Web Appendix to "Vertical Arrangements, Market Structure, and Competition"

August 1, 2007

Abstract

This document is a web appendix to the paper: "Vertical Arrangements, Market Structure, and Competition: An Analysis of Restructured U.S. Electricity Markets." It summarizes several robustness tests. First, we report the confidence intervals on prices given the uncertainty in estimating residual demand. Second, we test the sensitivity of our main results to different functional forms of residual demand. Third, we examine the firm level production implied by our three cases–perfect competition and Cournot with and without vertical obligations–as well as the actual production.

1 Confidence Intervals on Prices

First, we explore whether the conclusions implied by Figures 2, 5, and 6 of the text are sensitive to the errors in measuring the $\widehat{\beta}$ coefficient in equation (5) of the text. Figures W.1, W.2, and W.3 display a 95 percent confidence interval on our estimates. The confidence interval is determined by adding and subtracting 1.96 times the standard errors from (5) to the coefficient estimates of the fringe supply. Cournot prices are calculated for these upper and lower bounds. We also calculate similar bounds for the competitive prices and find tight bounds. As expected, the variation in elasticity produces more substantial differences in Cournot prices during very high demand hours, but the range of prices is still relatively narrow compared to the effects of eliminating the vertical arrangements. For all markets, the actual prices are within the 95 percent confidence interval for most high demand levels (though not at low demand levels for reasons discussed in the paper).

2 Robustness to Alternative Fringe Supply

Next, we test the robustness of our findings to alternative specifications of fringe supply. The first column of Table W.1 reports the average prices using or main log price specification (identical those in Table 3 of the text). The other columns report the average prices for the linear, square root, and cube root models. The results are qualitatively similar, though the prices for the Cournot with no vertical arrangements are smaller with these alternative specifications.

Table W.1 also reports the results of non-nested tests similar to those described in Section 3.A of the text. If a non-nested test both fails to reject Cournot pricing and does reject competitive pricing at the five percent level, then we conclude that the Cournot model is a better fit of the actual prices. In no market do we find the opposite: that the Cournot model can be rejected but that the competitive model cannot. Then, we perform similar tests between Cournot prices (with vertical arrangements) and Cournot prices without vertical arrangements for the Eastern markets. If a non-nested test fails to reject the Cournot prices but rejects the prices ignoring vertical arrangements, then we find that the Cournot model is a better fit of actual prices.

Generalizing across all specifications, we find that the actual prices were similar to the Cournot model prices in most cases but not similar to the prices of either the competitive or Cournot without vertical arrangements models. Our conclusion that the vertical arrangements in the Eastern markets were critical to their performance is robust across functional forms.

3 Firm Level Results

The paper's simulation results also provide measures of output quantities of specific firms. This section of the web appendix examines the firm level production implied by our three cases–perfect competition and Cournot with and without vertical obligations–as well as the actual production

recorded by the EPA's Continuous Emissions Monitoring System (CEMS) dataset. Table W.2 reports mean MWh production levels over our sample period for the largest firms in each market. The PJM Cournot simulation assuming no vertical arrangements is omitted. The vast majority of the equilibrium prices for that case were at the price cap of 1000 $/MWh. In such cases, there are in fact many possible Cournot equilibria, and reporting production from one such equilibrium is not very informative.

As with the pricing results the output levels of the individual firms fall, for the most part, between competitive and Cournot levels. Output levels in the California market seem to be most consistent with Cournot levels. It is important to note that, in several cases, the relatively small strategic firms produce less in the competitive simulation than in the Cournot simulation. This is because in the competitive scenarios, their output is displaced by that of the larger firms, who are reducing their production relatively more than these firms in the Cournot scenarios. In PJM, most firms produce between the Cournot and competitive levels on average.

In New England, the two largest firms produce more under the Cournot model (accounting for vertical arrangements) than under the competitive model. While the actual output levels of these firms are less than those predicted by the Cournot model, they are substantially greater than the levels indicated by the strategic model ignoring vertical obligations. This is likely reflective of a less extreme strategy choice than Cournot, and possibly an indication that these firms modified their net vertical position with subsequent secondary contracts.

Several caveats should be noted. First, data on the output levels of specific generation units are less reliable than market level data. Hourly output data, which are drawn from the EPA's CEMS dataset, are not available for certain small generation units.

