FURTHER ANALYSIS OF THE EXERCISE OF MARKET POWER IN THE CALIFORNIA ELECTRICITY MARKET

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November 21, 2001

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EXECUTIVE SUMMARY

Beginning in June of 2000, electricity prices rose in California to previously unprecedented and unexpected levels. Even more surprisingly, prices were high for sustained periods, not just periods of very high demand. The full story of the causes and consequences of these events is still unfolding. It is important to untangle this complex matter because it has pressing policy implications. The greater the exercise of market power through strategic withholding by generators, the greater the emphasis on repayment and actions to control or reduce market power. The less the role of strategic withholding, the more emphasis should shift to reform of market design, to actions to increase supply relative to demand, and to mechanisms permitting consumers to respond to wholesale price levels.

A full analysis of this subject is complicated by many factors including the unusual details of the California electricity market design. In addition, much of the critical data needed to resolve key questions are not in the public domain. The California Independent System Operator has the information, and the regulators should have access to these data. Absent details on outages, reserve requirements, ancillary services and so on, it is much harder to distinguish between the result of high prices caused by shortages and the result of high prices caused by strategic withholding.

Given the importance of the problem, there have been many studies done to isolate or illustrate the exercise of market power. These studies have precipitated a debate about the adequacy of available information in the public domain to reduce the uncertainty enough to provide guidance for policy decisions.

Ideally, it would be preferred to defer analysis until the data were all available. The urgency of the situation does not allow for this more systematic approach. Furthermore, recent analyses have challenged even the argument that this is a complicated empirical question, asserting that the theory clearly points to a strong incentive to exercise market power. The implication is that the incentive is so strong that limited evidence consistent with strategic withholding should be sufficient to conclude that exercise of market power was a major factor determining the resulting higher prices.

The present paper, therefore, carries the analysis forward to expand the discussion of the issues that must be addressed and to explain further what previously had been taken for granted. In short, the theoretical arguments are far from definitive. The explicit arguments offered have been highly specialized cases that may have little to do with the real market conditions. There may or may not have been a large incentive to exercise market power. There may or may not have been substantial exercise of market power. Theory is a limited guide, and the public data are inadequate. The necessary data are available, although not in the public domain. Determination of the extent of the exercise of market power in California remains an open empirical question.

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Scott M. Harvey and William W. Hogan[1]

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I. INTRODUCTION

Analysis of electricity market performance in California has focussed on the extent to which thermal generators exercised market power through strategic withholding of supplies in order to increase prices and profits. The issue is important both in terms of decisions about possible refunds of excess charges and for the larger prescription of reforms to deal with market failures. The greater the role of strategic withholding, the greater the emphasis on repayment and actions to control or reduce market power. The less the role of strategic withholding, the more emphasis should shift to reform of market design, to actions to increase supply relative to demand, and to mechanisms permitting consumers to respond to wholesale price levels.

Previous papers have considered whether empirical studies of the California electricity market provide a reasonable basis for concluding that the price increases during 2000 and early 2001 are largely attributable to the exercise of market power through strategic withholding.[2] We have argued that:

> "With the available data in the public domain, and the special complications introduced by the California market design, the margin of error in estimating the extent of the possible exercise of market power through strategic withholding of

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[2] Scott M. Harvey and William W. Hogan, "Issues in the Analysis of Market Power in California," October 27, 2000 (hereafter Harvey-Hogan (October)) and Scott M. Harvey and William W. Hogan, "On the Exercise of Market Power Through Strategic Withholding in California," April 24, 2001 (hereafter Harvey-Hogan (April)).

> electric generation is of the same order of magnitude as the effect being measured. On balance, to date the publicly available data provides no reason for the Federal Energy Regulatory Commission to change its conclusion that there is no evidence of strategic withholding nor any proof that no strategic withholding has occurred.
>
> By contrast, there is general agreement that the California electricity market design is 'seriously flawed.' Furthermore, there is evidence that the policy responses that have been adopted in California have accelerated an already serious market collapse. Hence, without dismissing the possibility of the exercise of market power, the principal policy focus should be on fashioning workable solutions for the other more serious problems in market design that relate to the underlying causes of the market meltdown."[3]

This analysis produced a number of reactions, including critiques of the analytical approach, further questions about the nature of the argument, and inferences about its implications. Much of the commentary has been informal, but there is at least one written response that makes the issues more concrete.[4] Given the importance of the topic for California and for every other effort to restructure electricity markets, further discussion is indicated to carry forward with the analysis.

Ideally, it would be possible to defer the analysis until all the data were available to resolve critical empirical issues. Unfortunately, the data are not all available in the public domain and policy choices are being made with incomplete information. Hence, without fully resolving all the issues, the present paper is a contribution to clarifying the subject, answering some of the questions that have been raised, and furthering some of the empirical analysis.

The structure of the present paper includes a discussion of the nature of the analysis and a discussion of the theoretical issues raised. This provides an expanded explanation of why the policy conclusion is largely an empirical matter as yet unresolved.

II. ON THE NATURE OF THE ANALYSIS

The responses to Harvey-Hogan (April) include informal comments and a detailed paper. Given the importance of the subject, this dialogue is both necessary and constructive. Given the controversial nature of the subject, clarity of the argument is also important. There are at least two issues that would benefit from further exposition on the nature of the analysis. These have to do with the definition of market power employed and the evaluation of the evidence regarding the exercise of market power.

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[3] Harvey-Hogan (April), p. ii.

[4] Paul Joskow and Edward Kahn, "Identifying the Exercise of Market Power: Refining the Estimates," July 5, 2001; hereafter referred to as Joskow-Kahn (July).

A. Market Power and Strategic Withholding

It is necessary to be explicit about what is meant by market power. For instance, Greg Werden of the U.S. Department of Justice has defined the market power of sellers as the ability to profitably maintain prices above competitive levels by reducing output below competitive levels. He has further defined the competitive price level as the marginal cost of the highest marginal cost unit necessary to satisfy industry demand.[5] His definition is consistent with that employed by the Department of Justice and Federal Trade Commission in evaluating mergers and acquisitions under the 1992 Merger Guidelines.[6] Withholding supply to increase prices and profits is also the definition adopted in Joskow-Kahn (March and July).[7] Similarly, we have previously defined market power in the electricity industry as "the ability to withhold production on some units in order to increase market prices and profit more from production on other units."[8] Figure 1 illustrates the conventional analysis of withholding supply to increase profits.[9]

In Figure 1, the underlying economics repeat the textbook case of monopoly pricing. The demand intersects the marginal cost curve (MC) at the competitive price (p_c) and quantity (q_c). However, the monopolist would maximize profit at the point where the marginal revenue curve (MR) intersects the marginal cost curve. This results in the monopoly price (p_m) and quantity (q_m). This outcome could be achieved even in a bid-based market by the monopolist could submit the higher bid curve, which would intersect demand at the monopoly solution. The result would be withholding of supply by the final amount q_m-q_c.

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5 See Gregory J. Werden, "Identifying Market Power in Electric Generation," *Public Utilities Fortnightly*, February 15, 1996, p. 1.

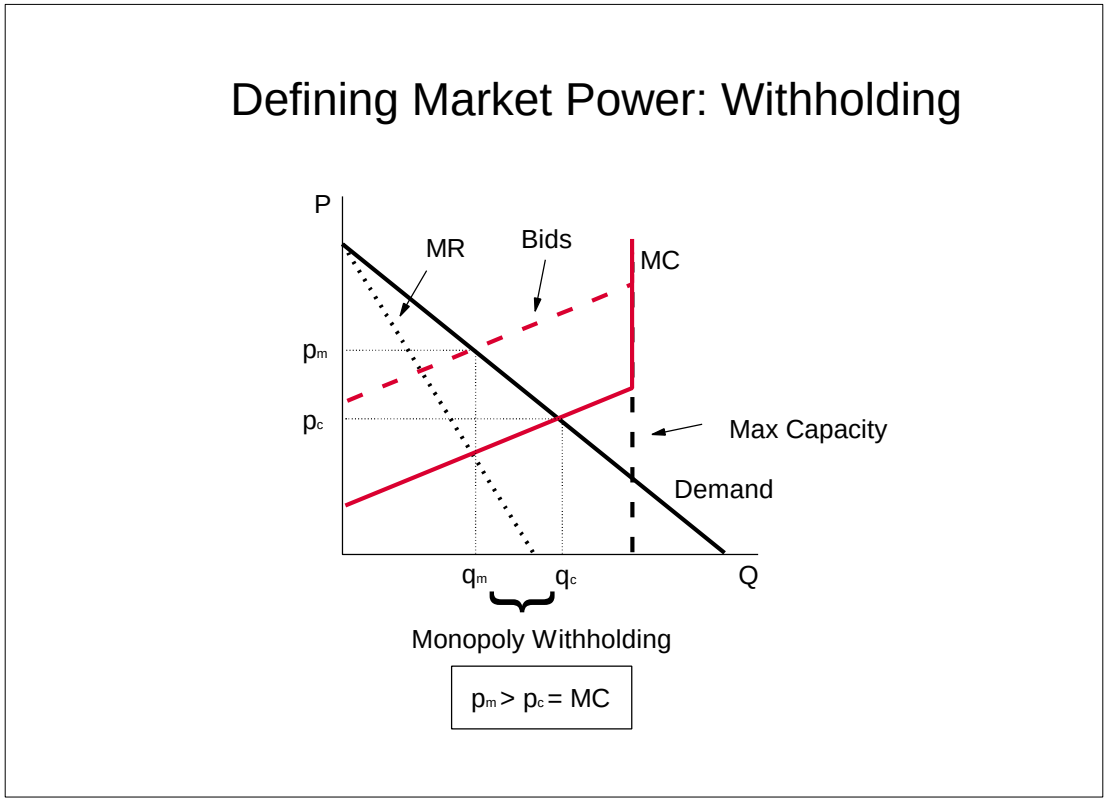
6 Department of Justice and Federal Trade Commission Horizontal Merger Guidelines, April 2, 1992, p. 4.

7 Paul L. Joskow and Edward Kahn, "A Quantitative Analysis of Pricing Behavior in California's Electricity Market During Summer 2000," March 2001 (hereafter Joskow-Kahn (March)) , pp.18-19. Joskow and Kahn (July), p. 2.

8 Harvey-Hogan (April), p. 1.

9 As discussed later, the situation could be different in the presence of transmission constraints. However, this is probably not relevant in the present instance.

