-i}) + (p_i - p^*) \frac{\partial x_i(p_i, \boldsymbol{p}_{-i})}{\partial p_i}.$$

For either type of firm, the condition $F_i(p_i) = 0$ represents the normal first-order condition for profit maximisation before giving any consideration to the impact that retail competition will have on the resulting wholesale equilibrium. There are two sources of difference between the two types of firm: First, the vertically-integrated firm's first-order condition includes the impact that its retail pricing decisions has on the profit it earns from the wholesale market, pq_i^*; and second, the own price effect, $\partial x_i / \partial p_i$, enters the first-order condition for a vertically-integrated firm, but not for a retail-only firm.

Substituting in the equilibrium wholesale values of p^* and q_i^* from Section 2, the first-order conditions can be rewritten as

$$\frac{\partial \pi_i^R(p_i)}{\partial p_i} = F_i(p_i) + x_i(p_i, \boldsymbol{p}_{-i}) \frac{1}{n+1} \sum_{j=1}^{n} \frac{\partial x_j}{\partial p_i} = 0, \tag{10}$$

$$\frac{\partial \pi_i^W(p_i)}{\partial p_i} = F_i(p_i) - p*\left(\frac{2}{n+1}\sum_{j=1}^{n}\frac{\partial x_j}{\partial p_i} - \frac{\partial x_i}{\partial p_i}\right) = 0. \tag{11}$$

Consider now the case where a firm of either type is competing against a retail-only firm for retail-market share—that is, assume that

$$\frac{\partial x_j}{\partial p_i} = 0,\ \forall j \neq i,\ j \in \{1..n\}.$$

In this case, we have

$$\frac{\partial \pi_i^R(p_i)}{\partial p_i} = F_i(p_i) = 0, \tag{12}$$

$$\frac{\partial \pi_i^W(p_i)}{\partial p_i} = F_i(p_i) + p\left(\frac{n-1}{n+1}\right)\frac{\partial x_i}{\partial p_i} = 0. \tag{13}$$

Since the second term in Equation (13) is negative, these first-order conditions show that a vertically integrated firm has an incentive to compete more aggressively for the customers of retail-only firms than does a retail-only firm, with the latter facing the same incentives as in a completely unintegrated market.

Now consider the case in which either type of firm is competing against a vertically integrated firm for retail-market share—that is, assume that

$$\frac{\partial x_k}{\partial p_i} = -\frac{\partial x_i}{\partial p_i},\ \text{for some } k \in \{1..n\},\ \text{and } \frac{\partial x_j}{\partial p_i} = 0,\ \forall j \neq i,k.$$

In this case, we have

$$\frac{\partial \pi_i^R(p_i)}{\partial p_i} = F_i(p_i) - x_i(p_i, \boldsymbol{p}_{-i})\frac{1}{n+1}\cdot\frac{\partial x_i}{\partial p_i} = 0, \tag{14}$$

$$\frac{\partial \pi_i^W(p_i)}{\partial p_i} = F_i(p_i) + p\frac{\partial x_i}{\partial p_i} = 0. \tag{15}$$

Again, these conditions show that the vertically integrated firm has an incentive to compete more aggressively in the retail market than a retail-only firm. It is also interesting to compare Equations (15) and (14) with Equations (13) and (12). The comparison between (15) and (13) reflects the intuition shown in Theorem 2. That is, for a given set of prices, a wholesale firm has a greater incentive to compete with other vertically integrated firms for retail share than with retail-only firms. In contrast, the comparison between Equations (14) and (12), show that a retail-only firm has less incentive to compete for retail share from vertically integrated firms than from other retail-only firms. The reason for this is that when a retail-only firm takes retail market share away from a wholesale company, it creates more monopoly power in the wholesale market and hence a higher wholesale price. This is not the case for retail competition between two vertically integrated firms.

