NRRI 98-15

HORIZONTAL MARKET POWER IN GENERATION

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May 1998

This report was prepared by The National Regulatory Research Institute (NRRI) with funding provided by participating member commissions of the National Association of Regulatory Utility Commissioners (NARUC). The views and opinions of the author do not necessarily state or reflect the views, opinions, or policies of the NRRI, NARUC, or NARUC member commissions.

EXECUTIVE SUMMARY

Industries with large market shares have consistently performed less well than industries with small market shares. Empirical studies using industry profit rates and industry concentration ratios consistently report that the more concentrated industries are more profitable than the less concentrated industries.[1] However, this well-established and well-regarded statistical relationship does not provide much information about the casual relationship between market performance and market concentration. This state of affairs is troublesome because the measurement of market concentration is supposed to lead to the prediction of the extent of any potential departure of market price from its competitive level.[2]

The causality flowing from market concentration to the efficiency of the market price is difficult to untangle because the various theories of oligopoly are tied to different optimal market concentration measures.[3] As a result, it is extremely important to model the behavioral characteristics of the firms when attempting to empirically assess the degree of horizontal market power within an oligopoly.[4] In this analysis, we model utility

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[1] See, J.E. Kwoka, Jr., "The Effect of Market Share Distribution on Industry Performance," *Review of Economics and Statistics* Vol. 61 (1970): 101-109; R. McF. Lamm, "Prices and Concentration in the Food Retailing Industry," *Journal of Industrial Economics* Vol. 30 (1981): 67-78; F.M. Scherer, *Industrial Market Structure and Economic Performance*, 2nd ed. (Chicago: Rand McNally, 1980); W.G. Shepherd, "The Elements of Market Structure," *Review of Economics and Statistics* Vol. 54 (1972): 25-37; W.G. Shepherd, *Treatment of Market Power* (New York: Columbia University Press, 1975), Ch. 4; J. Tirole, *The Theory of Industrial Organization* (Cambridge, MA: The MIT Press, 1989), Ch. 1.

[2] G.J. Stigler, "The Measurement of Concentration," in *The Organization of Industry*, G.J. Stigler, ed. (Homewood, IL: Richard D. Irwin, 1968), 30.

[3] J. Hause, "The Measurement of Concentrated Industrial Structure and the Size Distribution of Firms," *Annals of Economic and Social Measurement* Vol. 6 (1977): 73-103; J. E. Kwoka, Jr., "The Herfindahl Index in Theory and Practice," *The Antitrust Bulletin* (Winter 1985): 915-947.

[4] R.E. Dansby and R.D. Willig, "Industry Performance Gradient Indexes," *American Economic Review* (June 1979): 249-60.

and nonutility generators in the *spot market* for generation as Bertrand competitors with precommitted quantities, and hence they are nondominant firms.[5] That is, each generator commits a specific amount of its capacity to the spot market for generation and then selects its price aware of the strategic significance of these actions to its competitors.

We model the spot market for generation as either *open* or *super-closed*. The defining characteristic of the open spot market is that *actual* transmission constraints do not influence its performance. That is, only *potential* transmission constraints exist in an open spot market for generation. Conversely, the *existence* of actual transmission constraints is the defining characteristic of the super-closed spot market. On the one hand, some of these constraints prevent imported and exported electric power from passing over the politically and analytically determined geographic boundaries of the open spot market for generation. On the other hand, the remaining transmission constraints disrupt the directional flow of net electric power within the open spot market's geographic boundaries.

Actual transmission constraints are modeled as creating two distinct and separable super-closed spot markets for generation. The first super-closed spot market contains only *exploited* generators, and the second super-closed spot market contains only *exploiting* generators. In our modeling, exploited generators do not compete with exploiting generators. Moreover, there is no presumption of a dominant nonutility or utility generator in either super-closed spot market. An exploited generator is modeled as incurring a cost as a result of transmission constraints, and an exploiting generator is modeled as receiving a benefit. The cost incurred by exploited generators is *increases* in their elasticities of supply, which means they are more sensitive to changes in the spot market price for electric power as a result of transmission constraints. The benefit

[5] D.M. Kreps and J.A. Scheinkman, "Quantity Precommitment and Bertrand Competition Yield Cournot Outcomes," *Rand Journal of Economics* Vol. 14, No. 2 (1983): 326-337.

accruing to exploiting generators is *decreases* in their elasticities of supply, which makes them less responsive to changes in the spot market price for electric power.

The Lerner Index is used in this analysis as the *basis* for test statistics assessing the degree of *horizontal* market power in an oligopolistic spot market for generation. The Lerner Index was chosen for this purpose because it has been shown to be an essential element of precise measures of oligopolistic market power.[6] Test statistics for horizontal market power are derived for the open and super-closed spot markets. There are four test statistics in all. γ^o and γ_i^o are the statistics for the open spot market. γ^c and γ_i^c are the statistics for the super-closed spot market. γ^o and γ^c are the test statistics for *collective* horizontal market power. The statistics for collective market power are interpreted as assessing the *potential for collusion* in a spot market for generation.

The analytical formulas for the four test statistics are: [1] $\gamma^o = 1/(1 - [1/\varepsilon^o (HHI^o + \sum(1 - \tau_i^o)\alpha_i^{o2})])$, [2] $\gamma_i^o = 1/(1 - (1 + (1 - \tau_i^o)(\alpha_i^o/\varepsilon^o))$, [3] $\gamma^c = 1/(1 - [1/\varepsilon^c (HHI^c + \sum(1 - \tau_i^c)\alpha_i^{c2})])$, [4] $\gamma_i^c = 1/(1 - (1 + (1 - \tau_i^c)(\alpha_i^c/\varepsilon^c))$. The superscript, ^{o}, denotes the open spot market for generation, and the superscript, ^{c}, denotes a super-closed spot market. The subscript, $_i$, denotes the i^{th} generator in the spot market. This generator may be either a utility or nonutility generator. HHI is the Herfindahl-Hirschman Index for the spot market. ε denotes the spot market's elasticity of demand. τ denotes the spot market's elasticity of supply. α denotes market shares. Each of the parameters are *estimable* when sufficient data are available. Obviously, empirical estimates of the formulas' parameters are required to make them useful to regulators and others.

The variable, $(1 - \tau_i^o)$, is an instrument for estimating the *conjectural variation* by the i^{th} generation in the open spot market for generation. The variable, $(1 - \tau_i^c)$, is the instrument for estimating the *conjectural variation* by the i^{th} generator in the super-closed spot market. In our model, a conjectural variation captures the i^{th} generator's

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[6] V.A. Dickson, "The Lerner Index and Measures of Concentration," *Economic Letters* Vol. 11 (1979): 275-279.

beliefs about how its capacity commitments affect the spot-market bids of other exploited generators.

Although we believe that our test statistics represent an improvement over other approaches to assessing the degree of horizontal market power in the spot market for generation, we also recognize that they place considerable information demands on the regulators. For example, knowledge of the effects of transmission constraints is required in order to choose the proper collective and individual test statistics for assessing the degree of horizontal market power. They also have other shortcomings. They are static measures that provide only a first reading of market power. They ignore the past and future circumstances of the open and super-closed spot markets for generation. Lastly, they provide only limited information pertaining to the incentives influencing the strategic behavior of utility and nonutility generators as they compete with each other in these spot markets.

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FOREWORD

Market power has emerged as an important topic in the discussion of electric industry restructuring. State public utility commissions will play as yet some undefined role in preventing and monitoring market power. Measuring market power is one essential task in carrying out these functions. This report develops a variant of the Lerner Index to measure the degree of horizontal market power for spot-market generation. Although this index, like others, has limitations, it improves upon some alternative indicators in measuring market power. This report should advance the technical literature on testing for market power in the electric power sector.

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May 1998

ACKNOWLEDGMENTS

I would like to thank the many formal and informal reviewers of this report. I have benefitted greatly from the comments of consultants trying to assess market power at the state level and from analysts at state public utility commissions who are dealing with the same issue. Their comments often brought me back to reality.

I would like to thank Dr. Douglas Jones and Mr. Kenneth Costello for their thoughtful review of this report at various stages of its development. Many times, their comments helped me get back on track. Typically, they forced me to think about the cost to state commissions of implementing my test statistics for market power.

I would like to thank Dr. Kenneth Train, of the NRRI's Research Advisory Committee, for his review of the final draft of this report. He emphasized the need for operational definitions of key concepts developed within the report. Quite correctly, he argued that it would be very difficult to implement my test statistics, if one could not easily tell the difference between an "exploited generator" and an "exploiting generator."

I would like to express my deep debt of gratitude to Dr. Howard Marvel of The Ohio State University. His comments more than anyone else's helped to shape the content and define the tenor of this report. He forced me to clearly articulate and justify my modeling selections. His comments are the catalysts for the parts of the report arguing that the generation spot market in a restructured electric power industry should not be modeled as dominant firm and competitive fringe.

Lastly, it is important to note that all remaining errors in this report are my sole responsibility. Even the best reviewers cannot overcome the stubbornness of an author.

INTRODUCTION

The seminal analysis of market power by Abba Lerner examined the exploitation of consumers by a monopolist selling its service in an unregulated spot market.[1] This modeling effort did not address the possibility that the monopolist would enter into a variety of short-term and long-term contracts with its customers. Furthermore, the model did not provide any mechanism for resolving any contractual discrepancies in a complementary spot market for electric power. Instead, the modeled behavior is of a monopolist selling a service to consumers in much the same way as the proprietor of the only gas station on a lonely stretch of highway sells gasoline to travelers relocating from Springfield to Chicago.

Using the information now taught in introductory courses in microeconomics, Lerner constructed an index of monopoly power.[2] The index, $(P^* - MC) / P^*$, is a consistent measure of monopoly power.[3] Regardless of movement in the monopolist's costs and demand over time, its monopoly power always is the relative margin of its price to its marginal cost. This relative price margin can remain constant over time despite changes in market demand and the monopolist's costs. However, this price margin also can increase or decrease over time. If the demand for the monopolist's service increases, there is an increase in monopoly power when the percentage

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[1] A. Lerner, "The Concept of Monopoly Power and the Measurement of Monopoly Power," in *Readings in Microeconomics*, 2nd ed., W. Breit and H.M. Hochman, eds. (Hinsdale, IL: Dryden Press, 1971), 207-223.

[2] A monopolist chooses its profit-maximizing output by equating marginal revenue to marginal cost. It then leaves its marginal-cost and marginal-revenue scheduled and travels to its average-revenue (demand) schedule, where it selects its profit-maximizing price. Because a downward-sloping average-revenue schedule always "lies above" its associated marginal-revenue schedule, the monopolist's profit-maximizing price is greater than its marginal cost.

[3] P^* is the profit-maximizing price and MC is the marginal cost associated with the quantity demanded of the monopolist's service when marginal cost equals marginal revenue.

increase in price is greater than the percentage increase in marginal cost. Conversely, the Lerner Index records a decrease in monopoly power when the percentage increase in price is less than the percentage increase in marginal cost. Of course, monopoly power can change over time even if there are no changes in demand. An across-the-board increase in marginal costs induces a decrease in monopoly power and *vice versa*.

The basic mechanics of the Lerner Index also indicate that a cross-section of monopolists may possess different levels of monopoly power because of dissimilar cost and demand schedules. Production costs may be low for a particular monopolist, while its demand is high and inelastic. Because the margin between price and marginal cost is very large in this instance, this firm enjoys a significant amount of monopoly market power. Another monopolist may operate in a market with low and relatively inelastic demand conditions and high production costs. Its margin between price and marginal cost is depressed, which implies only a moderate degree of monopoly power.

