Price Spikes in Wholesale Electricity Markets: An Update on Problems and Policies

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1. Introduction

Deregulation of wholesale electricity markets in the U.S. and other countries has resulted in some expected and beneficial outcomes, but also several outcomes that have been neither. Prominent among the latter have been price spikes—periodic rapid price increases, often to levels representing one or two orders of magnitude above typical levels, followed by abrupt price collapses. In the New York ISO in 2001, for example, wholesale price varied in the narrow range between $40 and $50 per mwh until August, when on three consecutive days it reached $194, $917, and $180 per mwh. More recently PJM reported two episodes in 2006 when price exceeded $700 per mwh, while in Australia there were more than 40 instances of prices in excess of AUS$5000 (approx. US$4000) per mwh in June 2007 alone. Regulators in the Phillippines, the Nordic countries, and elsewhere continue to report price spikes on a regular basis.1

Spikes have, of course, been the cause of much concern due to their disruptive consequences and the difficulties in bringing about effective control. It is therefore of considerable interest and importance that the frequency of price spikes in some markets appears to have diminished. PJM has had no repetition of $700 prices and fewer instances of above-$400 prices over the past six years. Price spikes in the Netherlands in recent years also seem to occur with lesser frequency. On the other hand, some countries continue to experience price spikes with undiminished frequency.

This paper provides an update and analysis of these divergent experiences, with

particular attention to policy measures directed at controlling price spikes. We begin in next section with a brief summary of the relevant theories of price spikes, focusing on the difference between those that are demand-induced vs. those that are supply-induced. Based on this theory, Section 3 then discusses a variety of methods that have been used or considered for identifying and controlling competitively problematic price spikes, focusing on measures employed in the U.S. Section 4 turns to experience with price spikes in different wholesale electricity markets, examining the UK, the Netherlands, and Australia for divergent approaches. The final section draws inferences from and offers recommendations based on these experiences.

2. The Theory of Price Spikes

Price spikes have been examined using diverse analytical frameworks. Two approaches are outlined in this section, one based on micro theory and the other essentially an auction market approach. We discuss these in turn.

2.1 Microtheoretic Approach

The standard micro theory of price spikes derives from a simple market model adapted to the distinctive features of wholesale electricity markets. The fundamentals are illustrated in Figure 1. There S denotes a supply curve of electricity offers to the wholesale market and D is the vertical demand curve. Supply is essentially horizontal at marginal fuel costs up to (or near) capacity, at which point incremental supply is unattainable and S becomes vertical. Demand D

\[2\text{ A prominent alternative approach is represented by mean-reverting and jump-diffusion models from the stochastic process literature. See, for example, Deng (2000), and for a review, Higgs and Worthington (2005)}\]

\[3\text{ This section draws on Kwoka and Sabodash (2011).}\]
is essentially vertical, both because final customer demands are very inelastic but more specifically because the ISO typically establishes its requirements as a datum.

When demand intersects the offer curve in its horizontal segment (e.g., D₁), market price is at marginal cost and price spikes, at least in theory, are not a danger. But when demand presses on capacity—as on hot summer days that exhaust available capacity—a different regime applies.⁴ Thus at D₂, price may be some multiple of marginal cost, reflecting scarcity rather than explicit cost, and when demand recedes, price falls precipitously back to its original level.

An analogous phenomenon can occur if a generator that constitutes a significant portion of overall supply suddenly goes offline. Such an event would be described by a leftward shift of the offer curve, as, for example, the move from S₁ to S₂ in Figure 2. Once again, if this were to occur at offpeak demand D₁, price would not be affected since remaining capacity would be more than adequate. If demand were already close to exhausting capacity e.g., at D₂, the supply shift due to the outage would again result in a spike in price.

One important observation about these scenarios is that, while price may spike, it is still being determined by underlying demand and supply forces. The high price reflects scarcity, not monopoly, cartel, or strategic behavior. The rents generated during periods of such high prices in principle serve as a signal of the need for additional capacity. Theory predicts that sufficient rents—a high enough price for enough periods—should trigger new capacity additions, although in practice a number of factors are likely to impede that response.

