PANEL SESSION 2

Invited paper 6

Contracts and electricity pool prices

Joshua Gans*, Danny Price and Kim Woods**
***Melbourne Business School**
****London Economics**

6.1 Introduction

In recent years, the electricity sector has been transformed from a vertically integrated monopoly to a disintegrated one that is capable of generating competition in both generation and retailing. This change has been well established in England and Wales and now in Victoria and New South Wales. South Australia and Queensland face similar reforms with an eventual formation of the National Electricity Market (NEM).

The change in the structure of electricity production has come about because of the establishment of a spot or pool market for electricity generation. This pool is characterised by generators making half-hourly bids of generation and a price schedule and a pool operator using these bids as the basis for a dispatch schedule. Generators then receive the system marginal price (SMP) on all units dispatched. The SMP is the highest price paid for any unit dispatched. Economists have begun to model this pool market behaviour as either an equilibrium in supply functions (Green and Newbery 1990) or, alternatively, as a multi-unit simultaneous auction (von der Fehr and Harbord 1992). These analyses have shown that pool markets may not produce competitive outcomes if there are a small number of dominant generators. Hence, pool prices may be substantially above marginal cost.

Side by side with pool markets are both long and short-term contract markets for electricity. By writing contracts, generators and retailers can share risks associated with a fluctuating pool price. But concern has been raised that the imperfect competition of pool markets will simply translate into market power being exercised in contract markets. Therefore, the existence of a contract market may allow generators further leverage over retailers.

The purpose of this paper is to explore the linkages between pool and contract market power. Some of these issues have been considered by previous researchers. Von der Fehr and Harbord (1992) model the pool as a multi-unit auction and demonstrate that contracts give generators a strategic advantage in the pool market by allowing them to commit to supply greater quantities during peak demand periods. However, their model suffers from the disadvantage that the contract prices are held fixed when in reality they will adjust over time depending on potential pool market behaviour. On the other hand, Green (1996) appropriately looks at the endogenous formation of both pool and contract prices in a supply function model. His analysis in many ways mirrors some of the conclusions below. However, his reliance on the complex, albeit descriptively accurate, supply function model makes it difficult to analyse how alterations in the cost structure of generation influence the exercise of market power.

In this paper we use a Cournot model of pool market behaviour that lies at one extreme of the supply function models — where the ability of generators to influence market power by making quantity commitments is greatest.[1] In addition, we model both generators and retailers as risk neutral and hence, there are no risk sharing benefits in signing long-term contracts. Nonetheless, we are able to show that contracts are signed and, in contrast to the concerns of some, make electricity markets more, not less, competitive. The existence of contracts in some instances improves efficiency directly by affording more efficient generators a greater market share. We then turn to consider the effect of the contract market on entry decisions. A final section concludes with remarks about the role of contracts in investment.

6.2 An overview of electricity contracts

While the analysis to follow will eliminate risk sharing aspects of contracting, these are the concerns that provide a rationale for the existence of contract markets. Therefore, it is worth reflecting, initially, on the role of long-term contracts in this regard.[2]

To generators and retailers the greatest risk posed by electricity pools is the financial consequences of fluctuating pool prices. Pool prices will vary each half hour and will be determined by the balance of supply and demand. Whilst the level of demand can be estimated, the availability of generation capacity in the market is less predictable. Generators themselves will choose how much electricity they will offer to produce. The power station with the highest marginal bid that is operating at any point in time (and the price they require to operate) determines the pool price.

In addition, availability is also affected by forced/partial outages which are not anticipated. These uncertainties about availability consequently affect the stability of pool prices in the short, medium and long-term. Therefore, generators and retailers may wish to cover themselves for this pool price risk by taking out an option contract (which are known in the United Kingdom (UK) as Contracts for Differences or CfDs).

1 Grant and Quiggin (1996) demonstrate that Cournot outcomes naturally result in supply function models when capital pre-commitments are relatively inflexible, as in electricity generation investment.

2 A short-term day ahead contract market is also proposed for the NEM. This market is not the focus of this paper.

These contracts are purely *financial* transactions. When these option contracts are set alongside *physical* sales or purchases from the pool provide insurance against excessive fluctuations in the pool price. These contracts are used in the UK, Victoria, New South Wales and a similar contract market will operate in the NEM. For example, vesting contracts are simply a financial hedge with a range of cross-subsidies added into the contract price. The nature of these contracts is described below.

