Checking for Market Power in Electricity: The Perils of Price-Cost Margins

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Introduction

Concerns have been expressed around the world that the newly opened electricity markets have failed to be sufficiently competitive. The competitiveness of electricity markets in the U.K. has been questioned almost since their inception.[1] The California electricity market "meltdown" in the summer of 2000 brought with it numerous accusations and analyses of the role that inadequate competition played in creating price spikes and destabilizing the market.[2] Recently, Short and Swan have produced a thoughtful study of market power in the Australian electricity sector.[3] The study is especially valuable for clear and useful displays of bidding data.

There are sound theoretical reasons for believing that electricity markets may be unusually susceptible at times to the exercise of market power, compared to markets for other goods with otherwise similar competitive characteristics, e.g., measures of market concentration. When it comes to the empirical assessment of market power, however, the approach taken in most of the analyses of market power in electricity, rests on a flawed application of a standard measure of market power—the Lerner index, also known as the price-cost margin.[4]

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1 Richard Green and David. Newbery, "Competition in the British Electricity Spot Market," *Journal of Political Economy* 100 (1992): 929-53; John Kwoka, Transforming Power: Lessons from British Electricity Restructuring, *Regulation* 20 (1997), *available at* http://www.cato.org/pubs/regulation/reg20n3e.html.

2 Paul Joskow, "The California Market Meltdown," *New York Times*, Jan. 13, 2001; Severin Borenstein, James. Bushnell and Frank Wolak, "Diagnosing Market Power in California's Deregulated Wholesale Electricity Market," Working Paper PWP-064, University of California Energy Institute (2000); Paul Joskow and Edward. Kahn, "A Quantitative Analysis of Pricing Behavior in California's Wholesale Electricity Market During Summer 2000," Working Paper No. 8157, National Bureau of Economic Research (2001).

3 Christopher Short and Anthony Swan, "Competition in the Australian National Electricity Market," *ABARE Current Issues* (January, 2002).

4 Formally, the Lerner index or price-cost margin is

$$\frac{P - MC}{P},$$

where P is the price and MC is the marginal cost. For a profit-maximizing firm, The Lerner index is typically equal to $1/E$, where E is the elasticity of demand facing the firm.

In a nutshell, the flaw in this measure, as it has been applied in these electricity market studies, arises because "marginal cost" in these price-cost margins is typically the average variable or operating cost of the "last" generator that would be dispatched to meet energy demand.[5] Let us call this the PAVC test, for "price-average variable cost."[6] As we will see, the PAVC standard for competitive pricing would imply that no generator would enter. As Short and Swan put it,

> [Competitive] behavior will give rise to the lowest market price that ensures that all generators are at least compensated for any short-run marginal costs incurred. Under these conditions, the market price would reflect the short run marginal cost of the most expensive generation turbine called to supply into the market.[7]

However, in any market, competitive or not, even this most expensive "marginal" generator has to expect that prices will, on average, cover not just its variable costs but its fixed capital costs as well.[8] If not, it would find entry unprofitable. This can lead in simple cases to prices substantially above average variable costs in peak periods. From that starting point, it is not difficult to imagine enough real-world noise in the form of uncertainty regarding demand, generator outages, and market bids, to arrive at outcomes similar to those found in these studies, without necessarily indicating market power.

The intuition

The primary context in which market power might be exercised is when the industry is facing capacity constraints. In that context, when one is trying to discover what the (short-run) competitive price would be in a market where capacity is limited, one would not compare price to the average variable cost of the marginal plant, or even the next one that might have been brought online. In a simple model where there are only two levels of demand, peak and off-peak, one would predict that the peak price over the long run would equal that highest average variable cost plus the average capacity cost of the plant. The actual level of the on-peak price in the short run would be above or below this value, depending on whether demand was higher or lower than that expected when the unit was constructed.

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[5] See, e.g., Joskow and Kahn, n. 2 *supra* at 5.

[6] Also to be clear, we should note explicitly that the problem is not that marginal or variable cost is increasing within the capacity range of the generator itself. For simplifying purposes here, we can assume that average variable cost (hence marginal cost) is constant within a particular generator, up until it hits its capacity limit.

