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Publication Date
2005-08-29

CSEM
Center for the Study of Energy Markets

CSEM WP 148

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August 2005

This paper is part of the Center for the Study of Energy Markets (CSEM) Working Paper Series. CSEM is a program of the University of California Energy Institute, a multi-campus research unit of the University of California located on the Berkeley campus.

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Abstract

The competitive implications of the ability of firms to trade in transparent forward markets has received considerable attention in the academic literature. These implications have not had much impact on policy however. In this paper I examine the implications of forward contracts on oligopoly environments by extending the model of Allaz and Vila to an environment with multiple firms and increasing marginal cost. I then take estimates of key parameters of this model from existing electricity markets to predict the market impact of one round of public contracting, such as those seen in auctions for retail provision and resource procurement. The results imply that the importance of supplier concentration is magnified when forward contracts are present.

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1 Introduction

Under traditional competition policy, the evaluation of horizontal market power begins with an assessment of horizontal structure. Relatively simple measures of horizontal concentration, such as the Herfindahl index, still play an important role. Much of the intellectual grounding and practical implementation of competition policy goes further to consider the implications of equilibrium oligopoly models. Beyond an assessment of horizontal structure, there are many mitigating factors to consider, such as cost-reducing synergies and the potential for learning and innovation.

Another potentially important element to consider that has not received as much attention in anti-trust circles is the prevalence of fixed-price forward contracting in an industry. Starting with the work of Allaz and Vila (1988), a line of theoretical work has explored the extent to which the existence of forward markets can impact competition in oligopolistic markets. Much of this work has focused on the electricity industry, in part because it features three elements present in the Allaz and Vila model, oligopoly suppliers, homogenous commodity products, and robust forward markets.[1] Empirical research on the electricity industry also indicates the extent of forward contracting by suppliers has been an important determinant in the competitive performance of specific markets.[2] Forward obligations have generally been ignored by anti-trust authorities, but the Federal Energy Regulatory Commission is proposing changes to its horizontal market power screens that would account for such commitments.[3]

Despite the empirical and theoretical examination of the Allaz and Vila framework, relatively little insight has been developed about the implications of their model for general oligopoly environments. In this paper, I extend the model of Allaz and Vila, which features 2 firms and constant marginal cost, to accomodate a general number of oligopolists and increasing marginal costs. Both of these features are important characteristics of many markets subject to review by competition policy authorities. From this more representative model, I examine how specific market characteristics may influence the contracting decision and its impact on market prices. Since the impact

[1] See Powell (1993), Newbery (1998), and Green (1999).
[2] Wolak (2000), Bushnell, Mansur, and Saravia (2004).
[3] See FERC (2004).

of contracts depends upon the parameters of the model, I present these impacts in the context of parameter values drawn from several existing electricity markets.

The implications of the model are that the presence of a market where firms trade fixed price contracts that are publicly acknowledged can significantly reduce the impact of horizontal market power. A forward contract has the effect of publicly committing one firm to produce more, thereby inducing its rivals to react by producing less. As each firm considers the effect of a forward contract on its rivals' output, the forward market effectively increases the conjectural variation by firms. Since this is an oligopoly effect, there is no impact on a single firm market. The impact of a single forward market is weakest with relatively few competitors and increases rapidly with the number of firms. In fact for the case of constant marginal cost, the impact of introducing a single round of forward trading, as measured by the Lerner index, is equivalent to squaring the number of firms in the market. The relative impact of a forward market declines as the slope of marginal cost increases.

2 A linear demand model with n Cournot firms

Allaz and Vila develop a nested equilibrium model of duopolists engaging in foward and spot trading. They assume:

- Firms engage in Cournot competition
- All participants are risk neutral
- Demand is a passive participant in the market, represented by an inverse demand function
- Forward positions are public knowledge
- Forward and spot prices are efficiently arbitraged

Previous work has analyzed the implications of different aspects of these assumptions. Hughes and Kao (1997) demonstrate the importance of the public knowledge of the forward commitment. A stronger conjectured response by strategic players can weaken, or even reverse the results. Green

(1999) utilizes an assumption of linear supply-function competition, rather than Cournot competition in the spot market. This approach complicates the conjectured impact of contracts signed by one player on the output of other players. At an extreme opposite of the AV model, Mahenc and Salanie (2004) find that when firms engage in differentiated Bertrand competition in the spot market, the ability to sign forward contracts can reduce competition. Ferreira (2003) examines a context in which there are infinite forward contracting rounds and demonstrates that a kind of "folk-theorem" result can arise, supporting a range of equilibria.

