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"The Dynamics of Customers Switching Suppliers in Deregulated Power Markets"

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I. Introduction

As the possibility of effective competition is thought to arise in industries that were formerly characterized as natural monopolies, pressure by some customers and /or potential entrants is brought to bear on political and regulatory institutions to deregulate economically certain aspects of these industries, and to allow market pressures to substitute for regulatory oversight as a means of restraining excessive prices. The further hope is that once freed of rate-of-return restrictions imposed by regulators, service-providers will seek to compete technologically and to profit from cost cutting innovations that ultimately may be translated through market pressures into lower prices for customers.

The initial wave of deregulation in the United States focused on industries where the capital was largely mobile, but over the past twenty years the emphasis has shifted to utilities with substantial sunk capital (literally and figuratively), like long distance telephone service, the generation of electricity, and now basic exchange telephone service, and in the near future, retail purchases of electricity from alternative marketing agents. In the process, formerly vertically integrated industries have been separated into functional components, since in total, each industry is comprised of complex networks that would be uneconomical to duplicate in the whole. Thus the competitive aspects have been limited, to a large extent, to those components of the industry that are most economical to duplicate, given the scale and location of customer demand. And in many instances, like electricity transmission and distribution, the local feeder and distribution cables portion of telephone service, and the poles and conduits shared by both, it is both economically and aesthetically desirable to have all suppliers share the same physical facilities, which means that a substantial regulatory presence will remain to ensure that physical access to and the subsequent user charge allocations are assigned efficiently and equitably to all suppliers.

These concerns about fair and equal access to commonly used facilities, however, are not the focus of this analysis which presumes those difficult regulatory issues will be managed. Rather the concern here is that in markets for bulk power supplies, transmission losses, costs and capacity constraints may isolate customers from the effective reach of many generators, so the remaining suppliers may exercise market power and restrict prices from falling to competitive levels. In a previous static equilibrium analysis, Hobbs and Schuler, 1985, showed that in oligopolistic power markets, equilibrium bulk power prices might rise between 10 to 15 percent above regulated prices in the short run, but then 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.

These previous price estimates were, however, predicated upon equilibrium conditions in oligopolistic markets; the additional 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. By analogy, in the recently deregulated telephone industry in the U.S., a prolonged, slow transition to effective competition has been observed among long-distance telephone carriers, despite substantial price differences for similar services, following the inception of entry in 1984[1]. Here the factors that are likely to retard the onset of effective competition in retail markets for competitive power supplies are examined and projected, not as a function of restrictive operating and cost allocation practices, but rather merely as a result of intelligent pricing strategies by suppliers in response to lagged customer behavior.

The analysis begins with the observation that in many newly deregulated markets, and in markets where changing suppliers imposes significant costs on customers and/or customers do not have adequate information about the service quality and reliability of the new supplier, then when confronted with a lower price offered by an alternative supplier, not all customers switch instantaneously. But, when faced with a lag in customer response, what is the optimal price response for the supplier charging the higher price? In fact, the introduction of these market-clearing lags, or transactions costs, frequently stands neo-classical micro-economic prescriptions on their head.[2] Thus the objective of this analysis is to estimate how retail suppliers of electricity might price over time in response to the introduction of competition before market pressures begin to drive prices toward marginal cost, or at least a stable Nash equilibrium, as predicted by traditional theory and static equilibrium analysis.

II. Lagged Customer Response to Price Differences

Lags in customer response to price differences may arise because of search or transactions costs. Search costs may be incurred to learn about the availability of suppliers charging lower prices 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, 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 transportation required to reach a sufficient number of customers. Where transportation costs provide a buffer between two separately located producers, customer adjustments to price differences among them can lag appreciably because of both search and transactions costs. In certain circumstances, it may actually be in the dominant firm's interest to raise prices in response 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.

In fact substantial delays have been observed by customers responding to significant price advantages in the markets for a number of goods and services.[3] Furthermore, in the case of labor markets, considerable attention is paid to the average duration of unemployment in markets where numerous job opportunities exist in order to estimate a "structural" rate. These estimates acknowledge that the quantity adjustments by individuals do not occur instantaneously; the question raised here is that in the face of those lags in markets with few suppliers, what is their optimal price response?

