"The Dynamics of Market Power with Deregulated Electricity Generation Supplies"

Richard E. Schuler,
Professor of Economics
Professor of Civil and Environmental Engineering
Director, Cornell Institute of Public Affairs
466 Uris Hall
Ithaca, NY 14853-7601
res1@cornell.edu

ABSTRACT

Deregulated wholesale markets for bulk electricity supplies are likely to deviate from the perfectly competitive ideal in many areas where transmission losses, costs and capacity constraints isolate customers from the effective reach of many generators and limit the number of competitors. In those regions where a few suppliers or marketing agents dominate the market, prices may rise well-above the comptitive ideal of marginal cost. Furthermore, if all customers do not shift instantaneously to the lowest-priced supplier, perhaps because of inadequate information about the reliability of alternative generators and/or additional investments required to switch suppliers, then depending upon the duration of those lags, the optimal pricing policy of the existing dominant generators may be to ignore the competition for an appreciable period of time.

Using previously developed models of dynamic oligopoly pricing, estimates are provided of how rapidly and how far bulk power supply prices might deviate from competitive levels after the deregulation of those markets, depending upon the number of potential competitors serving a particular region and their individual market shares. These models have been calibrated and applied previously, ex-post, to the introduction of competition in long distance telephone service the United States, where they "predict" AT&T dynamic price behavior accurately, and they suggest that similar substantial lags may occur in the emergence of intensive price competition in some electricity markets.

1. Introduction

A primary motive for the deregulation of some utility services is that prices may fall appreciably as competitive pressures are substituted for administered pricing under deregulation. Effective competition should force all service providers to seek efficient, low cost methods, thereby exposing former utility and regulatory practices that are not economical. But if the markets for bulk power supplies are not perfectly competitive, as is likely in electricity supply because transmission losses, costs and capacity constraints may isolate many customers from the effective reach of many generators, then the remaining number of suppliers, if sufficiently small, may exercise limited market power and restrict prices from falling to a competitive level. In a previous static equilibrium analysis, Hobbs and Schuler, 1985, [1] showed that in oligopolistic power markets, equilibrium bulk power prices might settle between 10 to 15 percent above regulated prices in the short run, and fall to less than a 5 percent markup over a longer time horizon when new competitors could complete additional generating capacity. However, this loss of allocative efficiency might be tolerable if subsequent competitive pressures spur innovative advances in production technologies that result in offsetting cost reductions.

However, these previous price estimates are predicated upon equilibrium conditions in oligopolistic markets; the issue explored here is the likely dynamic interplay between customers and suppliers in bulk power markets, and estimates are provided of the time lags before buyers and suppliers reach an equilibrium. Meanwhile, some customers may be exposed to monopoly-level pricing, and a methodology is illustrated for estimating under what circumstances and for how long that market power might be exerted.

If, in fact, customers respond instantaneously to small price differences among suppliers who offer similar services, then it would be reasonable to expect that with the onset of competition, a price reduction by one firm would rapidly induce all other competitors to follow suit; otherwise, their customers would soon disappear to the low-priced supplier. With rapid adjustment by customers to minuscule price differentials, the new competitive (oligopolistic) equilibrium would soon be reached, and the estimates of subsequent oligopolistic equilibrium prices would be adequate for policy purposes.

However, if customers do not respond instantaneously to price differences, then it is possible that following the appearance of a competitor after deregulation, the dominant incumbent firm may disregard lower prices offered by the competitor, even though their market share is being eroded (See the previous theoretical papers by Schuler and Hobbs, 1992, [2] and by Schuler, 1997, [3] as examples). The key factors are: how rapidly is the high-priced firm losing customers, how high are its prices and profits and what is its initial market share? Once the reality of non-instantaneous customer response to price spreads is considered, suppliers can engage in a wide range of strategic behavior; it may pay to be the high-priced firm if all is not lost instantaneously.

These lags in customer response may arise because of search or transactions costs. Search costs may be incurred to learn about the availability of lower priced suppliers than the incumbent and/or to seek out and verify the satisfaction of other customers who have changed their suppliers recently. One example of transactions costs that may inhibit customers' responses to price differences is if they have substantial costs sunk in equipment that is necessary to use the service whose price has recently become unfavorable. In these circumstances, even where search costs are modest as in fuel switching between electric, oil, and gas heating suppliers, as an example, market-share adjustments to a substantial price spread might be quite slow because of the threshold cost of change. Here the shifts in suppliers may follow very slowly over time, depending upon how customer equipment ages and warrants replacement.