A different scenario may apply if any single generator is large enough so that, by

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⁴ This observation has suggested the value of a regime-switching approach that utilizes preconditions for price spikes to determine periods of time when they are a threat. See, for example, Mount, et al (2006).
deliberately taking some available capacity offline, it can raise price sufficiently that it earns more on its remaining output. This scenario is illustrated in Figure 3. We assume that N units of capacity, all of identical size, make up the offer curve. One firm owns two such units, one of which it takes offline. As in Figure 2, that shifts the offer curve from $S_1$ to $S_2$ (the horizontal displacement equal to one unit’s capacity), causing the supplier in question to earn even more on its remaining unit. Whereas at $P_1$ that supplier earned area $A$, the higher price results in profit in the amount of areas $A$ plus $D$ on that unit. So long as the incremental profit $D$ exceeds the lost profit $B$ on the other unit, strategic withholding is privately profitable and represents predictable behavior.

The magnitudes in question can be determined in a straightforward manner. Under exceedingly simple assumptions—identical units, one of which must be shutdown in its entirety; other generators at capacity throughout—it is easy to show that the necessary and sufficient condition for profitable withholding is simply that

$$P_2 - P_1 > P_1 - C$$

(1)

where $C$ is marginal cost. More generally, if generation units are of varying size, the condition becomes that

$$X_1 (P_2 - P_1) > X_2 (P_1 - C)$$

(2)

where $X_1$ and $X_2$ are the capacities of the remaining and the shutdown unit, respectively. Yet more generally, if the output choice is continuous, with $q_i \leq X_i$, the condition can be shown to be that

$$m = s \cdot W$$

(3)

where $m$ is the initial price-cost margin, $s$ is the post-withholding market share of the active firm,
and $W$ is the elasticity of price with respect to withheld output.

Simple numerical examples demonstrate that these conditions can be met under plausible circumstances by a single generator with a relatively small market share (Kwoka and Sabodash, op. cit.), underscoring the pervasive nature of this concern.

2.2 Auction Markets

While a microeconomic approach is straightforward and insightful, wholesale electricity markets are in fact auction markets, with possibly different equilibrium properties. More specifically, these markets are uniform-price procurement auctions where suppliers place offer bids with the ISO, and the ISO accepts enough bids to meet expected (and exogenously determined) demand. The offer price of the marginal accepted unit becomes the common price. The bidding behavior of that marginal unit is therefore crucial to price determination, and that behavior in turn depends on the information available to the bidder. Throughout, the bidder must trade-off the probability of its being selected (higher for lower price) and the return it expects (higher for higher price). We examine three cases.

First, suppose that the bidder has no information about other bidders’ costs, but knows only the total number of bidders $N$. Bidder $i$ can simply bid its own cost $C_i$ but that yields zero profit. Instead, it is readily shown that the bidder maximizes its expected return by bidding

$$P_i = C_i \left(1 + \frac{1}{N}\right)$$

that is, some amount above unit cost based on the number of other bidders. At the other extreme, bidder $i$ might have complete information about the costs of the other $N$ bidders, in which case bidder $i$ can determine which other bidder $j$ will be marginal in the market. The optimal bidding strategy for all bidders now is simply to price just below the cost of the next higher-cost bidder,
thus:

\[ P_i = C_j - \varepsilon \]  \hspace{1cm} (5) 

Finally, where the distribution of bidders’ costs is known, but which of them will be marginal is not, uncertainty about the identity of the marginal bidder causes a further trade-off between profit and probability: Now a bidder \( i \) maximizes its expected profit in an auction with \( N \) bidders by bidding the following price:

\[ P_i = C_j (1 - 1/N) \]  \hspace{1cm} (6) 

where \( C_j \) is the cost of the next highest-cost bidder. This is below the next higher-cost bidder by an amount reflecting the probability of being marginal.

Additional features of such markets can further complicate matters. A supplier’s incentive to price more aggressively is stronger yet in the case of a bidder with multiple units to offer.\(^5\) Such a bidder has more to gain on inframarginal units, and thus would strive yet harder to have the marginal, price-determining (and price-elevating) unit. To increase that likelihood, that bidder may raise price on more than one later unit. In the further case where the seller not only has multiple units but also submits an offer schedule consisting of its choices of both prices and the associated quantities, the bidder’s behavior is again different. As before, it would want to be the marginal bidder, but now it wishes this to be case only for the smallest necessary quantity-block.\(^6\) That would ensure the maximum inframarginal output on which excess profits could be earned. Moreover, as von der Fehr and Harbord (1993) and Fabra et al (2006) show,

\[^5\] See, inter alia, Ausubel and Cramton (2002).

\[^6\] The special features of multi-unit auctions were emphasized by von der Fehr and Harbord.
when more than one bidder might be marginal, no pure-strategy equilibrium exists for a wide range of demand distributions.