Both in the labor market analyses[4] and in previous work by Schuler[5] this lagged quantity adjustment process is shown to be of the S-shaped, logistic function form shown in Figure 1. Labor economists describe this relationship as a hazard function[6], and as applied to product markets, Schuler (1997) has described the relationship as being comprised of two

[1] See Schuler, R. And Schuler, R. Jr (1996), as an example.

[2] As an example, in the spatial economic literature where transportation costs cause the friction, Martin Beckmann (1971) has shown that following entry by competitors, incumbent firms who are charging mill prices can be expected to raise those prices.

[3] See Schuler (1997), for examples.

[4] See Kiefer, N. (1998)

[5] Op. Cit. (1997)

[6] See Kiefer, N. (1998)

phenomena. The first is the time required to have all potential customers become aware of the alternative opportunities to acquire the product from some other supplier at a lower price. The second step, which is conditional upon learning about the possible lower-priced opportunity, is gaining confirmation that the new supplier is in fact offering the identical service (in terms of location and quality) at a lower price, and in arranging to switch suppliers.

If customers are bombarded with information (advertising and dinnertime phone calls) at a steady (constant) rate per unit time, then the number (and proportion) of customers informed about the new opportunity who were previously not aware of it will decline over time. Thus a constant bombardment rate times a declining base leads to a declining rate of newly informed customers, and so while the number of customers who are aware of this opportunity increases continuously over time so long as the information campaign is sustained, the rate of change declines and faces a saturation effect as shown after time t_3 in Figure 1.

By comparison, if once informed, the rate at which customers agree to accept the new opportunity is proportional to both the potential gain (the price spread) and the ability to confirm the quality of the alternative service, which is proportional to the number of customers who have already experienced the new service, then the rate of acceptance should be an accelerating function of the number (or proportion) of customers who have already accepted the new service. The rate of conversion to the lower priced supplier should therefore be the product of these two phenomena, which results in the logistic function of equation (1).

$$S^i_{t+1} - S^i_t = \lambda(p^j_t - p^i_t)\, S^i_t\, S^j_t \qquad (1)$$

where:

S^i_t = Market share of supplier i at time t.

p^i_t = Price increment over marginal cost charged by supplier i at the time t, normalized by the spread between the monopoly price and marginal cost.

λ = Speed of adjustment parameter

$S^j_t = (1 - S^i_t)$, where there are only two suppliers.

One nice feature of this logistic relationship is that it is symmetric, so if at any time, the relative prices of the two suppliers is switched, the identical share adjustment