Figure 1



By contrast, it is not an exercise of market power for a generator to sell all its output at an offer price that exceeds its incremental cost. In this circumstance no output has been withheld from the market.[10] This distinction is important. Many complaints regarding the alleged exercise of market power in the California electricity market appear directed simply at higher prices. The objection is to an unwillingness of market participants to sell power for less than the market clearing price. The result is to categorize as the exercise of market power conduct that does not entail withholding output from the market.[11]

However, as discussed at length in Harvey-Hogan (April), the California market design and conditions include many features and circumstances where rational competitive suppliers would bid more than their direct marginal costs yet not be withholding and, therefore, not exercising market power. Faced with price discrimination, shortages, price caps, and opportunities to sell in

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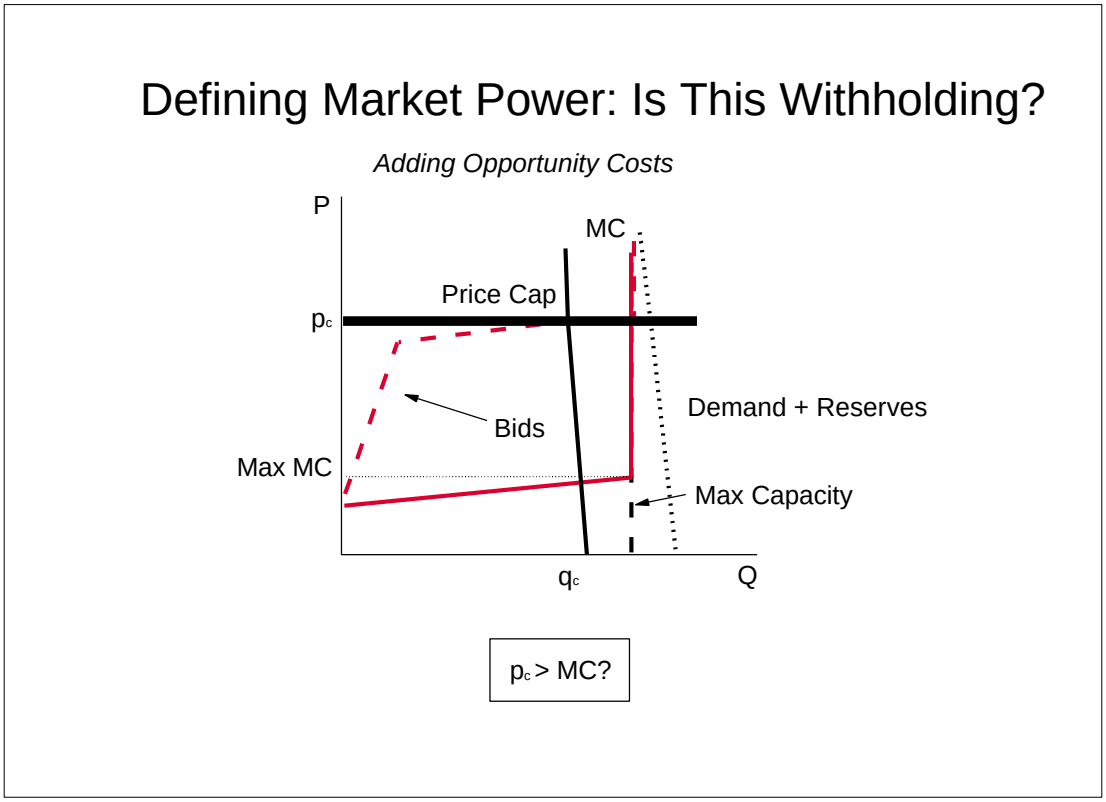
[10] Firms lacking market power but subject to price discrimination or operating within a pricing system with pay-as-bid elements would have an economic incentive to offer supply at prices related to the expected market clearing price rather than at their incremental cost. This incentive is discussed more fully in Harvey-Hogan (October).

[11] Sheffrin, Anjali, "Empirical Evidence of Strategic Bidding In California ISO Real-Time Market," March 21, 2000, pp. 8-9

other markets, generators would have incentives to bid well above marginal cost. As shown in Figure 2, this can lead to outcomes with high bids, energy production below capacity, overall shortages relative to aggregate requirements for energy and reserves, and high prices; but there is no withholding of capacity and no exercise of market power.

Figure 2



The meaning of market power is central to any discussion of the circumstances in which electricity suppliers in the western grid (the Western System Coordinating Council, WSCC) would find it profitable to exercise material market power. Firms exercise market power by reducing output below competitive levels so as to raise market-clearing prices. It is not an exercise of market power for firms to refuse to sell their output at prices below the competitive, market clearing level. It appears that there have been substantial periods during the 2001 in which the California Independent System Operator (CAISO) was short of capacity and the market price of capacity in California was the price cap. In such a shortage situation, the competitive market-clearing price may be far above the incremental cost of the highest unit running.

In such a shortage situation, a competitive firm, even one with a tiny percent of the market, would bid to ensure that it is paid the market clearing price (i.e., the price cap). Depending on

the pricing rules, this could entail bidding its costs[12] or bidding the price cap.[13] As observed above, it appears that many of the claims regarding the exercise of market power in California do not actually identify the exercise of market power through output withholding but merely efforts by sellers to be paid the market clearing price, particularly in shortage conditions.[14] This distinction is important, because conventional remedies for market power will be ineffective in inducing market participants to accept less than the market-clearing price for their output. Indeed, small suppliers may be more aggressive than large suppliers in seeking to be paid the market-clearing price.

The situation in which the CAISO does not have enough energy and reserves to meet load at the price cap is the normal outcome when price controls are binding. All output sells at the price cap, this price may be above the cost of many or all sellers, and no capacity is withheld from the market.[15] The existence of a shortage can be more subtle in an electric system than in other markets because the CAISO can be short of capacity and reserves before it reaches the point that it actually has to shed load. While the price for net buyers would be lower if supplies were offered at a price below the price cap, an unwillingness to offer supplies for less than the market clearing price does not reflect an exercise of market power. Furthermore, conventional market power remedies would not affect the willingness of net sellers to sell their output for less than the market clearing price.

On these points there is confusion in policy discussion, but there is no disagreement here with the analysis of Joskow and Kahn.

B. Analysis and the Role of Uncertainty

Going beyond this definition of market power, there is more difficulty and more controversy in collecting and evaluating the evidence. Here a further discussion is warranted to highlight what is at issue. Both informal comments and the details of Joskow-Kahn (July) suggest an interpretation of the argument in Harvey-Hogan (April) that would be inconsistent with the explicit content of that paper. The purpose of the analysis in Harvey-Hogan (April) was not to dispose of the task of measuring the degree of the exercise of market power nor did the analysis conclude that there was no exercise of market power in California. However, the responses appear to suggest that this was the purpose and the conclusion of Harvey-Hogan (April).

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[12] This would be rational if the pricing system paid all suppliers the price cap in a shortage situation. The California pricing system does not have this characteristic.

[13] As discussed at length in Harvey-Hogan (October), pp. 20-25, the CAISO pricing system has many pay-as-bid elements that will likely motivate firms to submit bids that are related to the expected market price, rather than their costs, under a variety of circumstances, including potential shortage conditions.

[14] See footnote 11.

[15] Similar shortages at the regulated price prevailed in natural gas markets during the 1970s and in gasoline supply in 1979. See Paul W. MacAvoy, *Energy Policy – An Economic Analysis*, 1983; Stephen G. Breyer and Paul W. MacAvoy, *Energy Regulation by the Federal Power Commission*,1974; Paul W. MacAvoy and Robert S. Pindyck, *Price Controls and the Natural Gas Shortage*, 1975; Joseph P. Kalt, *The Economics and Politics of Oil Price Regulation*, 1981; David Glasner, *Politics Prices and Petroleum*, 1985; M. Elizabeth Sanders, "The Regulation of Natural Gas, Policy and Politics 1938-1978," 1981.

For instance, consider the observation that "[Harvey and Hogan] do not contribute to identifying or measuring when or how much market power is being exercised, the ostensible topic of their paper."[16] Further, the Joskow-Kahn summary of Harvey-Hogan (April) is brief enough to include in its entirety:

> "The Harvey-Hogan paper is philosophically dedicated to the proposition that market structure inefficiencies and the uncertainties they create for generators potentially explain all behavior that might otherwise look like the exercise of market power. Harvey & Hogan never address the fairly obvious theoretical proposition that under conditions of inelastic demand and supply, generators selling into a spot market with California's market structure have substantial unilateral incentives and the ability to exercise market power; that is, they have the incentive and ability to exercise market power without any formal collusion between them. Nor do Harvey & Hogan provide alternative estimates of benchmark competitive prices or empirical measures of market power. Rather than engage these basic principles of oligopoly theory, for example by presenting and applying an alternative theory of oligopoly behavior or alternative measures of market power, Harvey & Hogan present a litany of largely unsupported arguments that ignore what economic theory and common sense suggest about behavioral incentives. Their approach focuses on raising questions rather than providing answers. Their paper does not offer alternative estimates of competitive benchmark price, alternative measures of the gap between competitive prices and actual market prices, or alternative measures of withholding behavior. We find this philosophical approach to understanding and measuring market behavior and performance to be unproductive. Harvey & Hogan make their most useful contributions when they discuss the data that we have used in our study and its interpretation."[17]

This summary misses the main and often repeated points of Harvey-Hogan (April). The first point goes to the use of incomplete evidence in the face of uncertainty. The simple and direct analogy is to the use of statistical evidence. Accumulation of statistics that are consistent with a hypothesis reinforces prior belief, but it is not in itself a proof that the belief is correct. The usual application of statistics is to reject hypotheses that are inconsistent with the data. There can be many hypotheses that are consistent with the data. In this circumstance, observing that the data are consistent with one of the hypotheses does not establish that it is true and others are false.

Carrying further the statistical analogy, the power of a test defines the ability of evidence to distinguish among hypotheses, rejecting some and not others. In the main, the Joskow-Kahn (March) analysis conducts tests that provide evidence that is consistent with the hypothesis that thermal generators withheld output in 2000. These tests involve many simplifying assumptions, as is necessary when relying only on publicly available data for a problem as complex as the estimation of the extent of the exercise of market power. Joskow and Kahn do conduct some

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[16] Joskow-Kahn (July), p. 1.

[17] Joskow-Kahn (July), p. 3.

sensitivity tests to determine the degree of possible error in their analysis, and argue that the errors are small.[18] The analysis in Harvey-Hogan (April) includes both theoretical and empirical additions to the list of sensitivity tests.

The second point in our earlier papers was the observation that the simulation analyses being employed to assess whether market power has been exercised are indirect methods of addressing this question.[19] Determining that simulated prices are less than actual market prices does not tell us why the simulated prices are lower. In particular, the simulation results do not tell us that actual prices were high because of economic or physical withholding by thermal generators. Are the simulated prices lower because actual demand is peakier than simulated demand? Are the simulated prices lower because the simulation assumes that more hydro, geothermal or wind energy would be available in peak hours than was actually the case? Are the simulated prices lower because the simulation assumes different reserve requirements than those observed by the CAISO? Are the simulated prices lower because the simulation assumes that hydro supplies are offered into the market as price takers? Moreover, except with respect to the peakiness of demand, no sensitivity analyses have been offered by Joskow and Kahn, BB&W or the MSC that would enable one to assess the likely impacts of any of these assumptions.