Search and transactions costs are frequently substantial in markets having a significant spatial dimension that must be bridged to reach geographically dispersed customers. Examples include electricity supply with generation (production) located at fixed points and transmission and distribution lines (transportation) required to reach far-flung customers, and basic exchange telephone service where the switch is located centrally and wire pairs or fiber optics are the transporation required to reach a sufficient number of customers. Where transporation costs provide a buffer between two seperately located producers, customer adjustments to price differences among them can lag appreciably because of both search and transactions costs. In certain circumstances, it may acutally be in the dominant firm's interest to raise prices in reponse to spatial competition if all customers are not lost instantaneously to the lower-priced firm.

Regardless of the reasons for lagged customer response to price differences for identical goods and services from different suppliers, when these conditions exist and there are a limited number of potential economic suppliers, the firms can be expected to behave strategically, and not all firms will rush to match the prices of the lowest-priced supplier. The necessary conditions for such behavior exist in electricity supply and various aspects of telecommunications markets (See the paper by Schuler, R. and Schuler, R, Jr., 1996, [4] that analyzes this problem in the context of long distance telephone markets). Unfortunately, a key determinant of the extent of strategic behavior is the size of a dynamic price elasticity that will be defined in section 3, but in gauging what may happen in markets that experience no competition at present, as in the case of bulk power supplies, data are not available to estimate the rate of customer responses to price differences before they occur.

2. Opportunities for market power in electricity supplies

Depending upon the reorganized structure of the electric industry, opportunities for exerting market power may differ, but so long as there are scale economies in production that exceed the demand at several locations and transportation costs are appreciable, then some market power may arise. Particularly if bilateral contracts are relied upon to link widely distributed generators with dispersed large customers (either industrials or municipal companies), spatial oligopoly should be the expected market structure.

If, however, as is proposed for most regions of the country, an independent system operator (ISO) is placed between generators and customers, and particularly if separate entities from the generators and large buyers act as the ISO and auctioneer, then if those auctions are efficiently designed (See the papers by Bernard, et. al., 1998, [5] and Denton, et. al., 1998, [6] that explore the design of efficient auctions), the generator may be isolated from the lagged response of individual customers since all buyers and sellers in the auction will receive/pay the same market-clearing price. With a limited number of generators and/or buyers, these parties may be able to "game" the auction, but that is not the market power problem being explored here. Instead, it is cases where buyers face different prices, but are slow to react that are being examined. One situation where this may arise in electricity markets with a centralized auction is where all consumers do not buy directly through the auction, but rather purchase their power through a limited number of "assemblers", as may be the case for many small residential and commercial customers. In particular, where the former vertically integrated utility spins off a seperate marketing entity with a familar name, many small customers may stick with their accustomed supplier relationship, initially.

A third circumstance where this customer-lag-induced type of market power might arise is if multiple unregulated acutions were relied upon, in place of a single controlled area-wide, bulk power market-place. In this circumstance, inspired by profit opportunities and the likely emergence of very few competitve auctions in the region, customers might be slow to switch from one auction to another, particularly if that switch required the construction of new transmission links and/or prices in all auctions were highly variable.

These are the market circumstances for which the following illustrations are thought to apply.

3. Nature of lagged customer response in bulk power markets

As described elsewhere (see Schuler, 1997, [3]), with a flow of information about lower-priced options being delivered at a steady rate, then as the share of customers availing themselves of the new opportunity increases, the rate at which additional converts are won may be expected to decline over time as the remaining pool of potential new customers shrinks, particularly when the total number of customers is relatively stable. However, in circumstances where very few customers have tried a new supplier and most customers require some assurance about the reliability of the new alternative before they are willing to switch, at the initial stages of competition the lower-priced firm with a small market share may experience an accelerating rate of market penetration. These two factors combined, both of which are likely to be relevant to the bulk power markets described, suggest that the customer share adjustment mechanism might be an S-shaped logistic function shown in equation (1).

$$S_{t+1}^{i} - S_t^{i} = \lambda(p_t^{j} - p_t^{i})S_t^{i}S_t^{j} \qquad (1)$$

Where: S_t^i = Market share of i^{th} firm in period t.
p_t^i = Price charged by i^{th} firm in period t.
p_t^j = Average price charged by competing firms in period t.
λ = Adjustment parameter.
$S_t^j = 1 - S_t^i$ Market share of all other firms in period t.

Unfortunately, without prior experience with widespread competition for bulk power supplies, there are no data that permit the direct estimation of the adjustment parameter λ. However, for the market circumstances cited in section 2, eventually many customers may be able to switch suppliers simply by making a phone call. In that case the adjustment parameter may be similar to the one estimated by Schuler and Schuler, 1996, [4] for long distance calling.

