V. The Influence of Electricity Spot Prices on Electricity Forward Prices

Summary of Results

The vital link between the spot price and forward price for a commodity is the ability to store the commodity. In essence, someone can meet future needs by purchasing the commodity now and storing it for future consumption. As a result, the forward price that someone is willing to pay will approximate the cost of purchasing plus the carrying cost involved with stockpiling and net of the risk associated with not holding the physical commodity. Since electricity has few storage applications, we would expect to see little or no relationship between spot electric prices today and the forward price of electricity. Instead, forward prices should mostly reflect a buyer's expectations of prices in the future. Since natural gas is the marginal fuel for producing electricity in the West, forward gas prices should, in large part, explain forward electricity prices. Our analysis shows, however, that the forward power contracts negotiated during the period 2000–2001 in the western United States were influenced by then-current spot prices, presumably because spot power prices influenced buyers' and sellers' expectations of spot prices in the future. The influence of spot prices on forward prices was the greatest for forward contracts with the shortest time to delivery (1-2 years) and varied by location. While Staff has found a statistically significant relationship, the magnitude of the impact is limited (that is, the impact of spot power prices on long-term power prices is clearly not dollar-for-dollar). Rather, a reduction of about one-third in the price of a 2-year forward contract would require a finding that spot power prices were three times above the just and reasonable level.

Background

The relationship between electricity spot prices and long-term contract prices has been the subject of debate since Enron filed for bankruptcy in December 2001. Questions have been raised in Congress and the media about whether Enron manipulated the spot market to influence the West forward market.

The Commission's February 13, 2002 Order establishing the fact-finding investigation specifically directed FERC Staff to look into whether manipulated spot prices resulted in unjust and unreasonable long-term power sales contracts.

In addition, a number of utilities[1] filed complaints with the Commission alleging that dysfunctions in the California electricity spot markets caused long-term contracts negotiated in the bilateral markets in California, Washington, and Nevada to be unjust and unreasonable. The complainants seek the extraordinary remedy of contract modification. The Commission issued an Order on April 11, 2002 consolidating these complaints and set them for an evidentiary hearing.[2] Subsequently, additional complaints were set for hearing.

Two studies that estimated the electricity spot/forward price relationship were filed in testimony in the proceeding.

On July 2, 2002, Snohomish submitted Mr. Robert McCullough's Direct Testimony. Mr. McCullough alleges a link between short-term prices and the prices of long-term contracts.[3] Mr. McCullough's analysis found a large, significant correlation between prices for short-term and long-term contracts.

On August 27, 2002, Mr. McCullough's analysis was challenged by Mr. William W. Hogan and Mr. Scott M. Harvey.[4] Representing Morgan Stanley Capital Group, Inc., Mirant Americas Energy Marketing, L.P., American Electric Power Service Corporation, and Reliant Energy Services in the same proceedings, Mr. Hogan and Mr. Harvey testified that no significant correlation can be demonstrated between spot and long-term power prices.

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[1]Nevada Power Company (Nevada Power) and Sierra Pacific Power Company (Sierra Pacific), Southern California Water Company (SCWC), and Public Utility District No. 1 Snohomish County, Washington (Snohomish).
[2]Consolidated proceeding: *Nevada Power Company and Sierra Pacific Power Company v. Enron Power Marketing, Inc., El Paso Merchant Energy, and American Electricity Power Services Corporation; Nevada Power Company v. Morgan Stanley Capital Group, Calpine Energy Services, Reliant Energy Services, and Mirant Americas Energy Marketing, L.P.; Southern California Water Company v. Mirant Americas Energy Marketing, L.P.; and Public Utility District No. 1, Snohomish County, Washington v. Morgan Stanley Capital Group, Inc.*—Docket Nos. EL02-28-000, EL02-33-000, EL02-38-000, EL02-29-000, EL02-30-000, EL02-32-000, EL02-34-000, EL02-39-00, EL02-43-000, and EL02-56-000.
[3]Testimony of Robert McCullough, Exh. SNO-17.
[4]Prepared Answering Testimony of Scott M. Harvey and William W. Hogan, Exh. No. MSC-65.

Comparison of the Two Studies

McCullough used different econometric models than Harvey and Hogan to estimate the spot/forward price relationship.