[7] Short and Swan, n. 3 *supra* at 2. Short and Swan's discussion here is somewhat ambiguous, because just before these sentences, they state that "where marginal costs can increase quickly as demand approaches capacity limits, competitive prices can exceed the marginal cost of producing the required electrical energy." However, they go on to state that prices must be less than "marginal cost of an additional unit of energy from another generator." This is not correct, as we see below.

[8] This point is not new. *See* Robert Dansby, "Capacity Constrained Peak Load Pricing," *Quarterly Journal of Economics* 92 (1978): 387-98, especially 394.

The measurement situation is even worse. Over the life of a peak plant, demand will vary. Some hours the demand will be high; some it will be low. Price will vary with demand, even if firms are price takers, while any measure of cost that one would want to use would remain constant. Consequently, any measure of market power based on a relationship between price and marginal cost will have to fail. A measure does not work if one can get different values while the underlying phenomenon—in this case, failure to act like a price-taker—does not change. Either a price-based measure does not indicate the level of market power in such industries, or one is claiming that peak prices are somehow anticompetitive, and more so as demand rises. Neither conclusion is acceptable.

With demand varying over time, the only way to know if these prices are inappropriately high relative to "marginal cost" would be to compare the discounted present value of revenues received from electricity sales from the unit to the total construction and operation costs of unit. Even if that virtually impossible task could be carried out, it would be impossible to conclude simply on that basis that firms had been acting anticompetitively. They may simply have underestimated demand when they constructed the units in the first place, or there may be regulatory rules that limit plant construction (or expansion).

Studies of market power based on price-cost margins reflect virtually no appreciation of these concerns. Marginal cost is not the average operating cost of the most expensive natural gas plant, based on gas prices, emission permit prices (in parts of the U.S.[9]) and other variable costs. Unless one posits that we have an overbuilt industry, in the sense that the peak plants are destined to lose money, peak plants are going to earn capacity rents.[10]

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[9] Some natural gas power plants in Southern California had to purchase permits, to emit nitrous oxides, a pollutant that contributes to the formation of particulates and ground-level ozone. Because the supply of such permits was fixed to limit nitrous oxide emissions, permit prices rose as electricity prices in California, so too did the permit prices, until regulators stepped in and substituted a fixed price for permits for the supply limitation. Joskow and Kahn, n. 2 *supra*, treat the permit price as an exogenous price which should included in calculating the average variable cost of the marginal gas plant, in estimating their price-cost margin. However, that permit price is not exogenous but endogenous. Even if electricity were being withheld, one would think that the price of nitrous oxide permits would be driven up to the difference between the market price of electricity and the marginal cost of a gas plant, taking into account the marginal emissions of that plant. That Joskow and Kahn find a difference between price and "marginal cost" (actually average variable cost of the marginal plant) even including these permit prices suggests that there is a difference between actual and measured marginal cost that their empirical procedures neglect.

[10] Marginal-cost based tests are not necessarily flawed, but the definition and measurement of marginal cost needs to be made carefully. A marginal plant recovers its capital costs in a competitive market because at some point the marginal costs *within the plant* are increasing. The example in the text—a unit with constant marginal costs within the plant (not across plants!) up to a capacity constraint—is an extreme example of that phenomenon. More generally, one would expect marginal cost to go up as one gets closer to "full capacity," if for no other reason than one may run a greater risk of a breakdown of the unit down the road. If so, those costs would need to be included in a Lerner index to see if prices are inappropriately high. Calculating marginal costs based on fuel prices and average operating and maintenance costs, as is typical in these studies, does not recognize this phenomenon. At peak periods, average variable cost is not a proxy for marginal cost, accurately conceptualized and measured.

Perhaps the best and least fortunate example is that the Federal Energy Regulatory Commission (FERC) has used the "highest average variable costs" standard in setting its wholesale price cap, explicitly saying that it will not allow higher prices so that firm could earn capacity rents.[11] Under such a policy, in the long run no firm would build a peaking plant. Moreover, no firm would enter the industry at all, if the firm with highest operating cost is not allowed to recover its capital expense.

