Preventing Monopoly or Discouraging Competition? The Perils of Price-Cost Tests for Market Power in Electricity

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Abstract

Allegations of market power in wholesale electricity sales are typically tested using price-cost margins. Such tests are inherently suspect in markets—such as electricity—that are subject to capacity constraints. In such markets, prices can vary with demand while quantity, and thus cost measure, remain fixed. Erroneous conclusions are more likely when the proxy for marginal cost is the average operating cost of the marginal plant. Measured this way, high Lerner indexes are consistent with competitive behavior. Using this proxy to cap wholesale prices, as the U.S. Federal Energy Regulatory Commission has proposed, would discourage entry by making it impossible for peak power suppliers to recover capital costs. The wholesale electricity sector may be susceptible to market power. But a preferable (if not unproblematic) test for market power would look not at prices but output, i.e., whether individual generators withheld energy that would have been profitable to supply at prevailing prices.

Key Words: market power, electricity, peak load pricing

JEL Classification Numbers: D42, L11, L51, L94

Contents

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Introduction

Concerns have been expressed around the world that newly opened wholesale electricity markets have failed to be sufficiently competitive.[1] The competitiveness of electricity markets in the United Kingdom has been questioned almost since their inception.[2] 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.[3]

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Comments from James Bushnell, Joseph Doucet, Andrew Kleit, Paul Joskow, Robert Michaels, Alan Moran, Karen Palmer, and Christopher Short were especially helpful. Neither they nor anyone else necessarily agrees with the views expressed here; some assuredly do not. All errors remain my responsibility.

[1] Essentially, "wholesale" electricity markets are those in which energy is purchased by entities responsible for delivering electricity to those who use it. "Retail" markets are those in which these end users purchase electricity. These definitions are somewhat fluid, in that large industrial electricity consumers may be able and willing to purchase electricity at wholesale, bypassing retail distribution companies. These definitions also are accompanied by legal technicalities, in that whether states or the federal government have regulatory authority over electricity production, delivery, and sale depends on whether those activities are "retail" or "wholesale" in nature. For a more detailed description of this distinction, see chapters 3 and 12 of Timothy Brennan, Karen Palmer, and Salvador Martinez, *Alternating Currents: Electricity Markets and Public Policy* (Washington, DC: Resources for the Future, 2002). A recent case examining these issues with regard to the U.S. Federal Energy Regulatory Commission's authority over transmission pricing is *New York et. al. v. Federal Energy Regulatory Commission et. al.*, U.S. Sup. Ct., *slip op*. 00-568, *dec*. March 4, 2002.

[2] 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).

[3] 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).

Recently, Short and Swan have produced a thoughtful study of market power in the Australian electricity sector.[4] 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). 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.[5] The fundamental rationale for using price-cost margins is essentially that, in a competitive market, price-taking firms will supply output up to the point where the marginal cost of production just equals the market price. Therefore, a substantial difference between price and marginal cost indicates that firms are not taking price as given.

In a nutshell, the flaw in many electricity market studies is not that the price-cost margin is theoretically inappropriate, but that the manner in which it has been implemented is. In these studies, the proxy for "marginal cost" used to estimate price-cost margins is typically the average variable or operating cost of the "last" generator that would be dispatched to meet energy demand.[6] Let us call this the PAVC test, for "price-average variable cost."[7] 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

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

[5] 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. See David Kaserman and John Mayo, *Government and Business: The Economics of Antitrust and Regulation* (Fort Worth, TX: Dryden Press, 1995): 101-02.

[6] See, e.g., Joskow and Kahn, n. 3 *supra* at 5.

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

conditions, the market price would reflect the short run marginal cost of the most expensive generation turbine called to supply into the market.[8]

The PAVC standard for competitive pricing would imply that no generator would be built. In any market, competitive or not, even the 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.[9] If not, it would find entry unprofitable. As we discuss below, using resort hotels as an example along with electricity generation, the need to recover fixed costs can lead 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 and supply shocks (e.g., unanticipated hot weather, generator outages) leading to patterns of market bids similar to those found in the aforementioned studies, without necessarily indicating market power. A better method for ascertaining the extent of market power in electricity would be to focus on output, looking for generation capacity that would have been profitable to run at prevailing market prices, but was not.

Erroneous use of price-cost margins to measure market power is not merely a matter of academic interest. Such measures could lead, and perhaps already have led, regulators to prevent sales of electricity above the highest average variable cost of the generators used to provide electricity. Keeping at least some firms from earning revenues in excess of their average variable costs will encourage present suppliers to leave the market and discourage new firms, particularly those needed to provide power during peak hours of use, from entering. Without such entry, opening electricity markets is likely to fail. Ironically, limited regulation intended to ensure competitive performance would subvert entry, leading ultimately to a reduction in such competition and perhaps a restoration of full-blown rate-of-return-based price controls.