However, monopolies are not the only markets characterized by an equilibrium where price exceeds marginal cost and the firms earn above normal profits.[4] Such equilibria also are associated with oligopolies. Yet, there is an important difference between monopoly power and the market power wielded by oligopolists. Monopolists do not interact with other firms, and consequently, it is appropriate to construct a model of monopoly power using the traditional tools of decision theory. Most oligopolists do interact significantly with other firms, and therefore, the tools of game theory are needed to construct a model of market power. Hence, the analysis of market power is more complicated than the analysis of monopoly power.

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[4] It is the custom of economists to include the competitive (a.k.a. the normal) return on the firm's investment in the firm's total cost function. Therefore, a firm earning above-normal economic profits is a firm that is earning a return on its investments that exceeds the competitive level, where the reference point for normal economic profits is a perfectly competitive market.

The initial analyses of market power were empirical studies using cross-sectional data on industry-wide profit rates and industry-wide market-concentration ratios. In general, they tended to be "short" on theory, but practically, they were useful as mortar for the structure-conduct-performance paradigm of industrial organization.[5] That is, a typical correlation drawn from these analyses is that industry profitability is positively related to industry concentration.[6] This correlation often was converted to the conclusion that more market concentration causes higher industry profitability. From here, it was a short step to the correlated conclusion that market concentration is the source of the industry's market power over consumers.[7]

But the truth is that a positive correlation between market-concentration ratios and industry profits does not prove that oligopolists necessarily possess market power. At best, this correlation may be interpreted as a warning that oligopolists have the potential to widen the difference between their price and their marginal cost as their market shares increase.[8] The actual presence of unacceptable levels of market-wide or

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[5] J. Bain, "Relation of Profit Rate to Industry Concentration: American Manufacturing, 1936-1940," *Quarterly Journal of Economics* Vol. 65 (1951): 293-324; J. Bain, *Industrial Organization* (New York: Wiley, 1956).

[6] R. Schmalensee, "Inter-Industry Studies of Structure and Performance," in *Handbook of Industrial Organization*, R. Schmalensee and R. Willig, eds. (Amsterdam: North-Holland, 1986). Although the statistical relationship between profits and concentration ratios disappears when market-share indices also are included in the empirical analysis, larger market shares continue to suggest high profits. See, F. Scherer, *Industrial Market Structure and Economic Performance*, 2nd ed. (Chicago, IL: Rand-McNally, 1980). However, as a reviewer noted, it is inappropriate to conclude that a positive relationship between market share and profits is indicative of increasing market power.

[7] Perhaps the early studies of market power were short on theory because it still is correct to say that no single theory of oligopolistic behavior conclusively explains how oligopolists set prices noncollusively and still manage to produce quantities clearing their markets. See J.E. Kwoka, Jr., "The Herfindahl Index in Theory and Practice," *The Antitrust Bulletin* (Winter 1985): 915-947.

[8] See D.S. Weinstock, "Using the Herfindahl Index to Measure Concentration," *The Antitrust Bulletin* (Summer 1982): 285-301; D.S. Weinstock, "Some Little-known Properties of the Herfindahl-Hirschman Index: Problems of Translation and Specification," *The Antitrust Bulletin* (Winter 1984): 705-717; F.A. Felder and S.R. Peterson, "Market Power in a Dynamic Setting," *The Electricity Journal* Vol. 10, No. 2. (April 1997): 12-19.

firm-specific market power is documented only by a detailed analysis of oligopolistic behavior within the industry.[9]

Extensive knowledge of the oligopolists' market conditions is necessary if industry analysis is to yield the conclusion that some or all of the firms comprising the industry have unacceptable market-power levels. Nowhere is this more true than with respect to market-power analysis of the electricity industry. Nonutility generators entered the industry subject to institutional conditions that were significantly different from the institutional conditions existing at the time the utilities and government formed this industry. These institutional conditions had an effect on the production technologies chosen by these two types of firms, and these technology choices had an effect on the existing institutional conditions. As a result, older utility generators tend to use technologies characterized by economies of scale.[10] Furthermore, they sometimes operate within the declining average-cost region of their technologies.[11] Meanwhile, newer nonutility generators tend to use technologies causing them to produce in the constant or increasing ranges of their average-cost schedules. However, attention is restricted in this analysis to generators that produce in the constant or increasing

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[9] However, it also is important to realize that this statistical relationship is a stylized fact because an industry's concentration ratio and profit rate are jointly determined by the behavior of the firms within the industry. Therefore, the wide array of empirical studies supporting this descriptive statistic do not tell us why a high industry profit rate tends to be associated with a high industry concentration ratio. As Tirole notes, this gap in knowledge only can be filled by carefully delineating the basic exogenous economic conditions of the industry and by obtaining an understanding of the behavior of the companies within it. These basic exogenous conditions, among other things, include learning curves, the structure of information about product quality, and the proportion of costs that are sunk as a consequence of the industry's technology. See J. Tirole, *The Theory of Industrial Organization* (Cambridge, MA: The MIT Press, 1989), Ch. 1.

[10] Evidence is beginning to be found that indicates economies of scale may no longer characterize the market for electric power. See H.G. Thompson, D.A. Hovde, L. Irwin, with M. Islam, *Economies of Scale and Vertical Integration in the Investor-Owned Electric Utility* (Columbus, OH: The National Regulatory Research Institute, 1996).

[11] It is important to recall in this regard that operating in the declining average-cost region of a production function is not a sufficient condition for also operating in the declining marginal-cost region of the same production function. The standard description of any firm's cost function has rising marginal costs leading rising average costs. As a result, a firm's marginal costs may be rising even as its average costs are falling.

ranges of their average costs. This restriction conveniently avoids the analytical complication that generators producing in the declining average-cost range of their production functions earn below-normal economic profits when they set their prices equal to their marginal costs.[12]

When a generator's average costs are constant over the pertinent range of its production, it breaks even economically by setting price equal to marginal cost because it also is true that its marginal cost equals its average cost under these circumstances. The generator's cost relationships, however, are significantly different when its range of production is characterized by increasing average costs. Then this generator earns above-normal economic profits when it sets its price equal to its marginal cost. Of course, as a matter of consistency, it must be true that the increasing-cost generator and the constant-cost generator must be able to sustain their prices in the generation market in order to consistently earn such profit levels.

Every generator produces a service for sale in a market that is unavoidably subject to random demand shocks that result from unanticipated weather patterns. By its very nature then, the demand for generation service is uncertain. A generator's typical reaction to this uncertainty is to hold capacity in "spinning reserves" to meet unanticipated increases in demand. The distinguishing attribute of this reserve capacity is that it can be put into service virtually immediately when the actual demand for power exceeds the expected demand for power at any point in time. If spinning reserves are offered for sale competitively by multiple generators in order to avert a short-term crisis, they would have to be offered in a *spot market*. Consequently, the market-clearing

[12] Total-cost curves constructed in the economic tradition include the competitive (a.k.a. the normal) return on the firm's investment. This is why the competitive (i.e., the normal) profit level for a firm is often translated as the firm earning zero economic profit. Therefore, a firm earning below-normal economic profits also can be described as earning negative economic profits even though its accounting profits may be positive. The proper interpretation of a situation where accounting profits are positive and economic profits are negative is that the firm is not earning enough to entice additional investors into the fold.

price for these reserves would equal the marginal cost of the last generator to be called upon to avert the crisis by selling its spinning reserve.[13]

However, a generator also may have reserve capacity that is functionally different from spinning reserves. These reserves are not "on line" in the sense that they can be brought into service immediately to avert a short-term crisis. However, under the appropriate conditions in the transmission market, these reserves can be used by a dominant generator to increase its profitability. In particular, computer simulations have revealed that a dominant generator facing a competitive fringe can increase its production for the spot market and increase the price it receives for all of its power sold in the spot market when transmission congestion is present.[14] However, it is important to remember the assumed market structure when interpreting this result. An *assumed* dominant firm facing an *assumed* competitive fringe is already empowered

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[13] In fact, the existence of spinning reserves points to the substantial difference between the sale of electric power by oligopolists without excessive market power and the sale of hotel rooms or airline seats by oligopolists without excessive market power. Spinning reserves exist because the production of electric power is an instantaneous physical phenomenon, which implies that power not sold in period t is impossible to sell in period $t + \epsilon$, where ϵ is a very small positive real number, because large amounts of power cannot be stored for future use. Hotel rooms and airline seats, however, can be stored in the sense that they can be held in reserve for higher paying customers who make travel arrangements on relatively short notice. Therefore, hotels and airlines can segment their customers in order to price their seats and rooms by the timing of the reservation. The usual rule is that price increases as the time between reservation and arrival decreases, which is consistent with the reality that profit maximization for hotels and airlines is never assured by marginal-cost pricing. Consider the marginal cost of an airline seat just before the airplane departs. It is virtually zero for the airline. Now, consider the marginal benefit of that seat for a customer that unexpectedly must get to the airplane's destination. It is very large. Hence, just before the plane's departure, marginal-cost pricing would seriously undervalue the seat. Obviously, the circumstances characterizing a utility or nonutility generator in the spot market for generation are not the same as those characterizing a hotel or airline. The marginal cost of electric power is not virtually zero just prior to a crisis point for an electric-power customer. Typically, the marginal cost of power is relatively high at this point in time. As a result, there is congruence between the marginal cost of power and the marginal benefit of power in times of crisis. Moreover, this congruence continues to exist after the crisis is averted or runs its course. Consequently, a utility or nonutility generator can assure profit maximization through marginal-cost pricing.

[14] J.B. Cardell, C.C. Hitt, and W.W. Hogan, "Market Power and Strategic Interaction in Electricity Networks," mimeo., November 30, 1996; W.W. Hogan, "A Market Power Model with Strategic Interaction in Electricity Networks," mimeo., Center for Business and Government, John F. Kennedy School of Government, Harvard University, February 1997.

to increase its production for the spot market in a unilateral and unchallenged manner and to receive consequently larger profits because it already knows that its *market dominance* in the spot market assures a higher spot price for its service.[15] These simulations simply do not show that a *nondominant* generator with a large market share can accomplish the same result. That is, these simulations do not demonstrate that a generator with a large market share is necessarily dominant in the spot market for generation when transmission constraints are present.

Furthermore, it needs to be noted that the presence of sufficient nonspinning reserves is not necessary for the exercise of market power in the spot market by a particular generator. The laws of physics virtually guarantee that the incumbent utility's transmission network will be congested during some days of the year because of the shifting pattern of the flow of electric power caused by customers defecting to the incumbent utility's rivals in the production of electric power. This congestion creates subregions of market power in the spot market, wherein some of the incumbent utility's generators *and* unaffiliated generators are able to substantially increase their generation prices by decreasing their output of electric power.[16] Consequently, market power in the spot market for generation is defined to exist when a generator can manipulate its production on a sustained basis such that it is paid higher *spot prices* than otherwise would be the case, thereby earning above-normal profits in this market.[17]

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[15] In addition to a high probability of transmission congestion, a reverse "L" shaped marginal-cost curve also is useful to a dominant generator facing a competitive fringe. The dominant generator can then hold capacity in strategic reserve while awaiting a transmission constraint and still break even in an economic sense as it uses marginal-cost pricing against its rivals. Recall a reverse "L" shaped marginal-cost curve is characteristic of a constant-cost generator, which means that average cost equals marginal cost in the pertinent range of production.