Hotel rooms

To get a feel for the flaw in the PAVC test, let us turn first to a more familiar industry—resort hotels. Imagine that in a seaside town, one can build hotels. The optimal size for a hotel is 100 rooms. Once built, it costs $50/day to maintain a room, including cleaning, electricity, water, and predictable wear-and-tear from usage. The fixed annual capital costs for the hotel are $1,095,000 per year ($30/day/room, for 365 days and 100 rooms). There is no relevant restriction on entry, i.e., if one thinks that one can profitably operate a 100-room hotel in this town, one can build it. To make the example simple, we assume that the firms are acting competitively, i.e., take the going room rate as given in making decisions whether to build a new hotel.

Suppose first that demand to use this resort is roughly the same all year round. In that case, hotels will enter up to the point where the price of a room is $80/day. $50 of that $80 covers the cost of maintaining a room—the average variable cost. $30 of that $80 goes to cover the capital cost of the hotel. At prices above $80, more hotels would be built. If price were forecast to be below $80, say $50, no one would enter. The PAVC test would fail to predict competitive prices in the market.

Next, imagine that demand for hotel rooms at this resort town is seasonal. For three months out of the year, people really want to come to the beach. The rest of the time, demand for rooms is weak. In such a situation, a decision to build a new hotel will be predicated on filling it up during the summer season. Accordingly, the price of hotels in the summer will be $170/day. $50 of this rate is the average variable cost, and $120 is needed to cover the cost of the hotel entirely from summer occupancy.

Because every hotel gets to charge this rate during the summer, not only those hotels built to serve summer clients, they all will capture their capital costs at that time. The price of a room off-season would then be only $50. The PAVC standard would predict off-peak rates, but would fail on-peak rates. Holding hotels to a PAVC standard would mean that not only that none would be built to serve summer visitors to the resort. It would also imply that year-round hotels would be unable to recover their capital costs as well.

There is one case when the PAVC test might be relevant. Suppose interest in visiting this resort fell dramatically after hotels were already built, e.g., because the water

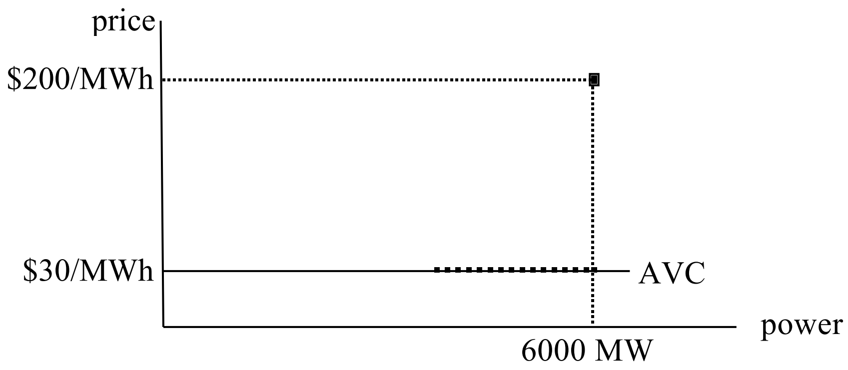
[11] Federal Energy Regulatory Commission, Order on Rehearing of Monitoring and Mitigation Plan for the California Wholesale Electric Markets, Establishing West-Wide Mitigation, and Establishing Settlement Conference, EL00-95-031et.al., issued June 20, 2001.

was found to be unsanitary leading to closed beaches. (This has happened in the U.S.) The hotels could not be "deconstructed," so to speak. Hotels would compete through reduced prices until the hotels already constructed were full at a rate below $170—perhaps visitors want to sit on the beach, and not go in the water—or prices fell to average variable cost, $50. Only if the market had large amounts of excess capacity, defined in terms of the long-run unprofitability of a new entrant, might we expect a PAVC standard to apply.