Contract components

All contracts types have two common elements: a strike price and a quantity. However, many are more complex, with multiple strike prices for different times of the day or periods of the year and contract quantities which may be 'sculpted' over the course of the year. Further, some contracts can only be 'called' during certain periods, such as peak times.

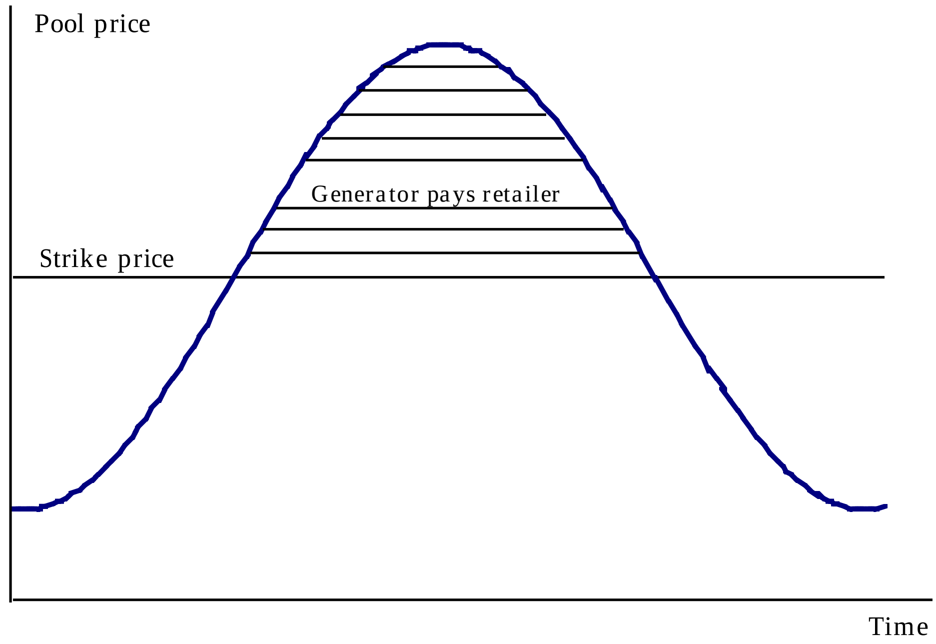
The key components of a contract are listed and briefly described below:

1. *one-way/two way options*: the contract may be called by the holder (retailer) or seller (generator) of the option, depending upon how the option is defined;
2. *firm/non-firm capacity*: the contract may be firm or related to the availability of particular generating sets;
3. *strike price*: this will set the price level at which the contract can be called. It can be varied by time or day. It can also be escalated from year to year;
4. *maximum capacity*: the amount of capacity for which the contract can be called can be sculpted by time of day or year to match a purchaser's load shape;
5. *maximum and minimum takes*: safeguards can be set against the contract being called too much or too little by constraining the number of takes;
6. *option constraint*: the hours in which the option can be called, whether or not the strike price is below pool price, can be limited; and
7. *length of contract*: this determines the overall commitment to the contract terms.

Basic contract types

There are essentially two forms of these contracts: *one-way* and *two-way*. One-way contracts establish a ceiling pool price (the strike price), as illustrated in figure 6.1. If the price is below the ceiling price retailers pay the pool price, if it is above the ceiling price retailers still pay the pool price but are compensated by the generator for the difference between the ceiling and pool price.