3. Withholding and Price Spikes

The price spikes described above fall into two categories—those resulting from ordinary supply-demand interactions, and those resulting from strategic withholding. While the former may be disruptive, especially if frequent and large, they do not raise the same kind of policy issues as do the latter. Strategic withholding represents the exercise of market power, that is, deliberate output contraction so as to raise price and profit, but creating consumer harm and deadweight loss. Unlike some other types of market power, strategic withholding does not involve cartel behavior or tacit cooperation by other sellers, much less abusive conduct toward rivals. Rather, it is simply a unilateral output reduction by single seller whose actions by themselves, under the right circumstances, can raise price and profit. This section addresses two closely related issues—first, identifying competitively problematic price spikes and the conditions conducive to them, and second, developing various possible methods for controlling price spikes.

3.1 Identification of Problematic Price Spikes

There have basically been two approaches to distinguishing competitively problematic price spikes from ordinary price increases. These may be labeled ex ante structural and ex post behavioral. We discuss each in turn.

3.1.1 Ex Ante Structural Measures

As is now well understood, conventional measures of market power do not capture the
phenomenon or likelihood of price spikes. Measures such as the HHI or traditional concentration ratios address the potential for coordinated behavior and have been used to assess the strength of competition and resulting performance in electricity markets by many authors. The price spikes analyzed above, however, are not the result of coordination but rather represent unilateral conduct by a single firm. A more relevant measure would therefore seem to be the market share of the largest supplier to the market. When that supplier’s share is sufficiently large, it is capable by itself of reducing aggregate supply to the point of creating a price spike.

From this latter observation comes the concept of a pivotal supplier, that is, a supplier without which total market demand cannot be satisfied. A supplier $i$ is determined to be pivotal if the following condition is met:

$$K_i > Q - K_{-i}$$

(5)

where $K_i$ and $K_{-i}$ are the firm’s capacity and all remaining capacity in the market, respectively, and $Q$ is total market demand. If this condition is satisfied, then all other producers cannot meet market demand and firm $i$ is pivotal—that is, it could unilaterally cause price to spike.

Identification of pivotal supply is now embedded in FERC and RTO orders and procedures for detecting market power. Somewhat more generally, if there is concern that two or more suppliers

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7 See, for example, Wolfram (1998); Crawford, et al (2007); and Hortacsu and Puller (...). These studies estimate some mean level of price or markup, from which they infer market power. But to the extent that market power is episodic—alternating periods of little or none, with other periods representing spikes—the mean level of market power does not capture an important feature of the market. For a discussion of the limited usefulness of concentration measures in electricity markets, see Borenstein, et al (1999).

8 This condition is not without some ambiguity if supply consists in part of must-run technology such as nuclear. Arguably, it is remaining—discretionary—supply against which a single supplier’s capacity should be measured.
suppliers might jointly coordinate withholding, then the pivotal supplier concept can be extended to incorporate two or more suppliers that collectively are necessary to satisfy market demand.\textsuperscript{9} 

A related measure of the possibly pivotal nature of supply is the so-called residual supply index, defined as follows for firm $i$:

$$RSI_i = (K - K_i)/Q$$

where again $K_i$ is the firm’s capacity and $Q$ is total market demand, while $K$ measures total capacity in the market.\textsuperscript{10} RSI therefore measures the fraction of demand that must be met by the firm in question. An RSI less than 1 signifies a supplier whose output might be necessary to meet total demand. If that firm is the only supplier with $RSI > 1$, then it is pivotal. Thus, RSI can be viewed as a more comprehensive, and continuous, version of the concept of pivotal supply in a market.\textsuperscript{11}

This discussion suggests that one ex ante structural response to the problem of strategic withholding would be simply break up any generation firm that is pivotal. Break-up—that is, the spinning off of sufficient assets to eliminate market power—is standard practice in antitrust cases where mergers otherwise would create such market power. Here the process of capacity accretion to the point of possessing pivotal power is fundamentally similar, and could be subject to similar remedies.