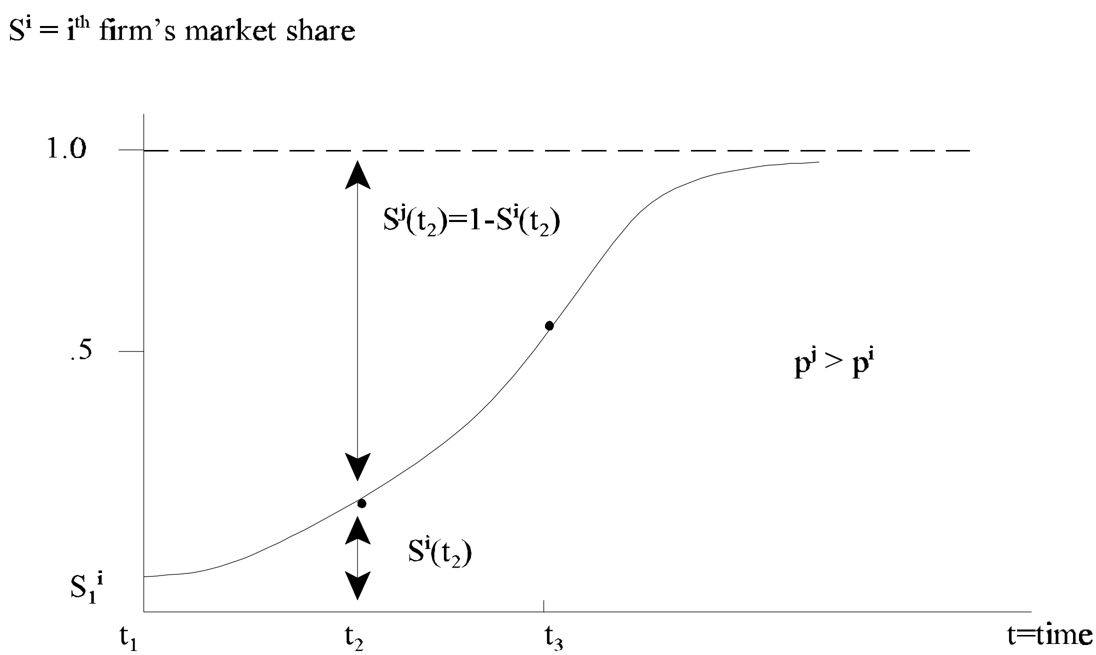

Figure 1. Logistic Market Share Adjustment Mechanism

equation holds. Furthermore, it has been shown elsewhere[7] that where there are more than two competitors, the same general relationship holds where p_t^j is replaced by the share-weighted price of all other competitors and $S_t^j = (1 - S_t^i)$, the market share held by all other competitors.

The time adjustment parameter, λ, can be thought of as a dynamic price elasticity (it has the dimensions of 1/time), and attempts to relate it to conventional notions of a price elasticity are assisted by the manipulation in equation (2).

$$\lambda = \frac{\Delta S^1}{S^i(1-S^i)(p^j-p^i)} = \underbrace{\left[\frac{\frac{\Delta S^i \bullet Q}{S^i \bullet Q}}{\frac{P^j - P^i}{P^i}}\right]}_{\eta_p} \bullet \frac{1}{\left(\frac{P^i}{P_M - m}\right)(1 - S^i)} \qquad (2)$$

where:

$$\Delta S^i = S^i_{t+1} - S^i_t$$

Q = total quantity of service in the market

$P^{i,j}$ = non-normalized price charged by suppliers i,j

P_M = monopoly price

m = marginal cost of production

η_p = traditional price elasticity of demand

As an illustration, a firm serving about half of its market who is charging the monopoly price and who has negligible marginal production costs, will have $\lambda = 2$, if its traditional price elasticity of demand is one.

III. Potential Application in Deregulated 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, and Denton, et. al., 1998, 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 emphasized 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 familiar 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 auctions 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 competitive 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.

IV. Optimal Dynamic Pricing Strategies by Suppliers

Given the lagged customer response to different prices among different suppliers, with a small number of vendors, the optimal pricing strategy for each firm can be deduced, given their assumptions about the pricing behavior of their competitors. Furthermore, if each firm believes the others are behaving in similar ways, equilibrium solutions of dynamic price patterns can be

[7] See Schuler and Schuler (1996).

explored, where each supplier's assumption about their competitors, and vice versa, are consistent with their own optimal behavior in those cases -- a Nash equilibrium.

As an example, consider a five period time horizon where each supplier seeks to maximize the net present value of their profits as in equation (3).

$$\Pi^i = S_1^i \pi^i(p_1^i) + \beta S_2^i \pi^i(p_2^i) + \beta^2 S_3^i \pi^1(p_3^i) + \beta^3 S_4^i \pi^i(p_4^i) + \beta^4 S_5^i [\pi^i(p_5^i) + V_5^i] \quad (3)$$

where: Π^i = firm i's net present value of profits.
S_t^i = firm i's market share in period t.
π_t^i = profit per customer earned by firm i in period t.
β = discount factor = 1/(1+r); r = discount rate.
V_t^i = residual value at period t.

Each firm's problem is to maximize equation (3) with respect to prices, subject to the share adjustment equation (1), the prices charged by its competitors and its initial market share, S_1^i. This is a dynamic programming problem that can be solved recursively starting with period five and moving backward to today, and so the solution to this dynamic game is sub-game perfect. 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. If the planning horizon is finite, V_t^i can equal the salvage value of assets, or the residual value that the current managers want to pass along to their successors. Because economic profits equal zero when prices equal marginal cost and all assets are earning a normal return commensurate with other investments of similar risks, one way of defining the time horizon of this game is at the time when intense competition is expected to ensue in this industry. From that point, T + 1, onward, $p^i_{T+1} = 0$ and $\pi^i_{T+1} = 0$, so $V^i_T = 0$.