Clearly the context in which forward markets exist is important to the implications of those markets for competition. The pro-competitive effects are likely to be strongest in markets for relatively homogenous commodities, where a finite number of publicly visible transactions play a significant role. Markets for electricity, crude-oil, gasoline, metals, and perhaps some agricultural products fit this description. Any realistic examination of even these markets requires extending the basic AV model.

In this section, I derive a variation of the AV model that incorporates a general linear demand function and an arbitrary number of symmetric firms with affine marginal costs. Market demand is modeled as $Q_t = a_t - bp_t$, or $p_t = \frac{a_t - Q_t}{b}$. For Cournot firm i, marginal cost is modeled as $c(q_i) = K + c_i q_i$. In the following subsections, I derive the equilibrium conditions for the spot market output of the Cournot firms. By nesting that spot market outcome within a 2 period model, I then derive the equilibrium level of forward market contracts.

2.1 Spot market

If firms have entered into forward contracts, then spot market profits will include a term q_i^f, denoting the forward position of firm i. The spot market profit of firm i is therefore

$$\pi_i = \left(\frac{a - Q}{b}\right)\left(q_i - q_i^f\right) - C(q_i)$$

where $Q = \sum_j q_j$, is the total output of all Cournot firms. For a given set of demand parameters a and b, the Cournot equilibrium is characterized by setting marginal revenue equal to marginal cost. If there are no contracts, the equilibrium is described by the following first order condition.

$$\frac{a-\left(q_i-q_i^f\right)-Q}{b}=K+cq_i$$

From this framework, I can state the first result of the model.

Lemma 1 *Assume a market of symmetric Cournot producers with costs and demand as described above. For firm i, with contract level q_i^f,the optimal production quantity, as a function of every firm's contract position, is*

$$q_i(q_i^f,q_{-i}^f)=\frac{(a-bk)+\left(\frac{(n+bc)q_i^f-\sum_{l\neq l}q_l^f}{(1+bc)}\right)}{(n+1+bc)}. \tag{1}$$

Proof. *To demonstrate that the production level given in equation (1) constitutes an equilibrium, first consider any firm i. By aggregating (1) for all Cournot firms, total market production is*

$$Q=\sum_j q_j(q_j^f,q_{-j}^f)=\frac{na+q_i^f+\sum_{j\neq i}q_j^f-nbk}{(n+1+bc)} \tag{2}$$

substituting (2) into the first order condition for firm i we have

$$\frac{a-\left(q_i-q_i^f\right)-\frac{na+\sum_{j\neq i}q_j^f+q_i^f-nbk}{(n+1+bc)}}{b}=K+cq_i$$

solving for q_i yields

$$q_i=\frac{(n+1+bc)\left(a+q_i^f-bK\right)-\left(na+\sum_{j\neq i}q_j^f+q_i^f-nbk\right)}{(1+bc)(n+1+bc)}$$

which reduces to

$$q_i=\frac{(a-bK)+\frac{(n+bc)q_i^f-\sum_{j\neq i}q_j^f}{(1+bc)}}{(n+1+bc)}$$

■

If symmetry is extended to the forward market, with all $q_i^f=q^f$, total market quantity and prices are therefore

$$Q=\sum q_i=\frac{n\,(a-bK)+\sum_j q_j^f}{(n+1+bc)}$$

$$Q=\frac{n\left(a+q^f-bk\right)}{(n+1+bc)},\quad p=\frac{a(1+bc)+nbk-nq^f}{b(n+1+bc)}$$

2.2 The Contract Market

I now calculate the 1st period equilibrium assuming a single spot period. Following Allaz and Vila, I assume that there are no arbitrage opportunities. In other words, I assume that the forward price equals the spot price. The first order condition for maximizing the profit of firm i in the forward market with respect to contract level q^f is

$$\frac{\partial \pi_i\left(q_i^f, q_{-i}^f\right)}{\partial q_i^f} = p\left(Q\right)\frac{\partial q_i}{\partial q_i^f} + p'(Q)q_i\frac{\partial Q}{\partial q_i^f} - C'(q_i)\frac{\partial q_i}{\partial q_i^f}.$$

Using the marginal impact of quantity commitment that can be derived by differentiating (1) with respect to q_i^f, I can express the above conditon as

$$\begin{aligned}\frac{\partial \pi_i\left(q_i^f, q_{-i}^f\right)}{\partial q_i^f} &= p\left(Q\right)\frac{(n+bc)}{(n+1+bc)\left(1+bc\right)} + p'(Q)q_i\frac{1}{(n+1+bc)\left(1+bc\right)} \\ &\quad -C'(q_i)\frac{(n+bc)}{(n+1+bc)\left(1+bc\right)}.\end{aligned} \tag{3}$$