[16] D.M. Newbery, "Power Markets and Market Power," *Energy Journal* Vol. 16, No. 3 (1995).

[17] P.L. Joskow, "Horizontal Market Power in Wholesale Power Markets," mimeo., August 1995, 11. This definition has to be restated as follows if the generator is assumed to produce in the declining cost range of its average-cost function. A declining average-cost generator is defined to possess market power when it can set its price above average cost on a sustainable basis by manipulating its production and letting consumers bid up the price.

Market power in an oligopolistic spot market for generation has been shown to be essentially a derivative of transmission phenomena even though regulators have acted by promulgating rules that prevent utilities from denying access to their bottleneck transmission facilities.[18] Interestingly, it appears that it is only transmission phenomena that create market power in the spot market for generation. Consider in this regard the newer regulations governing marketing behavior of incumbent utilities. On the one hand, there are rules allowing the utilities to respond to competition by segmenting customers and discounting prices. On the other hand, there are rules assuring that these utilities recover their stranded costs. If fixed costs unrecovered because of price discounting are deemed by regulators to be stranded costs, these two sets of rules, when combined, subsidize the utilities' generation prices, thereby creating an incentive for utilities to discount their electric-power prices aggressively for specific customers.[19]

Surely, an important consequence of using stranded-cost recovery to subsidize utility pricing is that utilities become unconcerned about realizing unused generation capacity as they respond to competition. If inadequately monitored by regulation, these subsidized generation facilities can be brought to the spot market and the associated electric power bid at spot prices equaling the facilities' average variable cost of generation.[20] Clearly, utility facilities, bid at these spot prices, represent a formidable

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[18] Federal Energy Regulatory Commission, 18 CFR Parts 35 and 385 [Docket Nos. RM95-8-000 and RM94-7-001] *Promoting Wholesale Competition Through Open Access Non-discriminatory Transmission Services by Public Utilities; Recovery of Stranded Costs by Public Utilities and Transmitting Utilities,* Order No. 888-Final Rule, Issued April 24, 1996.

[19] R.J. Graniere, "Creation of Stranded Costs By Specialized Discounting," NRRI Working Paper, February 9, 1998; R.J. Graniere, "Regulation of Specialized Discounting," NRRI Working Paper, January 15, 1998.

[20] The existence of excess capacity is a *de facto* representation for the existence of market power. Excess capacity supports price above marginal cost only after an incumbent has used it successfully to drive existing rivals from the market and to prevent potential rivals from entering the market. Thus at a minimum, the appearance of excess capacity in combination with volume discounting is a warning that an incumbent utility may be preparing the ground for higher future prices by aggressively discounting current prices. Thus, it cannot be asserted that all price discounting is competitive because it represents an attempt by the firm to realize very large cost efficiencies by retaining existing customers who are responsive to price cuts.

force in the spot market because they are supported by superior interconnections to the transmission network, customer loyalty, and customer inertia.[21] However, these subsidized facilities would not be a source of market power as market power pertains to the spot market for generation.[22] The approved subsidization of utility pricing in the spot market for electric power through stranded-cost recovery lowers the spot price, and the additional spot-market production makes it more difficult for anyone to manipulate this market by restricting its output.

It is sometimes argued that an incumbent possesses market power when its customers encounter significant transactions costs after they choose to switch to one or more of the incumbent's rivals. However, transactions costs of this genre are not encountered in the spot market for generation. Negotiating contracts and planning for contingencies in the event of breaches of contract are not concerns in this market. In addition, there is not any need for customers purchasing in the spot market to absorb any costs associated with a new learning curve.[23] Consequently, market power grounded in transactions costs is not an issue in this analysis.

Section 1 discusses the nature and structure of oligopolistic competition in the spot market for generation. Its focus is on the models of oligopolistic competitive interaction that reasonably represent the strategic behavior of utility and nonutility

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[21] W.G. Shepherd, "Dim Prospects: Effective Competition in Telecommunications, Railroads, and Electricity," *The Antitrust Bulletin* (Spring 1997): 151-175.

[22] Though not an obvious source of market power against consumers, the cross-subsidization of utility pricing through stranded-cost recovery is an entry barrier in Stigler's sense of the term. Stigler defines an entry barrier as a cost that has to be incurred by a market entrant and has not been incurred by an incumbent. See G.J. Stigler, "The Measurement of Concentration," in *The Organization of Industry*, G.J. Stigler, ed. (Homewood, IL: Richard D. Irwin, 1968), 30. Consider now a nonutility generator that wants to replace its existing generation facilities with newer generation facilities. Because this activity is being financed using traditional methods and not by stranded-cost recovery with its different and lower risk characteristics, the nonutility is experiencing a risk factor that is not experienced by the utilities.

[23] Several other possibilities emerge as sources of a utility's market power in generation. They are: (1) the sunk costs that have to be incurred by the nonutility generators, (2) the ability of a wealthy utility to capture new generation technologies through mergers, acquisitions, and joint ventures, and (3) the ability of a wealthy utility to retard the deployment of newly commercialized generation technologies through its purchasing practices.

generators. The selection of Bertrand competition with precommitted quantities as the *type* of oligopolistic competition characterizing the spot market for generation is discussed fully in this section. Section 2 describes the market power potential within the spot market for generation when transmission constraints are binding and nonbinding. It emphasizes the strategic and marketing differences characterizing two classes of generators when potential transmission constraints become binding. The labels for these classes are *exploiting* and *exploited* generators. Section 3 examines the economic relationships between the Lerner Index and the type of oligopolistic competition characterizing the spot market for generation. It also contains a review of the theoretically consistent formulas for assessing the degree of market power in this spot market when utility and nonutility generators behave in the posited manner. Section 4 critically appraises the role that empirical study plays in assessing the degree of horizontal market power. Section 5 restates Joskow's approach for assessing market power in the spot market for generation within the context of the Lerner Index and the type of oligopolistic competition expected to characterize this market. Section 6 contains the derivation of the *test statistics* for assessing the degree of horizontal market power in the spot market for generation and Section 7 contains conclusions.

OLIGOPOLISTIC COMPETITION IN THE SPOT MARKET FOR GENERATION

The textbook approaches for modeling oligopolists in competition with each other are to represent their strategic interactions *as if* they are competing myopically. That is, these firms do not recognize any interperiod linkages that are relevant to competition over time. Furthermore, these firms are modeled *as if* they do not and cannot know what other firms have done before they select a competitive strategy. Consequently, market dominance and the first-mover advantage it implies is not part of the market structure underlying the textbook models of oligopolistic competition. In game theoretic terms, that is, oligopolistic competition at the textbook level is modeled as a one-shot simultaneous move noncooperative game.

It may not be readily apparent that a textbook model is applicable to competition in a restructured electricity industry. Therefore in the next several paragraphs, we explain why the two textbook models presented below are appropriate for competition in the spot market for generation.[24] The reasoning lying behind the one-shot game characteristic of these models is presented in the next paragraph. The following paragraphs discuss the reasoning as to why a simultaneous-move game, which also is a characteristic of the models, is appropriate for modeling oligopolistic competition in the spot market for generation.

The "one-shot" characteristic of these models simply means that the utilities and the nonutilities compete in each period as if they learn nothing from their repeated interaction over time. At first blush, this trait of a one-shot game seems to be in direct opposition to the expected behavior in the spot market for generation. Surely, generators of every ilk learn something about each other each time they interact that they can use effectively in the next period's competition for generation customers in the spot market. In fact, it seems noncontroversial to assert that utilities and nonutilities always learn something in period t with probability equal to one that is competitively useful for competition in period $t + 1$. But, the relevant issue is not whether what they learn helps them in period $t + 1$. It is whether they play the *same* game in period $t + 1$ that they played in period t.

What the utilities and nonutilities learn in period $t + 1$ is that they are *not* playing the same game in each subsequent period. They learn that their rivals in the spot market change over time. They learn that long-time rivals tend to change their strategy sets over time in unpredictable directions. They learn that their rivals' payoffs change

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[24] The laws of physics virtually assure the emergence of a spot market for generation in a restructured electricity industry. Consider the inherent tendency toward disequilibrium in a restructured industry that is characterized only by contracts for the sale of electric power of varying durations. These contracts should contain specific contingencies for all possible disruptions to the delivery of electric power because there is no spot market for generation. However, information constraints and weather-related uncertainty prevent the creation of such complete contracts. As a result, the contract market for electric-power sales is continuously threatened with disequilibrium. This disequilibrium can be righted by a spot market for generation.

over time. They trust this knowledge for two reasons. They have objectively observed the entry of new rivals and the exit of old rivals. They cannot ignore that their payoffs and strategy sets have changed over time in a manner they had not predicted. Thus, it is appropriate to model competition in the spot market for generation service as a one-shot game. To model competition in this market in a different manner, it would be necessary to show that the reciprocity relationships that emerge over time among the rival generators converge to behavior persisting independently of the set of rivals, their strategies, and their payoffs.

The "simultaneous-move" characteristic of these models means that the utilities and nonutilities do not know what anyone else has done before they make their own moves in the spot market for generation. It is rational to play in this manner if any utility or nonutility can lock in something of economic value by moving before it actually knows what its rivals have done.[25] However, there is no economic advantage to be gained in the spot market by adopting a "wait-and-see" attitude. There is no second-mover advantage in a spot market, as long as no firm in this market is careful not to divulge its pricing strategy in a manner that provides an economic advantage to rivals. Clearly, no rational utility or nonutility participating in the spot market for generation would want to provide its rivals with a competitive advantage. Consequently, it is appropriate to model competition in the spot market for generation as a simultaneous-move game as long as all of the firms in the market are rational.

Of course, arguments favoring a simultaneous-move game are less compelling when one of the firms dominates the spot market for generation. A "second-mover" advantage exists in this case because it is rational for the nondominant firms to wait in order to observe the move by the dominant firm. For example, suppose the dominant

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[25] Although only indirectly germane to competition in the spot market for generation service, consider contracts for generation services. The successful negotiation of an exclusive contract locks in an economic value, and it prevents a rival from realizing the same benefit from the same firm. As a result, any nonutility generator or utility will attempt to negotiate an exclusive contract with a very large-volume user, even if this firm does not know what its rivals are doing. This does not mean that such a firm would not like to know what its rivals are doing with respect to contract prices, terms, and conditions. It simply means that they do not have to know these things in order to make a move.

firm is a price leader in the strict sense. That is, the dominant firm is the price leader because the nondominant firms know that it can retaliate and harm them more severely if they do not follow the dominant firm's price lead.[26] Under these circumstances, it is rational for the nondominant firms to observe and then react accordingly. In game theoretic terms, it is in the interests of the nondominant firms to adopt a strategy that ensures that its information sets in a pricing game are singletons. Therefore, in order to conclude that it is appropriate to model competition in the spot market for generation as a simultaneous-move game, convincing arguments must be made as to why no firm is apt to dominate this spot market.

A small number of arguments are needed to support the position (if not prove the claim) that nonutilities are nondominant. Nonutilities in general do not have any of the economic advantages of incumbency. Customer inertia does not work in their favor. They must compete vigorously with the utilities for their customers. Learning and transaction costs work against the nonutilities on average. Their customers must deal with new mechanisms for delivering electric power purchased in the spot market and new contingencies concerning the availability and reliability of the supply of power to and from the spot market. Lastly, the rapid diffusion of the nonutilities' generation services in the spot market is hampered by the fact that their facilities are relatively small with respect to the output of electric power. Consequently, it is not very likely that nonutilities will have very much residual electric power to sell in the spot market.