McCullough used a simple regression model to estimate the relationship between electricity forward and spot prices. This model uses only two variables: an explanatory variable and a dependent variable. McCullough attempted to estimate how the change of electricity spot prices (explanatory variable) correlates with electricity forward prices (dependent variable). By running this simple regression model with NYMEX strip prices[5] and spot prices from *Energy Markets Report*, McCullough estimated that, at the Palo Verde trading hub, 51 percent of the variance in the forward power price can be explained by the variance in the spot power price, and at the California-Oregon Border (COB) trading hub it is 40 percent. McCullough concluded that the change in the daily price was very closely correlated to the change of the forward price.[6]

Harvey and Hogan made several refinements to the McCullough analysis. First, they included forward gas prices and other independent variables designed to capture monthly and seasonal effects in their regression analysis. Second, they performed several analyses using alternative measures of forward power prices including NYMEX futures prices and forward prices reported by TFS, a major independent broker. Third, they employed econometric techniques specifically designed to address time-series data with "serial correlation."[7] Their analyses generally show small and statistically insignificant impacts of spot power prices on forward power prices.[8]

Neither study has the benefit of reliable data on long-term power sales contracts in the West during 2000–2001. There was little or no transaction volume in the NYMEX electricity futures market after February 2000. The electricity futures closing prices published by NYMEX until the product was delisted in February 2002 were not based on actual trading on the exchange. NYMEX maintained its index by surveying prices of bilateral trades.

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[5]NYMEX strip prices are an average of the daily settlement prices of the next 12 months of futures contracts.
[6]Testimony of Robert McCullough, Exh. SNO-17, pp. 86-87.
[7]Serial correlation is discussed at more length in Appendix V-D.
[8]Prepared Answering Testimony of Scott M. Harvey and William W. Hogan, Exh. No. MSC-65, p. 139, line 22 to p. 140, line 2.

Staff's Analysis

To help resolve the debate on this important issue, Staff performed its own statistical analysis with the help of an independent outside consultant, Robert S. Pindyck,[9] a nationally recognized econometrician with a specialty in energy futures markets, and consultants from Analysis Group/Economics. Our methods, data, models, and results are presented as follows: the basic economic logic and statistical methods that Staff employed, the data that Staff relied on for the analysis, the regression model used in detail, and the main results. Detailed results are provided in the appendices to this chapter.

Basic Economic and Statistical Methodology

Economics

For a storable commodity, such as crude oil, there is a clear relationship between spot and forward (or futures) prices that depends on the flows of benefits to producers and consumers from holding inventories.[10] Because of electricity's limited storability, the relationship between spot and forward prices is not as clear. Instead, forward power prices should largely reflect expectations of future demand and supply conditions.

Expectations, however, are often difficult to measure. In electricity markets, forward prices for fuel can provide an important measure of expectations about future electricity costs. In the western United States, natural gas is the marginal fuel for electricity in the short term, particularly in California and even in the Northwest when hydro water levels are low (as they were in 2000–2001), and in the long term for the construction of new generating capacity. As a result, forward gas prices should help explain forward electricity prices to the extent that prices reflect costs. The futures market for gas delivered to Henry Hub provides transparent signals about future input prices. Forward prices

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[9] Robert S. Pindyck is a professor of Economics and Finance, Sloan School of Management, Massachusetts Institute of Technology.

[10] See, for example, B. Routledge, D. Seppi, and C. Spatt, "Equilibrium Forward Curves for Commodities," *The Journal of Finance*, v. LV, no. 3, June 2000, pp. 1297-1338, and R. Pindyck, "The Dynamics of Commodity Spot and Futures Markets: A Primer," *The Energy Journal*, v. 22, no. 3, June 2001.

for delivery of gas to specific locations in the West are less transparent. Nonetheless, market participants had access to forward market price quotations for gas to be delivered in the western United States, and could use these to project likely power prices.

In power markets, a relationship between spot and forward prices can exist when current spot prices convey information about spot prices in the future. For example, if one component of the current spot price represents market "dysfunction," market participants might use current spot prices to formulate expectations about future dysfunction.

Statistical Methodology

We tested the relationship between forward and spot power prices using multiple linear regression, because there are many factors that potentially explain forward power prices. Multiple linear regression is a statistical method for decomposing the influence of different factors (independent variables) on a variable of interest (dependent variable). We seek to explain forward power prices as a function of current spot prices, forward gas prices, and seasonal factors. The forward gas price is the fundamental factor that drives the forward power price in the western United States because gas is the short- and long-term marginal fuel. Controlling for the forward gas price, we can test whether the current spot price can explain any portion of the variation in forward power prices.