In the end, the simulation studies do not establish that the simulated provision of energy and ancillary services (reserves and regulation) by the thermal generators exceeds the actual supply of energy and ancillary services from these units in the high priced hours. All that is known is that the simulated price is lower. Moreover, as we have also pointed out, even if it were established that the simulated output of the thermal generators exceeded the actual output of the thermal generators in the high priced hours, the simulation approach would still not permit one to infer whether the real-world output was lower than the simulated output because of the exercise of market power, or because of the outages that occurred in the real-world, capacity differences between the simulation and the real-world, or environmental limits not included in the simulation. One of the important elements of the debate over the exercise of market power is that a year after prices first rose in California, the CAISO has still not provided evidence of actual economic or physical withholding but continues to rely on these kinds of indirect analyses where many things other than the offer prices of the thermal generators are potentially varying.

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[18] Joskow-Kahn March, p. 14.

[19] The studies claiming that the exercise of market power accounts for a substantial part of the price increases are predominantly simulation studies that conclude that market power has been exercised because the simulated price is lower than actual market price. See Frank Wolak, Robert Nordhaus, and Carl Shapiro, "An Analysis of the June 2000 Price Spikes in the California ISO's Energy and Ancillary Service Markets," September 6, 2000 (hereafter MSC); Severin Borenstein, James Bushnell and Frank Wolak, "Diagnosing Market Power in California's Restructured Wholesale Electricity Market," August 2000 (hereafter BB&W); Paul L. Joskow and Edward Kahn, "A Quantitative Analysis of Pricing Behavior in California's Electricity Market During Summer 2000," March 2001; Eric Hildebrant, "Analysis of Market Power in California's Wholesale Energy Markets," November 21, 2000; Eric Hildebrant, "Further Analyses of the Exercise and Costs Impacts of Market Power in California's Wholesale Energy Market," March 2001. It is a commonplace experience with optimization models, such as GE MAPS, that they tend to over-optimize compared to what can be achieved in the real system. And this is with optimization models that include contingency constrained networks, dynamic limits, unit commitment, and so on. The danger of too perfect an answer is even greater with optimizing simulations that assume away these details.

We do not provide “alternative benchmark competitive prices” based on the simulation methodology because the available information would not permit us to simulate prices with sufficient accuracy to support more definitive conclusions. One could undertake a sensitivity analysis of the Joskow-Kahn simulation methodology, but due to the nature of some of the limitations of the Joskow-Kahn study, this would have required a major effort merely to illustrate the principle that one cannot resolve the ambiguity. A better approach would be to obtain data that are available to the regulators, although not in the public domain.

The third point of our paper was that the only empirical analysis in the Joskow-Kahn paper that was capable of identifying withholding (the Test 1 analysis of the CEMS data) overstated the output gap by including hours in which real-time prices were low or units would have been ramping, ignoring deratings and environmental output restrictions, and understating ancillary service procurement. Changing only a few of these features resulted in a calculated output gap, and a range of uncertainty for the size of the true gap, that made it impossible to conclude whether there had or had not been material economic withholding from that data. It is seen below that nothing in the more recent Joskow-Kahn paper provides any reason to change this conclusion. The overall point argued in the Harvey-Hogan (April) analysis is that with the publicly available data for the case of California, the margin of error was large and the power of the test was low.

This is not to say that it is not possible to determine if there has been a significant exercise of market power. To the contrary, another point of our paper was that: "A fuller analysis would require data available only to the California Independent System Operator, and has not been done."[20] The point was that the simplifying assumptions in Joskow-Kahn (March) were important enough that it would be necessary to obtain data not in the public domain in order to resolve the ambiguities and distinguish among the effects of strategic withholding, poor market design, higher supply costs and capacity shortages. We have not argued that no data capable of gauging the potential magnitude of economic withholding are available. Rather, we have pointed out that these data are in the hands of the CAISO, which has chosen not to produce these kinds of analyses. The CAISO knows which units were providing reserves with the capacity not dispatched to generate energy. The CAISO knows which hours were shortage hours in the real-world, in which there was not enough capacity to meet minimum operating reserve capability (MORC) requirements at any price. The CAISO knows which capacity that was not providing ancillary services was dispatched for energy, and knows which capacity that was not providing ancillary services was not dispatched for energy despite being in-merit because of ISO decisions or environmental limits known to the CAISO, and finally it knows which capacity that was not providing ancillary services was not dispatched for energy because of the level of its bid.

Reasonable people might disagree about the interpretation of the evidence and argument in Harvey-Hogan (April) as to the degree of uncertainty and the statistical power of the tests of the exercise of market power. But given the conclusions in Harvey-Hogan (April), it would have been surprising to see in that paper the "alternative estimates of benchmark competitive prices or empirical measures of market power" that Joskow-Kahn (July) found absent. The point was that

[20] Harvey-Hogan (April), p. ii.

we did not have access to the information needed to do the alternative tests. Hence, this response from Joskow-Kahn (July) misses the point.

The strongest conclusion found in Harvey-Hogan (April) is that "[t]he import of the sensitivity analysis here is not to prove that market power has not been exercised in the electricity market but, rather, to suggest that it is unlikely to be the dominant factor and may not even be significant."[21] The analytical task implied was to seek access to data not then in the public domain. The policy implication was to focus more on other problems where there is agreement that the California market is seriously flawed.

III. MARKET POWER IN CALIFORNIA: THEORY

The economic theory of the incentives for exercising market power plays a prominent role in the response to Harvey-Hogan (April). In particular, Joskow-Kahn (July) argues that Harvey-Hogan (April) did not "address the fairly obvious theoretical proposition that under conditions of inelastic demand and supply, generators selling into a spot market with California's market structure have substantial unilateral incentives and the ability to exercise market power; that is, they have the incentive and ability to exercise market power without any formal collusion between them."[22] This is not correct either in its statement of the argument in Harvey-Hogan (April) nor in its implications.

As for the argument in Harvey-Hogan (April), there was explicit agreement that there could be incentives for strategic withholding. "Suppliers could affect market prices by strategically withholding some capacity in order to profit on the capacity actually sold in the market."[23] Or, "[i]t is widely recognized that the potential for exercising market power through strategic withholding exists in electricity markets in many regions of the country, and California is no exception."[24] The analysis in Harvey-Hogan (April) explicitly accepted and did not dispute the underlying economic logic of these conditional statements. Under some circumstances, the potential exists for exercising market power, and under other circumstances it would not. Joskow-Kahn (March) state that "[i]t is clear from first principles that supply withholding could be the source of high prices. Whether this is in fact the case is an empirical question."[25] We interpret this as to saying that there are two related empirical questions, as to the incentive to exercise market power and as to the actual degree of withholding.

The implication of the comment in Joskow-Kahn (July) is that Joskow-Kahn (March) disposed of both of these questions. The argument in Harvey-Hogan (April) speaks largely to the evidence that thermal generators withheld a significant amount of output in a strategic effort to increase their profits. That is the main issue. However, we did not address the matter of incentives because in our reading Joskow-Kahn (March) never went beyond a conditional

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[21] Harvey-Hogan (April), p. ii.

[22] Joskow-Kahn (March), p. 18.

[23] Harvey-Hogan (April), p. 1.

[24] Harvey-Hogan (April), p. 2.

[25] Joskow-Kahn (July), p. 3.

assertion that there *could* be incentives to withhold, rather than a conclusion that these incentives were necessarily significant in California. By contrast, the implication from Joskow-Kahn (July) is there was clear evidence of ubiquitous and "substantial" incentives to exercise market power. This is not consistent with our reading of Joskow-Kahn (March).

Informal comments and questions from others about Harvey-Hogan (April) reinforce the importance of this matter regarding the theoretical foundations for an incentive to withhold. We have noted that several stylized facts regarding the California and WSCC electricity markets suggest that on balance the major sources of the price increases are more likely to be shortage and California public policy than a significant exercise of market power. As a result, we have been asked: “If firms aren’t exercising substantial market power in the California electricity market, why aren’t they?” This suggests a view that the incentives are clear and substantial. It also rejects on its face the argument of others that in the presence of high prices a generator would have to be "crazy" not to produce everything that it could. Apparently it would be useful to expand on the reasons why this is an empirical question.

In turning to this question, we first observe that we would be surprised if there were no instances of a firm in the WSCC exercising market power by restricting output in some circumstances. But we would also be surprised if such strategic withholding is a substantial or an important part of the explanation of for the high prices in California and the WSCC more generally during 2000 and 2001. We know that firms can and sometimes do exercise market power in other electricity markets. In these other markets, it has been possible to directly identify withholding by specific generators within the framework of the actual dispatch and constraints, not just to infer market power with a simulation model based on a hypothetical dispatch rather than the actual dispatch. Thus, in other electricity markets, there has been a smoking gun.

In the case of California, the apparent lack of such a smoking gun demonstration of withholding stands in contrast to experience elsewhere. We don't know enough to be sure about the explanation of the underlying reasons for the continued absence of the smoking guns. There are, however, several features of the California market that appear to us to be important in understanding why the exercise of market power *might* not be material.

- Mitigated locational market power.
- West-wide competition.
- Forward contracts.
- Generation heterogeneity and infra-marginal rents.
- Price caps.
- Price sensitive load.
- California market complexity.

It is important in discussing these features of the California electricity market to keep in mind that the potential to exercise market power exists both in the short-term and in the long-term and

the constraints on its exercise can be different in the different time frames. Thus, in assessing the profitability of withholding output in a particular hour in order to raise prices in that hour relative to other hours, reductions in demand attributable to price sensitive load may not have been a substantial deterrent to the exercise of market power during the summer of 2000. On the other hand, the profitability of such short-term price increases would have been reduced by forward contracts and the ability of energy limited suppliers throughout the WSCC to shift energy into the hours subjected to price increases.

In assessing the profitability of withholding output on a sustained basis in order to raise prices in all hours of the day over a long period of time, on the other hand, forward contract positions would only deter such withholding if they were very long-term fixed price or margin arrangements and energy limited resources would not be able to expand output across the board in response to such price increases. Conversely, however, such long-term sustained price increases would affect price responsive load throughout the WSCC and could also draw inactive plants throughout the WSCC back into the market.

Each of these influences on the exercise of market power is discussed below.