Perhaps surprisingly, only a few arguments are needed to make a plausible case that utilities are not dominant firms in the spot market for generation. By regulatory rule, utilities have to provide open access and comparable service to the nonutilities or the nonutilities' agents. Therefore, any market power over the spot market for generation that a utility might have from its ownership of the bottleneck transmission facilities has been mitigated significantly, if not eliminated entirely. In addition, regulators are

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[26] W. Shepherd and R.J. Graniere, *Dominance, Non-Dominance, and Contestability in a Telecommunications Market: A Critical Assessment*, (Columbus, OH: The National Regulatory Research Institute, 1989).

pushing for independent system operators (ISOs) to take over the day-to-day operation of the transmission systems. Although the utilities are allowed to retain their ownership of transmission facilities, the ISOs are being designed to have no business or organizational ties to the utilities. Therefore, in principle at least, the utilities cannot leverage the vertical integration of the electricity industry and their ownership of bottleneck transmission facilities to their economic advantage in the spot market for generation. In short, the source of a utility's dominance over this spot market has to be something other than its control of access to essential services or bottleneck facilities.

Superior management or superior production technologies could propel a utility to dominance in the spot market for generation. However, utility management teams have not been tested completely in competitive generation markets. In fact, it is easy to conjecture that the utilities' management teams, themselves, do not expect to do too well financially during their transition to the presumptively more competitive nonspot markets for generation, if we are to believe the utilities' claims relating to the magnitude of stranded costs. With respect to production technologies, it is well known that the nonutilities' generation technologies are more cost efficient on average than the utilities' technologies. Therefore, only the much "softer" sources of market dominance, such as customer loyalty, brand recognition, hidden contracting procedures, price discrimination, and large market shares are left to support claims that a utility dominates a spot market for generation.

Customer loyalty and brand recognition are not influences that carry much weight in the spot market for generation. Because the purpose for the spot market is to rectify discrepancies between contract power and the actual quantity demanded of power, the buyers in the spot market are not in the position to hold out for a particular supplier. Hidden contracting is impossible in the spot market. There are no contracts. Price discrimination is difficult to support in a market that exists to resolve a supply deficiency or a weather-related discrepancy between contract power and the actual quantities of power demanded by consumers at a particular point in time. Therefore, only large shares of the spot market for generation service are left as the source of market dominance. It has been noted previously, however, that the presence of a large market share is not sufficient to prove that a firm with this share has market power. Therefore, we have led ourselves to the conclusion that nothing at present is persuasive evidence of dominance of the spot market for generation by a utility.

Cournot and Bertrand competition are the two forms of myopic strategic behavior that we use as models of the spot market for generation. Bertrand competition is a not-too-familiar version of the commonly observed competition in prices. When modeling a market as behaving consistently with Bertrand competition, it is assumed that it is common knowledge among the firms that each is prepared to meet the quantity demanded of its service at the price it quotes for this service. It also is common knowledge that each firm wants to maximize its profits. Finally, it is common knowledge that each firm can achieve its objective only by constructing *rational* pricing strategies because each firm is known to behave rationally. In this context, a rational price strategy is a best reply to the rational strategies of the others. The firms then propose their prices to consumers without any knowledge of what their rivals have proposed to the same consumers. These prices are the firms' pricing strategies, and they are in equilibrium when the i^{th} firm's price is the best reply to the prices proffered by the j^{th} and other firms, and the j^{th} firm's price is the best reply to the prices offered by the i^{th} and other firms, and so on. If the market demand for generation is certain and common knowledge, and these firms have identical constant average costs of production, then market equilibrium is in first-best prices. Consequently, utilities and nonutilities, acting as Bertrand competitors in the spot market for generation, offer a price equal to marginal cost and each price is the same.[27]

Cournot competition examines the strategic interaction among the firms from the perspective of the supply of generation services. When these firms act as Cournot competitors, it is common knowledge that each firm is prepared to accept the market

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[27] R. Gardner, *Games for Business and Economics* (New York: John Wiley & Sons, Inc., 1995), 133.

price for the quantity of generation service that it produces. Identical to the circumstances underlying Bertrand competition, it is common knowledge that each firm wants to maximize its profits. In this context, a rational strategy is measurable in the quantities of generation services that the firms are prepared to offer to consumers. As always, a market equilibrium is achieved when the strategy profile, inducing the market equilibrium, contains only best replies to the rational strategies of others. However, the equilibrium achieved by Cournot competitors is not necessarily the same equilibrium realized under Bertrand competition. Whereas the Bertrand equilibrium for constant-cost firms always is an equilibrium in first-best prices, the Cournot equilibrium for constant-cost firms does not have to be in first-best prices. That is, the equilibrium price under Cournot competition can be greater than marginal cost. Consequently, utilities and nonutilities, acting as Cournot competitors, may earn above-normal profits in the spot market for generation.[28]

The next modeling step is to lay a foundation for the co-existence of utilities and nonutilities in the spot market for generation by cataloguing some of the causes and effects of restructuring the electricity industry. It is undeniable that many utilities are losing customers and contract sales to nonutility generators. As far as the utilities are concerned, both effects of industry restructuring either release generation resources for other uses or strand them. One of the other uses is an increased capability to make sales in the spot market for generation. Meanwhile, nonutility generators competing with the utilities generally produce in the range of the upward-sloping, average-cost, and marginal-cost segments of their cost functions.[29] Hence, they are in the position to gain economically by offering their residual (i.e., noncontracted for) electric power for sale in spot markets at prices that are greater than or equal to their short-run marginal cost. The spot market for generation is apt to offer economic opportunities of this nature for low-cost nonutilities, and if so, then the open access rules go a long way

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[28] Ibid., 119-124.

[29] Thompson et al., *Economies of Scale and Vertical Integration*, ii.

toward assuring its efficient delivery. Therefore, the odds are in favor of the spot market containing some nonutility generators.

The final modeling step is specifying the strategic behavior between utilities and nonutilities, utilities and other utilities, and nonutilities and other nonutilities. As we have shown already, the spot market for generation has characteristics that point toward either Bertrand or Cournot competition. However, there are characteristics associated with the larger electricity industry that suggest that only one of these simple models is most correct with respect to modeling the spot market for generation. Immediately following, we discuss two of these characteristics. The first is how the lumpiness of investments in generation affects their availability for the spot market as the electricity industry is restructured. The second is how transmission constraints alter the flow of electric power into the spot market for generation.

Investment in generation facilities is lumpy because nonutilities and the utilities alike have to select their "raw" generation capacity levels prior to their sales of electric power in the contract market for generation services. Capacity levels obviously affect the "raw" availability of electric power in the spot market. To show this, assume that utility and nonutility generators have not committed large percentages of their raw capacity to contract sales. Then both sets of generators have large percentages of "raw" capacity available for sale in the spot market. The converse naturally is true if these competing firms have committed large percentages of their capacity to contract sales. In either case, that is, regardless of whether they are long or short in generation capacity, these firms are in the position to choose to bid specific prices for their residual electric power and let their quantities adjust to these prices in an effort to bring their unused residual raw capacity into service. Consequently, lumpy generation investment pushes the modeling of the spot market for generation toward Bertrand competition. On the other hand, transmission realities constrain the competing utility and nonutility generators from bringing their residual raw capacity into service at will. The uncertainty accompanying the location of transmission constraints suggests that utilities and nonutilities can choose to compete in quantities and let the spot price adjust to their quantity bids. Therefore, transmission constraints push the modeling effort toward Cournot competition.

Fortunately, there is a middle modeling ground between Bertrand competition and Cournot competition that does not involve the assumption of market dominance. The utility and nonutility generators can commit privately to quantities of residual electric power for sale in the spot market for generation and then behave publicly as Bertrand competitors. Both types of firms are capable of making such a commitment because they already know how much of their generation capacity is under contract to wholesale and retail buyers before they have to offer electric power for sale in the spot market. The economic implications of this behavior have been studied under assumptions of demand certainty and uncertainty. Kreps and Scheinkman analyzed price competition with precommitted quantities when the demand schedule for electric power is certain and common knowledge.[30] They discovered that firms competing under these conditions settle in equilibrium on market prices that correspond to those obtained under Cournot competition. Klemperer and Meyers extended the analysis to include an uncertain demand for electric power, and they discovered that it is profitable for these firms to move away from the Cournot equilibrium and towards a Nash equilibrium that is described in terms of an upward-sloping market-supply schedule.[31] Because of the long-term unpredictability of weather, it would appear that the spot market for generation is best modeled by Klemperer's and Meyers' supply-function equilibrium.

A supply-function equilibrium for the spot market for generation is a consistent set of equilibrium spot prices that vary with changes in the supply of electric power to the spot market. Thus, a supply-function equilibrium for this spot market is constructed from the equilibrium behavior of those utility and nonutility generators who actually

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[30] D.M. Kreps and J.A. Scheinkman, "Quantity Precommitment and Bertrand Competition Yield Cournot Outcomes," *Rand Journal of Economics* Vol. 14, No. 2 (1983): 326-337.

[31] P.D. Klemperer and M.A. Meyers, "Supply Function Equilibria in Oligopoly under Uncertainty," *Econometrica* Vol. 57, No. 6 (1989): 1243-1277.

commit electric power for sale in the spot market. However, in order to be able to commit electric power for sale in the spot market, these firms must be certain of the *maximum* quantities demanded of their power as a result of contracts. But at the same time, they can never be certain that they always will be able to deliver their contract services to their wholesale and retail customers. The threat of transmission constraints creates a potential disconnection between the quantities of contract power actually delivered and the quantities of contract power actually sold. Therefore, it is inevitable that some of the utility and nonutility generators participating in the spot market for generation will find themselves with residual electric power when a transmission constraint is binding as compared to when it is not binding.

Given the inevitability that transmission constraints create a surplus of residual electric power on one side of the constraints and a deficit of residual electric power on the other side of these constraints, an important policy issue is whether utility and nonutility generators exploit these transmission constraints to their benefit in the spot market for generation. Borenstein et al. conclude that transmission constraints can be profitably exploited in the spot market for generation, but successful exploitation is dependent on the existence of known information pertaining to the competing generators' elasticities of demand, their capacities, and their cost schedules.[32] Hogan considers precisely this situation when simulating the behavior of a dominant generator facing a competitive fringe. Because the simulation is prewired to the model of a dominant firm and a competitive fringe, the firm modeled as dominant always is in control of its destiny regardless of whether transmission constraints are or are not present. Since a dominant firm controls its destiny, it possesses the market power to select at will the quantity of electric power that flows over a constrained transmission line when a transmission constraint is present. Hogan's simulations show that a dominant firm can exploit a transmission constraint by *increasing* the quantity of

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[32] S. Borenstein, J. Bushnell, E. Kahn, and S. Stoft, "Market Power in California Electricity Markets," mimeo., University of California Energy Institute, Berkeley, California, March 18, 1996, 16.

residual electric power it sells in the spot market, which causes as a consequence a contemporaneous decrease in the amount of residual electric power sold by the competitive fringe.[33]

However, the dominant firm/competitive fringe model is not necessarily the correct choice for modeling the spot market for generation services. A plausible case has been argued above that this spot market is not dominated by a utility or nonutility generator. On these grounds, it still is an open market-power issue whether one or more competitors in the spot market for generation can exploit transmission constraints for their own economic benefits. In the next section, the possibility of the exploitation of the spot market for generation by nondominant generation is established by comparing the market conditions that exist when transmission constraints are and are not present.