Alternatively, the "benefit denial principle" developed by Langlois and Sachs (1993) could be employed which suggests that after a initial jostling for position, each firm recognizes that in a game of infinite duration, the best it can do is to charge the monopoly price, the net effect of which is implicit collusion. In that case, V_T would be the net present value at time T of pure monopoly profits over an infinite time horizon. Because, the intention of deregulation is to encourage competition, the analysis employed here will assume perfect competition after a specific time period, T. The question to be explored is how rapidly prices will fall to that competitive level and how expectations about T affect that dynamic price pattern.

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 (3), $0 \le p \le 1$, where p = 0 represents marginal cost and p = 1 represents the monopoly price.

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

$$\text{Max. } p_T^i \; S_T^i \left[\pi^i(p_T^i) + V_T^i\right] \quad (4)$$

If this is the end of the time horizon, and with the market share, S, already established by prices in previous periods, then the optimal price for this last period is the monopoly price and p = 1 for all producers. In this case, equation (3) can be normalized by the level of monopoly profits, the game reduces to one of setting prices in only the first T-1 periods, and in each of these periods, normalized profits range between zero and one.[8] Thus,
$0 \le S_t^i, p_t^i, \pi_t^i \le 1$, and for perfect competition after T+1, V = 0.

V. Numerical Estimates

Analytical solutions to this out-of-equilibrium dynamic analysis are currently available only for the case where the initial market shares are equal, and since the focus of this analysis is upon the early stages of deregulation of a market that was formerly supplied by a monopoly, numerical illustrations are required to explore the dynamic price adjustment processes under a variety of parameter values. The initial illustrations restrict suppliers to offering only two prices, the perfectly competitive marginal cost-based price ($p_t^i = 0$) and the monopoly price ($p_t^i = 1$). Two advantages arise from restricting $p_t^i \epsilon [0;1]$: first, no assumptions must be made

[8] See Schuler (1997) and Schuler and Hobbs (1992), for details on the analytics of the game-theoretic solution.

about the shape of the demand curve other than it results in a monotonic increasing, concave profit function over the range of prices, $0 \leq p_t^i \leq 1$, and second, the number of possible pay-offs that must be explored in the search for a Nash equilibrium is reasonable for large T.[9]

The remaining parameter value to be set before numerical illustrations can be provided is λ which reflects the speed of customer response to price differences. Since there has been little experience with retail competitive response to different electricity prices, the parameter value selected is merely suggestive. As an example, in a previous paper[10] a value of $\lambda = .32$ is computed for electricity, based upon historic estimates of traditional price elasticities for various classes of electricity customers, with an adjustment to reflect that in a competitive world customers would experience a much wider range of choices with lower transfer costs. As an example, historic experience in long distance telephone markets has been used to estimate $\lambda = .23$ for that situation, and it is probable that transfers of electricity suppliers may become as easy for some of their customers in the future. Furthermore, with greater experience gained by customers in the future, speedier responses might be anticipated, and for this reason, numerical results are presented for $\lambda = .25$, .5 and 1.0 to explore the sensitivity of the suppliers' pricing behavior to different rates of customer response. In the case of $\lambda = 1$, the implied customer responsiveness is approximately a five percent loss, per year in market share to a competitor charging a ten percent lower price. In the first year, this represents the equivalent of a fairly inelastic equivalent of a static price elasticity ($\eta_p = .5$), but if the ten percent price spread is maintained over five years, the longer term equivalent price elasticity equals 2.26[11] a substantial response.

An example of a payoff matrix for a four period game (three active periods since both suppliers choose the monopoly price, p=1, in the final year) is shown in Table 1. Here, even with a quite rapid rate of customer response (λ=1.0) and with the dominant supplier, firm 2, having a 90 percent initial market share, a unique set of price strategies exist that represent a Nash equilibrium where the competitor charges marginal cost in the first two years and then raises its price to the monopoly level in the third and fourth years. Meanwhile the dominant firm never finds it profitable to budge from the monopoly price, even in the face of intense price competition.

In Table 2, the results for a five period game, with $p \epsilon [0;1]$, but with a range of values for the customer adjustment speed parameter, emphasize how at the potentially low levels of λ for competitive retail power markets, the suppliers are likely to be stubbornly strategic in their behavior. For the majority of cases explored, at least one of the suppliers is estimated to charge the monopoly price, and in many instances, both will price at the monopoly level without any need for explicit collusive activity; the monopoly price is seen by each firm to be in its own best interest.