Back to electricity

Peak-load pricing principles that hold for hotels regarding peak-load pricing hold for electricity as well. We will get to some important complications, but first imagine that there is only one kind of electricity generator with 100 megawatts of capacity, with average variable costs of (say) $30 per megawatt-hour (MWh). Suppose also that of the 8760 hours in a year, demand is at peak for 450 hours, about 2% of the time. Finally, suppose that the fixed annualized costs of building and maintaining the generator is $7.65 million, a figure chosen to come out to $170 per MW per peak hour. (This is also about 30% of the total variable cost of running a plant full out.) For simplicity, again, assume that at off-peak times capacity exceeds the amount of electricity demanded at $30/MWh.

By analogy with the hotel example, the price of electricity would be $30/MWh off peak and $200/MWh ($30 + $170) on peak. Finally, then, assume that during peak periods, the demand for power would be 6000 MWh. Were one to plot what the predicted price of electricity and average variable cost as a function of power demanded, one would then get the following graph:



Already we can see that during peak periods, price will be substantially above average variable cost. However, a number of significant complications must be added to this stylized picture to get a more realistic view of what the competitive supply curve would look like.

#1. If a generator is going to be operated only at peak periods, one would expect that it would have a lower fixed-to-variable cost ratio. Since a peak plant will have only a few hours of operation in which it could cover its capital costs, it will be more economical to use low capital/high variable cost technologies at peak periods, with high capital/low variable costs for baseload plants.[12] Thus, one would expect the average variable cost curve to slope upward to some extent as one approaches industry capacity.

#2. As noted above, the industry could be at peak capacity at different levels of demand. This would produce observed price-quantity points to fill in the vertical line between the peak price of $200/MWh and $30/MWh. The extra profits in these "shoulder" demand periods would induce entry, reducing the maximum peak price in this example. However, the possibility of a super-peak demand, reached on fewer than 5% of all hours, would tend to increase the maximum price. In any event, the supply curve would tend to have a vertical component as well as a horizontal one, forming a backwards "L."

#3. There is a separate set of fixed costs in electricity having to do with the costs of starting up and shutting down a generator altogether. A generator may be constructed, but prices will have to exceed not just average variable costs, but produce enough revenue to cover startup and shutdown costs, before a generator will find it appropriate to meet demand.[13]

#4. Perhaps most importantly, generators operate in an uncertain environment, in at least two important respects. They do not have perfect knowledge as to what demand will be at a given time. Neither need they know how many of their competitors' generators will be unavailable at full capacity due to scheduled maintenance or unforeseen shutdowns due to equipment failure, transmission congestion, fuel supply, or other contingencies. Thus, one would expect to see generators guess that price may be above variable cost at times when actual supply ends up being below the full industry capacity. This will tend to "fill in" that backwards L with observed quantity-price data points. One would expect greater density of data points toward the boundaries of the "backwards L."[14]

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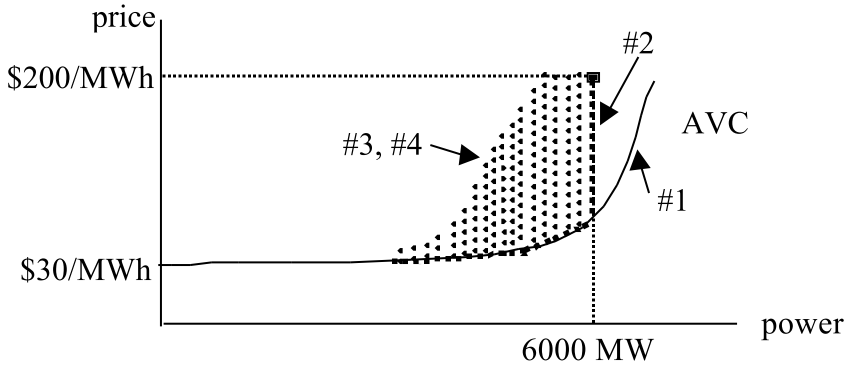
[12] Michael Crew and Paul Kleindorfer, *The Economics of Public Utility Pricing* (Cambridge, MA: MIT Press, 1986).

[13] When these, along with ancillary service revenues, are factored into profitability estimated, the decision whether a plant is profitable to operate at a seemingly high price becomes extraordinarily problematic. *See* Scott Harvey and William Hogan, "Identifying the Exercise of Market Power in California," Dec. 28, 2001, *available at* http://www.ksg.harvard.edu/hepg/Papers/Hogan%20Harvey%20CA%20Market%20Power%2012-28-01.pdf, especially 11-26.