EXPLOITATION OF THE SPOT MARKET FOR GENERATION

Before delving more deeply into the possible exploitation of the spot market for generation by utility and nonutility generators that are not dominant, it is necessary to carefully describe the potential structural effects of transmission constraints on the operation of this spot market and remind ourselves of their origin. It is perhaps most effective and efficient to take up the second task first. Throughout this analysis it has been emphasized that the long-term unpredictability of weather is the primary origin of transmission constraints. An unanticipated weather pattern induces an unpredicted pattern in the quantities demanded of electric power, which in turn introduces a random shock to the transmission system. This shock is either effortlessly accommodated by the transmission system with the result that potential transmission constraints remain just that, or it cannot be absorbed with the result that potential transmission constraints becomes actual transmission constraints and hence binding transmission constraints.

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[33] W.W. Hogan, "A Market Power Model with Strategic Interaction in Electricity Networks," mimeo., Center for Business and Government, John F. Kennedy School of Government, Harvard University, February 1997, 21.

The preceding explanation of the origin of transmission constraints indicates that the locations of actual transmission constraints are not known with certainty, while the locations of potential transmission constraints are predictable in the usual way. That is, the locations of potential transmission constraints are determined by inductive reasoning using the histories of past occurrences of actual transmission constraints. However, these histories cannot rule out the emergence of actual transmission constraints at new locations as the pattern of the quantities demanded of electric power change over time. As a result, every transmission system has one or more "hidden" actual transmission constraints just waiting to emerge on the shoulders of forces beyond the control of the utility and nonutility generators.[34] Therefore, no one entity or set of forces places transmission constraints at particular locations within the transmission system.

Although actual transmission constraints emerge and submerge depending on the quantities demanded of electric power, this fact alone is not sufficient to conclude that a vertically integrated nondominant utility cannot manage and operate a transmission system for its own economic benefit. In fact, it is undeniable that at the time they were constructed every transmission system favored the utility because there were no nonutility generators with transmission needs that had to be accounted for during the design of transmission systems. This institutional fact affects the pace of industry restructuring. For some time after the restructuring of the electricity industry, the owners of transmission systems, whoever they might be, will have to address the transmission needs of nonutility generators in an *ad hoc* manner until they can reconfigure their transmission systems in a manner that effectively and fairly implements open transmission access. Consequently, there is more than sufficient reason to believe that a vertically integrated utility, owning and operating transmission systems, could favor its own generation facilities for some period of time.

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[34] Of course, actions can be taken to reduce the number of potential transmission constraints by adding more transmission facilities or by attempting to alter consumption patterns.

As noted previously, the FERC has considered the strategic manipulation of the transmission system with respect to the sale of electric power to wholesalers. To mitigate the market power that the vertical integration of the electricity industry confers on the operator of the transmission system, it has encouraged the formation of ISOs to handle the day-to-day operation of transmission systems. ISOs being corporately unrelated to utilities reduce the probability that utilities with large investments in generation capacity will be able to strategically limit the availability of transmission capacity. Recall in Hogan's simulation of the exploitation of the spot market for generation that the dominant firm did not take any actions that actually lowered the total amount of transmission capacity. It simply increased its production of electric power because its market dominance allows it to "crowd out" the production of the competitive fringe throughout the transmission system and not just on the constrained transmission line. Presumably, this crowding-out effect is achievable because the dominant utility owns and operates the transmission system.[35]

We are now in the position to discuss the potential effects of transmission constraints on the electric power spot market. We embed these constraints in a nondominated but vertically integrated electricity industry. We chose this modeling approach because ISOs are assumed to manage and operate transmission systems on a day-to-day basis. Consequently, vertically structured utilities cannot use their ownership of bottleneck transmission facilities to dominate the industry. However, within this framework, unregulated ISOs can control the economics of the restructured electricity industry because they are in the position to extract any economic rents from the upstream generation oligopoly and the downstream wholesale and retail

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[35] The production of aluminum is the prototypical structure for market dominance when a single firm produces aluminum and controls the supply of bauxite, which is the raw material essential to the production of aluminum. Such a firm is not concerned with the competitive decisions of the other aluminum companies because it can thwart and impede their decisions simply by withholding the supply of bauxite. Meanwhile, the other aluminum companies can do nothing to this firm because they cannot stop this firm from producing as much aluminum as it desires.

oligopolies.[36] Thus, we choose to regulate the ISOs, which means that regulators would be solely responsible for using the ISOs to extract these rents for public-policy purposes.[37] Because regulators are part of our structural framework for the electricity industry, the ISOs' market power in relation to the market power that utility and nonutility generators may use against consumers is that regulators may not allow the utility and nonutility generators to retain the fruits of their exercise of market power.[38]

Our structural framework also allows for transmission rights for utility and nonutility generators, but it is important to note that these rights do not shield their holders from the effects of transmission constraints. To make this point, consider power pools that continuously import electric power into the pool and export electric power from the pool. Now imagine, utility and nonutility generators exporting electric power to other markets and selling directly to wholesalers, retailers, and direct-access customers within the pools' geographic boundaries. In addition, imagine that the retail, wholesale, and direct-access customers are able to import electric power for their use from other geographic markets. We designate such a market as *open*. Now, we introduce two transmission constraints to an open market. We let the first constraint prevent the exportation and importation of electric power. We let the second constraint

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[36] Wholesale power is resold to other wholesalers, retailers, and direct-access customers. When wholesale power is resold to other wholesalers, it is eventually resold to retailers, who then combine it with other inputs to produce the retail electricity services that are sold to industrial, commercial, and residential customers. Hence, the production of wholesale power requires only generation and transmission services, whereas the production of direct-access electricity requires generation, transmission, and distribution services. Finally, the production of retail electricity requires generation, transmission, distribution, and retailing services.

[37] R.J. Graniere, "Fair Recovery of Stranded Costs and the Parity-Pricing Rule," NRRI Working Paper, December 12, 1997.

[38] In theory, there is a residual threat that an ISO will exercise its market power against its owner's rivals. If the criteria for staffing an ISO are too lax, the managers and operators of the ISO may have lingering loyalties to the transmission owner. In fact, these loyalties may be more than lingering if personnel are assigned to the ISO on the basis of rotation from the company owning the transmission facilities.

restrict the north to south flow of electric power within the geographic boundaries of the market. The first constraint frees some transmission within the power pool without regard to transmission rights. The second constraint restricts the use of transmission rights on the south side of the transmission constraint that are owned by nonutility and utility generators on the north side of the constraint. Consequently, the possession of transmission rights for transmission facilities on the south side of the constraint does not guarantee that north-side generators holding these rights are able to sell their electric power on the south side.

When combined, the first and second transmission constraints are the foundation used to construct four types of spot markets for generation under the critical and essential assumption that the geographic boundaries for the *open market* are determined politically. Recall that our definition of an open market rests on the importation and exportation of electric power by generators and consumers *within* the market's geographic boundaries. Such actions are not possible in the sense that they are meaningless when the geographic boundaries of an open market are established by expanding these boundaries until exporting and importing electric power is no longer economic. However, significant and perhaps irresolvable problems of regulatory jurisdiction are raised when this approach is used to set geographic boundaries for an electric-power market. As a result, we choose to model the process of setting geographic boundaries for an electric-power market and hence the spot market as primarily political in the sense that regulatory jurisdictions choose to cooperate with each other. Consequently, it may be possible for utility and nonutility generators to profitably export electric power and for wholesalers, retailers, and direct-access customers to profitably import electric power under our definition of an open market.

Our first transmission-constrained spot market consists of utility and nonutility generators exporting their electric power and selling to wholesalers, retailers, and direct-access customers within the open market's geographic boundaries, while transmission constraints prevent these consumers from importing electric power for their own use. We designate this market configuration as *an open-closed market*, where the geographic market boundaries are open for utility and nonutility generators but closed for wholesalers, retailers, and direct-access customers. In this case, the spot markets for generation are different for generators and consumers. Utility and nonutility generators are in the positions to sell into their own spot market and export to other spot markets lying beyond the cooperatively set geographic boundaries, whereas the consumers buy only from their own smaller spot market. The second transmission-constrained market consists of generators selling to wholesalers, retailers, and direct-access customers within the geographic boundaries of the open market and not exporting beyond these boundaries, while the wholesalers, retailers, and direct-access customers are able to import electric power from beyond these boundaries. We designate this market configuration as a *closed-open market* — the market closed for generators and open to consumers. In this case, it is the utility and nonutility generators who participate in the smaller geographic spot market for generation.

The third transmission-constrained market consists of utility and nonutility generators selling only to wholesalers, retailers, and direct-access customers within the geographic boundaries of the open market, and these consumers buying only from the nonutility and utility generators within the boundaries defining the extent of their open market for electric power. We designate this configuration to be the *closed* market. Its distinguishing characteristic, as compared to other transmission-constrained markets, is that the transmission constraints restrict both generators and consumers to the confines of politically set market boundaries. The fourth transmission-constrained market is designated as *super closed*. On the one hand, it consists of utility and nonutility generators who are restricted with respect to the sale of electric power to wholesalers, retailers, or direct-access customers within the geographic boundaries of the open market. On the other hand, it contains consumers who cannot buy from any utility or nonutility generator within the politically determined boundaries of an open market. In other words, not every generator can sell to every consumers, and not every consumer can buy from every generator. In addition, transmission constraints prevent the utility and nonutility generators from exporting electric power beyond the geographic boundaries of the open market. Finally, consumers are prevented from importing electric power by the same transmission constraints.

Perhaps a useful conceptualization of a super-closed spot market is to imagine the creation of multiple spot markets within the politically set boundaries of an open market. Toward this end, imagine the construction of the former Berlin Wall that separated the Berlin of the former West Germany from the Berlin of the former East Germany. Such a wall would divide our open market into two halves. Now, imagine the construction of the Great Wall of China along the politically set geographic boundaries of our open market. This wall stops foreigners from impinging on the market power of producers and the sovereignty of consumers within our open market. That is, the Great Wall of China is an entry barrier sealing off the open market and also instigating a dominant directional flow of electricity from say west to east. Meanwhile, the Berlin Wall is an endogenous transmission constraint arising within the sealed-off open market that disrupts the west-to-east (net) flow of electric power. As a result, the utility and nonutility generators on the west side of the Berlin Wall cannot sell all the electric power they want to sell to the consumers on the east side of the Berlin Wall. Consequently, consumers on the east side of the Wall find it necessary to reduce their consumption of electric power or to replace the power from the west with electric power from utility and nonutility generators located in the east.

Per our definitions, the super-closing of any open spot market for generation alters the distribution of market power within the confines of politically set geographic boundaries. The transmission constraint reduces the market power of utility and nonutility generators on its west side and increases the market power of generators on the east side in the preceding example.[39] The west-side generators have lost some of their sales because they cannot deliver power to some or all of their east-side consumers, but their capability to generate electric power is unaltered. Meanwhile, the

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[39] A change in the distribution of market power as a result of a transmission constraint also can occur in the closed and open-closed markets. It does not apply to the closed-open spot market because only the generators are at a disadvantage under the conditions of this transmission-constrained market.

same transmission constraint increases the demand for east-side generation, which increases the market power of the east-side generators. *This change in the distribution of market power may be described as the exploitation of the west-side generators and the east-side consumers.* It is therefore natural on the one hand to designate the west-side generators as the *exploited* generators, which means that they are on the side of the transmission constraint that prevents them from sending some or all of their generation service to the east side. On the other hand, it is natural to designate east-side generators as *exploiting* generators because they are in the position to raise the price for electric power sold to east-side consumers as long as the transmission constraint is in existence.