In the cases analyzed, the initial market shares of the two suppliers are varied from .1 and .9, .3 and .7 to .5 and .5, and the consumer adjustment speed parameter, λ, is set at .25, .5, and 1.0. The real discount rate is set at .03 throughout[12]. The results in Table 2 emphasize how crucial reasonable knowledge of λ is in order to depict deregulated behavior. Near the previously estimated rate of λ for long distance calling ($\lambda = .23$), both firms behave in an implicitly collusive fashion, regardless of initial market shares. As the adjustment speed increases ($\lambda = .5$), the entrant begins to charge a competitive price in the early years in order to improve its market share, but the incumbent does not match this competitive price. Furthermore, if both firms begin with half of the market, then neither finds it profitable to compete.

Only when $\lambda = 1$, a value four times as fast as previously estimated, does some modest competition begin to emerge in the first three of the five periods, but as the entrant's

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[9] The number of cells in a pay-off matrix that must be evaluated with two competitors is: $[c^{T-1}]^2$, where c is the number of alternative prices considered by each competitor. In a five period game, with c=2, a 16 x 16 matrix of 256 alternatives must be explored. If however the range of prices considered is expanded to five, there are 625 possible pricing strategies for each firm ranging over the T-1=4 active periods, and a matrix with 390, 625 profit alternatives must be evaluated.

[10] See Schuler (1998).

[11] If $.5 = \eta_p = [\Delta S \bullet Q/S \bullet Q] \div [\Delta P/P]$, then the market share loss in the first year due to a 10 percent price disadvantage is five percent. In the second year, the remaining 95 percent market share is reduced by another five percent so that in any subsequent period, time = T, $S_T = S_0(1-\eta_p \bullet \Delta P)^T$. Thus, if $S_0=1$, $\Delta P=.1$ and $\eta_p=.5$, $S_5=(1-.05)^5=.774$, a 22.6 percent loss in total market share in response to a ten percent price disadvantage.

[12] A higher, realistic discount rate for competitive firms would result in even less competitive pricing behavior, since the firm's tradeoff is between higher profits now (p=1) versus larger market share in the future (p=0). However, if a growing market is anticipated, this factor can also be incorporated into β, having the equivalent effect of a lower discount rate.

market share rises to the neighborhood of 50 percent both firms stop competing. Only in the case where both firms' initial shares are fifty percent, do the firms engage in prisoners'-dilemma-type intense competition in the first two periods before settling back to monopolistic behavior. However, in all of these cases, the firms manage to extract combined economic profits that are 58 percent or more of the maximum possible monopoly profits.

Comparing the results in Table 1 for λ=1 and S_1^2=.1 with those in Table 2, there is little effect on pricing strategies by extending the time horizon by one year. However, in Table 3, the time horizon is extended to nine periods with all other assumptions and parameter values held the same as in Table 2. Once again, economic profits from period ten onward are assumed to be zero, so in the tenth year, either the managers retire or they expect perfect competition to ensue. With this longer time horizon, modest increases in competitive pricing are induced. As examples, even with extremely slow customer responses (λ = .25), the entrant with initial market shares less than one half is induced to offer competitive prices in the early years since they have a longer time horizon to profit from future monopoly rewards. Note, however, it is always the promise of larger future monopoly profits that induces competitive behavior in the present; by earning little or no profit today, a larger market share may be obtained in the future.

With this longer, nine year time horizon, as the speed of adjustment parameter increases, the entrant is induced to compete for many more periods (the first five years where λ = .5 and the first six year where λ = 1). But, only where λ = 1, a value at the upper range of what might be expected in power markets, is the incumbent firm with the dominant initial market share induced to meet the competitive price so that its market share does not fall below one half. In fact, in the nine period game with equal initial market shares and λ = 1, prisoner's-dilemma-type behavior does emerge over the first six years, and the competitors share only thirty percent of the maximum possible level of monopoly profits (in net present value terms). However, three of the nine cases analyzed in this nine period game do not yield Nash equilibria, probably because the price is restricted to two extreme values, the perfectly competitive and the monopoly prices.