Note that the second term in the marginal revenue equation differs from the standard Cournot best response because the term $\frac{\partial Q}{\partial q_i^f}$ is not the same as the term $\frac{\partial q_i}{\partial q_i^f}$. In other words, the choice of contract level by firm i affects the spot market production of all other firms. Firm i is making a public and credible commitment to produce more by taking on contract level q_i^f, thereby leading to a reduction in spot production by other firms. This implies that a confidential agreement, although it would impact a firm's own spot production, would not have an impact on the production of other firms. Given this fact, risk neutral producers would prefer not to enter into confidential contracts (see Hughes and Kao, 1997). From the above first order conditions, I derive the second result

Proposition 1 *For a symmetric market as described above, the equilibrium level of contracting by an individual Cournot firm in a single forward market will be*

$$q^f = \frac{(a-bk)\left(n-1\right)}{\left(n+bc\right)^2 + (1+bc)} \tag{4}$$

Proof. By substituting q_i and $Q = \sum_j q_j$ from (1) into (3), the first order condition for the optimal contract quantity of firm i is

$$\begin{aligned}\frac{\partial \pi_i\left(q_i^f, q_{-i}^f\right)}{\partial q_i^f} &= \frac{a(1+bc)+nbk-\sum_j q_j^f}{b(n+1+bc)^2}\frac{(n+bc)}{(1+bc)} \\ &-\frac{\left(a-bk+\frac{(n+bc)q_i^f-\sum_{j\neq i} q_j^f}{(1+bc)}\right)}{b\left(n+1+bc\right)^2} \\ &-\frac{bk\left(n+1+bc\right)}{b\left(n+1+bc\right)^2}\frac{(n+bc)}{(1+bc)} \\ &-bc\frac{\left(a-bk+\frac{(n+bc)q_i^f-\sum_{j\neq i} q_j^f}{(1+bc)}\right)}{b\left(n+1+bc\right)^2}\frac{(n+bc)}{(1+bc)}\end{aligned}$$

From symmetry, with all $q_i^f = q^f$ this reduces to

$$\begin{aligned}\frac{\partial \pi_i\left(q_i^f, q_{-i}^f\right)}{\partial q_i^f} &= \frac{a(1+bc)+nbk-nq^f}{b(n+1+bc)^2}\frac{(n+bc)}{(1+bc)} - \frac{\left(a-bk+q^f\right)}{b\left(n+1+bc\right)^2} \\ &-\frac{bk\left(n+1+bc\right)}{b\left(n+1+bc\right)^2}\frac{(n+bc)}{(1+bc)} \\ &-bc\frac{\left(a-bk+q^f\right)}{b\left(n+1+bc\right)^2}\frac{(n+bc)}{(1+bc)}\end{aligned}$$

By collecting terms, this reduces to

$$q^f\left[(n+bc)^2+1+bc\right] = [a-bk]\left(n+bc\right) - (a-bk)\left(1+bc\right)$$

or

$$q^f = \frac{(a-bk)\left(n-1\right)}{(n+bc)^2+(1+bc)}$$

■

Combining conditions (1) and (4) we have the following equilibrium spot quantities and prices.

$$Q = \frac{n\left[n+bc\right]\left(a-bk\right)}{\left[(n+bc)^2+1+bc\right]}, p = \frac{a+a\left[n+1+bc\right]bc+n\left[n+bc\right]bk}{b\left[(n+bc)^2+1+bc\right]} \tag{5}$$

2.2.1 Comparitive Statics

Given the above derivation, the ratio of production by Cournot suppliers that is sold forward is

$$\frac{q_f}{q} = \frac{(n-1)}{(n+bc)}.$$

This value rapidly increases in n between 2 and 8 suppliers and levels off in the range of 80-90% of the volume being contracted.

By comparing the equilibrium quantities implied by (5) to those that would result if there were no contracting, we can derive the differential impact of the addition of a forward contracting round.

Corollary 1 *The percent increase in output due to the existence of a single forward market is equal to*

$$\frac{\Delta Q}{Q} = \frac{n-1}{\left[(n+bc)^2 + 1 + bc\right]}$$

Note that while the percent change in output is sensitive to the slope of the demand function, the effect is independent of the demand function intercept. Figure 1 graphs level sets of the above relationship. The impact on production quantity is uniformly decreasing in demand slope. For a very small number of firms (less than four) the quantity impact is increasing in n. For example, with a demand slope value of 40, increasing the number of firms from 2 to 3 raises the percent increase in output from contracting from less than 12% to close to over 13.5%. For more than about four firms the impact becomes decreasing in n.