[14] One error avoided in some price-based studies of the California situation is that prices would be inflated by the prospect that bankrupt distribution utilities would not honor their promises to pay for wholesale energy, particularly when the courts mandated such sales to prevent blackouts. On this basis, James Bushnell does not base market power claims on California price data during the winter of 2000-01, when prices were at their highest, despite off-peak demand. James Bushnell, "What We Do and Do Not Know About How Electricity Markets Work," keynote address, NEMS/Annual Energy Outlook 2002 Conference, Crystal City, VA (Mar. 12, 2002), notes available at http://www.eia.doe.gov/oiaf/aeo/conf/pdf/bushnell.pdf.

Putting these together would give an observed set of quantity-price data points and an AVC graph that looks something like:



The numbers and arrows in the graph indicate the effects listed above. The dotted area of price and quantity observations does not represent a precise prediction of prices and outputs we would observe. The economics of peak load pricing with a bit of real-world noise could produce patterns like those observed by Short and Swan for Queensland and Victoria.[15]

Responses and rejoinders

One response to these objections to price-cost based market power tests is that the capacity costs of the last generator in do not matter. According to one view, generation companies own a portfolio of plants. Profits from the baseload plants can cover the capital cost of the peaking plant. But this seems to leave unanswered the obvious question of why such a company would own a peaking plant. It would have higher overall profits if it were not to build a peaking plant, if that plant would not recover its capital costs.

A second reason that capital costs should be irrelevant might be that they are recovered in a separate capacity market. If so, one needs at least to describe such a market, including the "strike price" at which the buyer or regulator could demand that excess capacity be brought online. The returns from those sales would then need to be factored in to determine whether the marginal plant is making excessive profits because prices are too high. PAVC based studies do not incorporate such an analysis.

If capital costs are left out, it should not be surprising that prices will exceed mar-

[15] Short and Swan, n. 3 *supra* at 5, 6. Their specific test for whether a market was not competitive if the median Lerner index over a given month exceeded .3. They are right to suggest that the pattern for Victoria is more likely to be suspicious than that for Queensland, but not necessarily because Victoria has more observations a certain percentage above average variable cost of the marginal plant. Rather, it is because the observations for Victoria appear to have more points farther above average variable cost *and to the left of the vertical "capacity" or "maximum output" line*. Such observations require greater amounts of seemingly profitable electricity to remain unsupplied. It is the quantity that matters, not the price. We return to this point below.

ginal costs, as defined by the average variable cost of the last firm in. But that is consistent with competition. If all firms were identical—of course they are not—price would have to equal minimum average total cost. If capital costs are trivial, then one would not need rents to cover them. Of course, that does not imply that capacity constraints would not be binding in between the time it takes to build plants. Scarcity rents do not imply anticompetitive conduct or effect. Again, the question should be not whether prices are higher than they would be if plants could be built instantaneously, but whether suppliers are withholding output to make the prices go even higher.

One possibility, of course, is that the industry is overbuilt, in the sense that the marginal plant is expected to lose money over the long term. However, such an explanation is inconsistent with the theoretical reason for predicting that market power is likely in electricity just because supply and demand are so inelastic. If there is excess capacity because of regulatory or ISO requirements, then the "price" of electricity on or off peak would have to include a capacity component of some kind. These considerations are also typically not present in price-cost based studies.

Theoretical market power concerns

Mismeasurement does not imply that generators lack market power, particularly in peak periods. Theory offers some suggestion that regulators might want to be on the lookout for the unilateral exercise of market power, particularly at peak periods.[16] To oversimplify a complicated subject, one can subdivide the possible models into those in which the firms choose prices, and those in which they choose quantities or outputs.

Models based on output may predict noncompetitive outcomes. Such models have two variants, but both are problematic. One variant involves firms undersizing plants to keep output low and prices high. Since capacity choices are made over the long run, this outcome is possible only where fixed costs are large enough and the market small enough to support only a few competitors.[17] These conditions do not appear to hold in the U.S. One would not expect them to hold in Australia, either, although in both places the legacy of franchise utility monopolies (in the U.S.) and public ownership (in Australia) could lead to concentrated markets absent divestitures to disaggregate ownership.