We also include dummy variables to capture seasonal effects.[11] Many seasonal factors influence energy markets. On the supply side, hydroelectric resources vary seasonally. On the demand side, weather varies seasonally and influences consumption. A spot price that appears high in the spring may be normal for the summer. By including season dummy variables, we attempt to isolate the effect of abnormal spot price movements on forward prices.

Most of our results are based on ordinary least squares (OLS) regression, but we employed several other linear regression techniques to address specific econometric issues.

[11]Dummy variables are the standard way of representing binary (yes/no) effects in regressions. The dummy variable for a season takes the value of 1 if the observation in question occurs during that season and is 0 otherwise.

Data

We requested data from wholesale sellers in the West on their electricity transactions during 2000 and 2001.[12] The data request was targeted at all marketers active in the West and compliance with the request was nearly universal.

The responses to the Staff data request were provided in electronic templates. These responses left some room for interpretation. As discussed below, we spent a considerable amount of effort in comparing different parties' responses and verifying responses against written contracts and other documentation provided by most, but not all, sellers. To the best of our knowledge, this is the most comprehensive database of forward power contracts for the period and locations in question.

Sample Size

In our March 5, 2002 Data Request, we asked market participants to report all of their short-term, monthly, and long-term energy sales. We defined short-term sales as transactions of a week or less. Monthly sales were defined as transactions with a period of 1 month. Long-term sales were defined as transactions with a contract duration of 1 year or more. We focused our analysis exclusively on long-term contracts.

The data reflect contracts for delivery during peak, off-peak, and all hours. The majority of contracts in the database are for peak deliveries. In addition, by definition, peak hours cover the periods of highest demand and hence are the most economically significant. Therefore, our analysis relies on contracts for peak delivery exclusively.

Staff received data on long-term transactions (a year or more in duration) that either included the period 2000–2001 or were signed after January 2000. We included in our analysis contracts signed from the beginning of 2000 through March 2002, when the data request was issued. For this 27-month period, we have 2,652 unique contracts for the 5 major delivery locations on which we focus our analysis.

We considered two major subperiods: the period from January 2000 leading up to and including the period of high Western power prices, and the period after June 19, 2001 (when West-wide price mitigation

[12]Staff data request to all jurisdictional sellers and all nonjurisdictional sellers in the West issued March 5, 2002 in Docket PA02-02.

went into effect)[13] through March 2002. As Table V-1 demonstrates, the number of observations varies by location and period. The first 18 months account for 1,066 observations, or 40.2 percent of the total. The last 9 months account for 1,586 observations, or 59.8 percent of the total.

Table V-1. Sample Size by Region and Period Definition

Hub	1/1/00 – 6/30/01	7/1/01 – 3/31/02
Mid-C/COB	199	163
NP15	136	429
SP15	314	635
PV	417	359
All Hubs	1,066	1,586

Hubs and Duration Classes

Our analysis considered contracts at the five main trading hubs in the West—COB, Mid-Columbia (Mid-C), Palo Verde (PV), and California Independent System Operator (ISO) zones NP15 and SP15. We treat Mid-C and COB as a single hub based on the high correlation of prices at these two locations.[14]

As discussed above, one key issue that we sought to address is how the relationship between spot and forward power prices changes with time to delivery. To simplify our analysis of this issue, we grouped contracts into time-to-delivery bins.[15] We initially assigned contract duration classes corresponding roughly to the time between each contract's signing date and the midpoint of its delivery window rounded to the nearest year—e.g., a contract for 10 years of deliveries signed and commencing today was assigned a duration of 5.

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[13]The June 19, 2001 Order marks the date when all sellers in the western United States were subject to a must-offer requirement and price caps. See 95 FERC at 62, 558.

[14]In addition, we performed statistical analyses in which we tested whether the relationship between spot and forward prices at the two locations was different. We could never reject the null hypothesis that the relationship at the two hubs was the same.

[15]Alternatively, we could have used more complicated nonlinear regression techniques in which we allowed various model coefficients to depend on time to delivery.

Forward Gas and Electricity Spot Price Data

We relied on two different commercially available databases for our independent variables. We obtained data on forward gas prices for various locations in the West from TFS, an independent power and gas broker[16] that has collected the most complete forward gas quotes covering the period and locations in question. Staff also obtained the forward gas prices that Williams and Enron used to price their own trades. Limited forward gas prices from Morgan Stanley are publicly available.[17] We have verified that the TFS quotes are broadly consistent with the forward curves used by these major market participants.[18] It is useful to know that expectations about forward gas prices were roughly similar among major market participants. For our analysis, however, we used TFS data because of their independence.