Corollary 2 *The change in the lerner index due to the existence of a foward market is equal to*

$$\Delta\frac{p-MC}{p} = \frac{a-bk}{a(1+bc)+nbk} - \frac{(a-bk)(1+bc)}{a+a\left[n+1+bc\right]bc+n\left[n+bc\right]bk} \tag{6}$$

The pro-competitive impact of forward contracting therefore depends upon the same factors that influence the competitiveness of the market absent a forward market. A natural question to examine is the extent to which the model predicts contracts offset an increase in market concentration. This is easiest to examine under an assumption of constant marginal cost ($c = 0$).

Corollary 3 *Assume constant marginal costs and the assumptions applied to previous results. The impact of one round of forward contracting on the Lerner index is equivalent to an increase in firms to a number equal to the square of the number of firms in the market.*

Proof. From equation (6), when $c = 0$ the lerner index without contracts is equal to $\frac{a-bk}{a+nbk}$, which equals $\frac{-1}{n\varepsilon}$ since the elasticity at the equilbrium price is $\frac{P\partial Q}{Q\partial P} = -\frac{a+nbk}{an-nbk}$. The lerner index with contracts is $\frac{(a-bk)}{a+nnbk} = \frac{-1}{n^2\varepsilon}$. ■

When $c > 0$, the interaction of the number of firms, contracting and the Lerner index becomes more complex. Increasing marginal costs tend to reduce the impact of contracts on the Lerner index. To make a valid comparison, we need to define firm specific marginal cost c in terms of a fractional share of total industry marginal cost, such that $c = nz$, where $k + zq$ represents the aggregate marginal cost function for the entire industry. With this representation, we can examine the impact of additional firms while holding the aggregate costs of production for the industry constant. Figures 2a and 2b illustrate the impact of adding a round of contracts as a function of the number of firms and the slope of marginal cost for a representative set of parameters drawn from the examples in subsequent sections, where Figure 2a assumes a demand slope of 25 and Figure 2b assumes a slope of 125. The impact of contracts declines with the slope of marginal costs, z, and how the marginal impact of an additional firm also declines sharply as the slope of marginal cost increases. This is in part because at higher marginal costs, overall mark-ups are lower even in the absence of contracts. The scope for contracts to reduce margins is therefore lessened with steeper marginal cost.

3 Application to The Electricity Industry

Experiences with electricity industry liberalisation have varied greatly around the world. Differences in market design, regulatory oversight, and market structure no doubt play important roles in determining the relative performance of markets. However, much recent research points to the degree of vertical commitments between generation and retail as a key determinant of an electricity market's competitive performance. Most of the "successes" of electricity restructuring have featured markets with either a large amount of long-term supply contracts between generators and retailers or a continued integration between generation and retail, with the retailer's ability to raise prices restricted by regulators or transition arrangements. By contrast, the California market was notorious for its lack of long-term arrangements between retailers and suppliers.

However, when one surveys the world's restructured electricity markets, a striking feature is the extent to which the degree of forward contracting has been driven by regulatory intervention. Regulators in many markets required that long-term vesting or "buy-back" contracts be linked to the divestiture of generation assets. The non-utility producers who purchased these assets were obligated to provide power to the utilities that had previously provided the generation and who remained responsible for serving retail load. In other markets, such as Texas and the mid-Atlantic region, utilities have transfered generation assets to non-utility affiliates, thereby remaining vertically integrated. These transfers have been accompanied by transition arrangements that restrain the prices that the distribution utility is allowed to charge its retail customers Although there is some dispute over whether regulators forbade the use of long-term contracts in California, the CPUC certainly did not encourage them. Thus while empirical research strongly supports the hypothesis that contracts have been critical to spot market performance, we remain relatively uninformed about the level of contracting we might expect if such decisions were left to the market, rather than dictated by regulatory policy. With transition arrangements set to expire over the next several years in many U.S. markets, this becomes an increasingly important question.