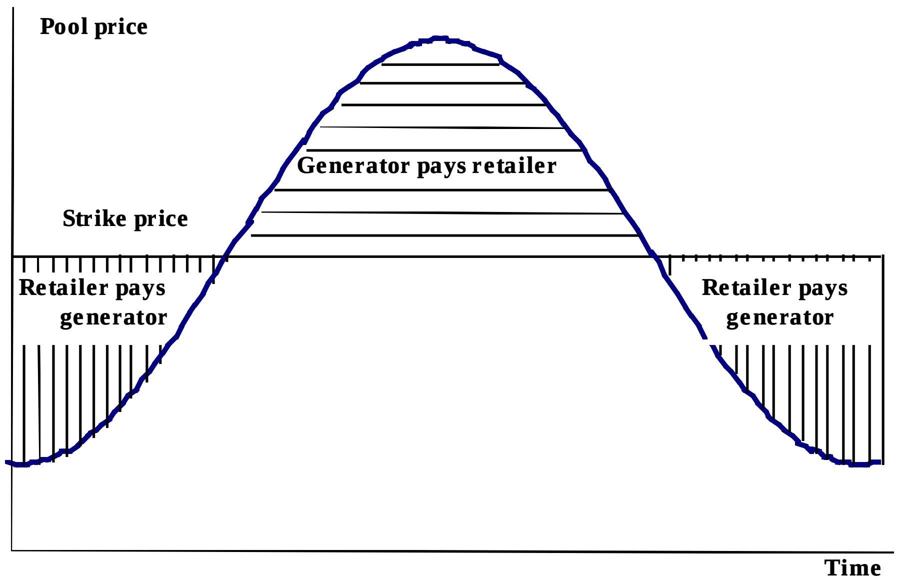
Figure 6.1 One-way contracts



Generators sell the contracts to distributors for a fixed option fee. If both contracting parties are risk-neutral, the value of the option fee would be equal to the net present value of the difference between expected pool purchase costs and purchase costs under the contract (net of the option fee). That is, the net present value of the expected pool price and the contract price is the same. Since the expected pool price is used to determine the amount that a buyer would pay for the option fee, it is important to redirect the future pool price path as accurately as possible to minimise contract trading costs.

Two-way contracts work in a similar way to one-way contracts. The difference is that a two-way contract establishes a firm price for both generator and retailer (see figure 6.2). Two-way contracts for differences are like forward contracts — retailers and generators essentially have agreed to buy/sell electricity for a fixed price over a fixed period in the future. Therefore, two-way contracts are not normally associated with option fees. Under a two-way contract, if the pool price rises above the strike price, generators compensate retailers for the difference. But if pool price falls below the strike price, then retailers compensate generators for the difference. The net present value of the strike price should approximate the net present value of the pool price.

Figure 6.2 Two-way contracts



Generally, one-way contracts are the preferred form of cover against infrequent events, such as pool prices moving above $300/MWh. Thus, the generator bears the risk if the pool price below the strike price; they will not be compensated for downward shocks.

Two-way contracts are preferred when broader coverage is required. In these events the main advantage of the two-way contract is that it reduces *generator* exposure to revenue risk when pool prices fall below contract strike price. Under a one-way contract generators are exposed to this risk. To the extent that generators will be risk adverse they will prefer two-way to one-way contracts. This has happened in Victoria. Two-way contracts are generally used to cover base load demand and part of their intermediate demand. One-way contracts are used for intermediate and peak demand.

While the role of one-way contracts is to hedge against the pool price risk borne by retailers, two-way contracts involve both retailers and generators sharing risk and, as will be demonstrated below, an additional strategic advantage to generators. As such, this paper will focus exclusively on two-way contracts for differences.

6.3 The strategic effects of contracts

We begin by considering a simple model of Cournot duopoly competition. As mentioned earlier, our decision to focus on the Cournot case is to demonstrate most clearly the existence of strategic effects to contracting. This allows us to use a simple framework to explore the comparative statics associated with such contracting (cf: Green 1996). The restrictive assumptions we employ are for ease of exposition and can be generalised quite easily.

There are two generators in the industry each subscripted by i = 1, 2. Inverse industry demand for electricity is a linear function $p = A - b(q_1 + q_2)$. This is simply the inverse load duration curve for a particular time period. It represents the choices of retailers and customers which are unmodelled in this paper. While industry demand is stochastic in practice, here we will ignore this possibility — this is a reasonable restriction given our assumption the generators and retailers are risk neutral. Generator production costs are linear with $C_i(q_i) = c_i q_i$, where we assume initially that $c_1 = c_2 = c$. There are potentially capacity restrictions on generators. Consideration of these will be left to a later section. Finally, we assume that $A > c_i$ for all i so that each firm's output is positive in equilibrium.

The game between generators proceeds in two stages. In the first stage, generators can pre-emptively contract with retailers. That is, they each choose, x_i, their contracted quantity, with the strike price, z, a function of their competition in contracting. In the second, spot market competition in the pool occurs. As will be shown, what occurs in the latter stage is influenced by the first. This is because both generators and retailers have rational expectations regarding what price will result in the pool in stage two. Indeed, given the assumption of risk-neutrality, no retailer will sign a contract with a strike price less than the expected spot price and generators will, in equilibrium, not find it advantageous to offer lower contract prices than expected spot prices. Therefore, agents will expect that $z = p$.