A. Mitigated Locational Market Power

The most common sources of market power in electricity markets are transmission constraints that limit the number of competitors capable of meeting incremental load within localized markets. It appears to us that locational market power in California has played little role in the high prices in the California electricity market during 2000 and 2001. To a considerable degree, the potential for the exercise of such locational market power had already been mitigated in California. In this period, there were RMR contracts to mitigate market power in those places and for those generators that were identified in advance as having the potential to exercise market power when local transmission constraints were binding. While the form of these RMR contracts may not be best long-run mechanism for mitigating locational market power, they were specifically intended to eliminate the potential for the exercise of local market power through strategic withholding.

It is of course possible that RMR contracts have not mitigated all locational market power and that the CAISO's intra-zonal redispatch costs were raised by the exercise of market power in some local areas. It does not appear to us, however, that this has been a significant issue. The CAISO has not identified local congestion as a significant concern with respect to the exercise of market power during 2000/2001, and none of the studies claiming to identify the exercise of market power focused on the exercise of such local market power.[26]

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[26] The absence of transmission constraints would simplify the analysis further by allowing a focus on withholding. In the presence of transmission bottlenecks, it would be possible in principle to exercise market power by increasing production from generators at one location, at a loss, in order to profit from higher prices at another location. See Judith B. Cardell, Carrie Cullen Hitt and William W. Hogan, "Market Power and Strategic Interaction in Electricity Networks," *Resource and Energy Economics*, Vol. 19, 1997, pp. 109-137.

B. West-Wide Competition

One of the striking features of the high prices in the California electricity market is that they often occurred during periods in which imports into California were not transmission constrained and the high prices were not limited to California. Thus, it is readily apparent from a review of industry electricity price reports that increases in the market price of electricity during 2000 were not limited to California. Higher prices appeared at the other major WSCC bilateral trading points, such as Mid Columbia, California Oregon Border, Palo Verde, Mead, and Four Corners.[27] Moreover, although we have not had access to the data required for a careful study, it appears to us that the wholesale prices in California were consistent with wholesale prices prevailing in wide regions in the WSCC including areas as distant as Alberta,[28] Idaho[29] and Montana,[30] as well as the desert Southwest and Pacific Northwest.

In addition, it is our understanding that transmission constraints into California from the Pacific Northwest and Southwest have generally not been binding.[31] While it is possible that there has been some withholding of transmission service that limited supplies from other regions in the WSCC even when transmission constraints were not binding,[32] we are not familiar with any such allegations. The combination of a lack of apparent transmission constraints into California, substantial amounts of power flowing into California from other regions in the WSCC and the WSCC-wide price increases strongly suggest that California thermal generators were generally competing at the margin not only with other California suppliers but with suppliers throughout the WSCC.

The empirical importance of this WSCC-wide competition arises from its implications for the residual supply elasticity confronting any individual market participant seeking to exercise market power (i.e., the supply elasticity of the other market participants). Although we have not had the opportunity to undertake quantitative analysis of this issue, it would not seem to be particularly surprising that generators, controlling virtually no generation in the WSCC outside California and only a few thousand MW inside California, might not find it profitable to withhold substantial capacity in an attempt to drive up prices throughout the WSCC. Any withholding by an individual firm would be offset in part by increases in the supply offered by other market participants (as well as reductions in demand throughout the WSCC).

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[27] See for example *Megawatt Daily*, Market Report, Trades for Standard 16-Hour Daily Products.

[28] Market Surveillance Administrator, "Report on Power Pool of Alberta Prices – Summer 2000," pp. 3-6. RBC Dominion Securities, "Alberta Is Jolted by Electric Deregulation," January 11, 2001.

[29] *Megawatt Daily*, May 7, 2001 "Idaho Power expects blackouts, high prices."

[30] *Megawatt Daily*, "Montana Power Buys Out Risky Supply Contract," June 27, 2001, p. 8.

[31] See, for example Western States Coordinating Council, Assessment of the 2001 Summer Operating Period, April 13, 2001, p. 5.

[32] By transmission constraint we mean the current contract path constraints in the WSCC, not the underlying reliability constraints that might only be binding at even higher levels.

1. Profit Maximization

In evaluating the potential incentive of individual market participants to unilaterally withhold output so as to affect the market clearing price, and the impact of WSCC-wide competition on this incentive, it is helpful to utilize the framework adopted in Joskow-Kahn (March) in their consideration of this incentive. This is the centerpiece of the Joskow and Kahn analysis to demonstrate the possibility of an incentive to withhold output and increase prices. The basic framework is:

> "This exercise explores the profitability of a generator withholding capacity relative to a competitive baseline in which price is set by industry marginal cost and all generation with marginal cost below the market-clearing price is dispatched. We assume that all other generators produce at competitive levels and demand is completely inelastic. Under these assumptions, the effect of withholding on price is the same as a leftward shift of the industry supply curve by the amount of withholding."[33]

Joskow and Kahn derived the following expression for the profitability of unilateral output withholding:[34]

$$\Delta\Pi = p_C \left(q_l - q_c\right) + \frac{\Delta p}{\Delta q}\,\Delta q\; q_l + .5\left(MC\left(q_l\right) + MC\left(q_c\right)\right)\left(q_c - q_l\right). \qquad [1]$$

Where:

p_c	=	Competitive market-clearing price,
q_c	=	Firm i competitive output at p_c,
p_l	=	Market-clearing price after unilateral output reduction by firm i,
q_l	=	Firm i output following unilateral output reduction,
$\frac{\Delta p}{\Delta q}$	=	Change in market-clearing price due to a unilateral output reduction by firm i,
Δq	=	$(q_c - q_l)$ = unilateral output reduction by firm i,
$MC(q_l)$	=	Marginal cost of firm i at output q_l,
$MC(q_c)$	=	Marginal cost of firm i at output q_c.

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[33] Joskow-Kahn (March), p. 34.

[34] Joskow-Kahn (March), p. 35.

Given these assumptions, Joskow and Kahn examine the incentive for a generator with 3000 MW of capacity who considers withholding half that amount. The starting point is a competitive benchmark price of $60 per MWh. They consider two cases that differ principally in the critical parameter $\Delta p / \Delta q$, the change in price for a given change in supply. In the first instance, the assumed slope is 0.011 which implies that "a withdrawal of 1000 MW results in a price increase of about $10 per MWh."[35] The second case produces only about a $1 price increase for the same capacity withdrawal.

Table 3

Unilateral Market Power Examples

Case	Fwd Sales *[0]*	p_c *[1]*	q_c *[2]*	q_l *[3]*	MC (q_c) *[4]*	MC (q_l) *[5]*	dp/dq *[6]*	Revenue Loss [7]	Revenue Gain [8]	Cost Saving [9]	Total Gain [10]	"Best" p_l [11]	"Best" q_l [12]
1	0	60	3000	1500	55	50	0.0110	90000	24750	78750	13500	72.2	1895
2	0	60	3000	1500	55	55	0.0010	90000	2250	82500	-5250	60	3000
3	0	60	3000	1500	55	50	0.0047	90000	10683	78750	-567	63.4	2285
4	0	88	3000	1500	55	50	0.0110	132000	24750	78750	-28500	88.0	3000
5	0	60	3000	1500	55	50	0.0033	90,000	750	78,750	-10,500	61.6	2507
6	0	60	3000	1500	55	-110	0.0110	90,000	24,750	-41,250	-106,500	60.03	2997
7	820	60	3000	1500	55	50	0.0110	90000	11220	78750	-30	68.2	2251
8	2500	60	3000	1500	55	50	0.0110	90000	-16500	78750	-27750	60.0	2980

[7]=[1]*([2]-[3])

[8]=[6]*([2]-[3])*([3]-[0])

[9]=0.5*([4]+[5])*([2]-[3])

[10]=[8]+[9]-[7]

11]=[1]+([2]-[12])*[6]

[[12] From marginal cost curve, vertical at 3000 MW

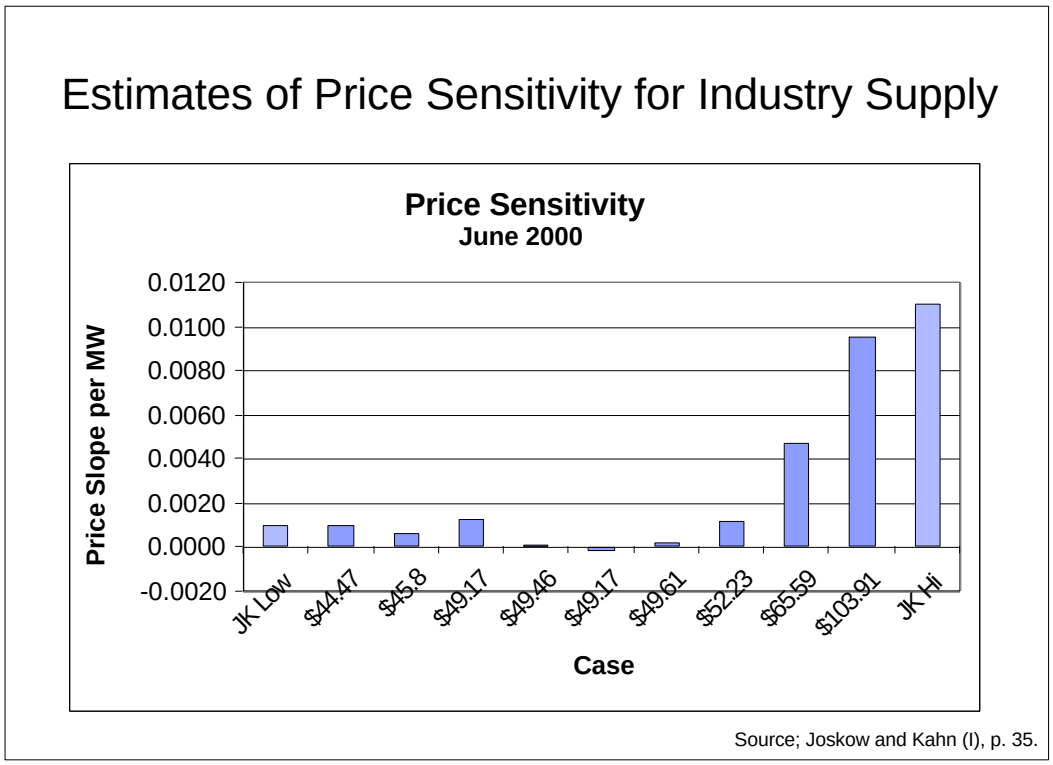
Table 3 repeats the calculations of Joskow and Kahn with a few additions. First, in anticipation of further discussion of the framework, we added three columns in [0], [11], [12], as discussed below. Second, we added some additional sensitivity analyses by considering a few different cases.

[35] Joskow-Kahn (March), p. 19.