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[16] For a related discussion of the theory and other issues raised regarding market power in electricity, see Timothy Brennan, *The California Electricity Experience, 2000-01: Education or Diversion* (Washington, DC: Resources for the Future, 2001): 37-40.

[17] In some industries, firms may not enter even when prices are high because they would predict that the added competition resulting from their entry might result in prices so low that they would not recover sunk costs incurred by coming into the market. This is especially true for industries in which fixed costs are so great that competition among just a few firms would generate too little revenue to cover them. Hence, one cannot say as a matter of absolute generality that entry cures all ills, and the prices can never be sustainably above competitive levels. However, the opening of electricity generating markets around the world has been predicated on the view that fixed costs and resulting economies of scale are not so large as to result in only a very small number of suppliers being viable.

The second output-based type of model is short-run, taking the number of competitors in the market as given. In this case, generators could make strategic choices to limit production in order to raise prices, taking the supply decisions of the other suppliers as given.[18] With a low elasticity of demand for electricity, this could lead to substantial price-cost margins, even with a relatively large number of competitors. For example, if the elasticity of demand for electricity is -.2, ten identical generators would, in such a model, set prices equal to double marginal cost.[19]

Such a strategy is not likely to be profitable at peak periods. If we are talking about withholding output below capacity, the relevant marginal cost will be something like the AVC. As we have seen, at peak periods one would expect prices to be set at many multiples of AVC. Even excluding the prospect of longer-term entry, firms may be better off producing up to their capacity limits and taking the competitive price, at peak periods, rather than withholding output. Such withholding may be more profitable off-peak, but one would expect the elasticity of demand for electricity to be greater off-peak as well, mitigating the incentive to withhold.[20]

With regard to price-based strategic models, the most important involve "dominant firms" that set prices assuming that competitors will take that price as given.[21] In these models, the price-cost margin at the profit-maximizing price is positively related to the market share of the dominant firm, and inversely related to the elasticity of demand for the product as a whole and the elasticity of supply of its competitors.[22] Off-peak, with capacity exceeding demand, the elasticity of supply of the other firms is likely to be quite high.[23] On peak, however, the elasticity of demand is

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[18] Limiting or withholding output could be accomplished either by simply not producing energy, or by offering to sell it only at prices above that which buyers are willing to pay. On either account, the result, a reduction in supplies actually purchased in order to drive up prices, is the same. We may also have situations in which prices are bid up, taking advantage of the design of the electricity market, but with no power being withheld. Pure price manipulation situations should be analyzed as failures of the design of the market, and not as the anticompetitive exercise of market power. Brennan, n. 16 *supra* at 33-35.

[19] The standard result for identical firms in a quantity-based model is that the price-cost margin (see n. 4 *supra*) equals $1/NE$, where N is the number of firms and E is the absolute value of the elasticity of demand.

[20] Obviously, this is not necessarily true. However, at any price, off-peak quantity demanded will be lower than on-peak quantity demanded at any price. If the slope of the demand curve at that price is the same off peak as it is on peak, then the elasticity off-peak will be greater. Of course, the off-peak demand curve could be steeper than it is on peak, producing an outcome counter to this intuition.

[21] William Landes and Richard Posner, "Market Power in Antitrust Cases," *Harvard Law Review* 94 (1981): 937-996.

[22] Formally, the expression is

$$\frac{P-MC}{P}=\frac{S}{E_D+[1-S]E_S},$$

where S is the firm's market share, E_D is the absolute value of the elasticity of demand, and E_S is the collective supply elasticity of the other firms.