Second, our data about long-term contracts are incomplete. Although we observe what we

believe are all of the major long-term arrangements between suppliers and retailers, details of other arrangements, particularly more short-term trades, have not been made public. Market level results will be less sensitive to the distribution of such arrangements than firm-level results. We do know that the contracts signed by retailers in California were minimal, so that any arrangements we have missed will be in the Eastern markets. Additional purchase arrangements by retailers in the East would make those markets look less competitive relative to a Cournot calculation, and therefore reinforce our general observation that it is very unlikely that California's market design was a major contributor to the crisis there.

Third, unit level operating constraints can cause deviations in actual production levels relative to a simulation such as ours that omits such constraints. These operating constraints include minimum output levels, ramping rates, and start-up costs. As Mansur (forthcoming) demonstrates, while these deviations may offset each other in determining average prices, the differences can be significant for individual plants or units.

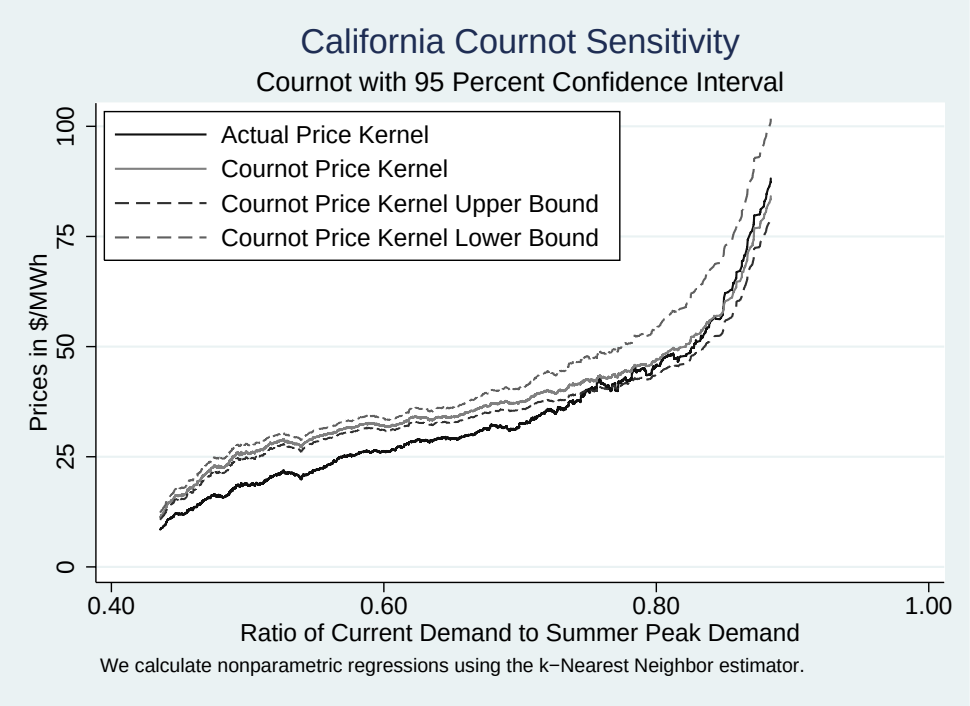
California Cournot Sensitivity
Cournot with 95 Percent Confidence Interval
Actual Price Kernel
Cournot Price Kernel
Cournot Price Kernel Upper Bound
Cournot Price Kernel Lower Bound
Prices in $/MWh
0
25
50
75
100
0.40
0.60
0.80
1.00
Ratio of Current Demand to Summer Peak Demand
We calculate nonparametric regressions using the k−Nearest Neighbor estimator.