The first two rows of the table repeat the detail from Joskow and Kahn.[36] In the first case, the reduction in output produces a net profit gain of $13,500, indicating an incentive to withhold. In the second case, with reduced sensitivity of price to output changes, the assumed reduction is unprofitable with a loss of –$5,250. This illustrates the importance of the assumed response of the rest of the market to the unilateral withdrawal of output by an individual supplier.

This raises the question as to the justification for either a high or low value of the price response parameter. Joskow and Kahn explain their approach as using their simulation model at different load deciles to calculate the industry supply curve for June 2000. Furthermore, they provide a detailed table of the results that "shows how to estimate the slope of the supply curve."[37] There is a methodological issue in this estimate, to which we return below. However, for the moment it is interesting to note that the price sensitivity used in case 1, the case with the indicated incentive to withhold, is larger than the price sensitivity (impact of output withholding on price) for any of the load deciles in the Joskow-Kahn calculation of the June 2000 supply curve.

Figure 4



[36] See Joskow-Kahn (March), p. 35-36. It appears that the slope used in the first case was slightly higher than 0.011, and the difference could be attributed to rounding error. Other than this, the calculations replicate the results of Joskow and Kahn.

[37] Joskow-Kahn (March), p. 35.

Figure 4 shows the implied slopes for the different deciles indexed by the benchmark market-clearing price for that load level. The two outer bars indicate the two cases used for the Joskow and Kahn analysis of the incentive for unilateral withholding. Apparently the high case is an outlier that exceeds the highest slope calculated for load at the upper decile. It is possible that this slope might prevail, but it is inconsistent with the basic Joskow-Kahn simulation methodology.

The Joskow and Kahn analysis in case 1 was thus based on a slope that is inconsistent with their assumed benchmark market-clearing price. To illustrate withholding incentives based on the supply response simulated by Joskow and Kahn at an assumed price of $60, we recalculated the results for the first case using the price slope of 0.0047, which better corresponds to the price sensitivity calculation for $65.59. The results for this case appear in the third row of Table 3. Apparently in this case, reducing output by half is slightly unprofitable, with a loss of -$567.

Of course, there is nothing special about withholding half of the output. Some other strategy might be preferred. To provide a simple way to illustrate the effect of other withholding levels, we added columns [11] and [12] to the table estimate the "best" price and output for the hypothetical generator. This gives a rough indication of the implications of the alternative assumptions for withholding at levels other than the 50 percent reduction assumed by Joskow and Kahn. The "best" price and quantity would maximize the generator's profits.

In the first row, we see that the 50 percent reduction was a little too much. It would have been more profitable to withhold a little less. In the low price case, there would be no incentive to withhold. In the third case, using the elasticity more consistent with the maintained assumptions, the 50 percent reduction is too much, but there is some incentive to withhold a smaller amount and increase price from $60 to $63.4 per MWh.

All of these calculations assume that the generator exercising market power has sufficient information to withhold output so as to elevate the price at which it sells its output. Output withholding combined with bids that fail to raise the price at which output is sold would not be profitable. In this regard, it is necessary to keep in mind the sequential structure of California energy and ancillary service markets. Thus, real-time capacity withholding that elevates real-time prices would not be profitable for the withholder if most of its capacity were sold day-ahead at low prices. Moreover, capacity withholding that drove real-time non-spinning reserve prices to the cap would not be profitable if the withholders' remaining capacity were sold in the real-time energy or spinning reserve markets at lower prices.

Joskow and Kahn present their two cases without further comment or interpretation of the implications for unilateral withholding. However, based on these cases alone and the additional sensitivity test indicated for case 3 in Table 3, this is hardly a demonstration of an "obvious" proposition that generators in California had "substantial unilateral incentives and the ability to exercise market power."

The only further statement in Joskow-Kahn (March) is that this analysis was for unilateral withholding and "[i]f multiple players are behaving strategically, the effect of withholding on

wholesale market prices could be larger."[38] Other things being equal, this statement is correct within their framework. However, in the context of a discussion of the incentives for unilateral withholding, it would be important to recognize that this does not imply that the incentive for unilateral withholding would necessarily increase.

If the price were higher than the competitive benchmark, because others were withholding, this would decrease the incentive for any individual generator to withhold. This is the classic problem of the incentive to defect from any cartel. This can be illustrated by raising the assumed price and observing that, other things being equal, the incentive to unilaterally withhold in the Joskow and Kahn model would be lower. In the fourth case of the table, we see that if the competitive price were $88/MWh, the generator has an incentive to produce 3,000 MW. This indicates another important feature of the Joskow and Kahn example. It is dependent on the assumption that the generator has its marginal costs close to the market price.[39]

Finally, moving beyond the Joskow-Kahn analysis of unilateral incentives to a broader game theory analysis of oligopoly would only raise more issues that would require empirical resolution. Given the complexity of the institutional details in the California market, it is not likely that such a theoretical analysis would replace the need to look for the data that could identify the smoking guns.

2. Consistency of Assumptions

The Joskow and Kahn illustration of a possible incentive for profitable unilateral withholding depends upon the particular assumptions for the supply response to higher prices. Given a starting assumption of completely inelastic California demand, the impact of an output reduction on the market price is determined solely by the slope of the industry supply curve. The value Joskow and Kahn assumed for $\Delta p/\Delta q$ is 0.011. This implies that WSCC suppliers as a whole, other than the withholding firm, would increase deliveries into the CAISO control area by 90.9 MW in response to a $1/MWh increase in the price of power within the CAISO control area. As noted above, this is less of a supply response than produced in the Joskow-Kahn model simulations near a price of $60. Furthermore, Joskow and Kahn assume that the slope of the marginal cost curve of the single withholding firm is extremely flat. Hence, a 1500 MW change in the output of this firm would only move it $5/MW down its marginal cost curve (from $55 to $50), or a change of 300 MW in response to a $1 change in the price in the CAISO market. Thus, the industry supply curve they assume for their demonstration of an incentive to withhold output is more than three times as steep as the hypothetical firm's marginal cost curve assumed in their illustrative calculation. Although these assumptions could be reasonable in analyzing the incentives of a particular firm operating generating assets that differ markedly from the assets of its competitors, this is not the case we understand Joskow and Kahn to be addressing.

While reaction functions are complex and reasonable people will disagree over the appropriate assumptions for modeling the expectations of a competitive or imperfectly competitive firm, the

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[38] Joskow-Kahn (March), p. 20.

[39] Note that the same result would be obtained in case 1 at $60 if the marginal costs of this generator were $30 and $25 rather than $55 and $50.

assumptions underlying the Joskow-Kahn calculations should be recognized as a specialized case rather than a general rule. It does not appear that such assumptions are internally consistent in analyzing the incentives of one out of many thermal suppliers in the WSCC. Moreover, these assumptions are critical to the Joskow-Kahn findings regarding the profitability of unilateral output withholding for this particular supplier.

Thus, if the industry were assumed to include ten other firms similar to those analyzed by Joskow and Kahn (which would be a conservative characterization of the WSCC) and the industry supply curve were thus assumed to be shaped like the individual firm's marginal cost curve, but with one-tenth the slope of the individual supply curve, rather than three times the slope of the individual supply curve as assumed by Joskow and Kahn, then the unilateral 1,500 MW output reduction hypothesized by Joskow and Kahn would be unprofitable, as shown by row 5 in Table 3.[40] The output reduction would be unprofitable because the impact on market prices would be much less than in the Joskow-Kahn hypothetical. These assumptions imply that it would be profitable to withhold about 500 MW, raising prices by $1.6/MWh. Similarly, if the individual firm's marginal cost curve were like the other firms assumed in the industry supply curve (i.e., very steep), very little unilateral withholding would be profitable because the implied cost savings would be too small and the foregone profit margin would be too great (see row 6 in Table 3).[41] It is the particular combination of assumptions that there is an elastic individual firm supply and an industry supply with a lower elasticity than either calculated in their simulation or assumed for a single firm, that combine to provide Joskow and Kahn with an example of profitability for significant unilateral withholding.

The implications for competition of a pricing model such as that postulated by Joskow and Kahn therefore depend importantly on the residual supply elasticity assumed for imports from suppliers located outside of the CAISO control area and for other suppliers located within the CAISO control area. Few studies have addressed the question of assessing the supply elasticity of imports into the CAISO control area. Joskow and Kahn rely on the work of Borenstein, Bushnell and Wolak[42] to obtain an estimate of the import supply elasticity.[43]

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[40] Eleven firms of the size assumed by Joskow-Kahn would account for around 25 percent of WSCC capacity. A considerable amount of WSCC capacity is nuclear, coal, or run of river hydro that would not be on the margin in competition with gas or oil fired generation. As of January 1, 2000 there was 37,410 MW of steam oil, steam gas, combustion turbine, combined cycle and internal combustion capacity in the WSCC; see WSCC 10-Year Coordinated Plan Summary 2000-2009, October 2000, p. 30. This corresponds to 11 firms with roughly 3,300 MW of total capacity each (3,000 MW available and 300 MW on outage). About 3,400 MW of this capacity is cogeneration capacity, which may not have an incentive to vary its output in response to market prices (see WSCC October 2000, p. 20). In the real world, the ownership of this capacity is spread over far more than 11 firms. Moreover, additional hydro and geothermal capacity is available to shift output across hours in response to price increases limited to particular hours, implying an even higher residual supply elasticity for short-term price increases.

[41] This case would be somewhat artificial as the cost curve would be negative for outputs below 2,994 MW, but this artificial outcome merely reflects the extremely steep firm supply curves implied by Joskow-Kahn's assumed industry supply curve.

[42] BB&W.

[43] Joskow and Kahn (March), p. 35.

The BB&W study of the California electricity industry used transmission congestion adjustment bids to estimate the supply elasticity of imports to the CAISO control area. They suggest that this measure of import elasticity overstates the actual import elasticity because it ignores restrictions in inter-scheduling coordinator trades.[44] This estimate of the supply elasticity of imports has unusual features, however. First, the bids they use to estimate the supply elasticity are apparently not supplementary energy bids but congestion adjustment bids. Except in the case of the PX, these bids were used only when transmission constraints were binding and the quantity of imports is fixed. While these bids may have something do to with which transactions are scheduled, it is not clear that they reveal anything about the actual supply curve for imports. Second, the BB&W analysis somehow combined these adjustment bids across multiple interfaces, some of which may have had congestion at different prices levels during the period studied. Thus, in the same hour in which there is substantial congestion from North to South into California from the Pacific Northwest in the spring, there might be no congestion between California and Arizona. It is not clear what it means to thus aggregate bids over different zones. Third, it is not clear whether the analysis of adjustment bids is based on day-ahead bids or hour-ahead bids or a combination of the two.[45] Fourth, it is clear that the BB&W analysis measures a short-run import supply elasticity (i.e., in response to hour-to-hour or, at most, day-to-day price changes). The estimated supply response does not reflect the impact of price increases in reducing consumption outside California and thus making additional energy available for export to California. BB&W indicate that the supply curve they estimate is very inelastic.[46]

Joskow and Kahn assume an import elasticity of 0.33 in their simulation analysis which is "loosely based on BB&W's claim that imports would be 5.3 percent lower and prices approximately 15.5 percent lower under marginal cost pricing."[47] Joskow and Kahn appear to base their overall supply elasticity on the supply curve in their simulation model.[48] In particular, they include a table setting forth the relationship between the average MCP in their simulation for the ten load deciles (load + reserves) during June 2000.[49] From these data they calculate $\Delta p / \Delta q$ based on the change in average price and load across the load deciles.