It is important to note that in the preceding example of an altered distribution of market power the emergence of an actual transmission constraint did not create a dominant utility or nonutility generator. Hence, we do not envisage a transmission constraint as establishing a "first-mover" advantage of any type for any generator on either side of the constraint.[40] Instead, the inevitability of a transmission constraint assures the existence of exploited generators on the west side of the constraint and exploited consumers on the east side of the transmission constraint. The exploited generators have to reduce their production of power in the interests of keeping the electric-power system operable, and typically, reduced production is the first step toward lower profits. Meanwhile, the exploiting generators are able to cash in on the network congestion that is created by these transmission constraints by raising the spot price paid by the *exploited* wholesalers, retailers, and direct-access customers.

The virtual guarantee of a constrained transmission system suggests a way to measure horizontal market power in generation by modeling the pricing behavior and production choices of exploiting and exploited generators differently. It is important to

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[40] If anything, a transmission constraint in our model can cause a loss in the scope of market dominance. To show this, assume there is a utility generator that dominates the open market and is located on the west-side (losing side) of an actual transmission constraint. This generator still dominates the west side of the super-closed spot market, but it cannot dominate the east side of this market. Hence, none of the generators on the east side of this market are members of a competitive fringe.

re-emphasize at this time what happens in our example to the spot market for generation after the emergence of an actual transmission constraint. The spot market associated with an open market is divided into two super-closed spot markets with one market on the east side of the constraint and the other spot market on the west side. At the same time, the transmission constraints cause the utility and nonutility generators to separate into a set of exploited generators and a set of exploiting generators. All of the exploited generators are found on the west side of the constraint, and all of the exploiting generators are located on the constraint's east side. Finally, the emergence of actual transmission constraints substantially reduces the spot-market competition between exploited and exploiting generators because the two sets of generators now restrict their competitive efforts primarily to their own super-closed spot markets. In summary then, utility and nonutility generators do not warrant the designations of exploited and exploiting generators each day of the year. These designations come into play only when transmission constraints are in force. The utility and nonutility are equals during all other moments of the year when their spot market is open.

The fleeting nature of exploited and exploiting generators indicates that transmission constraints do not induce market dominance in this model. It is misleading therefore to argue that exploiting generators manipulate transmission constraints by increasing their production as does Hogan's dominant firm or withholding production as does Newbery's oligopolists.[41] The proper perspective in the context of our model is that exploiting generators are able to benefit economically from actual transmission constraints because these phenomena increase the demand for the electric power in their own super-closed spot market. Another proper perspective is that the division of the open spot market for generation allows an exploiting generator to be considered

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[41] Cardell, Hitt, and Hogan, "Market Power and Strategic Interaction," Fig. 3, p. 9; Fig. 4, p. 14; and Fig. 5, p. 16.

only with the behavior of other exploiting generators and similarly for exploited generators.

We are now positioned to begin modeling the pricing behavior and production choices of exploiting and exploited generators. We note first that the cost of installing new electric-power capacity is very large relative to the marginal cost of producing electric power. We also know that firms operating under these cost conditions and competing in an efficient secondary spot market will behave as Cournot competitors when they select their production capacity before they choose their prices, if they know their demand schedules with certainty.[42] If we assume that actual transmission constraints cause the exploiting generators to know their demands for spot generation with certainty, then Cournot competition is the proper modeling choice for these firms. If we assume alternatively that transmission constraints cause additional demand uncertainty for the exploited generators, then a reasonable modeling choice is the supply-function (Nash) equilibrium with the attendant heightened interest among these firms as to how they expect their competitors to react to their capacity choices.

LERNER INDICES AND SPOT MARKETS FOR GENERATION

We begin this section, which lays the groundwork for our measures of market power for super-closed spot markets for generation, by recalling the well-established conclusion that an *individual* Lerner Index is an appropriate measure of a firm's market power. Now turning to exploiting generators, it is clear in the context of our model of spot-market competition that such generators, competing in their own super-closed spot

[42] M. Beckman, "Edgeworth-Bertrand Duopoly Revisited," in R. Henn, ed., *Operations Research-Verfahren, Vol. III* (Meisenheim, GR, Verlag Anton Hein, 1967); R. Levitan and M. Shubik, "Price Duopoly and Capacity Constraints," *International Economic Review* Vol. 13, (February 1972): 111-122.

market by committing capacity and then choosing spot-market bids, are not properly modeled as traditional Cournot competitors. Transmission constraints, in and of themselves, cannot make these firms certain of their market demand, even over the short time period that these constraints are expected to be in force. Instead, the competitive circumstances of the exploiting generators are structurally the same as the competitive circumstances of exploited generators and generators competing in the open spot market for generation. All three types of generators, competing as they do in capacity commitments and spot-market bids, know that their competitors will respond to their production decisions. Cowling and Waterson recognize this difference by appending a "conjectural variation" to the individual Lerner Index for a traditional Cournot competitor, thereby creating an *ad hoc* measure of the individual market power for exploiting and exploited generators who surely must know that their competitors will respond to their capacity commitments and their subsequent choices of spot-market bids.[43] That is, $L_i = (\alpha_i/\varepsilon)(1 + \lambda_i)$, where λ_i is the conjectural variation for the i^{th} exploited generator, $L_i = (P - MC_i) / P$, $\alpha_i \equiv q_i / \sum q_i = q_i / Q$, $\varepsilon \equiv -[(\partial Q/\partial P)][P/Q]$, $\partial Q/\partial P \leq 0$. In our model, this conjectural variation captures the i^{th} generator's beliefs about how its capacity commitments affect the spot-market bids of other generators.

Although individual measures of market power are apt to be the focal points of most regulatory analyses of the restructuring of the electricity industry, there will be times when regulators are worried about the threat of formal or informal price coordination among utility and nonutility generators. Whenever price coordination is a concern, regulators need measures of the *collective* market power of generators as they compete in the open or their respective super-closed spot markets. Kwoka's work on *market* Lerner indices is useful in this regard. In particular, he has derived a market

[43] K. Cowling and M. Waterson, "Price-Cost Margins and Market Structure," *Econometrica* (May 1976): 267-274.

Lerner Index that is applicable to generators who know that their competitors will respond to their capacity commitments and subsequent choices of spot-market bids. He begins his derivation by adopting Cowling's and Waterson's specification of an individual Lerner Index for a Cournot competitor that is not oblivious to the effect of its capacity commitments on its competitors, which is $L_i = (\alpha_i/\varepsilon)(1 + \lambda_i)$. Using market shares as weights and assuming the elasticity of demand for the market in question is constant, Kwoka derives a market Lerner Index from $L_i = (\alpha_i/\varepsilon)(1 + \lambda_i)$, which is $L = \sum \alpha_i[(\alpha_i/\varepsilon)(1 + \lambda_i)] = \sum \alpha_i^2/\varepsilon + \sum \alpha_i^2\lambda_i/\varepsilon = 1/\varepsilon\,(HHI + \sum\lambda_i\alpha_i^2)$.[44] In other words, the measure of *collective* market power for a spot market is related directly to the HHI and an interaction term involving the generators' conjectural variations and their market shares. If all the generators' conjectural variations are assumed to be negative, $\lambda_i < 0$, which indicates that each generator believes that each of its competitors' spot-market bids will deviate less from their marginal costs when it increases its capacity commitment to the spot market for generation, then the measure of collective market power for a spot market is negative, if $\sum\lambda_j\alpha_j^2 < -$ HHI.[45]

ROLE OF EMPIRICAL STUDIES

Simply stated, formulas for measuring market power are worthless without empirical studies to provide estimates of the parameters. Consider our collective market-power formula, which is $L = 1/\varepsilon\,(HHI + \sum\lambda_i\alpha_i^2)$. Someone has to determine the market share of each generator. Someone has to estimate the market elasticity of

[44] Kwoka, Jr., "The Herfindahl Index in Theory and Practice," 915-947.

[45] The market power of an exploited generator can be very small and even negative. Using the Cowling-Waterson formula, the firm-specific measure of market power for an exploited generator is negative when $\lambda_j < -1$, and j denotes an exploited generator.

demand for generation in the spot market.[46] Someone has to determine the geographic boundaries of the spot market. Lastly, someone has to estimate the value of the i^{th} conjectural variation, λ_i. But, the estimation of λ_i is not a trivial task because its value is dependent on the generator's beliefs about how its capacity commitments will affect the spot-market bids of the other generators.

It is readily apparent from our individual and collective measures of market power for generators that *intraindustry* studies using time series data are best suited for our purpose, which is to estimate the gap between the spot price and marginal cost. This time consider the formula for the individual market power of exploiting and exploited generators, which is $L_i = \alpha_i/\varepsilon(1 + \lambda_i)$. A linear estimating equation for $L_i = \alpha_i/\varepsilon(1 + \lambda_i)$ is $\ln L_i = \beta_1 \ln \alpha_i - \beta_2 \ln \varepsilon + \beta_3 \ln \lambda_i - \beta_2 \ln \varepsilon = \beta_1 \ln \alpha_i + \beta_3 \ln \lambda_i - 2\beta_2 \ln \varepsilon$, where ln denotes a natural logarithm. Unfortunately, there are only a few *intraindustry* studies of market power using market shares and demand elasticities because of the past dominance of *interindustry* studies in this research area, which used a four-firm concentration ratio (CR-4) and subsequently the Herfindahl-Hirschman Index (HHI).[47] However, the results contained in the initial *intraindustry* studies are promising for the measurement of market power at the individual and collective levels, even if they appear to be contrary to popular notions of market power.

There is evidence from one *intraindustry* study that large companies exert a pro-competitive influence on an industry when they are in the company of even larger

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[46] It is necessary to estimate only the own-price elasticity for electric power. Estimation of cross-price elasticities is not required because each generator is assumed to produce an identical service that is neither a substitute for nor a complement to another form of energy.

[47] During the heyday of the CR-4, some empirical evidence surfaced that pointed toward caution when using it to draw generalized conclusions about market power. The evidence is that a strong association exists between a firm's profits and its own market share, while a strong association does not exist between a firm's profits and the combined shares of the leading group of firms. See, W.G. Shepherd, "The Elements of Market Structure," *Review of Economics and Statistics* Vol. 54 (1972): 25-37, and W.G. Shepherd, *Treatment of Market Power* (New York: Columbia University Press, 1975), Ch. 4.

companies. It was reported that the firm with the third largest market share appears to depress industry profits, while simultaneously the firms with the first and second largest market shares tend to be associated with higher industry profits.[48] Another *intraindustry* empirical study suggests that the firm with the fourth largest market share in the industry has a pro-competitive influence on industry profits when the firms with the three largest market shares are statistically associated with higher industry profits.[49] These few pieces of empirical evidence hint that tests for market power at the individual and collective levels can be supported by *intraindustry* studies of the statistical association between profits and individual market shares.

Perhaps the difficulty of the required *intraindustry* empirical studies, especially with respect to obtaining raw data on conjectural variations, is the reason why *ad hoc* approaches are used to suggest the presence of market power at the individual and collective levels. Joskow, for example, proposes to measure horizontal market power in generation using three tests involving only the HHI and individual market shares.[50] He argues that each test is sufficient for classifying a generator or group of generators as being either at high-risk or a low-risk of collectively or individually exercising market power in the (open) spot market for generation. However, these pieces of data are not sufficient for this purpose in our model of market power. Recall that in addition to Joskow's data, we also need the market elasticity of demand to estimate individual and collective market power in an open spot market. As a result, an assessment of Joskow's battery of tests may prove to be enlightening.