\textsuperscript{9} PJM and CAISO now employ a three-firm version of the pivotal supplier test. For a more general analysis, see Perekhodtsev et al (2002).

\textsuperscript{10} Again, there are important details in implementing this concept. Capacity includes imports. The firm’s capacity excludes amounts contractually obligated.

\textsuperscript{11} Mount et al (2006) have used a regime-switching approach to show that price spikes occur more often when reserve margins are less than about 20 percent. While cruder than pivotal supply or the RSI, low reserve margins capture a similar phenomenon.
3.1.2 Ex Post Behavioral Approaches

The alternative approach to identifying problematic price spikes is to investigate episodes of price spikes after the fact and determine whether they were the result of deliberate reductions in capacity under conditions that would precipitate large price increases. This approach has the advantage of examining actual experience rather than relying on the imperfect predictive power of structural measures. An obvious disadvantage is that by itself ex post analysis does not prevent the occurrence of the spike. Moreover, establishing whether a price spike is due to withholding proves to be a difficult matter even after the fact. Causation in this area is often ambiguous since the conditions for strategic withholding and those for simple price increases are broadly the same, namely, shortness of supply relative to demand. Hence, the distinction between the two must ultimately appeal to other characteristics.

An early and important effort at ex post determination arose in the wake of the California electricity market meltdown of 2001. Joskow and Kahn (2002), among others, identified what they termed an “output gap”–the difference between generators’ profitable production capacity and that which they in fact utilized. Finding such a year-over-year gap, Joskow and Kahn concluded this likely represented strategically withheld capacity, which was in turn responsible for wholesale prices in California periodically reaching the cap of $10,000 per mwh.

A study of the New England wholesale electricity market during the same period of time similarly found unusually large capacity outages among generators serving that region during most of the time intervals in 1999 when prices exceeded $100 per mwh (Synapse, 2001). A more statistically based investigation was conducted by Kwoka and Sabodash (2011). That study explicitly tested whether generator offer curves to the New York ISO shifted leftward in
periods of strong demand, a phenomenon that would be inconsistent with competitive behavior. Focusing on the summer months of 2001 eliminated explanations for capacity reductions, such as outages for maintenance. Their test of test parameters showed that indeed the offer curve shifted inward in hours when forecast demand and resulting prices were high, as would be expected from strategic behavior.

### 3.2 Controlling Problematic Price Spikes

Neither ex ante structural measures nor ex post behavioral determinations suffice for the control of price spikes, albeit for different reasons. Structural measures are decidedly imperfect predictors, and ex post determinations are neither unambiguous nor, by themselves, deterrents. Consequently, a range of alternative approaches have been tried in various jurisdictions and countries. Here we review four approaches.

#### 3.2.1 Direct Price Controls

Perhaps the most obvious approach is simply to cap wholesale electricity prices, and indeed, several countries do in fact cap such prices. Often these caps are at extremely high levels, e.g., $10,000 per mwh, presumably to ensure the constraint binds only for prices that are certain to represent strategic behavior rather than ordinary supply-demand forces. But such extraordinarily high price caps fail to prevent more numerous instances of smaller price increases that are nonetheless profitable exercises of market power by generators. Another concern that has been expressed with the simple capping of prices is the possibility that doing so may truncate the distribution of price outcomes on the high side, thereby distorting price signals and investment incentives in this market (Stoft, 2000).

This latter concern almost certainly exaggerates the problem, since price spikes due to
strategic withholding do not represent informative signals about the need for capacity changes. Rather, they represent transient episodes of rent transfers from ISOs and their consumers to producers and generators. And these rent transfers may be of enormous magnitude, given the shape of the overall cost and offer curves in these markets. Figure 5 illustrates the rent consequences of price spike behavior in a uniform price auction market, with the shaded area representing the rents accruing to inframarginal supply. While ordinarily rent transfers might stimulate entry in the same manner as ordinary profit, the infrequent and uncertain nature of price spike episodes are deterrents to entry by new producers.

