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Pricing in Wholesale Electricity Markets

Summary

Electricity prices for residential consumers in New Zealand rose 20%, adjusted for inflation, between 1996 and 2004 (Ministry of Economic Development 2005).[1] Given these price increases, it is not surprising that the New Zealand electricity market has come under increased scrutiny. Some observers question the operation of the wholesale market, where a generator that announces willingness to produce electricity for a relatively low price is nevertheless reimbursed with the market price. This paper attempts to shed light on pricing in wholesale electricity markets, in New Zealand and around the world.

There are four main points:

- All major competitive electricity markets, including New Zealand's, are designed according to the principle that, in order to achieve an efficient allocation of resources, the market price should be determined by the marginal cost of production.

- When wholesale markets are *competitive*, the gap between market price and marginal cost that is enjoyed by some generators typically represents "scarcity rents", which compensate for fixed costs, and possibly also short-term "economic profits". These scarcity rents and economic profits play an important role in mobilising new investment and spurring efficiency. There may be some valid questions about distributional issues – in particular, about whether any economic profits could be better shared with consumers. However, it is difficult to think of a workable policy to redistribute these profits to consumers without distorting generators' incentives to operate and invest efficiently.

- International experience with electricity wholesale markets shows that it can be difficult to maintain an adequate level of competition: generators may sometimes be able to exercise "market power" and withhold capacity in order to intermittently earn excess "monopoly profits". We don't have any evidence that suggests this is currently

[1]This figure excludes GST. Although residential electricity prices increased over this period, real prices paid by industrial users remained fairly stable (on an annual average basis, which masks shorter-term fluctuations). Commercial users experienced real price declines.

a problem in New Zealand, but it is worth being aware of lessons learned overseas. A number of features can help promote competition, including adequate transmission capacity, low barriers to entry for new generators, ample scope for hedging and demand-side responsiveness.

- There is little reason to believe the alternative "pay-as-bid" mechanism for wholesale market pricing would improve market outcomes in New Zealand.

Competitive Electricity Wholesale Markets and Uniform Pricing

Electricity markets around the world are designed to set market price according to the industry's marginal cost.

The New Zealand wholesale electricity market is set up to achieve the welfare maximising benefits of competition. More specifically, the market is designed with the goal of achieving a market price equal to the industry's marginal cost of electricity production. Around the world, all major electricity markets are based on the premise that the market price ought to reflect the marginal cost of production, including markets in Australia, North America, England and Wales, New Zealand and other markets with substantial hydro generation (such as Norway).

Figure 1 represents an exercise that is replayed many times each day in a competitive wholesale market with uniform pricing. Generators regularly provide "bids" to the market operator, indicating the minimum price for which they would agree to operate various units of capacity in a given period.[2] (In the New Zealand market, bids are submitted on an half-hourly basis.) Each individual generating firm makes a bid for each unit of capacity that it owns (ie, an individual plant bids multiple units). The market operator ranks these bids and sets the market price at the level needed to just satisfy demand.[3] All units that are bid below the market price are called on to operate and receive the market price for their production. This is why this system is referred to as "uniform pricing": all generators supplying electricity are paid the same price per unit of electricity. Given a sufficient amount of competition, the market price determined by this system should equal the industry's true marginal cost of production.

[2] In New Zealand, the term "offer" is used instead of "bid". Although the New Zealand terminology is more intuitive – after all, the generators are *offering* supply – we use "bid" in order to keep our discussion closely linked to the international literature on the subject.

[3] The demand curve is often assumed by the market operator to be vertical. This is a reasonable representation of actual demand because consumers are largely insensitive to hourly price changes.