Currently in the United States, policy makers are still struggling with what the post-transition organization of the industry will look like. The provision of retail service to residential customers has not developed as a robust competitive enterprise, with the possible exception of Texas. Thus, the vast majority of residential utility customers will continue to have their electricity acquired for them by their incumbent distribution company. Regulators who had at one point imagined that restructuring would eventually bring an end to retail rate regulation have instead been forced to confront the task of setting rates for distribution companies that are large buyers on the wholesale market. In doing so, regulators have had to balance the desire to provide incentives to minimize purchase costs with a need for the utilities to recover their wholesale cost. While a fixed rate structure can provide very powerful incentives to a distribution company, if they are set significantly below wholesale costs the inevitable result is a financial crisis, as it was in California. Conversely, a blanket pass-through of costs provides no incentive for utilities to either aggressively seek low prices or hedge their cost risk.

Most restructured markets in the U.S. are now turning toward a process of organized procurement by utilities with varying degrees of oversight by local regulators. In the northeast, utilities are sub-contracting the role of Provider of Last Resort (POLR) to energy service firms who agree to serve utility demand at a contracted price for a period ranging from 6 months to several years. In California and other regions, it appears that the utility's role will be to directly acquire electricity supply from phyiscal producers.

The developments described above form the background to the stylized model developed in this section. The institutional framework I have in mind is a single procurement round, either through auction or a less formal process, that is reasonably transparent because of regulatory participation. This is in contrast to the short-term trading that goes on between utilities, suppliers, and speculative trading firms that is for the most part not publicly transparent. As described above, the public commitment of a physical producer to a retail supplier can play the role of a credible commitment to raise production, thereby causing competitors without such commitments to reduce output. The procurement occurs in an oligopoly environment with a finite number of producers capable of providing supply to the distribution company.

3.1 Empirical Model

Given the results of the theory model in Section 2 it is natural to ask what kind of pro-competitive impact a single contracting round would have on actual electricity markets. I utilize the theory model developed above to address this question. Using detailed data from several markets, I distill the supply and demand characteristics to match the framework of the theory model. I then demonstrate the results of the theory model for the range of parameter values taken from these markets.

I first calculate a term for the equivalent number of firms in a market by calculating a Hirschman-Herfindahl concentration statistic for the major thermal suppliers in a market and then mapping it to the equivalent number of symmetric firms that would generate the same HHI value. Supply costs are taken from aggregating the thermal generation within the control area to form a single supply function. Acutal supply costs are simplified to fit the affine function of the theory model.[4] The aggregate supply function is then subdivided into n affine supply functions according to the number of equivalent firms in a market.

Estimating Residual Demand

Demand is estimated from historic market data. I utilize a method similar to that used in Bushnell, Mansur, and Saravia (2004), but employ a linear functional form. The end-use demand in wholesale electricity markets is completely inelastic; therefore, the slope b of the model represents the residual demand faced by Cournot firms. This residual demand function is modeled as market demand minus the slope of the supply of net imports (imports minus exports) into the market and the production of other small, fringe plants located within the market.[5] For all markets, the sample period is the summer (June to September). I model both 1999 and 2000 for New England and California, while data from Mansur (2004) covers only 1999 in PJM.

For each hour t, I represent the production from fringe supply using daily temperature in bordering states ($Temp_{st}$),[6] and fixed effects for hour h of the day ($Hour_{ht}$) and day j of week (Day_{jt}). For each market and year, I estimate fringe supply (q_t^{fringe}) as a function of the actual market price p_t, proxies for cost shocks (fixed effects for month i of the summer ($Month_{it}$)), proxies

[4]Thermal generation costs are taken from previous empirical work studying these markets. For each market, previous work has estimated the market-wide marginal cost of serving demand for all observed demand levels. For more details see Borenstein, Bushnell, and Wolak (2002), Mansur (2003), and Bushnell, Mansur and Saravia (2004). These studies produce hourly MC - demand relationships. I regress MC on production quantity for each market to derive the constant (k) and slope (c) terms shown in Table 1

[5]In California, this supply includes net imports and must-take plants (see Borenstein, Bushnell, and Wolak, 2002). These plants include nuclear and independent power producers. In New England, net imports from New York and production from small firm generation comprise this supply (see Bushnell and Saravia, 2002). I estimate only net import supply in PJM as small independent generation sources are negligable in that region.