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[8] Short and Swan, n. 4 *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 the "marginal cost of an additional unit of energy from another generator." This is not correct, as we see below.

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

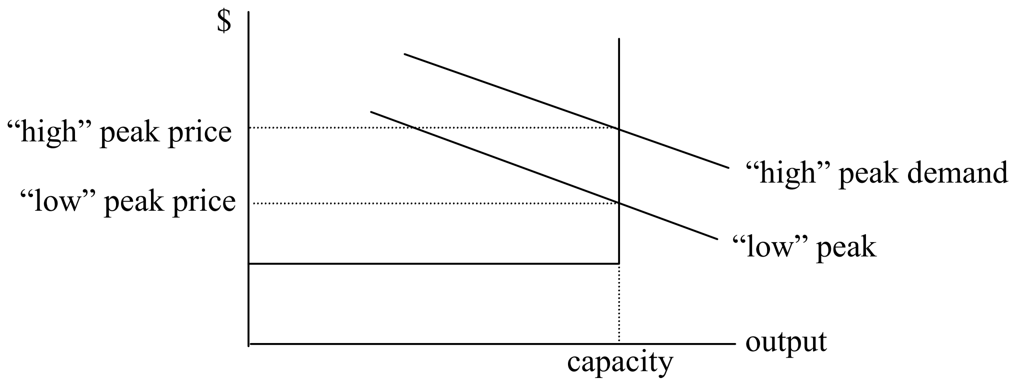
The intuition

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.[10]

Marginal-cost measures can be appropriate, but only if one rejects using average variable costs as a proxy. 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 used here—a generation unit with constant marginal costs within the plant (not across plants) up to a capacity constraint, at which point marginal cost is effectively infinite—is an extreme example of that phenomenon. Generally, one would expect marginal cost to increase 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 other 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 accurately conceptualized and measured marginal cost.

The measurement situation is even worse. Over the life of a peak plant, demand during peak periods itself will vary. During some peak hours, the demand will be high; during some it will be low, yet, absent outages, its output would be constant, as illustrated by the following diagram:

[10] 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 was expected when the unit was constructed. Leaving aside earning premiums to cover risk, if demand turns out to be greater than anticipated, the firms would earn long-run rents as the market-clearing price exceeds the expected level at which revenues would cover costs. If demand is lower than anticipated, the reverse holds—the market-clearing price is lower than that which would have covered cost.



Thus, peak period price can vary with demand, even if firms are price takers. Yet because output remains fixed, any measure of cost that one would want to use would remain constant. Consequently, a measure of market power based on a relationship between price and a static proxy for marginal cost, such as average variable cost, is inherently inadequate. 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 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 United States[11]) 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 in a well-functioning, competitive market.

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 firms could earn capacity rents.[12] 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.[13]

Illustrating the principle: 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

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[11] Some natural gas power plants in Southern California had to purchase permits to emit nitrous oxide, 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, as electricity prices in California rose, so too did permit prices, until regulators stepped in and substituted a fixed price for permits for the supply limitation. In estimating their price-cost margin, Joskow and Kahn, n. 3 *supra*, treat the permit price as an exogenous price that should be included in calculating the average variable cost of the marginal gas plant,. 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 there is a difference between actual and measured marginal cost that their empirical procedures neglect.

[12] 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 19, 2001, at 27-28, 34 (hereafter referred to as "FERC Mitigation Order").

[13] Imagine that, under competition, N firms would enter the market, and rank firms from lowest to highest operating cost from 1 to N. Under the FERC Mitigation Order's pricing rule, the Nth firm, the one with the highest operating cost, would not be allowed to ever set prices that would enable it to recover its fixed costs. Thus, it would not enter, making the N-1st firm the highest cost firm. But the rule would now reduce the maximum allowed price, so that the N-1st firm is now unable to cover its fixed costs, and thus it would not enter. With rational expectations by entrants, the situation would unravel to the point that none of the N firms would enter.

$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 when 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 the market 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.