The long-term transaction data used in our analysis are for periods of 1 year or more. The TFS forward gas quotes are for delivery periods of 1 month. In our regression analysis, we use averages of these monthly gas prices calculated over the entire delivery period of each forward power contract.

Because gas and electricity are traded at slightly different locations, we had to decide which forward gas price to assign to the forward power contracts at each location. Our assumed correspondence is as follows:

Power Trading Hub	Relevant Gas Hub Price
SP15	Topock
NP15	Malin
COB	Malin
Mid-Columbia	Sumas
Palo Verde	Permian

For spot power prices, we used the on-peak firm power prices reported by Bloomberg. For the two delivery locations inside the California ISO (NP15 and SP15), we compared the Bloomberg prices to the average of the hourly day-ahead prices for peak hours of the California Power Exchange (PX) during the period when the PX was still operating. The Bloomberg prices are consistent with the PX prices.

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[16]Information about TFS Brokers is available at http://www.tfsbrokers.com/.
[17]See Harvey and Hogan, op. cit., note 4.
[18]The details of this comparison are discussed in Appendix V-B.

Audit Process and Results

We performed a number of initial quality checks on the transaction data we collected and contacted respondents to resolve problems with the data. We undertook a comprehensive audit of the filed data by comparing reported transaction data with reported actual contracts and contract confirmations.[19]

We audited all contracts that were supported with appropriate documentation. Auditable transactions make up about 59 percent of the total number of transactions.[20] Once we verified the sales data for these auditable transactions, we compared the results of a statistical analysis that used just the audited data with the results of an analysis that used all transactions.[21] The regression results using the audited-only transaction data and the all-transaction data generally are not significantly different statistically. Therefore, we concluded that including the remaining unaudited data did not change our results and decided that further review of the data was not necessary.

Regression Specification

Definition of Sample Period

Our primary analysis covers the 18-month period from January 2000 through June 2001. The long-term transaction data we collected cover the period from January 1999 to March 2002. We focused our attention on the period through June 2001 because of the West-wide price mitigation put in place beginning June 19, 2001. We examined the period after June 2001 separately to assess whether the relationship between spot and forward power prices changed with this change in market structure.

[19]The details of this audit are discussed in Appendix V-A.
[20]Table V-A2 in Appendix V-A shows the breakdown of documented and undocumented contracts by seller.
[21]This analysis is shown in Appendix V-A, Tables V-A3 and V-A4.

Basic Equation

Our regressions have the following general form:

$$\log(FP_{ijt}) = a_{ij} + b_{ij}\log(SP_{it}) + c_{ij}\log(FG_{ijt}) + \boldsymbol{q} + e_{ijt} \quad (1)$$

For example, FP_{ijt} is the forward electricity price in year 2003 (time t) for delivery at Palo Verde (location i) in year 2008 (time j), SP_{it} is the spot price at Palo Verde in 2003, and FG_{ijt} is the forward gas price in 2003 for delivery at Permian in 2008. Factor q controls for seasonal variations[22] and e_{ijt} captures any remaining unexplained component of FP_{ijt}.

We estimate equation (1) in logs. A log specification has a number of desirable properties in the context of estimation such as ours. In particular, it captures a constant proportional relationship between the dependent and independent variables over a wide range of prices. For example, it assumes that an increase in spot power prices from $100 to $110 has the same percentage impact on forward power prices as an increase from $10 to $11.[23] When equation (1) is specified in logs, the coefficient on the spot electricity price, b_{ij}, is the elasticity of forward electricity prices with respect to spot electricity prices. The elasticity is the ratio of the percentage change in one variable with respect to the percentage change in another variable.

Aggregation

As discussed above, we examined data for five hubs and a number of duration classes. After some preliminary analysis, we decided to treat COB and Mid-Columbia as a single hub. In addition, we were able to obtain stable and precise results by aggregating the duration into three classes: (1) contracts with average times to delivery of less than 2

[22] We define seasons quarterly (i.e., spring is March to May, summer is June to August, fall is September to November, and winter is December to February).