As a check, historic evidence of dynamic price elasticities for electricity customers under the former regulated regime can be re-calibrated to approximate an adjustment parameter for the logistic equation (1). In that historic case, however, customers were restricted to switching fuels in response to price disparities, but since there were no effective options to using electricity for lighting and motors, smaller and slower responses to price differences might be expected than in the case of competitve electricity suppliers where no change is required in end-use equipment.

4. Strategic pricing behavior by suppliers

Consider a four period time horizon with two firms (or one firm competing with the average of all the rest), each with similar cost characteristics. Then each firm will attempt to set its prices in each of the four periods to maximize the net present value of its profits over that time horizon as shown in equation (2).

$$\Pi^1 = S_1^1\pi^1(p_1^1) + \beta S_2^1\pi^1(p_2^1) + \beta^2 S_3^1\pi^1(p_3^1) + \beta^3 S_4^1\pi^1(p_4^1) \qquad (2)$$

Where: Π^i = firm i's net present value of profits.
S_t^i = firm i's market share in year t.
π^i = profits per customer earned by firm i.
p_t^i = firm i's price spread above marginal cost in year t.
β = discount factor = 1/(1+r); r = discount rate.

For analytic convenience, all prices are normalized by the difference between the monopoly price and marginal cost. Thus $-1 \le p^j - p^i < +1$, unless predatory prices that are below marginal cost are tolerated. Furthermore, since if at marginal cost prices, economic profits equal zero, then without loss of generality in the net present value calculation of equation (2), $0 \le p_t^i \le 1$, where p = 0 represents marginal cost and p = 1 represents the monopoly price.

Given each firm's initial market share, S_1^i, each supplier will seek to maximize the net present value of its profits in equation (2), subject to the share adjustment equation (1). This is a dynamic programming problem that can be solved recursively starting with period four and moving backward to today. The outcome is dependent upon the prices selected by the competitor who faces a similar optimization problem, so with parameter values assigned to this model, a pay-off matrix can be constructed to explore the existence and nature of stable solutions to this game.

Futher numerical simplifications can be made by exploring the last period problem:

$$\text{Max.} \quad S_4^i \pi^i(p_4^i) \tag{3}$$

If this is the end of the time horizon, and with the market share, S_4^i, already established by prices in previous periods, then the optimal price for this last period is the monopoly price and $p_4^i = 1$ for all producers. In this case, equation (2) can be normalized by the level of monopoly profits, the game reduces to one of setting prices in only the first three periods, and in each of these periods, normalized profits range betweeen zero and one. This methodology can be extended to an infinite time horizon so long as the net present value of future profits is bounded (see the paper by Langlois and Sachs, 1993, [7] who show that a reaction function equilibrium leads to positive profits in an infinite time horizon super game, not the usually expected, prisoner's dilemma, zero profits); in that case the infinite game can be truncated and each period's profits normalized by the future value sum. Thus, $0 \leq S_t^i, p_t^i, \pi_t^i \leq 1$.

5. Numerical evalution

The remaining parameter to be calibrated in order to compute a pay-off table is the adjustment rate for market share, λ. Numerical illustrations are developed from dynamic price elasticities for electricity that were estimated by Chapman, Tyrrell and Mount, 1972, [8] (CTM). They estimate a long run residential price elasticity of 1.3 with 10 percent of the effect felt in this first year and a half life of 8 years. Since elasticities are pure numbers, they can be applied to current price and cost levels. For illustrative purposes, the model is calibrated with a long-run marginal cost of generation of 4.5¢/kWh and a fully allocated cost of transmission and distribution of 4.5¢/kWh for residential customers so that the price under regulation would be 9.0¢/kWh, typical of many areas of the northeast. If a linear demand function is assumed, a monopoly price of 8.0¢/kWh is estimated for the generator with the residential customer paying 12.5¢/kWh through a regulated transmission and distribution system.