This simulation methodology includes a simultaneous equation bias in estimating the supply elasticity because demand and imports are jointly determined. As shown in Figure 5, and as is familiar from the analysis of simultaneous equations bias, even with perfectly inelastic demand, a plot of the intersection points of demand and supply curves at different times does not

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[44] BB&W, p. 27.

[45] An analysis of supply elasticity that is based upon hour-ahead adjustment bids would likely understate the supply elasticity in response to sustained price changes because some suppliers likely bid inflexibly in short-term markets to ensure that their transactions flow but would respond to sustained changes in price. On the other hand, an analysis of supply elasticity that is limited to day-ahead adjustment bids and estimates the average elasticity over the range of the change in imports in the BB&W simulation, might materially understate the supply elasticity, particularly if the simulated change in imports is large relative to the actual level of imports.

[46] BB&W, p. 30.

[47] Joskow-Kahn (March), pp. 12.

[48] Joskow-Kahn (March), p. 35. They refer to using a similar methodology.

[49] Joskow-Kahn (March), p. 35.

necessarily trace out the supply curve. Apparently the load in the CAISO control area is correlated with load in the remainder of the WSCC. Hence, at any price the residual supply for imports is lower in hours in which CAISO demand is high, because the non-CAISO demand is also higher in those hours. Evidence of this correlation appears in the table Joskow and Kahn present in their paper, in which it can be seen that both actual and simulated imports decline at prices above $50/MWh, which likely reflects inward/upward shifts of the import supply curve in high load hours.[50] If high CAISO load is correlated with reduced import supply, the slope of the intersection points of supply and demand will trace out a curve that is less elastic than the actual import supply curve. But for purposes of the analysis of unilateral incentives to withhold, the relevant supply curve is the more elastic supply within each period.[51]

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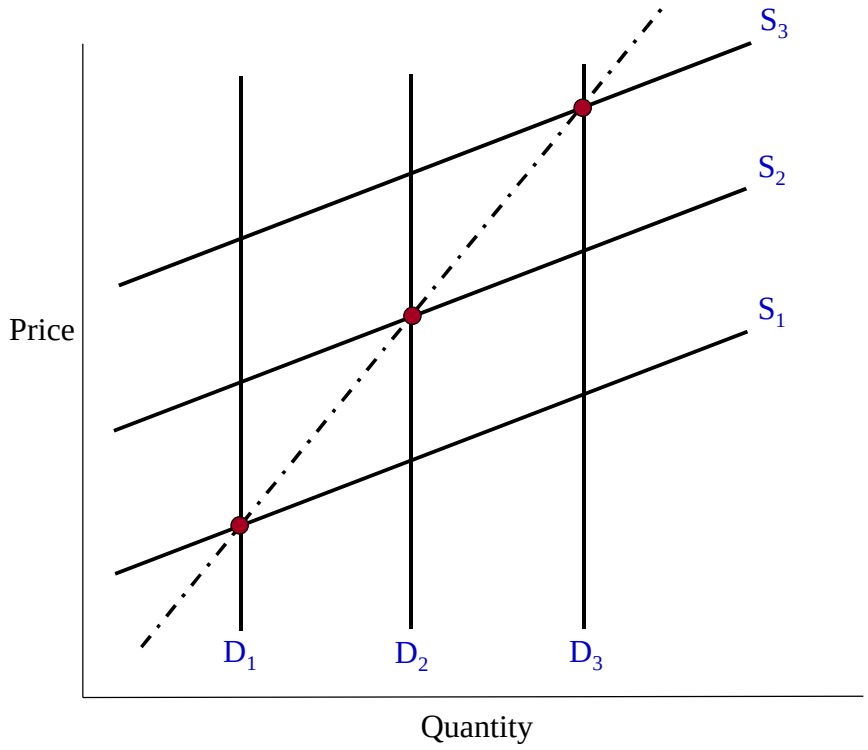
[50] Joskow-Kahn (March), p. 33.

[51] A second difficulty with the Joskow-Kahn import calculations is that the methodology is not applied to the actual empirical industry supply curve, but to the slope of the "competitive" supply curve assumed by Joskow and Kahn in their simulation. Some might argue that this supply curve would likely overstate the actual slope of the industry supply curve because it would not take account of withholding. Others might also observe that it might overstate the actual slope of the industry supply curve at low prices and understate the slope at high prices, because the hypothetical Joskow-Kahn supply curve does reflect the impact of start-up and minimum load costs and does not reflect environmental output restrictions other than RTC allowance costs. In addition, the hypothetical Joskow-Kahn supply curve assumes that energy limited resources within the California ISO control area, such as pondage hydro and geothermal, submit price taking bids, which is likely inaccurate and would understate the elasticity of industry supply.

Figure 5
Shifts in a Vertical Demand Curve
Will Not Identify a Shifting Supply Curve



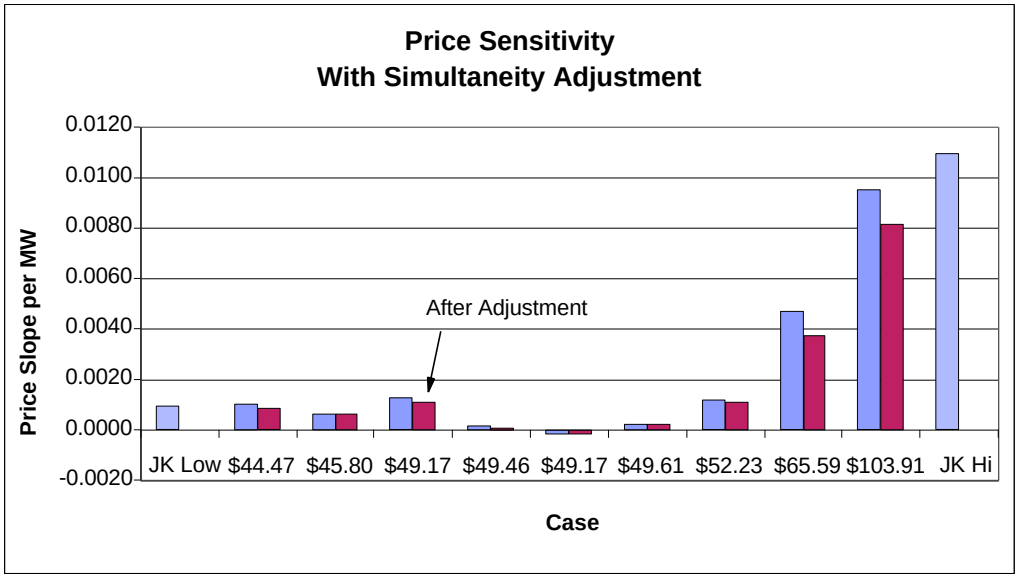
We can obtain a rough estimate of the effect of this simultaneity bias by removing imports from the calculation of simulated industry supply curve, and then adding the import elasticity to the elasticity of the internal California supply.[52] In addition, the separate treatment of the two supply curves, one for imports and one for generation within California, allows us to address the consistency of the supply assumptions.

For the first test, Figure 6 summarizes the recalculated total industry supply price sensitivity after adjusting for the simultaneity bias due to the shifts in the import supply curve. The adjustment turns out to be on the order of a 15 percent reduction in the price slope, which would further reduce the profitability of unilateral withholding.

[52] The import supply data reported in Joskow-Kahn (March) are for July (p. 33), and the industry supply curve simulation they report is for June (p. 35). The prices for the load deciles are similar, but not identical. For purposes of this rough sensitivity test, it is assumed that the differences are not important and we have combined the July 2000 simulated imports by load decile with the June 2000 California supply by load decile.

Figure 6

Estimates of Price Sensitivity for Industry Supply



Source: Joskow and Kahn (I), p. 35, plus simultaneity adjustments.

This correction to reduce the simultaneity bias would not produce a major qualitative change in the interpretation of the Joskow-Kahn examples, given the import supply curve slope they assume. The magnitude of the bias in the calculation of the slope of the overall industry supply curve depends on the true slope of the import supply curve. The greater the price response of the true import supply curve, the greater the bias. Furthermore, separation of the data for the supply within California and the supply from outside California provides an opportunity to examine the consistency of the respective assumptions regarding the slopes of these supply curves. Table 7 summarizes the detail for the two supply functions reconstructed using the information in Joskow-Kahn (March).

Table 7

Illustrative Industry Supply Curves									
	MCP	Simulated CAISO Supply	Simulated Import Supply	Simulated CAISO Supply Response	Simulated Import Supply Response	Total Simulated Supply Response	Actual Imports	Actual PX Price	Actual Load
Load	[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]
Decile	$/MW	MW	MW	MW/$	MW/$	MW/$	MW	$/MW	MW
1	$40.25	18074	4604				4575	$39.50	20616
2	$43.20	20277	4326	747	33	780	4438	$46.64	22366
3	$45.48	21970	4294	743	31	774	4533	$53.51	23877
4	$48.78	24954	3947	904	27	931	4121	$55.53	26274
5	$49.42	27711	3670	4308	25	4333	3963	$62.23	28529
6	$49.42	29712	3549	N/A	24	N/A	3968	$69.05	30238
7	$49.27	32042	3592	-15533	24	-15509	4239	$81.00	32394
8	$50.25	34163	3406	2164	23	2187	4476	$114.02	34154
9	$54.44	36985	2902	674	18	691	4385	$187.78	36262
10	$103.52	41460	2534	91	8	99	3802	$349.46	39996

[A]: From Joskow-Kahn, March 2001, p. 33.
[B]: (Load + Reserves) - Simulated July 2000 Net Imports = (1.1* Load) - Simulated July 2000 Net Imports.
[C]: Simulated July 2000 Net Imports, from Joskow-Kahn, March 2001, p. 33.
[D]: 1/((change in [A])/(change in Load + Reserves))
[E]: 0.333 * ([G]/[H]) * ([A]/[H])^(0.333-1)
[F]: ((change in Load + Reserves)/(change in [A])) + (0.333 * ([G]/[H]) * ([A]/[H])^(0.333-1))
[G]: From Joskow-Kahn, March 2001, p. 33.
[H]: From Joskow-Kahn, March 2001, p. 33.
[I]: From CAISO website.