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[48] J.E. Kwoka, Jr., "The Effect of Market Share Distribution on Industry Performance," *Review of Economics and Statistics* Vol. 61 (1970): 101-109.

[49] R. McF. Lamm, "Prices and Concentration in the Food Retailing Industry," *Journal of Industrial Economics* Vol. 30 (1981): 67-78.

[50] Joskow, "Horizontal Market Power," 7-9.

JOSKOW'S APPROACH TO HORIZONTAL MARKET POWER IN GENERATION

Joskow's approach to collective market power is that it can be exercised only through collusive activity. A generally accepted theoretical result from this perspective is that collective market power is not exercised when profit-maximizing firms are observed to earn only the competitive rate of return on their investments. The reasoning underlying this result is that these firms would choose collusively to reduce their output, if the expected outcome of this behavior is an increase in each oligopolist's individual profitability. Thus, Joskow proposes that an (open spot) market is at low risk in terms of the exercise of collective market power (i.e., collusion) when this market's HHI $\leq .25$, where $0 \leq \text{HHI} \leq 1$.[51]

An open spot market for generation is analogous to the economic conditions encountered by exploited generators when they compete in their super-closed spot market. Because electric power can be imported and exported and the directional flow of net electric power is unimpeded by transmission constraints, each utility and nonutility generator competing in an open spot market has to be aware of how its capacity commitment to this market affects the spot-market bids of the other generators. Thus, per our model of market power, the market Lerner Index for an open spot market needs to be very close to zero when its HHI is less than or equal to .25.

The market Lerner Index for utility and nonutility generators competing in an open spot market for generation is $L = 1/\varepsilon\ (\text{HHI} + \sum\lambda_i\alpha_i^2)$. The maximum value of L cannot be achieved without realizing the maximum value of the market's HHI, the maximum value of $\sum\lambda_i\alpha_i^2$, and the minimum value of ε. Per Joskow's test, the maximum value for the HHI is .25 when addressing the potential for collusion. However, we know nothing from Joskow about the minimum value of ε and the maximum value of $\sum\lambda_i\alpha_i^2$.

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[51] Joskow justifies this particular value for the HHI by recalling that the U.S. Department of Justice chose it when it considered the deregulation of oil pipelines. Ibid., 8.

In fact, we do not even know if the elasticity of demand for the market is $\varepsilon = 1$, $\varepsilon < 1$, or $\varepsilon > 1$.

When $\varepsilon = 1$, $max\ L = max\ HHI + max \sum \lambda_i \alpha_i^2 = .25 + max \sum \lambda_i \alpha_i^2$. If each generator chooses the same price and has the same marginal cost, then $max\ P = MC/[1 - .25 - max \sum \lambda_i \alpha_i^2]$.[52] If we assume further that the conjectural variation for each of these generators is negative because each generator decreases the margin between its spot-market bid and its marginal costs when its competitors commit more capacity to the spot market, then $max\ P$ approaches $P = MC/[1 - HHI] = MC/.75$ as λ_i approaches zero for all utility and nonutility generators. In other words, an open spot market with an $HHI = .25$ can support a spot price that is 33 percent greater than marginal cost with this price declining as the λ_i's decrease. If $\varepsilon = .75$, then $max\ L = [1/\varepsilon] max\ HHI + [1/\varepsilon] max \sum \lambda_i \alpha_i^2$. Hence, $max\ P = MC/\{[1 - [1/.75][.25] - [1/.75][max \sum \lambda_i \alpha_i^2]\}$. When each generator sets the same price and has the same marginal cost, then $max\ P$ approaches $P = MC/.67$ as all λ_i's approach zero. Thus, this open market can support a price that is approximately 50 percent greater than marginal cost with this price declining as the λ_i's decrease. If $\varepsilon = 1.25$, then $max\ P = MC/\{[1 - [1/1.25][.25] - [1/1.25][max \sum \lambda_i \alpha_i^2]\}$. If each firm sets the same price and has the same marginal cost, then $max\ P$ approaches $P = MC/.80$ as all λ_i's approach zero. Therefore, this open

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[52] If the marginal costs are not necessarily equal across all firms but there is a single market-clearing price, it follows that $L = \sum \alpha_i [(P - MC_i)/P][1 + \lambda_i] = 1/[\alpha_1 MC_1 + \alpha_2 MC_2 + \alpha_3 MC_3 + ... + \alpha_n MC_n] = HHI/\varepsilon$ because $L = HHI/\varepsilon$. Proof: $L = \sum \alpha_i [(P - MC_i)/P][1 + \lambda_i] = \alpha_1 [(P - MC_1)/P][1 + \lambda_1] + \alpha_2 [(P - MC_2)/P][1 + \lambda_2] + \alpha_3 [(P - MC_3)/P][1 + \lambda_3] + ... + \alpha_n [(P - MC_n)/P][1 + \lambda_n]$. Multiplying by P yields: $PL = \alpha_1 (P - MC_1)[1 + \lambda_1] + \alpha_2 (P - MC_2)[1 + \lambda_2] + \alpha_3 (P - MC_3)[1 + \lambda_3] + ... + \alpha_n (P - MC_n)[1 + \lambda_n] = \alpha_1 P[1 + \lambda_1] - \alpha_1 MC_1 [1 + \lambda_1] + \alpha_2 P[1 + \lambda_2] - \alpha_2 MC_2 [1 + \lambda_2] + \alpha_3 P[1 + \lambda_3] - \alpha_3 MC_3 [1 + \lambda_3] + ... + \alpha_n P[1 + \lambda_n] - \alpha_n MC_n [1 + \lambda_n]$. Isolating P yields: $PL - \alpha_1 P [1 + \lambda_1] - \alpha_2 P[1 + \lambda_2] - \alpha_3 P[1 + \lambda_3] - .... - \alpha_n P[1 + \lambda_n] = - \alpha_1 MC_1 [1 + \lambda_1] - \alpha_2 MC_2 [1 + \lambda_2] - \alpha_3 MC_3 [1 + \lambda_3] - .... - \alpha_n MC_n [1 + \lambda_n]$. Factoring out P from the left hand side yields: $P\{L - \alpha_1 [1 + \lambda_1] - \alpha_2 [1 + \lambda_2] - \alpha_3 [1 + \lambda_3] - .... - \alpha_n [1 + \lambda_n]\} = - \alpha_1 MC_1 [1 + \lambda_1] - \alpha_2 MC_2 [1 + \lambda_2] - \alpha_3 MC_3 [1 + \lambda_3] - .... - \alpha_n MC_n [1 + \lambda_n]$. Multiplying by -1 yields: $P\{\alpha_1 [1 + \lambda_1] + \alpha_2 [1 + \lambda_2] + \alpha_3 [1 + \lambda_3] + ... + \alpha_n [1 + \lambda_n] - L\} = \alpha_1 MC_1 [1 + \lambda_1] + \alpha_2 MC_2 [1 + \lambda_2] + \alpha_3 MC_3 [1 + \lambda_3] + ... + \alpha_n MC_n [1 + \lambda_n]$. Collecting terms yields: $P\{ \sum \alpha_i [1 + \lambda_i] - L\} = \sum \alpha_i MC_i [1 + \lambda_i]$. Substituting $\sum \alpha_i = 1$ yields: $P\{1 + \sum \alpha_i \lambda_i - L\} = \sum \alpha_i MC_i [1 + \lambda_i]$. Isolating P yields: $P = \sum \alpha_i MC_i [1 + \lambda_i]/(1 + \sum \alpha_i \lambda_i - L)$. Substituting $L = [1/\varepsilon][HHI + \sum \alpha_i \lambda_i^2]$ yields $P = \sum \alpha_i MC_i [1 + \lambda_i]/(1 + \sum \alpha_i \lambda_i - [1/\varepsilon][HHI + \sum \alpha_i \lambda_i^2])$. Consequently, the market-clearing price can be determined with knowledge of market shares, marginal costs, conjectural variations, and the market's demand elasticity.

spot market can support a price that is 25 percent greater than marginal cost with this price declining as the λ_i's decrease. Consequently, Joskow's test for collective market power provides the utility and nonutility generators with real opportunities to earn above-normal economic profits.

Joskow's test for determining whether a firm is at low risk of the exercise of individual market power is a market share of 20 percent or less.[53] This criterion requires a minimum of five equal-sized companies in the market.[54] In this instance, the HHI is .20. Replicating the preceding analysis, it follows that the *max* P approaches P = MC/[1 - HHI] = MC/.80 as λ_i approaches zero for all utility and nonutility generators when $\varepsilon = 1$ and each company produces at the same marginal cost. Therefore, the maximum supportable price is 25 percent greater than marginal cost. If the market, instead, is characterized by $\varepsilon = .75$, and once again each firm produces at the same marginal cost, then *max* P = MC/{[1 - [1/.75][.20] - [1/.75][*max* $\sum\lambda_i\alpha_i^2$]}. *Max* P approaches P = MC/[1 - (.20/.75)] = MC/[1 - .27] = MC/.73 as all λ_i's approach zero. Thus, the maximum price is 37 percent greater than marginal cost. An appreciable excess of price over marginal cost continues to exist even if $\varepsilon = 1.25$. Since *max* P = MC/{[1 - [1/1.25][.20] - [1/1.25][*max* $\sum\lambda_i\alpha_i^2$]}, *max* P approaches P = MC/[1 - (.20/1.25)] = MC/[1 - .16] = MC/.84 as all λ_i's approach zero. Consequently, this spot market for generation can support a price that is a little more than 19 percent greater than marginal cost. In summary then, Joskow's test for individual market power provides the utility and nonutility generators with real opportunities to earn significant above-normal economic profits, even if there are five equally sized firms in the market.

Joskow's third test also addresses the individual exercise of market power by the larger utility and nonutility generators in the spot market for generation. A generator is

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[53] Joskow's justification for this particular market share is its consistency with the FERC's policies on market-based pricing.

[54] The selection of five equally-sized firms as the market-share structure is not an arbitrary choice. The Lerner Index for the individual firm is the same as the Lerner Index for the market.

classified as being at low risk of individually exercising its market power against consumers when its market share is less than or equal to 35 percent *and* the HHI is less than or equal to .25.[55] Clearly, this test has problems. On the one hand, it has been shown that a utility or nonutility generator with a market share of 20 percent is a threat to consumers when demand elasticities are within the range of .75 to 1.25. On the other hand, an HHI of .25 has been shown to be a credible and unacceptable threat of the collective exercise of market power against consumers.

ALTERNATIVE TESTS FOR HORIZONTAL MARKET POWER

Joskow's battery of tests rests on a battery of analytical and political processes that generate the data necessary for setting the geographic and product boundaries of the spot-market for electric power. In addition to an understanding of the political-jurisdictional requirements, the geographic boundaries for this market are determined by transmission constraints, transportation costs, and entry barriers.[56] Meanwhile, data on the cross-price elasticities of demand are critically important for determining the product boundaries of the spot market for generation because a number of substitutes exists for electric power purchased on the spot market.[57] Some substitutes include self-

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[55] Joskow's justification for selecting a share of 35 percent is that it is below the market-share value commonly used to suggest excessive market power under Section 2 of the Sherman Act.