We will analyse the model by working backwards considering stage two pool market behaviour contingent on any feasible contract set signed and then looking at contract market behaviour in which all parties expected the predicted stage two behaviour.

Stage two: the spot market

Suppose that both generators have signed contracts for amounts (x_1, x_2) in stage one. A generator's profits in stage two will then be:

$$_i = p(q_i - x_i) + zx_i - cq_i \, .$$

Given our Cournot assumption, each generator chooses q_i to maximise this function, holding the quantities of all other generators as given. The first-order condition for this maximisation problem is:

$$\frac{{}_i}{q_i} = -b(q_i - x_i) + p - c = 0 \Rightarrow q_i = \frac{A - bq_j + bx_i - c}{2b} \, .$$

This equation defines the reaction function for generator 1. The key feature to note about this function is that it is increasing in own level of contract cover and only depends on the level of contract cover of the other generator through that generator's quantity. The intuition for this relationship can be best demonstrated graphically. Figure 6.3 depicts the inverse demand curve facing generator 1 for a given q_2. It also depicts the marginal revenue curve facing that firm when it has no contract cover. However, if it has x_1 units of contract cover at a strike price of z, this effectively flattens its inverse demand and marginal revenue curves over this range. While for quantities beyond x_1 the demand curve continues as before, the origin of the downward sloping portion of the marginal revenue curve is x_1 rather than zero. For a constant marginal cost, the quantity at which marginal revenue equals marginal cost is greater when the generator has signed a forward contract for some quantity. This occurs regardless of the quantity chosen by the other generator, hence, pushing the reaction curve upwards.

It should be noted that when a generator contracts some output, regardless of the strike price on that contract, it should bid that contracted amount into the pool at marginal cost. This ensures that when the pool price is above marginal cost, the generators contracted amount is dispatched. If it were not dispatched it would be effectively forced to act financially as if it had bought the unproduced portion of the contract at pool prices. Thus, if individual demand facing a generator where relatively low, as in figure 6.4, it may find itself not producing its full contracted amount. While this is optimal if the pool price is below marginal (or avoidable) cost, the generator is strictly better producing this quantity if the pool price is above marginal cost. Note that a firm whose output is entirely contracted, that is with $x_i = q_i$, ends up with price equal to marginal cost. This mirrors a result demonstrated by Green (1996) for restricted supply function equilibria.

Figure 6.3 Effect of contracts on pool quantities

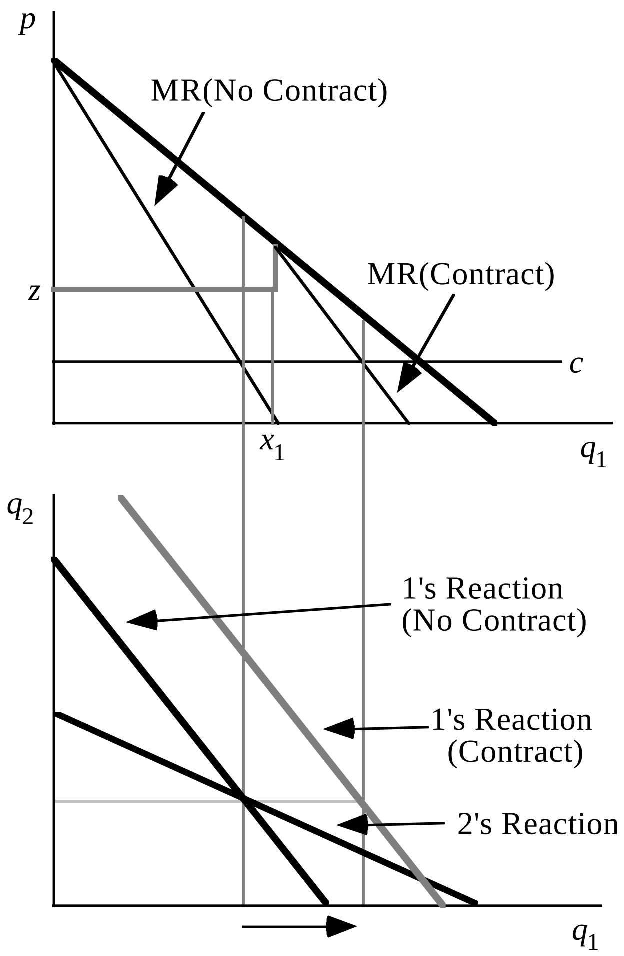
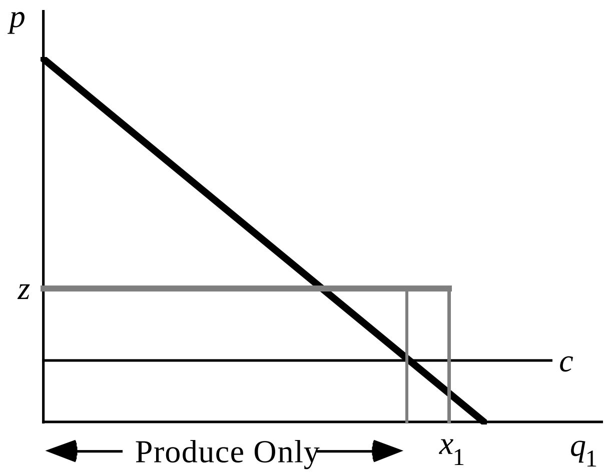