3.2.2 Supply-Side Approaches

Another approach to the problem of strategic withholding focuses on the incentive of a generator to take capacity offline. That incentive, of course, follows from the fact that under tight-supply circumstances the generator knows that it will be called upon to produce essentially regardless of price. Thus, it follows that the firm’s incentive to engage in this behavior can be blunted to the degree that some uncertainty can be instilled as to whether it will in fact be called upon. One method of creating such uncertainty is for the ISO to build or contract for available back-up capacity in the amount necessary to render that supplier non-pivotal. Then, if that

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12 For discussion of the efficiency and price consequences of uniform vs. discriminatory auctions, see Fabra et al (2006)

13 Kwoka (2008) discusses the entry and investment deterring effects of uncertainty in these markets.

14 Put differently, a firm which faces no risk or penalty from raising price will surely do so. The same incentive is the foundation for the theory of price cycles developed by Maskin and Tirole (1988): a firm in Bertrand equilibrium has nothing to lose by suddenly and unilaterally increasing price, though predictably that firm’s rivals will raise price to a level just below the leaders, thereby creating a cycle.
supplier were to initiate withholding, this threat capacity could be brought online and the attempt to trigger a price spike would be defeated.

Clearly, for such a threat to be credible, it would have to be available, that is, otherwise unused or used only on an interruptible basis. If unused, it would manifestly be expensive, equivalent to simply building a plant and leaving it idle.\textsuperscript{15} If available on an interruptible basis, that would moderate the costs but possibly compromise the need for the capacity to be available. It is perhaps for these reasons that this approach does not seem to have been pursued for any electricity market.

\textit{3.2.3 Demand-Side Approaches}

Since the magnitude of the market power possessed by a pivotal supplier derives from the inelasticity of demand, another type of policy might seek to increase that elasticity. One small measure would be to ensure that wholesale market demand at least reflected the modest degree of elasticity of retail customers’ demand, rather than the zero-elasticity configuration of most ISO auction markets. Beyond that, there have been a growing number of efforts to increase demand responsiveness both for reasons of market power and also reflecting environmental and conservation concerns.

FERC Order 719, issued in 2008, provides that retail customer aggregators must be allowed to submit demand bids directly to the ISO, a process that results in day-ahead load that is priced according to users rather than against a fixed forecast load. This initiative was directed primarily at CAISO and MISO, the two RTOs that did not already have such provisions. It

\footnote{\textsuperscript{15} For estimates of the cost of generating capacity, see Kwoka (2008) and more specifically, for the costs of holding capacity in reserve, see Blumsack and Lave (2002). Clearly, improving transmission capacity serving a particular market would have similar effects.}
would impart greater elasticity to the demand component of wholesale auction markets, increase the probability that excessively high-priced capacity might not be dispatched, and thereby further blunt the incentive for generators to withhold capacity.\footnote{Rassenti et al (2003) provides experimental evidence of the effectiveness of demand-side bidding in controlling price spikes.}

Beyond that, environmental objectives have spawned an array of “smart grid” and other techniques by which customers can adjust usage to take greater advantage of availability of electricity at certain times. These will have the corollary and beneficial effect of increasing demand elasticity, especially at certain times. PJM, for example, reports that a combination of emergency demand response and economic demand response— basically, administered load reductions plus reductions due to pricing—is increasingly serving to reduce loads at peak intervals below otherwise-predicted levels (PJM, 2011).

Demand-side measures can reduce pivotal market power and thereby the incidence and magnitude of price spikes. Thus, in Figure 6 the price effect of strategic withholding of a unit of capacity is less when demand is more elastic, as shown by the difference between D\textsubscript{1} and D\textsubscript{2}. A useful caution about this effect, however, should be noted in the case of the marginal (i.e., pivotal) supplier in the auction model. As shown in Figure 7, so long as demand response does not affect which unit is pivotal, the effect may be quite limited.

\textbf{3.2.4 Administrative Controls}

The effort to ensure that all suppliers, and especially pivotal suppliers, declare profitable capacity to the market has been addressed in some jurisdictions through administrative controls. Such controls—sometimes called “conduct and impact” controls—were put in place ISOs and
RTOs in the U.S. in the wake of the California price experience of 2000-01, when strategic withholding was widely suspected and ultimately confirmed. Some form of administrative control, supplemented by market monitoring, is now common in all RTOs.