[23] There are technical reasons for preferring a log specification. The error for regressions based on price data usually is thought to be proportional to price, i.e., a $10 error for a $100 price is equivalent, by some measure, to a $1 error for a $10 price. If the error is in fact proportional to the level of prices, specifying the estimation in logs guarantees that the individual elements of the error are homoscedastic, i.e., equal in variance, and hence that our parameter estimates are unbiased and efficient. In other words, a log specification guarantees that our parameter estimates are as accurate and precise as possible. If the elements of the error are not homoscedastic, not only are parameter estimates from OLS regression inefficient, but estimated standard errors are biased and hence can lead to incorrect statistical inference. For a discussion of these issues see R. Pindyck and D. Rubinfeld, *Econometric Models and Economic Forecasts*, 4th edition, New York: McGraw-Hill, 1998, pp. 146-152.

years, (2) contracts with average times to delivery of 3 to 4 years, and (3) long-term contracts with average times to delivery of 5 years or greater.[24]

Instrumental Variables

Statistical inference using OLS regression rests on a set of assumptions. One assumption is that the error, i.e., the component of the dependent variable that is not explained by the statistical model, is uncorrelated with any of the independent variables. Given that forward gas and power prices are simultaneously determined, i.e., the forward gas price is a major input to the generation of electricity and the generation of electricity is a major source of demand for gas, this assumption may not hold in our case. Hence, estimation of equation (1) may show a correlation between forward gas and power prices, but that correlation cannot be interpreted as causal.

We address this econometric issue using a technique known as instrumental variables (IV) estimation,[25] which attempts to break the circle of simultaneity by using proxy variables, or instruments, that are not plagued by the same simultaneity problems. "Good" instruments have two characteristics: (1) they are exogenous, i.e., they are uncorrelated with the error, and (2) they are correlated with the variable for which they are instruments.

Our instrument for the forward gas price was the contemporaneous forward gas price at Henry Hub. Henry Hub, near the production basins along the Gulf Coast, is a large and liquid trading hub. Gas originating at or near Henry Hub has a variety of uses throughout the United States, including electricity generation, chemical processing, and heating. Demand for gas for electricity generation in the western United States should have relatively little impact on Henry Hub prices, and the Henry Hub forward price therefore meets the first criterion of a good instrument. With respect to the second criterion for a good instrument, because there is some transportation between Henry Hub and locations in the West, Henry Hub prices are usually correlated with prices in the West.

Absent the ability to store electricity, there is no reason to believe that current spot power prices are influenced by expectations about future gas and power prices as reflected in forward prices, so we treat spot power as exogenous in our estimation, i.e., we do not instrument for it.

[24] Detailed results based on the disaggregated data are presented in Appendix V-D.
[25] See R. Pindyck and D. Rubinfeld, op. cit., Chapter 7.

Under the assumption that a set of instruments is "valid," the extent of any bias due to simultaneity can be assessed by comparing instrumental variables and ordinary least squares parameter estimates.[26] When these estimates are close, any presumed simultaneity problem is negligible. In the next section, we present the regression results using both ordinary least squares with and without instrumental variables. Our estimates tell us that any simultaneity problem is negligible. Therefore, we believe that the results using the ordinary least squares method are appropriate for use in the long-term power contract proceeding.

Regression Results

Our analysis is summarized below. We performed separate analyses for the periods before and after West-wide price mitigation was introduced. The subsequent section discusses a few minor extensions and modifications of our analysis.

"During" Period Results Summary

We found that spot power prices influence forward power prices in a statistically significant and economically important way. In the simplest formulation, in which we estimated a single average elasticity for all contracts of different times to delivery and different locations, the elasticity is 0.07. This formulation masks substantial variation in the elasticity by region and time to delivery—the longer the contract duration, the lower the impact of spot market prices upon the forward price.

Table V-2 shows results based on an analysis that combines data from all five trading hubs, and shows the effect of time to delivery. As expected, the effect declines with time to delivery. Using ordinary least squares, the point estimates of the spot power coefficients range from 0.05 to 0.33. These estimates imply that for each 10-percent increase in the spot price, forward power prices rose by approximately 0.5 percent to 3.3 percent. These effects are larger for contracts with short times to delivery than contracts with longer times to delivery.

[26]This comparison can be formalized as a Hausman test. See R. Davidson and J. MacKinnon, *Estimation and Inference in Econometrics*, New York: Oxford University Press, 1993.

Table V-2. Spot Power Coefficient by Time-to-Delivery Class: "During" Period

Time-to-Delivery Class	**Ordinary Least Squares (OLS)**			**With Instrumental Variables (IV)**			Number of Observations
	Spot Power Coefficient	Standard Error	t-Statistic	Spot Power Coefficient	Standard Error	t-Statistic	
1-2 Years	0.33	0.03	9.80	0.27	0.04	6.34	451
3-4 Years	0.12	0.02	6.54	0.11	0.02	5.73	398
5-8 Years	0.05	0.01	3.36	0.06	0.01	4.18	217

The regression results with instrumental variables are generally close to those without instrumental variables. This may indicate that simultaneity is not a significant concern. Alternatively, the results may indicate that, even if the forward gas price is endogenous, it does not bias our estimate of the coefficient on spot power.