Figure 6.4 Excessive contract cover



Solving out for the unique equilibrium in the stage two sub-game, we have:

$$q_i = \tfrac{1}{3}\left(\tfrac{1}{b}(A-c)+2x_i - x_j\right) \text{ for all } i \text{ and } p = \tfrac{1}{3}\left(A - b(x_1 + x_2) + 2c\right).$$

Observe that price is lower when the sum of contract cover is greater. Moreover, whenever one generator increases its contract cover relative to the other, its quantity sold is greater while the quantity sold by its rival is lower. As depicted in figure 6.3, the assumption of Cournot competition means that each generator's quantity choice is decreasing in those of its rivals (that is, they are strategic substitutes). Greater individual contract cover raises the returns to having higher quantities in the pool, it raises a given generator's output but also results in reduced output by other generators and a lower pool price overall.

Therefore, by encouraging generators to bid a greater quantity into the pool at any given time, contracts have a *strategic effect* on the equilibrium in stage two. Note that in Bertrand competition the pool price equals marginal cost always so that the amount of contract cover does not have this strategic effect. It is only when generators can make quantity commitments (even partly) that the strategic implications of contracting are realised.

Stage one contract market

Each generator and retailer realises that contracts have effects on pool prices. For each generator, greater contract cover raises their incentives to bid larger quantities in the pool and forces others to reduce their quantities, all other things being equal. The lower pool prices will mean that retailers will demand a lower strike price for any contract signed, however. The question is, what will happen when each generator competes for these contracts?

As noted earlier, in equilibrium $z = p$, that is, $z = \tfrac{1}{3}\left(A - b(x_1 + x_2) + 2c\right)$. Each generator, therefore, anticipates the following profit in stage two:

$${}_i = (p-c)q_i = \tfrac{1}{9b}\left(A - b(x_i + x_j) - c\right)\left(A + b(2x_i - x_j) - c\right).$$

Once again, using this payoff, generators choose their level of contract cover, holding the contract choices (but not the ultimate spot market choices) of the other generator as given. In general terms, the marginal return to contracting is:

$$\frac{{}_i}{x_i} = \underbrace{\tfrac{dq_i}{dx_i}\left(p - b(q_i - x_i) - c\right)}_{=0} - \underbrace{\tfrac{dq_j}{dx_i}bq_i}_{\text{Strategic Effect}}.$$

The first term is zero by the envelope theorem. Under risk neutrality, there is no direct cost or demand advantage from contracting. Therefore, the effect is purely a strategic one (a 'top dog' strategy in Fudenberg and Tirole's (1984) terminology). This is positive for, as noted earlier, increased contracting raises own output in the spot market reducing the quantity bid by the rival generator.

Considering our specific model, the first order condition for the profit maximising choice of contract level is:

$$\frac{\quad_{i}}{x_i} = -\tfrac{1}{9}\left(A + b\left(2x_i - x_j\right) - c\right) + \tfrac{2}{9}\left(A - b\left(x_i + x_j\right) - c\right) = 0$$

which, in the unique symmetric sub-game perfect equilibrium, yields:

$$x_1 = x_2 = \frac{A - c}{5b} \text{ and } z = \frac{A + 4c}{5}.$$

Observe that the resulting level of output (both contracted and spot) for a generator is:

$$q_1 = q_2 = \frac{2(A - c)}{5b},$$

twice the contracted level. So in this specific example, generators contract half of their output in equilibrium.