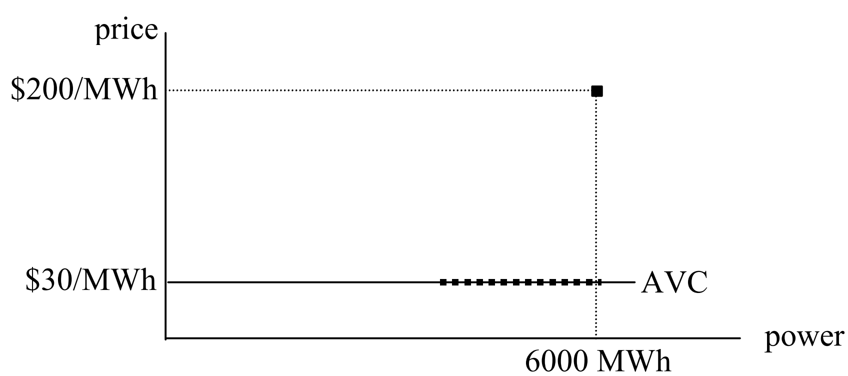
Because every hotel gets to charge this rate during the summer, not only those hotels built to serve summer clients, they all will capture their capital costs at that time. The price of a room off-season would then be only $50. The PAVC standard would correctly predict off-peak rates, but would fail on-peak, setting them also at $50 when the competitive rate would be $170. Holding hotels to a PAVC standard would mean not only that none would be built to serve summer visitors to the resort, but 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 was found to be unsanitary or fear of shark attacks. 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 the average variable cost of $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. But expecting excess capacity as a permanent feature would be unrealistic unless the tourism industry was in permanent decline.

Back to electricity

Peak-load pricing principles that hold for hotels hold for electricity as well. We will get to some important complications, but first imagine 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 8,760 hours in a year, demand is at peak for 450 hours, about 2% of the time. Finally, suppose 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 at full capacity.) For simplicity, again, assume that at off-peak times capacity exceeds the amount of electricity demanded at $30/MWh.

Using the hotel analogy, 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 at the peak price would be 6,000 MWh and that the industry has sufficient capacity to meet that demand. 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:



The solid line indicates average variable cost at $30/MWh; the dots along that line and the solid dot at $200/MWh at 6,000 MWh supplied are the predicted prices.

Already we can see that during peak periods, price will be substantially above the 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.[14] 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's capacity could be exhausted at different levels of demand. This could produce the observed price-quantity points filling in the vertical line at the capacity level of output (between \$30/MWh and \$200/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 in 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" shape.
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 go on-line to meet demand.[15]
4. Perhaps most importantly, generators operate in an uncertain environment, in at least three important respects. They do not have perfect knowledge as to what demand will be at a given time. Second, they also may be uncertain as to how much they might be able to reap from selling electricity in other markets.[16] Finally, they will not

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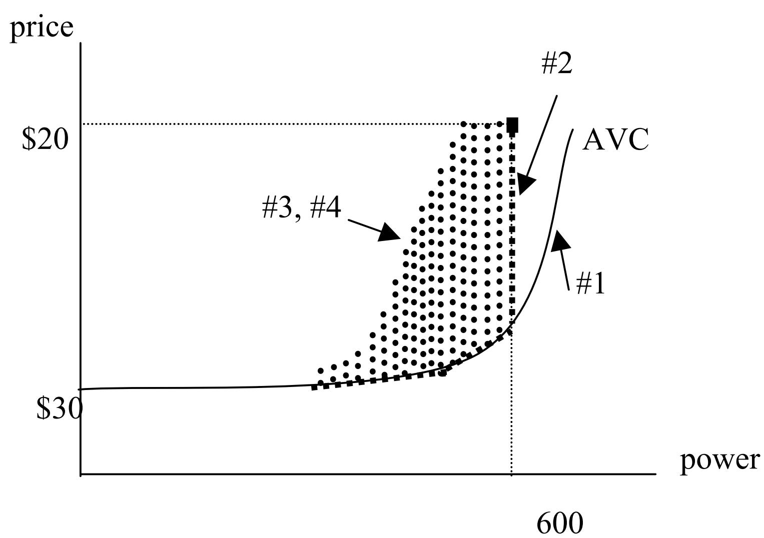
[14] Michael Crew and Paul Kleindorfer, *The Economics of Public Utility Pricing* (Cambridge, MA: MIT Press, 1986).

[15] When these, along with ancillary service revenues, are factored into profitability estimates, the decision whether a plant is profitable enough 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.

[16] I thank Bob Michaels for this observation regarding the "opportunity cost" of selling electricity within a particular region.

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.[17]

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. Of course, the dotted area of price and quantity observations does not represent a precise prediction of prices and outputs

[17] 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 rely on California price data during the winter of 2000-01 to support market power claims, 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.

we would observe. However, 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.[18]

Responses and rejoinders

One response to these objections to price-cost-based market power tests is that rates need not be set to recover capacity costs of the last generator. According to this view, generation companies own a portfolio of plants. FERC said, "Amounts earned on the more efficient plants [owned by a generation company] will cover the investment in the marginal plant."[19] But this leaves unanswered the obvious question of why such a company would build and operate that marginal peaking plant. That company would have higher overall profits if it did not to build such a plant if it would not recover that unit's capital costs.

A second reason one might posit 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. 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 marginal 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 during 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.