The first step is to convert the long run residential price elasticity, 1.3, into an average annual response. Averaging CTM's first year response, 1.3 x .1 = .13, and the average annual response over their half-life, ½ x (1.3 ÷ 8 yrs.) = .08, provides a mean response of .11 per year as the customers' annual elasticity (η_c = .11). However, since competiton occurs at the generation level, this elasticity must be reduced by the ratio of generating to total price paid by customers. Therefore, η_G = (.045/.09) x (.11) = .055, which is developed at the regulated level of prices -- the system in place when CTM estimated their elasticities. Finally, this dynamic price elasticity parameter, which implies that for a one hundred percent advantage in generation prices, a competitor might expect to gain 5.5 percent in sales to end-use customers each year, so long as the 100 percent price spread is maintained, can be converted into the normalized share adjsutment parameter by inserting the definition of a price elasticity into a rearranged equation (1).

$$\lambda = \frac{\Delta S^i}{S^i(1-S^i)(p^j-p^i)} = \underbrace{\left[\frac{\Delta S^i \bullet Q_{tot}/S^i \bullet Q_{tot}}{\frac{P^j - P^i}{P^i}}\right]}_{\eta_G} \bullet \frac{1}{\left(\frac{P^i}{P_M - m}\right)(1-S^i)} \tag{4}$$

Where: Q_{tot} = total market demand.
P^i = non-normalized prices.
P_M = monopoly generator price.
m = long run cost of generation.
$p^i = P^i/(P_M\text{-}m)$.
η_G = dynamic price elasticity at generator.

For purposes of analyzing the oligopoly pricing game, λ is a constant, so it is evaluated at an average market share of .5, and λ = .055 ÷[(.045/.08-.045) x .5] = .085. A similar process is used to estimate λ for industrial customers, who however, are assumed to face lower average transmission and distribution costs, in this case equal to 2.5¢/kWh. CTM's estimate of a long run elasticity for industrial customers is 1.7 with an 11 percent first year adjustment and a seven year half life. The resulting average annual elasticity of .16 is reduced to .10, however, when adjusted back to the impact of the generator's price, and results in an estimate of λ = .091, not very different than for residential customers.

This estimate, however, reflects only the portion of the likely competitive response by electricity customers to price differences among suppliers due to the switching of fuels. A much larger response may result from merely switching suppliers and billing records, much as has been the experience with long distance calling. Schuler and Schuler, 1997, [4] estimate that parameter value at λ = .23 for telephone. Since two different effects are being estimated, the two estimates are added to yield a combined total speed of adjustment parameter, λ = .23 + .09 = .32.

6. Results of dynamic game

In fact in order to test the sensitivity of expected strategic responses by generators in their pricing decisions, a response speed three times as great as the one estimated in section 5 was used in this numerical illustration. Here λ = 1, the real discount rates is set at three percent so β = .971, and for tractability in the size of the pay-off table, prices are restricted to either marginal cost, 0, or the monopoly level, 1, so normalized profits are also restricted to $\in$ [0;1],

The payoffs shown in Table 1 are representative of a new compeitior who gains an initial 10 percent first period market share against a dominant supplier who holds the remaining 90 percent of customers. In this case there is a stable Nash equilibrium over the four periods where the dominant firm holds to the monopoly price (p^2 =1) throughout the four periods, even though the new firm is charging the much lower, marginal cost price ($p^1 = 0$) in the first two periods, thereby gaining market share. Note, that the entrant moves to the monoply price in the third period, having acquired a substantial market share (34 percent).

Table 1. Payoff table for four period pricing game (λ = 1, S_1^1 = .1, β = .971)

Firm 1's payoff in NE corner; 2's payoff in SW corner

p^1 / p^2	000	001	010	100	011	101	110	111
000	.092 .820	.095 .83	.11 .91	.11 .91	.11 .92	.11 .91	.11 .92	.11 .92
001	.17 1.5	.19 1.7	.11 1.7	.12 1.8	.12 1.8	.12 1.8	.11 1.8	.11 1.9
010	.17 1.6	.18 1.6	.19 1.7	.12 1.9	.19 1.7	.12 1.9	.12 1.9	.12 1.9
100	.17 1.6	.19 1.7	.22 1.8	.19 1.7	.22 1.8	.20 1.7	.21 1.8	.21 1.8
011	.31 2.2	.35 2.4	.26 2.4	.14 2.8	.28 2.5	.14 2.8	.13 2.8	.13 2.8
101	.29 2.6	.35 2.4	.24 2.4	.27 2.4	.25 2.7	.29 2.6	.21 2.6	.22 2.7
110	.31 2.3	.34 2.3	.36 2.4	.27 2.5	.37 2.5	.28 2.5	.29 2.6	.29 2.6
111	.52 2.7	* .64 2.9	.47 2.9	.41 3.1	.54 3.2	.45 3.3	.36 3.3	.38 3.4

* = Nash equilibrium

Table 2. Equilibrium dynamic price patterns in oligopolistic markets with lagged customer response