Under administrative controls, bids are compared to reference levels intended to replicate competitive bids. Those bids that diverge from reference levels by more than a specified amount and thereby affect market price may be replaced with the reference price. Complementing these measures are measures designed to identify strategic withholding on an ex ante basis. Versions of these are present in three RTOs—New York, New England, and the Midwest ISO. The nature of these can be illustrated by closer examination of New York ISO’s tariff. That tariff identifies the concern as “conduct that is significantly inconsistent with competitive conduct,” explaining further that this is conduct that “would not be in the interest of the Market Party in the absence of market power.” It enumerate three specific concerns, two of which are relevant here:

1. Physical withholding of an Electric Facility, that is, not offering to sell or schedule the output of...an Electric Facility capable of serving an ISO Administered Market. Such withholding may include, but not be limited to, (i) falsely declaring that an Electric Facility has been forced out of service..., (ii) refusing to offer bids or schedules..., or marking (sic) an unjustifiable change to one or more operating parameters of a Generator that reduces its ability to provide Energy or Ancillary Services..., or (iii) operating a Generator in real-time to produce an output level that is less than the ISO’s dispatch instruction...

2. Economic withholding..., that is, submitting bids for an Electric Facility that are unjustifiable high so that (i) the Electric Facility is not or will not be dispatched or scheduled, or (ii) the bids will set a market clearing price.

Physical withholding can be viewed as an extreme form of economic withholding, with

17 For a summary of provisions in other RTOs, see Brattle Group (2007)

18 The third concern is so-called “uneconomic production,” essentially excess production designed to causes a transmission constraint. We will not discuss this issue here.
the offer price above the choke price for market demand, so that it effectively is not offered at all. These stated concerns are followed by a lengthy and detailed discourse on the criteria defining such behavior. For physical withholding, these include the following:

• “withholding that exceeds the lower of 10 percent or 100 MW of a Generator’s capability, or the lower of 5 percent or 200 MW of a bidding entity’s total capability”

• operation “at an output level that is less than 90 percent of the ISO’s dispatch level for the Generator”

The criteria for identifying economic withholding are divided into those applicable to an unconstrained area and a constrained area. For the former, the criteria are as follows:

• Energy bids constituting “a 300 percent increase or an increase of $100 per Mwh, whichever is lower...”

• Start-up cost bids that increase by 200 percent

In the case of a constrained area—basically, New York City—more stringent criteria are invoked. Among them are the following:

• Energy bids where, for intervals in which an interface...has a shadow price greater than zero, the lower of the thresholds specified for areas that are not Constrained Areas or a threshold in accordance with the following formula:
  
  \[ \text{Threshold} = 2\% \times \text{AveragePrice} \times \frac{8760}{\text{Constrained Hours}}. \]

• Start-up cost bids that increase by 50%

The intent of such detailed rules is to determine whether a specific generator outage is strategic or not. Non-strategic outages do occur, of course, as a result of planned maintenance or for unexpected reasons out of the control of the generator itself. While the actual reason for

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19 Wolak (2003) likens a generator’s claim that an outage is forced to an employee calling in sick and taking a sick day. The employer cannot readily determine the veracity of the worker’s claim. At the time of the California meltdown, stories circulated about ISO inspectors showing up at the gates of a withdrawn generator for this very purpose, and being turned away.
any particular outage is known with complete certainty only to the generator, the use of these
detailed administrative controls in RTOs has been linked to the apparent reduction in the
incidence of price spikes in U.S. electricity markets. Table 1, for example, reports the incidence
of excessive prices in PJM over the past decade. While the small sample makes inferences
problematic, it seems possible that at least over the past five years the frequency of price spikes
has diminished. If such is the case (as Bushnell et al, and others suggest), that would represent a
considerable achievement in preventing the exercise of market power and the disruptive pricing
episodes that had been common occurrences in the early years of these markets.

In the next section we shall compare this country’s experience with that of others that
have adopted different approaches, or none at all.