[23] Because electricity is by and large a homogeneous good, when firms are choosing prices, the outcome is likely to be competitive, e.g. price equal to marginal cost, when capacity constraints do not intervene. *See* Jean Tirole, *The Theory of Industrial Organization* (Cambridge, MA: MIT Press,

likely to be very small, perhaps approaching zero. With a small elasticity of demand as well, a firm with even a small market share may find it profitable to withhold output and set prices substantially above marginal cost.[24]

As with the quantity-based models, on peak we would expect substantial price-cost margins in any event, so we may not observe such an exercise of market power. We might instead simply see everyone finding it optimal to supply up to capacity and charge prices exceeding marginal (or average variable) cost. However, the possibility of very low supply and demand elasticities at peak periods implies that one cannot dismiss market power claims, even if a generation market "looks" competitive by conventional measures.[25]

Quantity-based empirical approaches

Some defend price-cost studies at least in part on the basis that critics have not suggested alternative tests for market power.[26] This seems unfortunately to be too much like the "looking where the light is" punch line to the standard economist joke.[27] But there are, if one focuses not on prices, which can exceed average variable costs, sometimes by orders of magnitude. The focus should be not on price but on output, i.e., withholding. Specifically, one should seek to identify generation capacity that would have been profitable to run at prevailing market prices, but was withheld from sale.

Econometric tools could offer some insight. The increased profits achieved by withholding output accrue not just to the withholder, but to all electricity suppliers. This suggests that all else equal, a power producer is more likely to withhold capacity the greater is its share of overall capacity in the market. That, in turn, suggests a hypothesis: If output is being withheld to exercise market power, one should observe

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1989). To some extent, "electricity" might be a differentiated product, particularly if some consumers are willing to pay a premium for so-called "green" power. *See* Timothy Brennan, "Green Preferences as Regulatory Policy," Discussion Paper 01-01, Resources for the Future (2000).

[24] For example, applying the equilibrium condition in n. 22 *supra*, we might observe a firm with 10% of the market ($S = .1$) setting price at about 50% (10/19) above its marginal cost if the elasticity of demand is .2 and the elasticity of supply of the other firms is .1.

[25] The prospect of profits exceeding competitive levels would be expected to attract entry. But under the very low supply and demand elasticities associated with electricity at peak periods, it is not clear whether such entry would preclude the exercise of market power, even in the long run, or whether it would merely spread the profits among a larger set of firms. If the latter is the case, entry might depress profits per firm, but not peak-period prices.

[26] Severin Borenstein, "The Trouble With Electricity Markets: Understanding California's Restructuring Disaster," *Journal of Economic Perspectives* 16 (2002): 191-212.

[27] For those who may not know the joke, it begins with someone crouched under a streetlight at night, looking for something. A second person walks over and asks, "Do you need any help?" The first responds, "I'm looking for my car keys."
"Where did you leave them?"
"Over there," the first replies, pointing down the street.
"Why are you looking here, then?"
"Because this is where the light is."

"maintenance shutdowns" disproportionately among producers with larger market shares.

One might see this empirically in two ways. If shutdowns are random, a firm with X% of capacity should see X% of shutdowns, all else equal. A simple measure of concentration (e.g., the Herfindahl-Hirschmann Index, or HHI[28]) of outages could exceed the measure of concentration of capacity as a whole. More accurately, were one to regress likelihood of outages on firm characteristics, the coefficient of a term relating to market share should significantly exceed one. The larger the firm, the even more likely it is that it would have a generator shutdown.

Finally, and perhaps most notably, would be direct examination of output, rather than indirect inferences using econometrics. Few industries offer the level of firm-specific cost and output data available regarding the electricity generation sector. If those data are reliable, one should not have to resort to statistics to infer market power. One would not expect generators to be taken offline voluntarily when prices are at their peak. If anticompetitive withholding is going on, the regulator ought to be able to "name names"—identify those generators that have withheld electricity that otherwise would have been profitable to generate, if one were taking prices as given. Regulators could investigate specific incidents of peak-period maintenance to see if the output reductions were warranted.