Table V-2 gives point estimates, standard errors, and t-statistics for the spot power elasticities. The standard error measures the precision of the estimate, i.e., the smaller the standard error the more precise the estimate. The standard error of the OLS estimate for duration class 1-2 years is 0.03. A one standard error band around the point estimate defines a 68-percent confidence interval, i.e., there is a 68-percent probability that the "true" elasticity (i.e., the one we are attempting to estimate) lies between 0.30 (0.33 – 0.03) and 0.36 (0.33 + 0.03). Naturally, our best estimate is in the middle of this range.

The t-statistic, which is commonly used to assess whether a parameter estimate is statistically significantly different from zero, is simply the point estimate divided by the standard error. Statistical significance is usually measured at the 90- or 95-percent confidence level. A coefficient is considered statistically significant at the 95-percent confidence level if the value of zero is not within a band around the coefficient value of 1.96 standard deviations. For example, for the OLS for duration class 1-2 years, the 95-percent confidence band is .33 plus or minus (1.96 times .03 = .0588) or between .2712 and .3888. All of the parameter estimates in Table V-2 are statistically significant at the 95-percent level.

Table V-3 shows disaggregated results by hub. The OLS and IV coefficients are generally close considering the precision of the estimates. Most estimates of the spot power coefficient are statistically significant at the 90-percent level or higher. For most hubs, we observe the expected pattern of the magnitude of the coefficient on spot power falling with time to delivery.

The significance of these results is weakest for contract duration class 5-8. Only for the Palo Verde hub are these results significant at the 95-

percent level. For the other hubs in the 5-8 class, the estimates are not significant at the 90-percent level.

Since the effects in Table V-3 seem to vary by location, any policy conclusions should be based on the coefficient for the relevant location.

Table V-3. Spot Power Coefficient by Time to Delivery and Hub: "During" Period

Hubs	Time-to-Delivery Class	Ordinary Least Squares (OLS)			With Instrumental Variables (IV)			Number of Observations
		Spot Power Coefficient	Standard Error	t-Statistic	Spot Power Coefficient	Standard Error	t-Statistic	
Mid-C/COB	1-2 Years	0.38	0.09	4.16	0.21	0.13	1.66	101
	3-4 Years	0.13	0.04	3.12	0.19	0.05	3.58	62
	5-8 Years	(0.00)	0.03	(0.13)	(0.01)	0.03	(0.41)	36
NP15	1-2 Years	0.22	0.13	1.64	0.29	0.14	2.10	40
	3-4 Years	0.14	0.04	3.16	0.14	0.05	3.01	72
	5-8 years	0.06	0.05	1.33	0.06	0.05	1.20	24
PV	1-2 Years	0.38	0.06	6.58	0.40	0.06	6.90	221
	3-4 Years	0.09	0.04	2.37	0.08	0.04	2.14	122
	5-8 years	0.07	0.02	3.36	0.07	0.02	3.35	74
SP15	1-2 Years	0.23	0.08	2.99	0.14	0.08	1.69	89
	3-4 Years	0.07	0.03	2.33	0.07	0.03	2.28	142
	5-8 years	0.04	0.03	1.29	0.04	0.03	1.35	83

"After" Period Results Summary

Next, we examine whether the relationship between spot and forward power prices changed after the spot market prices stabilized following the introduction of West-wide price mitigation. Tables V-4 and V-5 show these results for the July 2001 to March 2002 period in the same format as Tables V-2 and V-3. They generally show a persistence of the effects found during the crisis, i.e., statistically significant positive elasticities of the forward price with respect to the spot price.

Table V-4. Spot Power Coefficient by Contract Duration Class: "After" Period

Time-to-Delivery Class	Ordinary Least Squares (OLS)			With Instrumental Variables (IV)			Number of Observations
	Spot Power Coefficient	Standard Error	t-Statistic	Spot Power Coefficient	Standard Error	t-Statistic	
1-2 Years	0.12	0.02	7.15	0.13	0.02	7.41	887
3-4 Years	0.12	0.02	7.12	0.14	0.02	7.35	473
5-8 years	0.15	0.02	6.83	0.17	0.02	7.22	226

TableV-4 does not show the decline in elasticity with contract duration observed in Table V-2. On average, the point estimates are smaller than those in Table V-2.