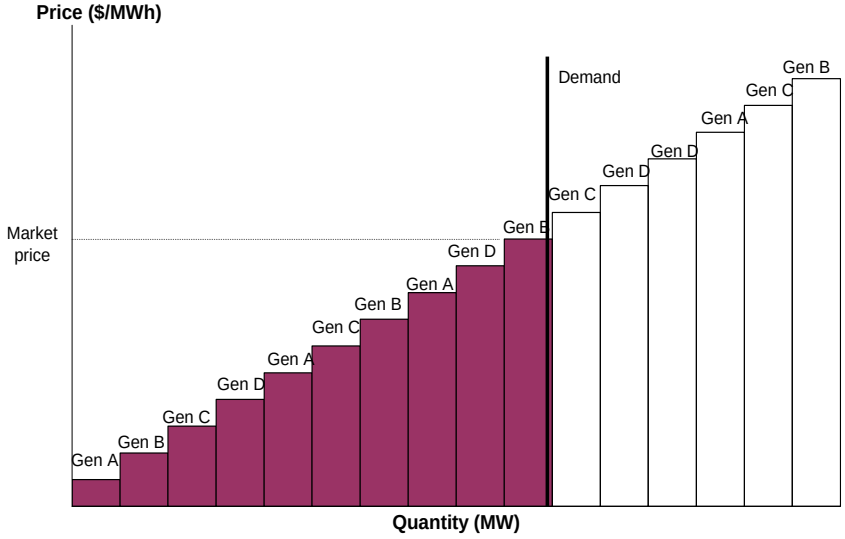
A uniform pricing mechanism is one way to get generators to reveal the marginal cost of production.

To understand this, note that each generator has incentive to bid a price that is equal to its marginal costs of production. Consider a firm, call it Gen A, which owns a unit of capacity that costs $30 to run.[4] When the market operator asks for bids, Gen A could bid the unit at $35, but it would run the risk of not being chosen for production at a profitable market price (eg, $32). Gen A could also bid $25, but might then be called on to produce at a market price of $28, in which case Gen A would lose money. So, it is in Gen A's interest to bid $30, the marginal cost. If all generators follow this self-interest, then the ranking of bids should ensure that lower-cost units are dispatched first and that the market price equals the industry-wide marginal cost of production.[5]

Problems arise when the market is insufficiently competitive.

As is apparent from Figure 1, in each period, low-bid units are paid more than their marginal cost of production – we'll call this the price-bid margin. To some observers, this may appear inequitable. Why should a firm that signals its willingness to produce a unit of capacity at a relatively low price be rewarded with a higher market price? Isn't this a bad deal for consumers? The short answer is that a competitive market with uniform pricing produces an efficient outcome that benefits consumers. In a competitive market, the difference between market price and a given unit's bid price represents a legitimate *scarcity rent* or *economic profit.* However, as we will see later, if the market is not competitive, generators can earn excess or "monopoly" profits which are undoubtedly a bad deal for consumers, particularly if they reoccur frequently.

Figure 1: Determination of electricity market price under uniform pricing



Note: Based on Hunt (2002).

[4] Units of electricity are typically priced in terms of dollars per megawatt hour (MWh).

[5] "Dispatched" means that a unit of capacity is called on to produce.

The Price-Bid Margin in a Highly Competitive Market

This section seeks to explain the price-bid margins described above, in the context of a market with plenty of competition between generators in the wholesale market. In other words, we will attempt to explain why, at any given point in time (such as the bidding round represented in Figure 1), some units of electricity are paid more than their bid price. In the next section, we will discuss the case where the market is not always sufficiently competitive.

The price-bid margin plays an important role in allowing firms to cover the fixed costs of plant and machinery. Any residual revenue (after subtracting fixed and variable costs) is economic profit.