4. International Experience with Control of Price Spikes

Most wholesale electricity markets are subject to price spikes for the simple reason that
the preconditions for price spike episodes are periodically met and the incentives for generators
to engage in withholding are straightforward. The precondition that demand presses on capacity
is a circumstance that must occur on occasion in these markets unless there is persistent
redundant capacity–itself an inefficient condition. The incentives follow from the ordinary profit
opportunity from output reduction, made even more attractive by virtue of the fact that it does
not require collusion or merger.

Most countries undergoing electricity market reform have therefore had to contend with
price spikes, but in fact they have dealt with them in quite different ways. This section recounts
experiences in the UK, the Netherlands, and Australia. The U.S. example has largely been
covered through illustrations of policies and outcomes in the preceding section.

4.1 Price Spikes in the UK

As the first country to systematically deregulate its electricity market, the United Kingdom was also the first to encounter the problem of market power. Much early attention was focused on price elevation due to coordination by small numbers of generation companies, although some observers contended that withholding—either unilateral or joint by the two leading companies—also posed a substantial concern. Recognizing these concerns, the British regulator Ofgem sought to deconcentrate the generation sector during the 1990s, but with little effect on wholesale prices.

After further consideration of the problem of market power in general and unilateral withholding in particular, Ofgem in 2000 concluded as follows:

Neither...can the potential abuse of substantial market power be adequately regulated under general competition legislation...nor financial services legislation. This is because of the particular physical and economic conditions associated with electricity wholesale markets and electricity networks.

Accordingly, as part of the New Electricity Trading Agreement, Ofgem sought to have all “significant” generators sign a “market abuse licence condition” (MALC) that would subject signatory firms to fines and penalties if they were found to engage in withholding for the purpose of price elevation. Two generators refused to sign, and Ofgem’s proposed mandate was referred to the Competition Commission. The Commission ultimately concluded that, due to the difficulty of distinguishing ordinary unilateral behavior from abusive behavior, the mandate was

20 See, for example, Newbery (1995)


22 Ofgem (2000).
not operational and should not be implemented.

Analyses of pricing and output decisions in subsequent years were not entirely reassuring. A London Economics report found that over the period 2000-04 there were a significant number of episodes when price exceeded 200 euros per mwh, and even some in which price exceeded 450 euros. The Report went on to examine capacity and output decisions by major generators, finding several whose output fell short of capacity a significant fraction of the time, at least suggesting the possibility of strategic withholding.\footnote{London Economics (2007).}

4.2 Price Spikes in the Netherlands

The Netherlands has been among the earliest and most thorough electricity reforming countries in the EU. The state-owned transmission company TenneT is supplied by six domestic generation companies as well as by imports from neighboring countries. Half-hourly prices are determined in a day-ahead auction. Boogert and Dupont (2006) report, however, that over 15,000 reporting periods between 2004 and 2006, spot price exceeded 200 euros per mwh nearly 1 percent of the time. During this period price spikes seem to have been a persistent phenomenon in the Netherlands.

Boddeus (2008) employs a direct but ex post method for indication of strategic withholding by generators in the Netherlands. He computes each firm’s extent of unloaded but profitable capacity, and relates that to the firm’s residual supply index and to its extent of inexpensive inframarginal capacity. The latter reflects the magnitude of the generator’s incentive to withhold capacity and thereby raise price and profit on its remaining capacity. Boddeus’s empirical work finds that these two factors are strongly and significantly associated.
with unloaded but profitable capacity, consistent with strategic withholding.

Mulder (2012), however, reports that price spikes in the Netherlands, which had often ranged up to 1000 euros per mwh, have diminished dramatically in magnitude and frequency in recent years Mulder, Fig. 1). Several factors appear to be responsible for this improved performance, notably, growth of decentralized generation, capacity expansion by incumbent generators, and increasing interconnection with neighboring countries. The effect of the latter is illustrated by the much reduced differences between the wholesale price in the Netherlands and those in Germany, Belgium/France, and Nordpool. In his statistical examination of the period 2006 through 2010, Mulder finds that the association between conventional structural measures such as the residual supply index and the markup of price over cost declined markedly, suggesting that these other factors had resulted in substantial decline in market power-based price anomalies.