The results in Table V-5 show elasticities that are sometimes smaller and less significant than those in Table V-3, but in other cases the opposite is true. There are regional variations. The SP15 elasticities have larger t-statistics in the "after" period. Several large elasticities estimated for shorter term contracts (0.35 for Mid-C/COB and 0.38 for PV) in Table V-3 are absent from Table V-5. The largest elasticity after the price mitigation is for class 3-4 years at Mid-C/COB. It is unclear why this is the case.

Table V-5. Spot Power Coefficient by Hub and Duration: "After" Period

Hubs	Time-to-Delivery Class	**Ordinary Least Squares (OLS)**			**With Instrumental Variables (IV)**			Number of Observations
		Spot Power Coefficient	Standard Error	t-Statistic	Spot Power Coefficient	Standard Error	t-Statistic	
Mid-C/ COB	1-2 Years	0.03	0.05	0.67	0.05	0.05	1.05	91
	3-4 Years	0.38	0.08	4.83	0.37	0.08	4.46	45
	5-8 years	0.14	0.07	1.94	0.17	0.08	2.16	27
NP15	1-2 Years	0.08	0.02	3.17	0.08	0.02	3.43	204
	3-4 Years	0.02	0.02	0.90	0.03	0.02	1.17	145
	5-8 years	0.02	0.03	0.70	0.03	0.03	0.96	80
PV	1-2 Years	0.10	0.06	1.74	0.10	0.06	1.74	197
	3-4 Years	0.02	0.05	0.53	0.03	0.05	0.57	106
	5-8 years	0.13	0.06	2.30	0.13	0.06	2.27	56
SP15	1-2 Years	0.07	0.02	3.26	0.06	0.02	3.04	395
	3-4 Years	0.09	0.02	3.82	0.09	0.02	3.88	177
	5-8 years	0.09	0.04	2.29	0.09	0.04	2.28	63

The results for the "after" period show persistence in the relationship between spot and forward power prices. This indicates that the process for forming expectations that developed during the crisis period did not instantly disappear or reverse itself following the implementation of the spot power mitigation measures required by FERC's June 19, 2001 Order.

We have conducted a number of other tests that are described in more detail in Appendix V-C. These are variations on the basic equation using different pooling approaches. The results are broadly consistent with Tables V-2 to V-5. We also report more disaggregated results in this appendix. Finally, we address another econometric issue in Appendix V-D, namely, whether serial correlation affects the estimates and their precision. In Appendix V-D, we show results indicating that this is not the case.

Interpreting Regression Results

To illustrate the implications of the estimated spot power elasticities on forward power prices, we construct some stylized examples.

For each of our time-to-delivery classes, we calculated the average forward power price (FP) for all Mid-Columbia and Palo Verde contracts signed between January 1, 2001 and March 31, 2001. To apply the estimated spot power elasticities from Table V-3, we need to assume spot power prices were distorted and by how much. We consider two hypothetical cases: 100-percent and 200-percent distortion.

Hypothetical spot power price distortions of 100 percent and 200 percent can be roughly justified with reference to the implied system heat rate calculated in Table V-6 below. The implied system heat rate is simply the spot power price divided by the spot gas price and is a convenient measure of market performance that is sometimes used by traders. Under normal conditions, it would typically be in the range of 10,000 to 11,000 Btu/kWh, representing the thermal efficiency of older steam boilers that typically serve marginal demand in California. Under short supply market conditions the implied system heat rate might be higher than this level. For a useful point of reference, we have calculated the relevant average of "clearing" heat rates that have been used in the California refund case.[27] For the same period, these heat rates are in the 15,000 to 17,000 Btu/kWh range during peak demand periods. These values represent very inefficient peaking plants that operated for many peak hours during this period. In comparison, the implied system heat rate for Mid-C and PV in Table V-6 is 2 to 3 times higher.[28] This suggests that 100-percent to 200-percent spot price excess may not be unreasonable.

[27]See Exhibit ISO-6 in the refund case. This exhibit was originally protected; however, the protection was removed by Administrative Law Judge Birchman on December 16, 2001.
[28]The data in Table V-6 are simple averages over the period between January 1, 2001 and March 31, 2001.

In Table V-6, we calculate the mitigated forward power price (MFP) for each combination of hub and assumed level of spot price distortion using the following equation:[29]

$$MFP = FP \times (1+\gamma)^{-\beta}$$

where γ is the assumed percentage spot price distortion and β is the estimated elasticity.