First consider the relevant definitions of revenue and cost. Total revenue for any firm is simply the market price multiplied by the number of units of electricity produced by that firm. Total cost for any firm is composed of two components: fixed costs and variable costs. *Fixed costs* are the costs associated with inputs that cannot be readily expanded without substantial amounts of time – typically plant and machinery. *Variable* costs are the costs associated with dispatching *marginal* units of production (usually fuel and some labour costs). We have already seen that, in a competitive market, a generator has incentive to reveal its marginal or variable costs in the form of its bid price. Now we can define "economic profits" as total revenue minus total costs.[6]

The upshot of these simple relationships is that the price-bid margin can be thought of as having two components: payments that cover fixed costs (often called "scarcity rents") and economic profits. It is important to recognize that this does *not* mean that generators always earn a positive economic profit. Economic profits can also be negative (whenever fixed costs exceed the price-bid margin) or zero (whenever fixed costs just equal the price-bid margin).

Scarcity rents fluctuate with demand and help compensate firms for the fixed costs associated with seldom-used units of capacity. To see this, recall that some units of capacity have high marginal cost (which is the reasons for the rising "merit" ranking in figure 1). Consider again the firm Gen A, which owns a single generating plant. In the last section, we looked at how Gen A bids a single unit of capacity in its generating plant in a single period. Gen A makes several such bids (one for each unit of its capacity) every period. Most plants have increasing marginal costs, meaning that it becomes increasingly expensive for the plant to produce an additional unit of electricity as the plant nears capacity. In a period where Gen A is called on to operate near capacity – for example, an hour when demand is

[6] There is often confusion between economic profits and the "profits" referred to in accounting (and newspaper) discussions. Accounting profits include the payments firms make to cover capital costs. From an economic point of view, these payments are similar to payments made to cover labour costs: both are payments for inputs. Economic profits are what is left over when a firm pays for all inputs (labour, capital, land, etc.). A firm that earns accounting profits will not necessarily earn economic profits.

particularly high due to cold weather – then its low-priced units will each earn a large positive price-bid margin.[7] These margins allow the firm to recoup the fixed costs associated with a plant that is only intermittently required to run near full capacity. [8]

Scarcity rents and economic profits provide incentives to firms thinking of entering the electricity market.

In a market with plenty of competition, scarcity rents and economic profits send incentive signals to new firms considering entry into the market. These signals are important in mobilising new investment and spurring innovation that ultimately benefit consumers. Over the long term, new generators should enter the market and "compete away" any positive economic profits. However, it is important to remember that planning and building new plants can take years, so the process can be slow. Economic profits that persist for long periods of time may raise questions regarding whether the economic profits might be better shared with consumers. There are two points that should be made in response. First, it is difficult to implement a policy that would "capture" economic profits, partly because it is difficult, in practice, to distinguish between economic profits and scarcity rents. Policies to capture economic profits could easily damage incentives for investment and innovation, harming consumers in the long run. Second, any economic profits are typically passed back into the economy in the form of new investment or dividends to shareholders (including government). In this sense, depending on the ownership of shares and the government's role in society, it may sometimes be valid to say any economic profits are widely "shared". [9]

It is worth noting that some government polices can affect marginal costs and thus bidding behaviour, the price-bid margin and economic profits. For example, hydro firms do not always bear the full economic cost of the water that they use. A reasonable policy might be to develop a system so that water prices take into account the value of water, particularly in circumstances where water is a productive input for competing uses (eg irrigation and hydro-generation). To the extent that this raises the firms marginal costs, it would force the firm to increase its bids and thus reduce the price-bid margin and economic profits.

[7] In terms of Figure 1, during periods of high demand, the vertical demand line shifts rightwards, the market operator dispatches rarely-used units with relatively high marginal cost and the market price rises.
[8] See Joskow (2003) for further discussion on scarcity rents and fixed costs in the U.S. context.
[9] If a state-owned generator were privatised, the sale price should reflect (the net present value of) future profits.

Price Spikes and the Problem of Market Power

Electricity markets have several unusual characteristics that generate price volatility.