Figure W.1:

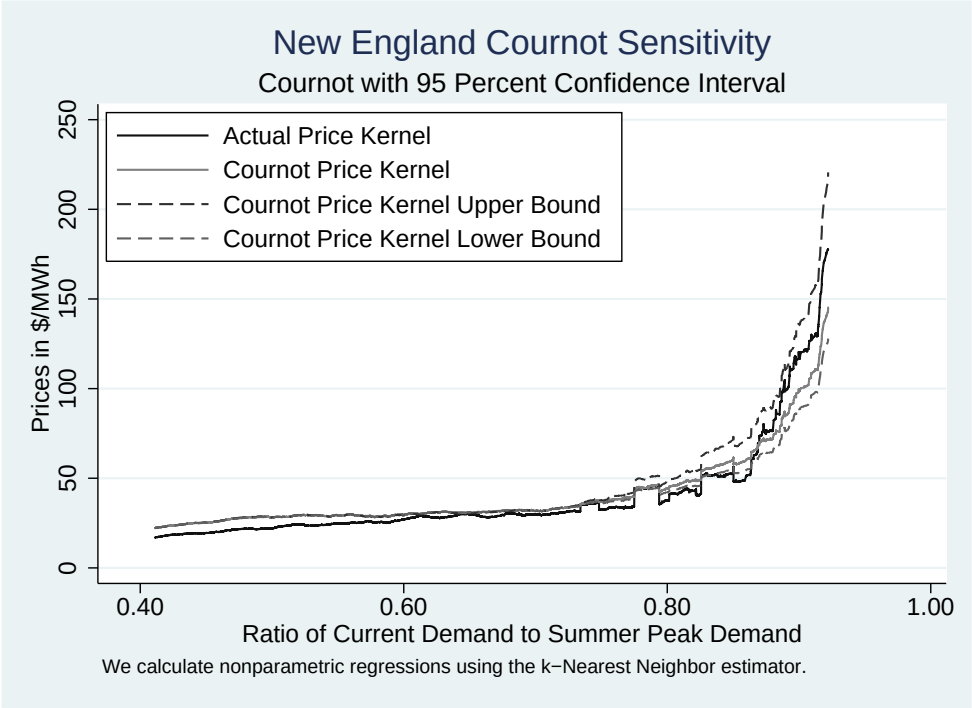

Figure W.2:

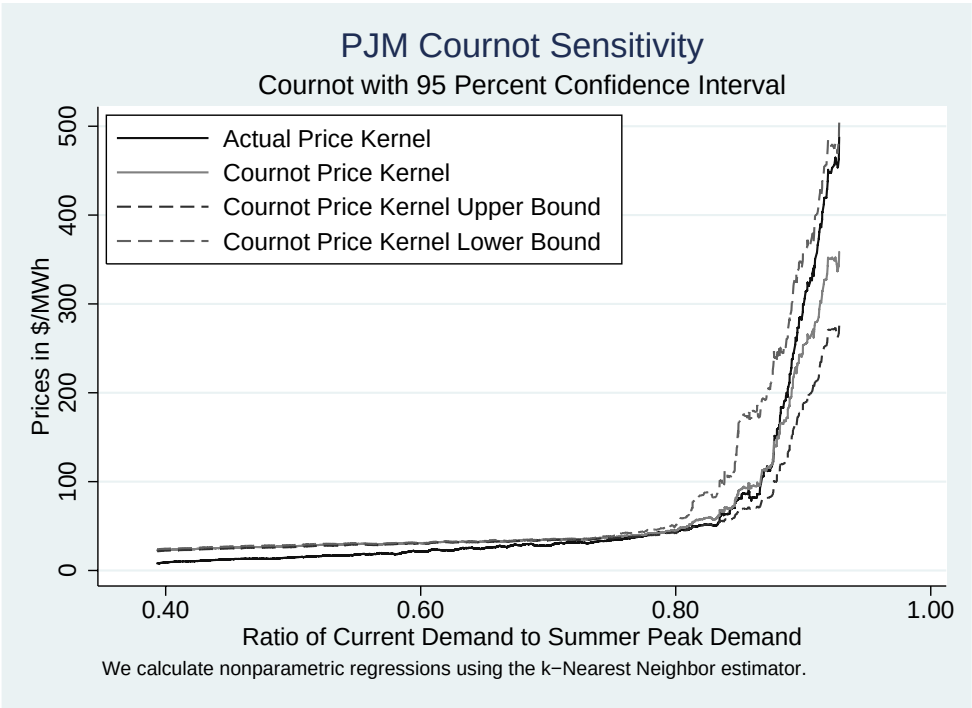

Figure W.3:

Table W.1: Robustness of Prices to Functional Form of Import Supply Function

Panel A: Peak Hours (11AM to 8PM Weekdays).