Given the composition of the sources of supply inside and outside the CAISO, it would seem reasonable to expect that the supply response for each dollar increase in the price would be of the same order of magnitude. This might not be true if imports were high and transmission constrained. But as can be seen from the table, the Joskow-Kahn simulations suggest that imports would be high only at low load levels, the situation in which there is no unilateral incentive to withhold.

When load is high and supply responses are lower, imports are also low because of the increased competition of load outside the CAISO. However, at these high prices, the Joskow-Kahn assumed supply responses within CAISO and outside CAISO differ by more than an order of magnitude! Hence, at a $65 benchmark competitive price, a $1 per MWh increase produces 248 MW inside CAISO but only 18 MW outside CAISO. Compared to the CAISO supply curve, the import supply curve is practically vertical. This is noteworthy because the amount of gas-fired thermal generation located outside the CAISO is about the same as the amount located within the CAISO.

It is reasonable to look for some justification of this remarkable difference. Joskow and Kahn recognize the difficulty of estimating the import supply curve. As discussed in Harvey-Hogan (October), there are many reasons to be skeptical about this large divergence. However, this

particular combination of assumptions is crucial for the Joskow-Kahn examples of unilateral incentives to withhold production. If the import supply curve were assumed to have about the same slope as the domestic supply curve in the Joskow and Kahn simulations, then again the illustrative generator would find withholding unprofitable.

The point of these assumptions and calculations is not to definitively establish, based on the assumed industry supply curve, that the WSCC electricity industry must operate competitively at all times. Rather, it is to point out that it is not a forgone conclusion from the Joskow-Kahn analysis that the WSCC electricity industry will fail to operate competitively.

C. Forward Energy Contracts

It has been observed by the California ISO, MSC and others that forward energy contracts would diminish the short-term incentive of generators to exercise market power because such contracts would reduce the benefits of short-term increases in the market-clearing price.[53]

It is our understanding that the thermal generators in California that have been the focus of much of the attention have already sold forward a portion of (or in some cases perhaps all of) the output of their plants, limiting their short-run incentive to reduce incremental output so as to raise prices. While there has been much discussion in California of the restrictions that were placed on forward purchases by utilities, the existence of these restrictions did not translate into a corresponding inability of the thermal generators to sell their output in forward markets. The counter-parties in such forward transactions might be loads in other states, California loads other than those served by the investor owned utilities, or marketers operating in California.

If the contract is in form or in effect a financial contract like a CFD, for delivery or settlement, but not a contract that somehow gives the buyer control over the physical dispatch, then by all the usual arguments about the effect of forward contracts on the incentives for generators, these contracts correspondingly reduce the incentive of generators to withhold physical supply. In the case of forward contracts that are physical rather than financial, the incentive of the seller to withhold output would be reduced or eliminated but the incentive and ability to withhold output might be transferred to the buyer. We have seen samples of WSCC contracts, and these look like they are effectively CFDs, but we do not have comprehensive data on the extent or nature of all the contracts that already exist. Joskow-Kahn (July) argues that Duke was 90 percent forward contracted and did not have an incentive to withhold. Likewise, AES had a contract relation with Williams as the operator of its plants, and reportedly lost money in California in 2000 because AES could not keep the plants producing at the contracted requirement.[54] There is a general understanding that forward contracting has occurred. If forward contracts are largely financial, then there is less incentive to withhold output in the short-run than has been commonly assumed.

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[53] See, for example, Frank A. Wolak, Robert Nordhaus and Carl Shapiro, "An Analysis of the June 2000 Price Spikes in the California ISO's Energy and Ancillary Services Market," September 6, 2000 (hereafter MSC 2000); Frank A. Wolak, Robert Nordhaus and Carl Shapiro, "Analysis of Order Proposing Remedies for California Wholesale Electric Market (issued November 1, 2000)," December 1, 2000.

[54] AES, January 29, 2001, press release regarding annual earnings. Aesc.com/investor/press/index.html

We don't know of anyone who has been in a position to measure the overall level of such forward sales, but it could be important.

To illustrate this point, Table 3 above with the extensions of the Joskow-Kahn analysis of incentives for the unilateral exercise of market power includes two sensitivity cases in the last two rows. The first case (row 7) takes the Joskow-Kahn example with a steep industry supply curve and flat firm supply curve and asks what level of forward contracting would make the assumed 50 percent reduction in output unprofitable. As can be seen, with 820 MW under forward contract, less than a third of the competitive output, this strategy would be unprofitable. The second case (row 8) illustrates that with 2,500 MW contracted, slightly over 80 percent of capacity, there would no incentive to withhold at all. Even under the assumptions of the Joskow-Kahn example, therefore, lower levels of forward sales would affect withholding incentives. Although we do not yet have data on the forward contract positions of other thermal generators, these hypothetical illustrations and supporting anecdotes suggest that it would be dangerous to assume no significant contracting and wrong to assume that contracts have little effect on short-run incentives.

The impact of such forward sales on the incentive of sellers to exercise market power is most relevant in the short-run in which the forward contracts and their terms are fixed. In evaluating the incentive of sellers to increase the long-run price level in the WSCC, however, forward contracts would only be relevant to the extent that they were long-term arrangements whose terms would not be affected by long-run increases in the market price of power in the WSCC.[55]

D. Generation Heterogeneity and Inframarginal Rents

Other things equal, a supplier with a large share of the California electricity market would have a larger incentive to withhold output in order to elevate price than would a supplier with a small share of the California market. The incentive to withhold the output of an individual unit also depends, however, on the margin that unit would earn if it operates. Thus, there is less incentive even for a supplier with a large market share to withhold the output of a unit that would earn a significant margin if it operated than to withhold the output of a unit that would barely cover its running costs if it operated. It is potentially significant from this perspective that the thermal generating plants in California vary in start-up costs, minimum load costs, incremental heat rates and NOx emissions rates. At high load conditions with high gas and emission allowance prices there would be considerable rents earned on the operation of inframarginal capacity, at competitive price levels. Large price impacts from withholding might therefore be required to make it profitable to withhold such inframarginal capacity from the market.

It is therefore important that assessments of the profitability of withholding output reflect the reduced incentive to withhold the output of infra-marginal units. That is, the lower the cost of a given unit, the less incentive the owner would have to withhold the output of that unit in order to

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[55] See Scott M. Harvey and William W. Hogan, "California Electricity Prices and Forward Market Hedging," October 17, 2000.

affect price in either the long or short-run, holding market share constant.[56] The point here is not that it would necessarily be unprofitable to withhold any capacity, but that the amount of capacity withheld will be less if the capacity available for withholding is infra-marginal at the competitive price than if it is marginal. Moreover, the point is not that increases in market share cannot increase the profitability of withholding. But holding market share at the competitive price and output constant, the amount of withholding that is profitable will be less if the capacity to be withheld would be infra-marginal even well below the competitive price (see row 6 in Table 3).

E. Price Sensitive Load

While electricity end-users in California have had limited opportunity to respond to short-term variations in the price of electricity, sustained price increases have decreased consumption in the WSCC outside California, as customers outside California have responded to higher prices. The WSCC forecasted that the summer peak in the Pacific Northwest would be 2.4 percent lower in 2001 than in 2000 in part due to more moderate weather but also due to reduced consumption, particularly by aluminum plant shut downs.[57] The WSCC reported 1,800 MW of industrial load buy downs in the Pacific Northwest.[58]

Bonneville Power Authority (BPA) in particular took steps to substantially buy down its loads, in order to avoid the need for the large purchases at high prices that would otherwise be required. While it is sometimes unclear from the press reports whether the "load curtailments" by public utility and IOU customers were actual reductions in end-use or only reductions in BPA contractual obligations, the load curtailments by BPA direct service customers (such as Golden Northwest and other aluminum smelters) were in excess of 1,000 MW alone.[59] These load reductions were a direct result of high prices in the WSCC and were equivalent to increased output by generators in response to the high prices.

Overall, the Readiness Steering Committee of the Pacific Northwest estimated total demand reductions during the summer of 2001 in excess of 4000 MW. These included an estimated load

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[56] It is important to distinguish the role of infra-marginal rents from the amount of infra-marginal capacity. Catherine Wolfram, for example, has developed a model of two generators in which one generator has a large quantity of infra-marginal capacity, and both generators have one unit of higher cost capacity. She shows that the generator with the large quantity of infra-marginal capacity has an incentive to set a higher price on its high cost capacity than does the firm owning only the high cost capacity. This is a different incentive than we consider. Importantly, Wolfram's results apply to the incentive to withhold the high cost capacity, not the infra-marginal capacity and her conceptual experiment varies both market share and costs. See Catherine D. Wolfram, "Strategic Bidding in a Multi-Unit Auction: An Empirical Analysis of Bids to Supply Electricity in England and Wales," January 1997. Our point considers the impact of variations in cost rather than variations in market share. Holding market share constant, incremental output withholding will become unprofitable at a higher output level for a firm with a very steep marginal cost curve around the competitive price and output than for a firm with a very flat marginal cost curve around the competitive price and output.

[57] WSCC, Assessment of the 2001 Summer Operating Period, April 13, 2001, p. 6 (hereafter WSCC 2001 Summer).

[58] WSCC 2001 Summer, p. 7.

[59] "BPA makes strides in load reductions, expects smaller rate hikes," *Megawatt Daily*, June 28, 2001, p. 7.

reduction of 500 MW by customers of Tacoma Power, Montana Power, Puget Sound Energy and BPA that were paying market prices; 1,200 MW by customers with take-or-pay contracts that chose to forgo consumption of the power; 1,100 MW of aluminum smelter power buybacks, and smaller reductions from a variety of other sources and programs.[60]

While such long-term demand responses to higher energy prices would not deter the exercise of market power in particular hours, the profitability of exercising market power by raising prices throughout the WSCC on a sustained basis would be constrained by the long-term effect of such price increases on loads throughout the WSCC. If it is believed that generators in the WSCC have been withholding capacity in order to drive up prices throughout the WSCC, an assessment of the profitability of such withholding should recognize that overall WSCC demand is price elastic in this range and that the reduction in loads has been relatively large relative to the output of individual generators, and appears likely to persist for some time. The existence of such price-responsive load outside California implies that the residual supply elasticity facing thermal generators for sustained price increases would be more elastic than implied by supply curves alone.