Table V-6. Impact of Estimated Spot Power Elasticity on Forward Price of Power (January 1, 2001 – March 31, 2001)

Hub	Time-to-Delivery Class	Average Spot Power Price ($/MWh)[30]	Average Spot Gas Price ($/MMBtu)	Implied System Heat Rate (Btu/kWh)	Spot Power Elasticity	Assumed Spot Power Distortion	Average Forward Power Price ($/MWh)	
					β	γ	Observed[31] FP	Mitigated MFP
	1-2 Years				0.38		153.75	101.28
	3-4 Years				0.13	200%	84.02	72.84
Mid-C/ COB	5-8 years	284.21	6.30 (Sumas)	45,113	-		54.86	54.86
	1-2 Years				0.38		153.75	118.15
	3-4 Years				0.13	100%	84.02	76.78
	5-8 years				-		54.86	54.86
	1-2 Years				0.38		123.28	81.21
	3-4 Years				0.09	200%	71.43	64.71
	5-8 years				0.07		52.68	48.78
PV	1-2 Years	220.88	6.25 (Permian)	35,341	0.38		123.28	94.73
	3-4 Years				0.09		71.43	67.11
	5-8 Years				0.07	100%	52.68	50.18

The calculations in Table V-6 are intended to indicate plausible applications of the statistical results. When we use our estimates of the regression coefficients from Table V-3 under the assumption of 100- to 200-percent spot price excess, we get substantially lower forward

[29]Starting from the main regression equation $FP = \alpha \times SP^{\beta} \times FG^{\delta}$ (expressed in equation (1) in logarithmic form), we assume that the observed spot power prices are γ percent inflated over the mitigated spot power prices (MSP), or mathematically, $SP = MSP \times (1+\gamma)$. Substituting for SP we then get

$$MFP = \alpha \times MSP^{\beta} \times FG^{\delta} = \alpha \times \frac{SP^{\beta}}{(1+\gamma)^{\beta}} \times FG^{\delta} = FP \times (1+\gamma)^{-\beta}$$

[30]We calculated the average daily peak spot power prices using historic Bloomberg quotes from January 1, 2001 to March 31, 2001.

[31]The average observed forward prices were estimated using the actual long-term sales contract data for contracts signed during the period January 1, 2001 to March 31, 2001.

contract prices for time-to-delivery class 1-2. Under the 200-percent spot power prices excess case, the implied reduction in contract price is about one-third. For the 100-percent spot power inflation case, the reduction is about 23 percent for this class. These effects are much smaller for time-to-delivery classes 3-4 and 5-8.

Conclusion

Our analysis shows that there is a statistically significant relationship between spot and forward power prices during the period from January 1, 2000 through June 30, 2001. This relationship is somewhat unexpected in a market for a commodity with little storability and reflects the fact that market participants used current spot prices to form expectations about future spot prices during the period in question.

Although estimated elasticities vary by hub and time to delivery, the results show that the influence of spot on forward power prices declines with longer times to delivery. This pattern is consistent with the notion that current spot prices convey more information about spot prices in the near future than the distant future.

If, as we maintain in earlier chapters, spot power prices were distorted, these results imply that the price distortion flowed through to forward power prices, particularly those for contracts of short (1-2 years) time to delivery.

Our analysis shows clearly (Tables V-2 and V-3) that the elasticity of forward power prices with respect to spot power prices is much greater for forward contracts of 1-2 years (about 33 percent) than for contracts of 3-4 years (about 12 percent) and is very small for contracts of longer average time to delivery.

Because spot gas prices influence spot power prices, the manipulation of spot gas prices could have led to power prices that were distorted above and beyond the levels established in the refund hearing. According to the analysis in this chapter, this additional distortion would have influenced forward power prices. The magnitude of such an effect can be calculated in the manner illustrated in Table V-6.

In addition, because spot and forward gas prices are linked through arbitrage, spot gas manipulation may have influenced forward power prices by inflating the price of forward gas. We have made no estimate of the magnitude of this second effect.

Recommendation

Given the finding that forward power prices were distorted and a detailed statistical analysis providing estimates of the extent of the distortion based on a certain level of distortion in spot power prices, we present the following recommendation:

- For contracts that are subject to a just and reasonable standard of review in the ongoing complaint proceeding (see footnote 2), the Commission should send this analysis to the Administrative Law Judges to use as they see fit to resolve the complaints.