Variable	$ln(Price)$	$Price$	$\sqrt{Price}$	$\sqrt[3]{Price}$
California Actual	43.15	43.15	43.15	43.15
Competitive	35.01	36.26	36.01	35.73
Cournot	45.17*	45.66	44.00	44.02
New England Actual	55.05	55.05	55.05	55.05
Competitive	41.72	46.18	45.46	44.52
Cournot	54.63*+	65.32+	56.43	54.56+
Cournot n.v.a.	280.47	176.69	154.91	169.65
PJM Actual	97.31	97.31	97.31	97.31
Competitive	35.08	49.55	36.31	36.24
Cournot	87.05*+	71.26*+	59.99	78.46*+
Cournot n.v.a.	1000.00	482.35	821.13	991.86

Panel B: Off-Peak Hours.

Variable	$ln(Price)$	$Price$	$\sqrt{Price}$	$\sqrt[3]{Price}$
California Actual	23.90	23.90	23.90	23.90
Competitive	26.10	27.95	26.80	26.52
Cournot	30.00	32.93	30.53	30.20
New England Actual	29.18	29.18	29.18	29.18
Competitive	31.73	32.93	32.57	32.33
Cournot	32.63*+	32.63+	33.17	32.92*+
Cournot n.v.a.	86.16	104.23	76.76	74.41
PJM Actual	23.84	23.84	23.84	23.84
Competitive	25.42	25.60	25.54	25.50
Cournot	32.73*	36.18+	33.28*+	25.37*+
Cournot n.v.a.	900.57	315.18	476.15	698.73

Panel C: All Hours.

Variable	$ln(Price)$	$Price$	$\sqrt{Price}$	$\sqrt[3]{Price}$
California Actual	29.69	29.69	29.69	29.69
Competitive	28.78	30.45	29.57	29.29
Cournot	34.56*	36.75*	34.58*	34.36*
New England Actual	36.96	36.96	36.96	36.96
Competitive	34.73	36.91	36.44	35.99
Cournot	39.24+	42.45+	40.16	39.43+
Cournot n.v.a.	144.56	126.01	100.25	103.03
PJM Actual	45.92	45.92	45.92	45.92
Competitive	28.32	32.80	28.78	28.73
Cournot	49.06*+	46.72	41.30	41.33*+
Cournot n.v.a.	930.45	365.42	579.83	786.83

Note: This table reports the average actual prices and estimates of competitive and Cournot prices by market and time of day (Peak and Off-Peak) during the summer of 1999. Table summarizes the results of several non-nested tests. First, we compare whether the Cournot or competitive prices were better predictors of actual prices. We denote that the Cournot prices fit the data better with a *. Then, we compare whether the Cournot or Cournot with no vertical arrangements (n.v.a.) prices were better predictors of actual prices. We denote that the Cournot prices fit the data better with a +.

Table W.2: Comparison of Firm Level Actual and Simulated Quantities

Panel A: California Firm Quantities (hourly average MWh).

Firm	Actual	Competitive	Cournot	Cournot n.v.a.
AES/Williams	847	1101	856	856
Reliant	1087	1578	943	943
Duke	689	315	628	628
Mirant	566	795	808	808
Dynegy/NRG	744	1591	1018	1018

Panel B: New England Firm Quantities (hourly average MWh).

Firm	Actual	Competitive	Cournot	Cournot n.v.a.
Northeast Util.	3420	3275	4227	2058
PG&E N.E.G.	1634	2042	2352	953
Mirant	716	785	199	743
Sithe	621	518	151	719
FP&L Energy	496	536	202	696

Panel C: PJM Firm Quantities (hourly average MWh).

Firm	Actual	Competitive	Cournot	Cournot n.v.a.
Public Service Elec.	4169	4095	5554	*
PECO	5283	5446	4573	*
GPU, Inc.	5475	5794	5166	*
PP&L Inc.	4373	5374	3664	*
Potomac Electric	3091	2654	3422	*
Baltimore G & E	3476	3849	3846	*

Notes: Cournot n.v.a. means no vertical arrangements. For the PJM no vertical arrangement simulation, in most hours (90 percent), the equilibrium price is at the price cap. For these hours, there are multiple equilibria of firm quantities. For this reason, we leave the column blank. For those hours with price below the cap, all strategic firms produce substantially less than the observed levels.