To explore the impact of considering a wider range of price choices, the simulations are repeated in Table 4 where p$\in$[0, .25, .5, .75, 1], and an explicit demand relationship must be assumed in order to estimate the per customer profits in the non-end-point cases of p$\in$[.25, .5, .75]. A linear demand relationship is adopted for this five price case, and the corresponding profit levels are $\pi\in$[0; .44; .75; .94; 1]. Because of computational constraints, this five price case is analyzed for only five periods, and the results may be compared with the two price case in Table 2. The greater freedom of price choice tends to move the competitors away from the extreme prices. In particular, firms are less likely to charge the monopoly price (p = 1) if at p = .75, they can still earn 94 percent of the monopoly profit (a concave function in price) but reduce the possible rate of market share loss by at least 25 percent (a linear function in price). Thus, with this wider array of prices, the entrant is more likely to compete price-wise in the early years, but it rarely offers prices as low as marginal cost. In fact, the entrant only sets its price at marginal cost for at most one period, even with λ = 1, since at a price of .25 it earns 44 percent of monopoly profits. Similarly, the incumbent firm is more likely to respond to the competitor's price cuts early on in the game, when compared to the case where p$\in$[0; 1], but those price cuts are far more modest and never fall below p = .25. As a result, while aggregate profits fall slightly below 100 percent of the monopolist's maximum for λ = .25 (98.2 to 99.8 percent), even in the case with fairly rapid customer response (λ = 1), the competitors can be expected to be reaping 77 to 79% of the maximum monopoly level profits.

VI. Conclusions

This analysis illustrates a useful technique for both regulators and competitive suppliers for estimating likely pricing consequences in deregulated power markets. Given the previous observed lagged response by consumers in switching to lower priced suppliers in deregulated telecommunications markets, and if the number of likely suppliers in any particular deregulated power market turns out to be relatively small, the game-theoretic analysis illustrated here may be a useful method to estimate realistic market outcomes of that deregulation.

The results in Table 4 may be most relevant to the regulator, and they emphasize the overwhelming importance of both massive information campaigns and the facilitation of customer transfers from one supplier to another (large λ) if substantial monopoly rents are not to be earned by the dominant supplier. If rapid customer adjustment rates are achieved, the onset of competitive pricing is also facilitated by reallocating initial market shares so the dominant firm holds 70 percent or less of the market. Otherwise, the benefits to electricity customers will have to be derived largely from cost-cutting technological advances induced by the large potential profits; immediate price-cutting incentives cannot be solely relied upon. This tool is also useful for competitors in these newly deregulated markets since it illustrates their best dynamic pricing strategies.

Future analyses should focus on the consequences of longer time horizons, since with lagged customer responses to price cuts, a primary reason for cutting prices today is the hope of obtaining much greater rewards in the future. Those future benefits could arise because of a rapidly growing market, or the prospect that after some future date, implicit collusion may characterize the market ($V_T > 0$). If, however, intense price competition is expected to break out at some future date ($t = T+1$) and to drive all suppliers to price at marginal cost, then this dynamic game over a finite time horizon is the proper way to analyze the price and market share adjustments following deregulation. The other worthwhile extensions of the model would be to include the entry decision explicitly and to consider a game with more than two competitors.

Table 1. Payoff table for four period pricing game, two competitors (λ = 1, S_1^2 = .1, r=.03, pϵ[0,1])

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

p^2 / p^1	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 Nash Equilibria Pricing Strategies and Profits in a Five Period Dynamic Game with Two Competitors, (p∊ [0,1], r=.03)

Market Adjustment Speed, λ	**.25**			**.5**			**1.0**		
Competitor's Initial Share S12	.1	.3	.5	.1	.3	.5	.1	.3	.5
Competitor's Behavior:									
Price = p2	[1,1,1,1,1]	[1,1,1,1,1]	[1,1,1,1,1]	[0,0,1,1,1]	[0,1,1,1,1]	[1,1,1,1,1]	[0,0,0,1,1]	[0,0,1,1,1]	[0,0,1,1,1]
Share = S2	[.1→ .4]	[.3 → .3]	[.5 → .5]	[.1 → .2]	[.3 → .4]	[.5 → .5]	[.1 → .57]	[.3 → .52]	[.5 → .5]
NPV Profit = Π2	.47	1.42	2.36	.57	1.51	2.36	1.03	1.40	1.37
Dominant Firm's Behavior:									
Price = p1	[1,1,1,1,1]	[1,1,1,1,1]	[1,1,1,1,1]	[1,1,1,1,1]	[1,1,1,1,1]	[1,1,1,1,1]	[1,1,1,1,1]	[1,0,1,1,1]	[0,0,1,1,1]
Share = S1	[.9 → .9]	[.7 → .7]	[.5 → .5]	[.9 → .79]	[.7 → .6]	[.5 → .5]	[.9 → .43]	[.7 → .49]	[.5 → .5]
NVP Profit = Π1	4.25	3.30	2.36	3.91	2.91	2.36	3.08	2.05	1.37
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Combined Profit	4.72	4.72	4.72	4.48	4.42	4.72	4.11	3.45	2.74
Percent of Maximum Profits (4.72)	100%	100%	100%	95%	93.7%	100%	87.1%	73.1%	58.1%