Adjustment Speed, λ	1			2		
Initial Share, S_1^1:	.1	.3	.5	. 1	.3	.5
p^1, competitor's price	[0, 0, 1]	[0, 1, 1]	[0, 1, 1]	[0, 0, 1]	[0, 0, 1]*	[0, 0, 1]
p^2, dominant firm's price	[1, 1, 1]	[1, 1, 1]	[0, 1, 1]	[1, 1, 1] or [1, 0, 1]	[0, 0, 1]*	[0, 0, 1]

* A second, unstable equilibrium exists where p^1 = [0, 1, 1] and p^2 = [1, 0, 1]

Additional simulations have been run for larger initial market shares than 10 percent for the new competitior, and for even more rapid market share adjustment parameters, as summarized in Table 2. For the same adjustment rate (λ = 1) shown in Table 1, with rising initial market shares, the new competitor prices less agressively, sooner (p^1 = [0, 1, 1] instead of [0, 0, 1], and with S_1^1 = .5, the existing firm is induced to compete price-wise in the initial period (p^2 = [0, 1, 1]). In all cases, however, this is far from a competitive pricing scenario even with adjustment speeds three times as fast as expected.

When those adjustment speeds are increased to six times faster than estimated (λ = 2), additional price competition is induced, but only when the new firm's initial market share is 30 percent. Other refinements would be to consider the effects of longer time horizons. Schuler & Hobbs (1992) provided estimates of results for a shorter three period game with λ = 2 and found somewhat less competitve pricing than reported in Table 2 for the four period game, so time horizons longer than four years may induce greater price competition. Nevertheless, the results seem unambiguous that in the early stages of compeition where existing firms have a dominant share of the market in excess of seventy percent, those existing firms are unlikely to match competitive prices for several years.

7. Conclusions

This analysis suggests that in emerging, unregulated markets for bulk power supplies, if customers do not switch suppliers instantaneously in response to price differences, then if an existing dominant supplier has a large intitial market share (larger than 70 percent), compeitive pressures cannot be expected to be effective in forcing those firms to lower their prices initially. For speeds of customer response estimated here, in fact market shares of existing firms must fall to fifty percent before price competition might be expected to emerge early on. Even, if the customers' response speeds were six times faster than estimated, the market share of the existing firm must approach 70 percent before an early price response to competition might be expected.

The policy implication is that in markets where an unregulated supplier deals directly with its customers, and the number of effective competitive suppliers is limited because of tramsmission costs and/or bottlenecks, then deregulating bulk power markets may result in the prolonged exercise of market power if a dominanat existing supplier has more than seventy percent of the market. Institutional examples where the necessary conditions may exist are: (1) where large customers are seved directly through bilateral contracts with individual generators, or (2) where there are a small number of marketing groups assembling supplies through an ISO or other neutral auctioning mechanism and then reselling to individual customers.

References

1. Hobbs, B. and Schuler, R., "An Assessment of the Deregulation of Electric Power Generation Using Network Models of Imperfect Spatial Models," *Papers of the Regional Science Association*, 51, 1985, p. 75-89.

2. Schuler, R. And Hobbs, B., "Price Adjustments in Oligopolistic Markets: The Impact of Lags in Customer Response," in Gee, J. M. A. And Norman, G., eds., Market Strategy and Structure, London: Harvester-Wheatsheaf, 1992, p. 125-142.

3. Schuler, R., "Dynamic Price Patterns in Spatial Oligopolistic Markets: The Impact of Lagged Quantity Adjustments," in Chatterji, M. ed., Regional Science: Perspectives for the Future, Macmillan, 1997, p. 43-69.

4. Schuler, R. and Schuler, R., Jr., "How Rapidly Might Prices Fall Following Competition in Telecommunications Markets?," Proceedings of the Tenth NARUC Biennial Regulatory Information Conference, Columbus, OH, Sept. 11-13, 1996, p. 3-18.

5. Bernard, J., Ethier, R., Zimmerman, R., Gan, D., Murillio-Sanchez, C., Schulze, W., Mount, T., Thomas, R., and Schluler, R., "Experimental Results for Single Period Auctions," Thirty-First Hawaii International Conference on Systems Science, Jan. 6-9, 1998.

6. Denton, M., Rassenti, S., and Smith, V., "Spot Market Mechanism Design and Competitivity Issues in Electricity Markets, " Thirty-First Hawaii International Conference on Systems Science, Jan. 6-9, 1998.

7. Langlois, J-P. And Sachs, J., "Existence and Local Stability of Pareto Superior Reaction Function Equilibria in Supergames," Journal of Mathematical Economics, 22, 1993, p. 199-221.

8. Chapman, D., Tyrrell, T. And Mount, T., "Electricity Demand Growth and the Energy Crisis," Science, 178, Nov. 17, 1972, p. 703-708.