F. Price Caps and Shortages

One circumstance in which it has been suggested that it is particularly likely that suppliers would exercise market power is during very high load periods in which virtually all available capacity is needed to generate energy or provide reserves. Some of the early claims regarding the exercise of market power in California appeared to take the view that the exercise of market power was limited to high load periods in which this concern might be applicable.[61] More recently, however, the CAISO has argued that market power is exercised in all periods and that periods of shortage account for relatively little of the claimed overcharges arising from the exercise of market power.[62]

In terms of the framework developed earlier in this paper, the shortage situation can be modeled as one in which the supply curves of the marginal suppliers are very steeply sloping in the vicinity of the market clearing price. There are, however, several special factors that are applicable in analyzing the potential for the exercise of market power during high load conditions that tend to limit the incentive to exercise market power.

As Frank Wolak and others have pointed out, there may be discontinuities in the residual demand curves at high demand and price levels.[63] Thus, the residual demand curve may be relatively flat

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[60] Readiness Steering Committee, Special Report, "Coping with the 2000-2001 Energy Crisis," October 2001, pp. 5-9.

[61] See MSC 2000, pp. 4, 5, 15, and Severin Borenstein, James Bushnell and Frank Wolak, "Diagnosing Market Power in California's Restructured Wholesale Electricity Market," August 2000, pp. 32-36.

[62] Eric Hildebrandt, Department of Market Analysis, California ISO, "Further Analyses of the Exercise and Cost Impacts of Market Power in California's Wholesale Energy Market," March 2001.

[63] See Frank A. Wolak and Robert H. Patrick, "The Impact of Market Rules and Market Structure on the Price Determination Process in the England and Wales Electricity Market," February 1997; Nils-Henrik March von

at normal to high demand levels making the exercise of market power unprofitable as discussed above in sections B and C. If demand is very price inelastic, however, there may nevertheless be very high demand levels at which the exercise of market power could be profitable, because sufficiently large output reductions would cause the market to clear on the vertical portion of the residual demand curve. While the potential for the profitable exercise of market power in these circumstances cannot be dismissed, there are several important limitations that suggest that market power might account for relatively little of the high prices in the WSCC during the past year.

First, the potential for the profitable exercise of market power is premised on very price inelastic demand, contributing to a highly inelastic residual demand curve. As discussed above, while this assumption may be plausible with respect to the demand response to the withholding of capacity in a particular hour, it does not appear reasonable when applied to long-term increases in the price of electricity such as those that have occurred over the past year. The data suggest that there has been a material demand response to the long-term price increases and some of this demand response may not be quickly reversed. Because prices have been high for the past year, industrial plants have been shut down and these plants will not reopen merely because prices decline for a few weeks or months. Thus, the high prices over the past year may lead to lower demand and lower prices than would have otherwise been the case over the next year. Thus, an entity that withheld capacity to raise prices over the past year, would forgo profits on all of its capacity for the coming year.

Second, if inelastic demand/inelastic residual demand circumstances are limited to very high demand hours, the proportion of the price increases over the past year potentially explained by the exercise of market power is limited. Furthermore, the potential incentive to withhold output would only exist in hours in which demand was very high, but not high enough to give rise to a shortage (prices would rise to the price cap in a shortage without the exercise of market power). The usual economic incentive for a supplier with market power to withhold output in order to affect the market clearing price does not exist if price caps are binding and the withholding of output would not affect the settlement price. In many of the high priced hours during summer 2000 there was a shortage of capacity in California at the price cap. If suppliers recognized or anticipated this situation, they would also anticipate that all of the capacity they offered would be taken at the price cap, because the market-clearing price was above the price cap. In these circumstances, economic withholding of capacity would reduce profits, regardless of the size of the supplier and the supply elasticity of other producers and consumers.

The CAISO has operated under similar shortage conditions for long periods during early 2001. For example, the CAISO operated in a state of emergency for 38 consecutive days in late January and early February.[64] Moreover, the CAISO was in a Stage 3 emergency for all or part of 32 of these days, implying that a lot more capacity could have been sold had it been available to be offered, without affecting the market price of capacity. During this period any additional

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der Fehr and David Harbord, "Spot Market Competition in the UK Electricity Industry," *Economic Journal*, May 1993.

[64] California ISO, "California ISO Declared Emergencies for 2001."

capacity made available would have been purchased by the CAISO, so there was no apparent incentive to withhold capacity in order to affect the market price.

We don't suggest that it could never be economically profitable to withhold capacity in order to create a shortage of low-cost capacity and raise the market-clearing price to the price cap, but in the many hours in which the market clearing price exceeded the price cap (i.e., the CAISO did not have enough capacity to meet its minimum operating reserve criteria (MORC)), there would have been no incentive at the margin to economically withhold capacity, as all incremental output would be accepted at the price cap.

There would be an incentive to sell for more than the price cap if CAISO did not enforce the cap on out-of-market purchases. However, by definition the higher price would not apply to all the market transactions but only those that were purchased in this category. This presents a more limited scope for the exercise of market power without the incentives for higher profits on infra-marginal production.

A third consideration is that even at very high load levels, the short-run residual demand curve facing California generators is very likely downward sloping as a result of price elastic reserve demands of other control areas in the WSCC. Thus, although retail demand in California and even the rest of the WSCC may not respond to real-time price variations, the residual demand curve for California generators would nevertheless likely be downward sloping, as other control area operators would reduce the level of operating reserves they would seek to maintain as the price of capacity rises. We have not attempted to estimate the slope introduced into the residual demand curve by this behavior of control area operators, but do not believe that it should be assumed to be insignificant.[65]

Finally, the shortage problem was compounded in late 2000 and beyond by the credit risk of dealing with buyers in California. There is little doubt that withholding occurred because of the fear of not being paid. Of course, such withholding is not an exercise of market power. It does, however, create shortages and greatly complicate any analysis of strategic withholding to raise price.

G. Everybody, Always, Everywhere

In summary, there is far from a definitive case that there have been substantial opportunities and incentives to exercise market power through strategic withholding. It is too easy to focus on the extreme example of the isolated case where all other sources of supply have been exhausted, every generator is pivotal, and there are no demand responses at all. Under these extreme assumptions, a single generator could extract the entire state product of California. But it is a long leap from this example to a belief that many generators, virtually all the time, and throughout the WSCC, can and do exercise market power; i.e., everybody, always and everywhere. Nonetheless, some have made this leap. A succinct summary of this view comes from the chair of the CAISO Market Surveillance Committee:

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[65] In the long run there is much more slope to the demand curve due to the ability of industrial customers such as aluminum smelters to reduce consumption.

> "A number of independent studies have quantified the extent of market power exercised by firms in the California electricity market. Using a similar methodology to that employed by Borenstein, Bushnell and Wolak, Paul Joskow and Edward Kahn quantified the extent of market power exercised during the summer of 2000. Moreover, they provided firm-level evidence of supply withholding to exercise market power during many hours of the summer of 2000. Eric Hildebrandt of the Department of Market Analysis of the California ISO also documented the degree to which prices exceeded levels that would exist in market where no firms exercised market power over period May 2000 to February 2001. Anjali Sheffrin, Director of the Department of Market Analysis of the California ISO examined bidding behavior in the California ISO real-time energy market and found that economic withholding, exercising market power by bidding substantially in excess of production costs was observed in virtually all hours during May 2000 to November 2000.
>
> These studies demonstrated that contrary to their filings stating otherwise, all five of the out-of-state generators–AES/Williams, Duke, Dynegy, Reliant and Southern (recently renamed Mirant) possess and have exercised significant market power in the California electricity market. The study prepared by Anjali Sheffrin also demonstrates that the large suppliers located outside of the California ISO control area also possess and have exercised substantial market power in California electricity market. These entities include British Columbia Hydro, the Los Angeles Department of Power and Water, and the Bonneville Power Administration."[66]

However, the logic of the extreme case does not give a good guide. The sensitivity analyses above show that the result is not very robust. Demand is not completely inelastic, other supplies are seldom fully exhausted, and it is not so easy to anticipate the second order effects of your actions on the rest of the market. Knowing that supply is scarce and that a generator can demand and get a high price is not the same thing as this generator knowing that withholding its supply will produce an even higher price with enough increase in profit to compensate for the reduced sales.

Based on experience in other markets, our intuition on these matters of shortage, but not extreme shortage, is not good. But one idea that comes from experience in other markets is that a generator with less than 5 percent of the capacity in the western market would find few opportunities to exercise a significant amount of market power. Absent transmission congestion, there is good reason to believe that this intuition survives even in the case of electricity.

To be sure, few opportunities is not the same thing as no opportunities. And there is more than enough uncertainty in the models and the data to admit the possibility that there is a large opportunity and incentive to exercise market power. This was not disputed in Harvey-Hogan

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[66] Frank A. Wolak, Chairman, Market Surveillance Committee, California Independent System Operator, "Statement Before the Senate Committee on Governmental Affairs," Washington, DC, June 13, 2001, pp. 10-11.

(April) because we did not disagree with the conditional view that this was and is an "empirical" matter.

It was only later when the argument became so explicit that market power was exercised by almost everybody, always and everywhere, that the discussion became relevant. Further, we did not "engage these basic principles of oligopoly theory" because we did not disagree with Joskow-Kahn (March) that this is an empirical matter. We do disagree with the possible implication of Joskow-Kahn (July) that the argument in their earlier paper somehow disposed of the issue of incentives.

Overall, the most important factors in assessing the incentives for WSCC thermal generators to exercise market power during the past year are the recognition that locational market power within California has been mitigated through the RMR contracts and that transmission constraints into California have generally not been binding. Thermal generators within California appear to have been competing with suppliers throughout the WSCC throughout the period of high prices. Moreover, while WSCC electricity demand is relatively price inelastic, it is not completely so, particularly outside California. Output reductions by thermal generators intended to raise prices would be offset by reductions of interruptible load, reduced reserves, and reduced consumption by loads outside California. Finally, any incentive to withhold material amounts of capacity would have been further reduced by both forward contracts and the high opportunity cost of withholding infra-marginal capacity.

In the absence of a smoking gun, and setting aside the usual source of market power created by locational constraints, it is entirely plausible that competition in the west-wide market would substantially limit the scope and duration of the exercise of market power. It is possible that despite these considerations they would have the incentive and ability to profit by withholding real-time output or capacity. But its far from obvious that this is true. It is an empirical question.

IV. CONCLUSION

Strategic withholding of supply to increase market prices is an exercise of market power, and would be a legitimate concern of electricity regulators. Although no market is immune to some exercise of market power, substantial excursions from competitive market outcomes would produce a regulatory response. The most visible symptom of an exercise of market power is high prices. Unfortunately, this same symptom could arise from a conventional shortage, or from unconventional market failures in a complex market design. The policy prescription would be quite different for each diagnosis of the disease. Hence the importance of untangling the conflicting evidence to determine the relative importance of the different market failures in California. Theory is a limited guide, and the public data are inadequate. The necessary data are available, although not in the public domain. Determination of the extent of the exercise of market power in California remains an open empirical question.

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