[6]For California, this includes Arizona, Oregon, and Nevada. New York is the only state bordering New England, while in PJM, bordering states include New York, Ohio, Virginia, and West Virginia. The temperature variables for bordering states are modeled as quadratic functions for cooling degree days (degrees daily mean below 65° F) and heating degree days (degrees daily mean above 65° F). As such $Temp_{st}$ has four variables for each bordering state. These data are state averages from the NOAA web site daily temperature data.

for neighboring prices $(Temp_{st}, Day_{jt}, Hour_{ht})$, and an idiosyncratic shock (ε_t):

$$
\begin{aligned}
q_t^{fringe} &= \sum_{i=6}^{9} \alpha_i Month_{it} + \beta p_t + \sum_{s=1}^{S} \gamma_s Temp_{st} \\
&\quad + \sum_{j=2}^{7} \delta_j Day_{jt} + \sum_{h=2}^{24} \phi_h Hour_{ht} + \varepsilon_t.
\end{aligned} \tag{7}
$$

As price is endogenous, I estimate (7) using two stage least squares (2SLS) and instrument using hourly quantity demanded. The instrument is the natural log of hourly quantity demanded inside each respective ISO system. Typically quantity demanded is considered endogenous to price, however, since the derived demand for wholesale electricity is completely inelastic, this unusual instrument choice is valid in this case. I exclude demand from the second stage as it only indirectly affects net imports through prices.

Table 1 describes the relevant market parameters for the 3 markets studied. Table 2 presents the results of the residual demand elasticity regressions. California experienced a dramatic reduction in imports during 2000 that also resulted in a much lower residual elasticity compared to 1999. The PJM market, which is roughly comparable in size to California and is twice the size of New England, imports very little power and has very few small producers. PJM had the smallest fringe elasticity of the markets studied. The increase in natural gas prices during 2000 is reflected in the higher cost terms for New England and California for that year relative to 1999.

Table 3 presents the implications of the model for contracting and competition. The contracting levels predicted by the model are relatively similar to those actually in place in 1999, with the important exception of California. The relative inelasticity of residual demand in the PJM market is offset by the higher number of firms. The presence of contracting in PJM is therefore most important. Impact is greatest in relatively low elasticity environments with modest concentration of supply.

3.2 Relative value of contracting vs. demand elasticity

The above theoretical results, as well as the empirical literature on electricity markets indicate that markets with the best competitive performance are those where the large retailers, who are the buyers on the wholesale market, pursued vertical arrangements with suppliers. At the same time, both theoretical work and empirical simulations support the argument that increasing the elasticity of end-use demand through a wide-spread implementation of the real-time pricing of electricity to end users would have substantial pro-competitive effects, in addition to providing other benefits.[7]

These two effects would, at first glance, appear to be at odds with each-other. On the one hand, there are pro-competitive benefits from retailers entering into long-term vertical arrangements with suppliers. Yet in the absence of retail competition, the strongest motivation a retailer could have for entering into such arrangements would be regulatory restraints on the ability of that retailer to adjust customer tariffs in response to wholesale price shocks. If retailers are simply allowed to completely pass on wholesale price shocks, as they would in a pure real-time pricing environment, their incentive to hedge wholesale price risk is greatly reduced if not eliminated. Of course end-use customers would now have a stronger incentive to hedge wholesale price risk, but this group constitutes a much more disparate collection of small consumers many of whom spend relatively small amounts of their individual budgets on electricity.

Borenstein (2004) outlines the solution to this seeming paradox. A utility retailer would offer a real-time pricing tariff bundled with fixed-quanitity hedge that would preserve end-user's marginal incentive to adjust to wholesale prices. The utility has therefore still committed to provide large amounts of energy at fixed prices, while end-users still face the wholesale price as the marginal opportunity cost of deviations from the quantity they have hedged. Despite the strong merits of such a system, its adoption in practice has been extremely limited. It is therefore still interesting to explore the relative pro-competitive benefits of increasing demand elasticity and introducing a single round of long-term contracting by utilities.

I approach this question by calculating for each market the alternative demand slope, $\widehat{b}$, that would equilibrate a no-contract Cournot price in each market with the price resulting from one round of contracting (using the estimated slope b). I rotate the demand curve around the 'with-contracts' equilibrium price-quantity point to produce a new demand curve with slope $\widehat{b}$ and horizontal intercept $\widehat{a}$. In other words, for a peak demand hour, I calculate the equivalent slope $\widehat{b}$ such

[7]See Borenstein (2000) for a discussion of these issues. Oligopoly simulations in Borenstein and Bushnell (1999) as well as Bushnell (2004) show that the California market would have been much more competitive with even a modest adoption of real-time pricing by end-users.