The results above combine to produce a general conjecture about the impact of vertical integration on the overall market:

Conjecture 1:

Consider a retail market with some vertical integration, and a parallel market in which the retail operation of each formerly vertically integrated firms has been divested into a separate firm. Under some mild regularity conditions to ensure a unique retail equilibrium, a market with some vertical integration will produce both a lower wholesale price and, for a given wholesale price, lower retail mark-ups on that price than would occur with a fully separate market.

Proof:

A formal proof of this conjecture awaits further work.

5. Concluding Remarks.

The results of this paper show that, provided there is a strong competitive market for fixed-price forward obligations, either through a forward-contracting market or vertical integration with a retail market, there is no reason to expect that monopoly power in the wholesale electricity market would be priced into the forward commitments. In contrast, vertical integration can be a force to reduce market power in the wholesale and retail markets simultaneously.

In deriving these results, however, we have abstracted away from two potentially important aspects of the New Zealand electricity market. The first is supply uncertainty that introduces a second motivation for the existence of either a forward market or fixed-price retailing with vertical integration. This is potentially important for equilibrium outcomes in the retail market with integration as, in a market such as New Zealand's, where some generators are more exposed to seasonal fluctuations in weather than others (due to having more or their generation capacity being based on hydro), the extent to which a generator has a net long or short position in the wholesale market will also fluctuate with the weather. The second abstract concerns the nature of the uniform-price rather than Cournot auction used in the wholesale market.

It seems unlikely that modifying the analysis to incorporate either aspect of reality would change the essence of the intuition presented in this paper, but these extensions remain for further work.

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Appendix

In this appendix, we redo the analysis of Section 3 for the case where buyers purchasing forward cover are a representative cross-section of the overall market, implying a proportionate reduction in the quantity demanded at any price for those buyers remaining in the wholesale market.

In this version, we assume that firm i sells fixed-price forward contracts to a fraction, θ_i, of buyers. Let $\theta = \sum_i \theta_i$ represent the total fraction of buyers with fixed-price forward contracts. Let x_i and X, continue to represent the total quantity sold in forward contracts by firm i and the full market, respectively. For simplicity, we will assume that firm i sells all its forward contracts at a single price, p_i, but the results do not depend on this assumption. In this case, we have

$$x_i = \theta_i(1 - p_i).$$

Again, let q_i and Q denote the total quantity produced by firm i and the entire market, respectively, whether sold at the wholesale market price or at pre-determined forward prices. The wholesale market price is determined by the residual supply and demand into that market. That is,

$$Q - X = (1-\theta)(1-p)$$

$$\Rightarrow \quad p = \frac{1-\theta-Q+X}{1-\theta}.$$

The profit function, first-order condition, and equilibrium values of the key variables are then

$$\pi_i(q_i) = p(q_i - x_i) + p_i x_i, \text{ and}$$

$$\pi_i'(q_i) = p - \frac{q_i - x_i}{1-\theta} = 0,$$

$$q_i^* = (1-\theta)p^* + x_i,$$

$$\Rightarrow \quad Q^* = n(1-\theta) - nQ^* + (n+1)X,$$

$$\Rightarrow \quad Q^* = \frac{n}{n+1}(1-\theta) + X,$$

$$p^* = \frac{1}{n+1} \tag{A1}$$

$$q_i^* = \frac{1-\theta}{n+1} + x_i \text{ and} \tag{A2}$$

$$\pi_i(q_i^*) = \frac{1-\theta}{(n+1)^2} + p_i x_i. \tag{A3}$$

In this model, the effect of the proportional reduction in demand is that selling forward cover will not result in a lower equilibrium wholesale price. While the purchasing of forward cover does not therefore confer any benefit on wholesale customers, however, the results of Theorems 1 and 2 still hold: First, any firm selling forward contracts will impose a cost on all other firms, and thus the profit-neutral price of the forward contracts will be lower than the equilibrium price. Second, it is profit increasing for a firm to acquire a greater share of a fixed forward market, at any price in excess of marginal cost.