4.3 Price Spikes in Australia

The Australian electricity market was deregulated in 1998. Its National Electricity Market is comprised of four regional markets—New South Wales, Queensland, South Australia, and Victoria—together with a grid coordinated by the National Electricity Market Management Company. Distances and transmission constraints result in these markets being largely separate. Generators submit bids for half-hourly periods on a day-ahead basis, and receive the resulting uniform auction price.

The NEM has attracted considerable attention since it has remained among the most free of regulation since inception. The Australian Energy Regulator annually reports, in a matter-of-fact way, occurrences of very high prices: The 2010 report, for example, states that price, which
averaged between AUS$30 and AUS$82 per mwh in the different regions, exceeded AUS$5000 in 95 half-hour trading intervals during the year. It further reports that most of these occurred in two states and were the result of what is called “opportunistic pricing.” The latter is explained in the following account (AER, 2011, p. 30):

AGL Electric owns the Torrens Island power station, which accounts for around 40 percent of South Australia’s generation capacity. Transmission limits on important electricity from Victoria mean AGL Energy can, on days of high electricity demand, bid a significant portion of its capacity at prices around the market cap and drive up the sport price. It adopted this type of bidding strategy during many of South Australia’s 47 extreme price events in 2009-10. There was also evidence AGL Energy engaged in opportunistic bidding in the market for frequency control ancillary services on two days in April 2010, such that the cost of those services to South Australian consumers averaged around $4 million per day, compared with the typical daily rate of less than $3000.

It is notable that similar behavior appears to have been characteristic of the Australian electricity market since 1999. Thomas and Mitchell, for example, reported more than 70 “extreme returns price spikes,” defined as more than four standard deviations from the mean, each year between 1998 and 2005. Although the AER and others have expressed concern over this volatility, noting the uncertainty it creates for generators’ revenues and suppliers’ costs, there are only weak protections against such behavior. The principle constraint appears to be a price cap that is applied only in cases where the unusually high price persists. At present, the cap would be invoked “if the sum of half hourly bid prices over a rolling seven days exceeds a cumulative threshold (currently $187,500 per mwh),” which amounts to an average price of about AUS$558 over this period. Moreover, even if invoked, price would be reduced according

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24 See Higgs and Worthington for an expression of such concerns. Ullrich disputes the proposition that price volatility in Australian exceeds that elsewhere, although basic comparisons suggest it is indeed higher.

to a procedure that would limit it to about AUS$300. On their face as well as from their effects, it seems clear that this constraint does not tightly bind spot market prices in Australia.

5. Conclusions and Recommendations

A decade ago, price spikes were viewed with considerable concern in wholesale electricity markets. They represented frequent and disruptive influences on nascent market processes. They were often seen as exercises of single-firm market power that were not clearly violations of competition statutes but also not clearly distinguishable in a regulatory context from ordinary business behavior. This perspective often led to pessimistic assessments of the prospects for controlling price spikes.

Experience suggests that these concerns may have been exaggerated. Evidence from several countries and markets shows substantial reductions in price spikes, and some indications of strategies that may have been responsible. Three in particular deserved mention. First, regulatory actions to strengthen competition in wholesale electricity markets generally appear to have had a noticeable deterrent effect on price spike behavior in particular. These measures include broadening markets through interconnection and deepening markets by encouraging entry of new generators. Second, demand response measures have had the salutary effect of increasing demand elasticity and thereby diminishing incentives for withholding. While demand response is also motivated by conservation and other objectives, it is well understood to be an important aspect of improving performance in wholesale electricity markets. And third, effective administrative controls over the very act of strategic withholding seem to have been devised. Contrary to some early predictions, it appears possible to identify and restrain such
behavior without unduly interfering with ordinary and necessary capacity adjustments.

These experiences suggest that countries determined to control price spikes have a menu
of tested and seemingly effective approaches for doing so. Such case study evidence is only
suggestive, of course, so any firmer conclusion requires further research and testing.
Nonetheless, there seems to be grounds for optimism regarding control of one of the more
troublesome features of liberalized wholesale electricity markets.
Figure 7
### TABLE 1

**Frequency of Price Spikes in PJM**

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<th>Year</th>
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</tbody>
</table>

Source: PJM website.
REFERENCES


Higgs, Helen and Andrew C. Worthington. “Modeling Spot Prices in the Australian wholesale electricity market.” 2005