[56] Transmission constraints are very important in this context. They can intermittently constrain the amount of power entering and exiting "nodes" within a transmission network, thereby creating sub-regions of market power. They also can significantly restrict the amount of power flowing into and out of a geographic area over the long term, thereby creating a market boundary.

[57] A cross-price elasticity measures the percentage change in the quantity demanded of service A that is generated by the percentage change in the price of service B. If, for example, service A is electric power purchased on the spot market and service B is self-generation, then the cross-price elasticity for spot power with respect to self-generation is the percentage change in quantity demanded of spot power that is created by the percentage change in the price of self-generation. Because these two services are substitutes, the resulting cross-price elasticity is positive; that is, an increase in the price of self-generation induces an increase in the quantity demanded of spot power. Conversely, a decrease in the price of self-generation induces a decrease in the quantity demanded of spot power.

generation, load management, demand-side management, natural gas back-up systems for heating and cooling, wood-burning furnaces, and candles. In addition, data on market shares are needed to calculate the spot market's HHI and as benchmarks for some of Joskow's tests. However, Joskow's tests do not require any data on the elasticities of demand and supply for the market. In actuality then, Joskow is not concerned with how the demanded and supplied quantities of spot power react to endogenous changes in spot prices when he is assessing the rent potential for this market.

Our proposed approaches to the measurement of market power in the spot market for generation are certainly more data extensive. In addition to everything required by Joskow, a political-analytical process is required for the purpose of defining and refining the unacceptable level of market power in the spot market for generation as measured by the gap between the spot price and marginal cost.[58] As noted several times above, we need data on actual transmission constraints in order to identify exploiting and exploited generators and the geographic boundaries of the super-closed spot markets. We also need data for the estimation of the utilities' and nonutilities' marginal generation costs and the demand elasticities for an open spot market and super-closed spot market.[59] Finally, we need data that can be used to estimate the utility and nonutility generators' conjectural variations.

Obviously, the estimation of conjectural variations is the most challenging of these tasks. Conjectural variations are not observed directly because they are beliefs

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[58] In the past, federal agencies have used a 5 percent rise in market price above marginal cost as the threshold value for fixing the geographic boundaries of a market. Perhaps a 5 percent margin between the spot price and marginal cost also is appropriate as a *de jure* statistic establishing a credible threat of the collective or individual exercise of market power in the spot market for generation. However, it cannot be forgotten that such a "5-percent statistic" is arbitrary. Therefore, there are practical reasons for wanting a political process to select the value for this statistic.

[59] Since there always are disputes with respect to the measurement of these data, it would be convenient if the market participants could agree on the estimation methods for market shares, costs, and demand elasticities. If such an agreement cannot be reached, then the alternative, as typically is the case, is that the participants fight over estimation methods in a regulatory hearing.

held by utility and nonutility generators dealing the expected actions of their competitors. In our model, the belief deals with expectations of how generators will alter their spot-market bids as a result of the expected actions of their competitors. Our hypothesis is that utility and nonutility generators competing in an open spot market for generation expect their competitors to narrow the gap between their spot-market bids and their marginal costs when they increase their capacity commitments to this market. Our extended hypothesis with respect to conjectural variation is that exploited generators, competing in their super-closed market, will behave exactly the same as all generators competing in an open spot market for generation. Thus, we predict the generators' conjectural variations will be negative.

Still, there is the matter of finding an instrument or instruments that are suitable tools for constructing estimates of the generators' conjectural variations. This is surely a daunting empirical challenge, if we are required per the theory to produce an estimate of each generator's conjectural variation. Fortunately, this challenge can be met and overcome for an open spot market by defining the i^{th} generator's conjectural variation as $\lambda_i^o \equiv 1 - \tau_i^o$, where τ_i^o is the i^{th} generator's elasticity of supply for the open spot market. If $\tau_i^o > 1$, which means the i^{th} generator's supply response to a change in the spot price is *elastic*, then $\lambda_i^o < 0$ as expected.[60] This relationship between τ_i^o and λ_i^o implies that a generator with an elastic response to a change in the spot price has less market power than a generator with an inelastic response in the open market.

Individual elasticities of supply also are instruments for estimating the i^{th} generator's conjectural variation in its particular super-closed market. For this situation, we define a conjectural variation for a super-closed spot market as $\lambda_i^c \equiv 1 - \tau_i^o + (\tau_i^o - \tau_i^c)$, where τ_i^c is the elasticity of supply for this market. We let the expected behavior of

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[60] An elasticity of supply for service A measures the percentage change in the quantity supplied of service A that is generated by the percentage change in the price of service A. An elasticity of supply is designated as elastic, if the percentage change in the quantity supplied is greater than the percentage change in price. An elasticity of supply is designated as inelastic when the percentage change in the quantity supplied is less than the percentage change in price. When the percentage change in the quantity supplied is equal to the percentage change in price, the elasticity of supply is designated as unitary.

λ_i^c be determined by the following three beliefs. The first is an expected negative correlation between market power and the elasticity of supply, which requires that an increase in τ reduces market power. The second is an expected short-term decrease in the exploiting generators' elasticities of supply caused by the emergence of actual transmission constraints. The third is that the exploited generators are expected to experience a short-term increase in their supply elasticities as a result of these same transmission constraints.

It is easily shown that $\lambda_i^c \equiv 1 - \tau_i^o + (\tau_i^o - \tau_i^c) = 1 - \tau_i^c$ conforms to these beliefs. If $\tau_i^o < \tau_i^c$, then $1 - \tau_i^o > 1 - \tau_i^c$. Hence, $\lambda_i^o > \lambda_i^c$. Next, recall that $(1 + \lambda)$ is an adjustment to the individual Lerner Index, and this index increases as λ becomes more positive. Thus, the Lerner Index for a super-closed market is *lower* than the Lerner Index for the open market when transmission constraints cause the elasticity of supply in the super-closed market to be greater than the elasticity of supply in the open market. And, this is the required outcome per our third belief, where we expect the *exploited* generators to experience *increases* in their supply elasticities as a result of transmission constraints. Now for completeness, consider when $\tau_i^o > \tau_i^c$, then $1 - \tau_i^o < 1 - \tau_i^c$. Hence, $\lambda_i^o < \lambda_i^c$. So, the Lerner Index for a super-closed market is *higher* than the Lerner Index for the open market. But, this is the required outcome per our second belief, where we expect the *exploiting* generators to experience *decreases* in their supply elasticities.

We now have the *estimable* parameters necessary for constructing test statistics for collective and individual market power for open and super-closed spot markets for generation. We turn first to the test statistic for collective market power in an open spot market. Per Joskow's approach, the purpose of this statistic is to assess the potential for collusion in this market. Recalling Kwoka's market Lerner Index, $L = \sum \alpha_i L_i$, and rearranging to yield $P = \sum \alpha_i MC_i/(1 - L)$, we can rewrite $P = \sum\alpha_i^o MC_i^o/(1 - [1/\varepsilon^o (HHI^o + \sum\lambda_i^o\alpha_i^2)])$ since $L^o = 1/\varepsilon^o (HHI^o + \sum\lambda_i^o\alpha_i^{o2})$ for the open spot market. Next, $1 - \tau_i^o$ is substituted for λ_i^o to yield $P = \sum\alpha_i^o MC_i^o/(1 - [1/\varepsilon^o (HHI^o + \sum(1 - \tau_i^o)\alpha_i^{o2})])$. Finally, we designate γ as the margin of P over $\sum \alpha_i MC_i$.[61] Then, the test statistic, γ^o, for collective market power for the open spot market for generation is:

$$P = \gamma^o \sum \alpha_i^o MC_i^o,$$

where

$$\gamma^o = 1/(1 - [1/\varepsilon^o (HHI^o + \sum(1 - \tau_i^o)\alpha_i^{o2})]) \qquad (1)$$

The corresponding test statistic, γ_i^o, for the individual exercise of market power in the open spot market for generation is derived from $L_i^o = (1 + \lambda_i^o)(\alpha_i^o/\varepsilon^o)$.

$$\gamma_i^o = 1/(1 - (1 + \lambda_i^o)(\alpha_i^o/\varepsilon^o))$$

$$\gamma_i^o = 1/(1 - (1 + (1 - \tau_i^o)(\alpha_i^o/\varepsilon^o)) \qquad (2)$$

Next, we derive test statistics for collective and individual market power for any super-closed spot market for generation by modifying equations (1) and (2). The necessary modification to (1) and (2) is to substitute $\lambda_i^c = 1 - \tau_i^c$ for $\lambda_i^o = 1 - \tau_i^o$, HHI^c for HHI^o, α_i^c for α_i^o, and ε_i^c for ε_i^o. Hence, we write:

$$\gamma^c = 1/(1 - [1/\varepsilon^c (HHI^c + \sum(1 - \tau_i^c)\alpha_i^{c2})]) \qquad (3)$$

$$\gamma_i^c = 1/(1 - [1 + (1 - \tau_i^c)(\alpha_i^c/\varepsilon^c)]) \qquad (4)$$

Although γ^o, γ_i^o, γ^c, and γ_i^c enable us to sneak a better glimpse of the structure of horizontal market power within spot markets for generation than tests relying on only

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[61] The cost statistic, $\sum \alpha_i MC_i$, suggests that first-best prices are economically viable for the firms in this market. If, however, first-best prices are not economically viable, then the appropriate cost statistic is $\sum \alpha_i AC_i$, where AC_i denotes the firm's average cost.

the Herfindahl Index or market shares, these four test statistics do have obvious shortcomings. Similar to the existing tests for market power, they are best interpreted as providing a first reading of market power. These statistics do not take the passage of time into account, and therefore, they do not capture the effects of technological innovation, availability of new substitute products, and changes in barriers to entry.[62] Furthermore, they ignore the effects of the market's past conduct and performance, and the likelihood of changes in existing market conditions.[63] They severely discount the influence of habits, customs, and beliefs.[64] Finally, they do not shed light on the natures of oligopolistic competition and economic incentives facing the firms and their customers.[65]

CONCLUSIONS

Test statistics have been derived from horizontal market power in open and super-closed spot markets for generation. An open spot market exists whenever transmission constraints are not in force. A super-closed market exists when some transmission constraints prevent the import and export of electric power beyond the spot market's politically and analytically determined geographic boundaries, and other transmission constraints disrupt the directional flow of net electric power within the open spot market's geographic boundaries. Two distinct and separable super-closed spot markets have been associated with the emergence of transmission constraints. The first is the super-closed market for exploited generators, and the second is the super-

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[62] Weinstock, "Using the Herfindahl Index to Measure Concentration," 287, fn. 5.

[63] Weinstock, "Some Little-known Properties," 710.

[64] L.E. Sleuwaegen, R.R. DeBondt, and W.V. Dehandschutter, "The Herfindahl Index and Concentration Ratios Revisited," *The Antitrust Bulletin* (Fall 1989): 625-640.

[65] Borenstein et al., "Market Power in California Electricity Markets," 14.

closed market for exploiting generators. These spot markets have been shown to be distinct and separable from each other and the open spot market for generation whenever transmission constraints cause new elasticities of supply for the super-closed spot markets that differ from the elasticity of supply associated with the open spot market. Therefore, regulators need to be able to reasonably predict how actual transmission constraints divide the open spot market for generation.

The collective and individual horizontal market-power test statistics, γ^o, γ_i^o, γ^c, and γ_i^c, for the open and super-closed spot markets for generation are derivatives of the Lerner Index of monopoly power. The Lerner Index is a compelling measure of horizontal market power in the spot market for generation whenever utility and nonutility generators are able to maximize their profits by raising their prices and restricting their output.