that

$$\frac{\widehat{a}(1+\widehat{b}c)+n\widehat{b}k}{\widehat{b}(n+1+\widehat{b}c)}=\frac{a+a\left[n+1+bc\right]bc+n\left[n+bc\right]bk}{b\left[(n+bc)^2+1+bc\right]}$$

where the left term is the equilibrium price without contracts and the right term is the price with one round of contracts. The new intercept, $\widehat{a}$, is equal to $Q_c + P_c * \widehat{b}$, where Q_c and P_c are the 'with-contracts' Cournot equilibrium quantity and price, respectively. The results are presented in table 4. The first column presents the actual residual demand slope from the empirical estimation described above. The second column describes the equivalent slope that would produce the same Cournot equilibrium price in the absence of forward contracting. The last two columns calculate the elasticities implied by those slopes evaluated at the Cournot equilibrium price-quantity point. In every market, the value of a round of contracting is equivalent to a massive increase in demand elasticity. Adding contracting is equivalent to a 400% increase in elasticity in California and a 600% increase in PJM.

4 Conclusion

Traditionally, competition policy has operated with a focus on market structure, particularly the horizontal organization of supply. It has long been recognized that other factors may be important in mitigating, or amplifying the market power implied by a given horizontal concentration. Many of these factors, such as vertical relationships, have been given serious weight in the application of competition policy in practice. The competitive implications of the ability of firms to trade in transparent forward markets has received considerable attention in the academic literature. Their implications have not had much impact on policy however.

In this paper, I examine the implications of forward contracts on oligopoly environments by extending the model of Allaz and Vila to an environment with more than two firms and increasing marginal cost. The number of firms is an important factor in determining the interaction of forward markets and competition. In the case of constant marginal cost, the competitive impact of firm concentration is exponentially greater with the existence of a single forward market relative to a single spot market. While the interaction of increasing marginal cost and firm size is complex in this model, it appears that increasing marginal cost reduces the impact of firm size on contracting for a range of parameter values drawn from existing electricity markets, but the impact is still substantial. For those parameter values, the model indicates that the addition of one round of forward contracting is equivalent to a major increase in demand elasticity in terms of its effect on mitigating the market power of Cournot producers. These results imply that in markets where fixed price forward trading is common, the importance of firm size is greatly magnified.

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Table 1: Market Parameters

Market	n	b	k	c
California				
1999	5.25	125	24.00	.00305
2000	5.25	28	25.25	.02872
New England				
1999	4.55	15	22.19	.00469
2000	6.86	37	36.50	.01091
PJM				
1999	6.45	8.5	0.00	.00623

Table 2: Two Stage Least Squares Estimation of Fringe Supply from July to September

Second-stage dependent variable is hourly fringe supply by market.

	Cal. 99	New Eng. 99	PJM 99	Cal. 00	New Eng. 99
Price	124.8*	15.6 *	8.5*	28.12 *	37.2 *
	(11.8)	(3.26)	(2.39)	(8.22)	(1.58)
AR(1) coef (ρ)	0.77	0.76	0.78	0.87	0.69
Sample size	2,922	2,927	2,890	2,927	

Notes: Table presents 2SLS coefficients. First we estimate 2SLS and use the errors to correct for serial correlation by estimating an AR(1) coefficient (ρ). Then we quasi-difference the data by calculating $\Delta x = x_t - \rho x_{t-1}$ for all data. We re-estimate the 2SLS results using these quasi-differenced data. Robust standard errors are given in parentheses. Significance is marked with (*) at the 5% level and (#) at the 10% level. Regression includes fixed effects for month of year, day of week, and hour of day. Also weather variables for bordering states are included and modeled as quadratic functions for cooling degree days (degrees daily mean below 65° F) and heating degree days (degrees daily mean above 65° F). In the first stage, we regress price on the exogenous variables of hourly load (MWh) in each market.

Table 3: Model Results

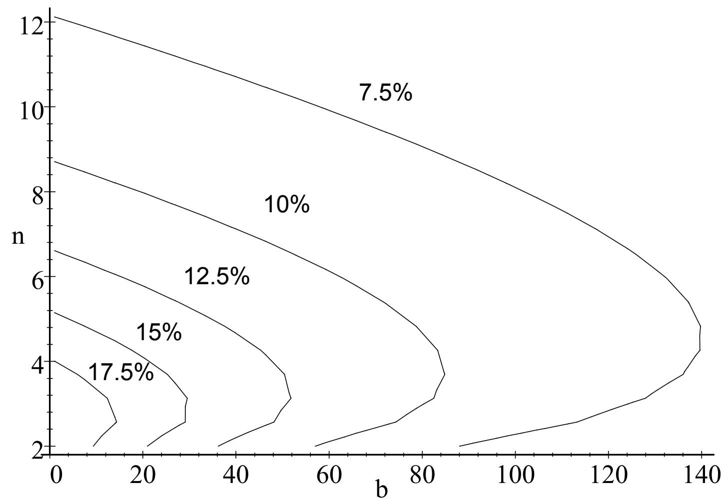
Market	Actual Contract %	Predicted Contract %	No Contracts Avg. Price	w/ Contracts Avg. Price
California				
1999	0	55	29.75	26.94
2000	0	56	134.13	99.12
New England				
1999	50	71	137.54	59.86
2000	40	68	67.86	51.27
PJM				
1999	85	81	522.42	120.02