Table 3-Nash Equilibria Pricing Strategies and Profits in a Nine Period Dynamic Game with Two Competitors, (p∈[0,1], r=.03)

Market Adjustment Speed, λ	**.25**			**.5**			**1.0**		
Competitor's Initial Share S12	.1	.3	.5	.1	.3	.5	.1	.3	.5
Compeitior's Behavior:									
Price = p2	[3-0's; 6-1's]	[2-0's; 7-1's]	[9-1's]	[5-0's; 4-1's]	NO	NO	NO	[6-0's; 3-1's]	[6-0's; 3-1's]
Share = S2	[.1 → .18]	[.3 → .41]	[.5 → .5]	[.1 → .51]				[.3 → .51]	[.5 → .5]
NPV Profits = Π2	.92	2.48	4.01	1.69	NASH	NASH	NASH	1.24	1.22
Dominant Firm's Behavior:									
Price = p1	[9-1's]	[9-1's]	[9-1's]	[9-1's]				[1;5-0's; 3-1's]	[6-0's; 3-1's]
Share = S1	[.9 → .82]	[.7 → .59]	[.5 → .5]	[.9 → .49]	EQUIL.	EQUIL.	EQUIL.	[.7 → .49]	[.5 → .5]
NPV Profits = Π1	6.74	4.90	4.01	5.28				1.90	1.22
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Combined Profit	7.66	7.38	8.02	6.97				3.14	2.44
Percent of Maximum Profits (8.02)	95.5%	92.0%	100.0%	86.9%				39.2%	30.4%

Table 4-Nash Equilibria Pricing Strategies and Profits in a Five Period Dynamic Game with Two Competitors, (p∈[0, .25, .5, .75, 1], r=.03)

Market Adjustment Speed, λ	**.25**			**.5**			**1.0**		
Competitor's Initial Share S12	.1	.3	.5	.1	.3	.5	.1	.3	.5
Competitor's Behavior:									
Price = p2	[.5,.75,.75 ,1, 1]	[3-.75's, 2-1's]	[2-.75's, 3-1's]	[0,.5,.5, .75,1]	[.5,.5,.75, .75,1]	[.5,.75,.75,1, 1]	[0,0,.25, .75,1	[0,.25,.5,.75,1]	[.25,.25,.5, .75,1]
Share = S2	[.1 → .12]	[.3 → .33]	[.5 → .5]	[.1 → .23]	[.3 → .38]	[.5 → .5]	[.1 → .37]	[.3 → .47]	[.5 → .5]
NPV Profits = Π2	.50	1.42	2.30	.62	1.42	2.17	.76	1.31	1.66
Dominant Firm's Behavior:									
Price = p1	[5-1's]	[.75,4-1's]	[2-.75's, 3-1's]	[5-1's]	[3-.75's, 2-1's]	[.5,.75,.75,1, 1]	[4-.75's, 1]	[3-.5's,.75,1]	[.25,.25,.5, .75,1]
Share = S1	[.9 → .88]	[.7 → .67]	[.5 → .5]	[.9 → .77]	[.7 → .62]	[.5 → .5]	[.9 → .63]	[.7 → .53]	[.5 → .5]
NPV Profits = Π1	4.17	3.20	2.30	3.91	2.98	2.17	3.34	2.27	1.66
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Combined Profit	4.67	4.62	4.60	4.53	4.40	4.34	4.10	3.58	3.32
Percent of Maximum Profit (4.72)	98.9%	97.9%	97.5%	96.0%	93.2%	91.9%	86.9%	75.8%	70.3%

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