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[18] Short and Swan, n. 4 *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 than a certain percentage above the 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.

[19] FERC Mitigation Order, n. 12 *supra* at 34.

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.[20] Congested transmission lines can exacerbate market power by creating "load pockets" within which competition from imported power is limited.[21] 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.[22] These conditions do not appear to hold in the United States.

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[20] 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.

[21] Brennan, Palmer, and Martinez, n. 1 *supra* at Ch. 9; Thomas Leautier, "Transmission Constraints and Imperfect Markets for Power," *Journal of Regulatory Economics* 19 (2001): 27-54.

[22] 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.[23] 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, 10 identical generators would, in such a model, set prices equal to double the marginal cost.[24] 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 may well be something like AVC, if marginal costs within the firm are relatively constant. 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.[25]

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.[26] 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.[27] Off-peak, with capacity exceeding demand, the

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[23] 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 also may 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. 20 *supra* at 33-35.

[24] The standard result for identical firms in a quantity-based model is that the Lerner index or price-cost margin (see n. 5 *supra*) equals $1/NE$, where N is the number of firms and E is the absolute value of the elasticity of demand.

[25] 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 of off-peak will be greater. Of course, the off-peak demand curve could be steeper than on-peak, producing an outcome counter to this intuition.

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

[27] Formally, the expression is

elasticity of supply of the other firms is likely to be quite high.[28] On peak, however, the elasticity of demand is 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.[29]

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.[30]

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.[31] This seems, unfortunately, to be too much like the "looking

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

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.

[28] Because electricity is by and large a homogeneous good, when firms are choosing prices, the noncooperative (Bertrand) outcome is likely to be competitive, e.g. price equal to marginal cost, when capacity constraints do not intervene (see Kaserman and Mayo, n. 5 *supra* at 187-88). One can get higher prices when goods are differentiated (see Eric Rasmusen, *Games and Information* (Cambridge, MA: Blackwell, 1994): 314-18). In the market, electricity could be a differentiated product, e.g., 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, Washington, DC: Resources for the Future (2000)).

[29] For example, applying the equilibrium condition in n. 27 *supra*, we might observe a firm with 10% of the market (S = .1) setting its 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.

[30] 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.

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

where the light is" punch line to the standard economist joke.[32] But there are alternative tests, if one focuses not on prices, which under competition can exceed average variable costs, sometimes by orders of magnitude. The focus of assessments of market power in electricity 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 being 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 a disproportionate number of "maintenance shutdowns" among producers with larger market shares.

One might see this empirically in two ways. If shutdowns are random, a firm with X percent of capacity should see X percent of shutdowns, all else being equal. A simple measure of concentration (e.g., the Herfindahl-Hirschmann Index, or HHI[33]) of outages could exceed the

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[32] For those who may not know the joke, it begins with an economist 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 economist replies, pointing down the street.

"Why are you looking here, then?"

"Because this is where the light is."

[33] 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 United States, 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 of which are 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 where customers shop is a function of the HHI. (see 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 (see 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.

measure of concentration of capacity as a whole. More accurately, were one to regress the likelihood of outages on firm characteristics, the coefficient of a term relating to market share should significantly exceed 1. The larger the firm, the more likely it is that it would have a generator shutdown.

A potentially better tactic might be to examine output decisions directly, rather than indirectly infer withholding via 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.

Whether one employs econometric techniques or analyzes specific supply decisions made by electricity suppliers, output data will not be free from ambiguity.[34] 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.[35]

To meet an appropriate legal burden before enforcing any policies or punishments, one would need to evaluate other explanations for alleged withholding. Without such careful evaluation, regulators could end up imposing possibly unwarranted mandatory supply requirements on generators.[36] But output-based approaches remain at least as practical and are, theoretically, better alternatives 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.[37]

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[34] For detail, *see* Harvey and Hogan, n. 15 *supra* at 47-71.

[35] 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.

[36] See FERC Mitigation Order, n. 12 *supra* at 8, 12-18, ordering that generators in the western United States "must offer" unscheduled nonhydroelectric capacity unless committed to maintain minimum operating reserves.

[37] 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.

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 do not seem to be generating nominally profitable electricity, and then see if any excuses are sound. If regulators attempt to set prices equal to a measure of costs that does not allow firms to earn rents sufficient to cover fixed costs, entry will be discouraged and competition subverted.

Finally, a philosophical observation: different approaches may arise out of different interpretations of what "market power" is about. From the neoclassical perspective, questions about market power are about looking for efficiency losses, which fundamentally follow not from higher prices *per se* but from 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.[38] But to the extent one combines those under the same heading, one

[38] See n. 23 *supra*.

might be drawn more to price tests for market power. Unfortunately, they do not work very well in addressing that specific concern.