Such data will not be free from ambiguity.[29] Generators frequently need to be taken offline for maintenance purposes and, as noted earlier, the costs of starting up and shutting down units may make generation companies less willing to operate than might seem immediately profitable. Fox-Penner also notes that firms may end up holding capacity in reserve against outages, and such capacity may remain unsold even during a price spike.[30] To meet an appropriate legal burden before enforcing any poli-

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[28] The HHI is the sum of the squares of the market shares of sellers in the market. In a monopoly market, where one firm has 100%, the HHI is 10,000. In an atomistic market, as market shares approach zero, so will the HHI. If there are N equal-sized firms in a market, the HHI will be 10,000/N. For a discussion of how the HHI is used in electricity mergers in the U.S., see Federal Energy Regulatory Commission, "Inquiry Concerning the Commission's Merger Policy Under the Federal Power Act: Policy Statement, Order No. 592 "Docket No. RM96-6-000 (December 18, 1996), especially Appendix A at 59-62, 74-79, *available at*
http://www.ferc.fed.us/Electric/mergers/mrgrpag.htm#PolicyStatement.

The HHI has three theoretical rationales, none especially compelling. A first, due to Stigler, is a model in which the likelihood that a firm in a cartel would detect that a loss of market share is the result of nonrandom price-cutting by someone else rather than random variation in where customers shop is a function of the HHI. George. Stigler, "A Theory of Oligopoly," in George Stigler, *The Organization of Industry* (Homewood, IL: Irwin, 1968). A second is that in a Cournot model, the HHI is proportional to the welfare increase attainable from increasing industry output by a fixed amount. Robert Dansby and Robert. Willig, "Industry Performance Gradient Indexes," *American Economic Review* 69 (1979): 249-60. Third, in a Cournot model with constant demand elasticity in which firms have different marginal costs, the mark-up of price over a share-weighted average of marginal cost will be proportional to the HHI.

[29] For detail, see Harvey and Hogan, n. 13 *supra* at 47-71.

[30] Peter Fox-Penner, Comments Before the Federal Energy Regulatory Commission, Investigation of Terms and Conditions of Public Utility Market-Based Rate Authorization, Docket No. EL01-118-000 (Feb. 11, 2002): 44.

cies or punishments, one would need to evaluate other explanations for the withholding. But this is a practical and I think better alternative than price-based approaches. A helpful sign is that Joskow and Kahn, among those who have adopted the price-cost method criticized here, are giving more weight to output based studies.[31]

Conclusion

Criticisms of the competitiveness of generation markets are widespread. Unfortunately, many of these criticisms are based on comparisons of prices to average variable cost. However, even in a competitive electricity market, one would expect to see prices substantially above average variable cost during peak demand periods. Variation in demand, increasing average variable cost curves, and particularly uncertainty among generators regarding market demand and supplies from their competitors can give price-cost data patterns not unlike those used to support claims that the industry is not behaving competitively. Last and not least, the prospect of entry could dampen market power over the longer term.

That said, low supply and demand elasticities for electricity, particularly at peak periods, support some degree of concern that generation markets may not be competitive. Better tests for market power would look to quantities, not prices, e.g., by seeing if firms with larger market shares are disproportionately more likely to have outages. Perhaps the best test, with the data available, would be for regulators to identify directly the suppliers that seem not to be generating nominally profitable electricity, and then see if any excuses are sound.

Finally, a philosophical observation: The different approaches may arise out of different interpretations of what "market power" is about. From the neoclassical perspective, questions about market power of looking for efficiency losses, which fundamentally are not based on price but on reduced output. By that criterion, "market power" is fundamentally about withholding. A less neoclassical perspective may focus on the distributive effect of higher prices.

To the extent one cares about distributive effects, one might be drawn more to price than to output. If demand for wholesale power is perfectly inelastic, e.g., because retail prices are fixed by regulation (as was the case in California), one could observe higher prices without the output reductions characteristic of the exercise of market power. I would include "price but no output reduction" effects as questions of "market design" or "gaming the auction," but not "market power," a term that I reserve for practices that lead to reductions in supply in order to raise prices and profits.[32] But to the extent one combines those under the same heading, one might be drawn more to price tests for market power. Unfortunately, they just do not work very well in addressing that specific concern.

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[31] Paul Joskow and Edward Kahn, "A Quantitative Analysis of Pricing Behavior in California's Wholesale Electricity Market During Summer 2000: The Final Word," mimeo, Feb. 4, 2002.

[32] *See* n. 18 *supra*.