Table 4: Equivalent Implied Elasticities

Market	Actual Slope	Equivalent Slope	Actual Elasticity	Equivalent Elasticity
California				
1999	125	509	-0.37	-1.49
2000	28	94.5	-0.25	-0.85
New England				
1999	15	67.3	-0.09	-0.38
2000	32	171	-0.19	-1.03
PJM				
1999	8.5	52.9	-0.03	-0.21

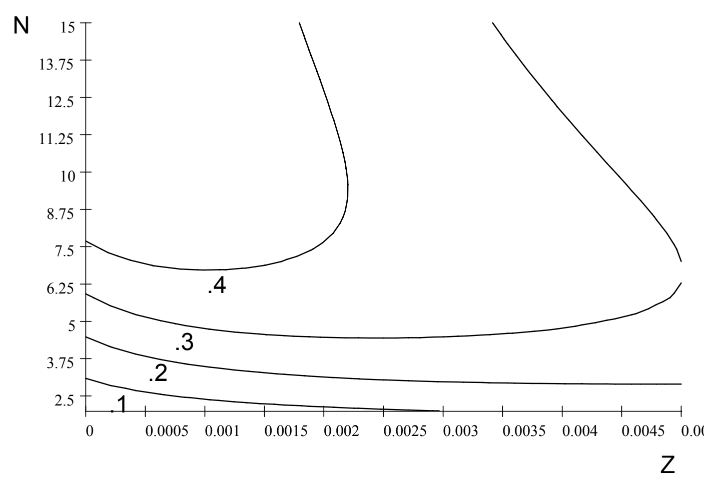
Notes: Table presents alternative values of demand slope, $\hat{b}$ which equilibrate a no-contract Cournot price from each market with the price produced from 1 round of contracting using the original demand slope, b from each market. The alternative slope is applied to a demand curve that passes through the "with contracts" equilibrium price and quantity. Elasticity is calculated at the Cournot equilibrium prices and quantities based upon the average of the 25 highest quantity hours from June 1999 or Sept. 2000.

Figure 1: Percent change in Cournot quantity from 1 contracting round



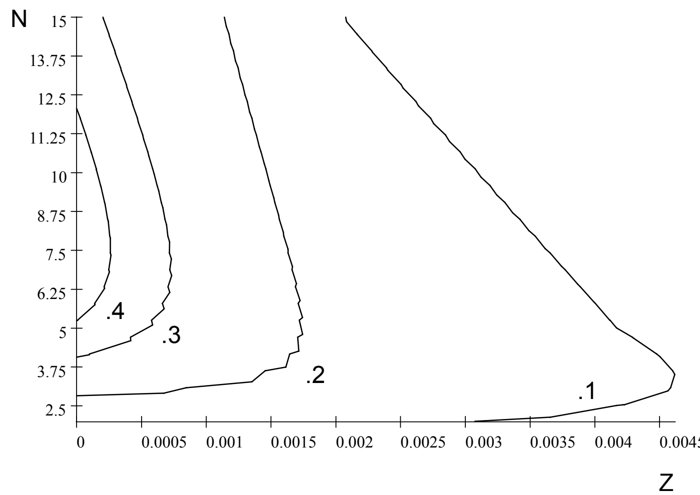
notes: marginal cost of each firm is equal to k+c, where c is assumed to be .015 for this example.

Figure 2a: Decrease in Lerner Index from 1 contracting round – increasing MC



notes: marginal cost of each firm is equal to k+n*z, where k is assumed to be 20. Demand is defined by the function a – b*p, where a is set equal to 25,000 and b equal to 25 for this example.

Figure 2b: Decrease in Lerner Index from 1 contracting round – increasing MC



notes: marginal cost of each firm is equal to k+n*z, where k is assumed to be 20. Demand is defined by the function a – b*p, where a is set equal to 25,000 and b equal to 125 for this example.

Figure 3: Calculation of Equivalent Elasticity