Wholesale electricity prices tend to be more volatile than prices for other commodities, sometimes spiking sharply for hours, days or even weeks at a time. Price may still be equal to industry marginal cost during these spikes. In other words, price spikes in the wholesale market may simply be an efficient reflection of high demand (or the loss of supply from inexpensive units due to malfunction or routine maintenance) requiring that high-marginal-cost units come into operation. As suggested in the preceding section, price fluctuations can play an important role in covering the costs of rarely used capacity. However, we will see in this section that there may also be situations where competition is insufficient, market price deviates from marginal cost and price spikes are not efficient.

There are several reasons why wholesale prices can be volatile. First, electricity generally cannot be stored, so there are no inventories as in other markets. Second, demand is not very responsive to changes in price (in more technical terms, demand is "price inelastic") on an hour-by-hour or day-by-day basis. This is because most consumers cannot see, and therefore cannot respond to, hourly price fluctuations.[10] Even if consumers could see wholesale market price fluctuations, price elasticity would still be fairly low. Once a consumer has purchased a TV or refrigerator, the price of power at any given hour will have to fluctuate significantly in order to influence consumer decisions about usage across the day or week. Third, supply can also be inelastic in the short run when capacity is tight. As a result, changes in conditions, including transmission constraints and hydro levels, can lead to large swings in market price. For example, if the transmission link between the North and South Islands temporarily loses capacity, North Island consumers are suddenly faced with reduced generation capacity and North Island generators are called upon to run expensive generating capacity that is seldom used. The industry's marginal cost of meeting demand becomes very high and the price jumps.

Electricity markets can also be susceptible to bouts of inadequate competition when generators can earn monopoly profits.

When competition is weak, price spikes may not be benign. International experience shows that individual generators are sometimes able to manipulate the market price and exacerbate price spikes by withholding capacity and driving prices above marginal cost.[11] This happens when an individual generator finds itself facing little competition and is temporarily able to act as a monopoly, that is, able to exercise "market power". These conditions tend to arise when prices are already spiking – such as in the transmission constraint example, above. International experience indicates

[10] Some large industrial users have meters that allow them to respond to hourly prices, but most households do not.

[11] Newberry(2002) discusses electricity restructuring and market power in the European context; Wolak (2003) discusses the role of market power in California's electricity crisis; Hunt (2002) provides an accessible overview.

that market power may appear, in an unpredictable fashion, for minutes or hours at a time. However, it is important to stress that we do not have clear empirical evidence on whether generators in New Zealand actually exercise market power or earn monopoly profits. Episodes of market power are very difficult to identify empirically.

What does this market power mean for our analysis of the price-bid margin introduced in the previous sections? Recall the incentives faced by the hypothetical firm Gen A when deciding how to bid each unit of its plant's capacity. In its competition with other firms, Gen A realises it is in its own interest to bid each unit of capacity according to the true marginal cost. But, to paint the picture in stark terms, imagine Gen A suddenly faces *no* competition for a day – that is, it knows that it will be called on to satisfy *all* demand for electricity from a particular city or region. In this situation, Gen A has the ability to unilaterally drive up the price and earn large price-bid margins on the units that it produces. To highlight the difference from the competitive market situation described in the previous section, we can refer to these extra profits achieved by market power as "monopoly profits". While the economic profits that may be earned in a highly competitive market play an important role in stimulating efficiency and ultimately benefit consumers, the monopoly profits earned in uncompetitive episodes hurt consumers with high prices and scarce supply.

Electricity markets can be susceptible to market power because of the unusual characteristics described above (no inventories, inelastic supply and demand, the need to maintain voltage and keep the electricity flowing) and also because entry by new generators tends to take a significant amount of time, particularly in countries with extensive permitting requirements. A number of features can help mitigate the scope for market power, including adequate transmission capacity, low barriers to entry of new generators, ample scope for hedging and demand-side responsiveness.[12]

An Alternative to Uniform Pricing?

Pay-as-bid is sometimes considered as an alternative wholesale market pricing mechanism.