What is the impact of contracting upon price? To conduct this experiment, observed that if no contracts were allowed, then:

$$p = \frac{A + 2c}{3} \text{ and } q_1 = q_2 = \frac{A - c}{3b}.$$

Therefore, it is easy to see that by allowing for contracting, price is lower and output is greater. So while each generator has a strategic benefit from pre-emptive contracting, in equilibrium this possibility harms their profits. Each would prefer to commit not to contract, but in a similar vein to the Prisoner's Dilemma, each chooses to contract a positive amount imposing a negative effect on the other's profits (see Allaz and Villa 1993 for extensions of this idea).

6.4 Asymmetries between generators

The previous analysis considered the role of contracts in a symmetric environment. While the strategic role of contracts and its competitive benefits continue to hold with non-linear demands and costs, one cannot analyse whether more efficient generators use contracts relatively more or less than less efficient ones in a symmetric environment. Therefore, in this section, we extend our basic model to consider heterogeneous cost structures among generators.

Consider first a situation in which generators differ in their marginal costs, that is $c_1 > c_2$. In this case, the equilibrium is no longer symmetric. It is still unique, however, and has the solution:

$$x_1 = \frac{A - 3c_1 + 2c_2}{5b} \text{ and } x_2 = \frac{A - 3c_2 + 2c_1}{5b}$$

$$q_1 = \frac{2(A + 2c_2 - 3c_1)}{5b} \text{ and } q_2 = \frac{2(A + 2c_1 - 3c_2)}{5b}$$

$$z = p = \frac{A + 2(c_1 + c_2)}{5}$$

Note that even though $q_1 > q_2$, each generator continues to contract half of its output.

Without contracting, we would have:

$$p = \frac{A + c_1 + c_2}{3}, \; q_1 = \frac{A + c_2 - 2c_1}{3b} \text{ and } q_2 = \frac{A + c_1 - 2c_2}{3b}$$

Once again, the output of both generators is higher and price lower when contracting is possible. One can also compare the market shares of generators when contracting is and is not allowed. Interestingly, with contracting, the market share of the more efficient plant is higher than the case where contracting is not possible.

These conclusions are not robust to alternative cost specifications. Suppose that $C_i(q_i) = c_i \frac{1}{2} q_i^2$. It is cumbersome but not difficult to show that while the results of section 6.3 continue to hold for this cost function, generators contract a third of their output in equilibrium but the market shares in the contracting as compared with the no contracting case are exactly the same. Nonetheless, as one increases the marginal costs of one generator, its output falls, the output of its rival rises, total industry output falls, contract levels fall and each firm continues to contract one third of its output.

This example of increasing marginal costs captures part of the technology of electricity generation. In reality, however, the capacity constraints on a generator are such that marginal cost is relatively flat for most output below a certain level at which it becomes very step (that is, the marginal cost curve is an inverted L-shape). Capacity constraints of this form are difficult to analyse. If both generators are expected to be constrained in a given period (that is, in periods of high demand), then neither one gains a strategic advantage from pre-emptive contracting as this does not reduce the quantity the other bids into the pool. On the other hand, in periods of low demand, both have strategic incentives similar to those analysed in this paper. Thus, one would expect the degree of contract cover to vary with the intensity of demand.

One can also ask whether large versus small generators have a greater incentive to contract, all other things equal. Assuming equal marginal costs, small generators are likely to be constrained more often. In a duopoly, this means that a large generator will have a reduced strategic incentive to contract as they cannot influence the quantity the small generator bids into the pool. In reality, when there is no duopoly, however, it is difficult to say whether large or small generators will have a greater incentive to pre-emptively contract.

6.5 Contracts and entry

The previous sections demonstrated that contracts have the effect of diminishing the overall price for electricity and, hence, the profits of individual generators. In a static setting, where there is no possibility of entry, this represents a welfare improvement through greater allocative efficiency in electricity. However, lower prices and industry profits make entry unattractive. While this would not be a concern in industries where entry can be smooth and entrants have considerable flexibility over the scale of production, in electricity, this is not a reasonable assumption. Entry will give rise to discrete changes and potential entrants will have to take account of larger changes in prices received.

Once again, we ask the question: what does the existence of a contract market have on pool prices? Newbery (1997) has analysed the interaction between contracts and entry deterrence in electricity markets. In a model in which only incumbent generators were able to sign contracts, he demonstrated that such contracts facilitated entry deterrence by committing generators to lower pool prices — below the level that would allow for entry. In contrast, we allow a potential entrant as well as incumbents to compete for pre-emptive contracts for differences. This seems reasonable as it will, potentially, be in retailers' interests to encourage entry.

We analyse this case as follows. Suppose that there are two incumbent generators, 1 and 2, as in section 6.3 who have symmetric marginal costs, c. In addition, suppose there are no capacity constraints. There is a potential entrant, 3, who has marginal cost of $\underline{c} \leq c$, but must incur a sunk entry cost of $F > 0$. It will, therefore, enter if its expected profits $\pi_3 \geq F$.

It is quite easy to demonstrate that entry profits are lower when there is a contract market compared with a situation in which such a market does not exist. Therefore, there exists a range of sunk costs, F, such that the entrant would choose to enter if there was no contract market but would enter otherwise. If this is the case, then the price that prevails when there is no contract market is $\frac{1}{4}(A+2c+\underline{c})$, as entry has occurred. However, when there is a contract market, entry does not occur so the price remains at its duopoly level, $\frac{1}{5}(A+4c)$. In this case, a contract market serves to lower electricity prices if, and only if, $A-c \geq 5(c-\underline{c})$, that is if the cost differential is small. For a large entrant cost advantage, if F is such that entry might be deterred by having a contract market, then the existence of contracts is potentially anti-competitive.[3]

6.6 Conclusions

This paper has demonstrated that contract markets can serve to make oligopolistic spot markets more competitive. Generators have a purely strategic incentive to sign forward contracts so as to raise their share of the overall electricity market. However, this option has a negative effect on the profits of other generators. Each is caught in the equivalent of a Prisoner’s Dilemma motivating them to sign contracts when it is in their mutual interest to refrain from so doing. The result is an electricity market with prices closer to marginal costs.

Our conclusion, however, was qualified by the possibility that the contract market might deter entry that might otherwise occur and, hence, could lead to higher electricity prices in the long-run. This analysis of the possible dynamic consequences of contracts is only a beginning. In particular, signing a contract can make current generators less flexible to informational changes. A fruitful direction for future research, therefore, is to consider the interaction between pool and contract markets in a dynamic setting where each sends signals and provides incentives for entry and investment (as in Aghion and Bolton 1987; and Innes and Sexton 1994).

[3] Of course, as the cost advantage grows large the range of sunk costs that might deter otherwise possible entry grows smaller.

References

Aghion, P. and Bolton, P. 1987, 'Contracts as Barriers to Entry', *American Economic Review*, 77(3), pp.388–401.

Allaz, B. and Vila, J-L. 1993, 'Cournot Competition, Futures Markets and Efficiency', *Journal of Economic Theory*, 59(1), pp.1–16.

von der Fehr, N-H., and Harbord, D. 1992, 'Long-Term Contracts and Imperfectly Competitive Spot Markets: A Study of the UK Electricity Industry', *Memorandum*, No. 14, Dept of Economics, University of Oslo.

Grant, S. and Quiggin, J. 1996, 'Capital Precommitment and Competition in Supply Schedules', *Journal of Industrial Economics*, (forthcoming).

Green, R. 1996, 'The Electricity Contract Market', *Cambridge University DAE Working Paper*, No. 9616.

Green, R. and Newbery, D. 1990, 'Competition in the British Electricity Spot Market', *Journal of Political Economy*, 100, pp.929–953.

Fudenberg, D. and Tirole 1984, 'The Fat Cat Effect, the Puppy Dog Ploy and the Lean and Hungry Look', *American Economic Review*, 74(2), pp.361–368.

Innes, R. and Sexton, R. 1994, 'Strategic Buyers and Exclusionary Contracts', *American Economic Review*, 84(3), pp.566–584.

Newbery, D. 1997, 'Competition, Contracts and Entry in the Electricity Spot Market', *Cambridge University DAE Working Paper*, No. 9707.