Policymakers in some countries have considered the "pay-as-bid" system as an alternative to uniform pricing (which, as described above, is the system used in the New Zealand wholesale market).[13] As part of the broader "New Electricity Trading Arrangements", regulators in England and Wales implemented a pay-as-bid pricing scheme to replace uniform pricing in 2001. Under a pay-as-bid pricing system, the bids are ranked, as in

[12] It is beyond the scope of this paper to explain how these market design features can mitigate market power. There is a substantial body of international literature on this subject. See, for example, Hunt (2002) and Newberry (2002).

[13] As noted in an earlier footnote, the term "bid" is used in the UK and other countries where "offer" is used in New Zealand. In the New Zealand context, "pay-as-bid' might be more appropriately called "pay-as-offered". Nevertheless, we use the term "pay-as-bid" because it is common in the international literature.

uniform pricing. However, unlike uniform pricing, the dispatched generators (i.e., those called on to produce because of their relatively low bids) are not paid the market price; as the pay-as-bid name suggests, the market operator only pays each generator the actual amount bid.

Some proponents of pay-as-bid contend, inaccurately, that it is a way to reduce electricity market prices. They say that the bids in Figure 1 need not be rewarded with the market price; if the bids were rewarded just "as bid" then consumers, on average, would pay less (relative to uniform pricing). On the surface, this argument has intuitive appeal. However, it fails to recognize a crucial point: moving from uniform pricing to pay-as-bid *changes the way that generators bid*. Under uniform pricing, as described above, each generator has incentive to bid its true marginal cost. Under pay-as-bid, each generator has incentive to bid its guess of the marginal producer's cost (i.e., the market price that uniform pricing would produce). Take the example of a generator that knows it has fairly low costs, but doesn't know the exact costs of other generators. If it bids its own marginal cost (say $30), then it is sure to be dispatched and earn $30. If it bids a bit higher, it will again probably be dispatched and earn a bit more. The firm would like to raise its bid all the way up to the level of the marginal bid, but must make an estimate of what this level will be. So each firm wants to do its best to figure out the costs of other firms and bid the marginal industry cost. This predicted change in bidding behaviour appears to be just what happened in England and Wales after pay-as-bid was introduced (2001). [14]

Pay-as-bid tends to produce broadly the same results as uniform pricing.

In general, a pay-as-bid system will tend to arrive at the same market price and dispatch schedule as uniform pricing. The low cost firms will still generally earn the same scarcity rents and economic profits and the market price will still tend to be the industry marginal cost of production. The big difference is that pay-as-bid requires each firm to invest a lot of effort guessing other firms' costs. Inevitably firms will make errors and bid a guess of the industry marginal cost that is too high or too low. Some economists point out that, although these errors cancel out over time, their existence still means that there will be inefficiencies: sometimes high-cost units will be dispatched when a lower-cost unit is accidentally bid too high (Kahn 2001). Other economists have put forward sophisticated theoretical analyses that suggest pay-as-bid may have some desirable properties that mitigate market power under some assumptions about market conditions. However, after a careful review of the theoretical arguments, Fabra *et al* (2002) conclude that there is little reason to prefer pay-as-bid to uniform pricing.

In sum, pay-as-bid tends to arrive at broadly the same result as uniform pricing (in terms of market price, output level, economic profits and scarcity rents), but in a messier and arguably less efficient fashion. There is no

[14] Electricity prices did fall in England and Wales after the implementation of the New Electricity Trading Arrangements, but this is likely due to the effects of the broader policy package, not to the move to pay-as-bid (Frontier Economics 2001).

clear argument in favour of switching the New Zealand wholesale market to a pay-as-bid scheme.

Conclusion

This paper examined several aspects of the operation of wholesale electricity markets. The uniform-pricing bidding procedure used in the New Zealand market is sound. We have emphasized that the efficient operation of the wholesale market, and the overall electricity industry, depends on sufficient competition among generators. The overarching challenge is to ensure that the broad market environment – including transmission and hedging arrangements, conditions for entry, and demand responsiveness – supports adequate competition.

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