Supplemental Materials for Severin Borenstein and James Bushnell, "An Empirical Analysis of the Potential for Market Power in California's Electricity Industry", *The Journal of Industrial Economics*, 47(3), September 1999, pp. 285-323.

Appendix A - Simulation Results

Table IX: Market outcomes for base case with elasticity = 0.1

Demand Level	Peak	150th highest	300th highest	450th highest	600th highest	744th highest
March						
Competitive Price ($/MWh)	26.69	25.95	25.95	25.25	23.97	22.96
Cournot Equilibrium Price ($/MWh)	58.35	27.45	27.45	27	25.18	24.2
Market Quantity	40092	38966	36638	31242	26397	23425
June						
Competitive Price ($/MWh)	30.44	26.18	25.23	24.41	23.16	20.84
Cournot Equilibrium Price ($/MWh)	419.95	27.45	26.24	25.42	24.2	20.83
Market Quantity	44743	42693	37758	32082	27078	22003
September						
Competitive Price ($/MWh)	124.88	33.93	32.09	26.78	24.37	22.96
Cournot Equilibrium Price ($/MWh)	4829.2	932.17	555.08	63.08	25.42	24.2
Market Quantity	39047	35206	33737	34749	30327	26342
December						
Competitive Price ($/MWh)	34.01	28.73	28.82	26.98	25.76	25.16
Cournot Equilibrium Price ($/MWh)	421.22	150.88	137.58	28.13	28.06	25.42
Market Quantity	37454	35703	33960	32661	28113	24380

Table X: Market outcomes for base case with elasticity = 0.4

Demand Level	Peak	150th highest	300th highest	450th highest	600th highest	744th highest
March						
Competitive Price ($/MWh)	27.5	27.06	27.01	26.18	24.37	23.47
Cournot Equilibrium Price ($/MWh)	43.52	27.46	27.9	27	25.42	25.18
Market Quantity	42089	42904	40236	34471	29324	26022
June						
Competitive Price ($/MWh)	34.74	27.3	26.18	25.43	23.89	22.18
Cournot Equilibrium Price ($/MWh)	58.17	31.55	27.9	27	25.18	22.46
Market Quantity	51375	45917	41394	35313	30079	24729
September						
Competitive Price ($/MWh)	68.62	43.44	36.71	28.19	25.43	23.56
Cournot Equilibrium Price ($/MWh)	89.6	63.08	58.17	43.31	27	25.18
Market Quantity	50236	42725	39749	33085	33382	29263
December						
Competitive Price ($/MWh)	38.49	30.25	30.42	28.19	26.18	25.43
Cournot Equilibrium Price ($/MWh)	58.35	51.58	50.31	33.94	28.13	25.99
Market Quantity	42986	38602	36657	34703	30861	27000

Table XI: Market outcomes for base case with elasticity = 1.0

Demand Level	Peak	150th highest	300th highest	450th highest	600th highest	744th highest
March						
Competitive Price ($/MWh)	31.64	28.91	29.88	28.19	26.18	24.7
Cournot Equilibrium Price ($/MWh)	36.35	32.07	32.07	30.34	27	25.42
Market Quantity	49110	48691	45783	39972	35361	32089
June						
Competitive Price ($/MWh)	44	29.75	28.69	27.46	25.25	23.47
Cournot Equilibrium Price ($/MWh)	45.97	33.85	30.54	28.17	26.15	24.3
Market Quantity	56792	52065	48120	42254	36684	30501
September						
Competitive Price ($/MWh)	59.77	48.8	45.5	32.84	27.3	24.96
Cournot Equilibrium Price ($/MWh)	60.55	50.72	47.9	38.2	29.72	26.15
Market Quantity	53060	45638	42975	41752	39054	35688
December						
Competitive Price ($/MWh)	46.49	36.14	36.2	30.91	28.19	26.18
Cournot Equilibrium Price ($/MWh)	48.89	41.91	42.12	34.47	33.27	29.02
Market Quantity	45992	43559	41028	39539	34587	31715

Table XII: Partial Divestiture, elasticity = 0.1

Demand Level	Peak	150th highest	300th highest	450th highest	600th highest	744th highest
March						
Competitive Price ($/MWh)	26.69	25.95	25.95	25.25	23.97	22.96
Cournot Equilibrium Price ($/MWh)	27.45	27	27	25.42	25.18	23.87
Market Quantity	38128	35554	33545	28017	24819	22657
June						
Competitive Price ($/MWh)	30.44	26.18	25.23	24.41	23.16	20.84
Cournot Equilibrium Price ($/MWh)	64.19	27	25.42	25.18	24.2	20.83
Market Quantity	51906	42723	37805	32092	27079	22003
September						
Competitive Price ($/MWh)	124.88	33.93	32.09	26.78	24.37	22.96
Cournot Equilibrium Price ($/MWh)	427.83	159.13	121.2	28.05	25.18	23.87
Market Quantity	48810	41255	38444	36223	30337	26355
December						
Competitive Price ($/MWh)	34.01	28.73	28.82	26.98	25.76	25.16
Cournot Equilibrium Price ($/MWh)	129.62	54.93	54.93	28.13	27.04	25.42
Market Quantity	41394	38286	36155	32661	28156	24381

Table XIII: Partial Divestiture, elasticity = 0.4

Demand Level	Peak	150th highest	300th highest	450th highest	600th highest	744th highest
March						
Competitive Price ($/MWh)	27.5	27.06	27.01	26.18	24.37	23.47
Cournot Equilibrium Price ($/MWh)	28.17	27.46	27.9	27	25.18	24.2
Market Quantity	42185	38942	36900	31161	26658	25199
June						
Competitive Price ($/MWh)	34.74	27.3	26.18	25.43	23.89	22.18
Cournot Equilibrium Price ($/MWh)	45.97	27.46	27	26.07	24.2	22.17
Market Quantity	54176	47010	41616	35511	30263	24775
September						
Competitive Price ($/MWh)	68.62	43.44	36.71	28.2	25.43	23.56
Cournot Equilibrium Price ($/MWh)	69.34	52.36	46.72	31.55	25.42	24.2
Market Quantity	53771	44642	41770	38991	33703	29439
December						
Competitive Price ($/MWh)	38.49	30.25	30.42	26.78	26.18	25.43
Cournot Equilibrium Price ($/MWh)	48.92	33.68	33.68	28.05	27.83	25.42
Market Quantity	44755	42109	39765	35875	30916	27094

Table XIV: Full Divestiture, elasticity = 0.1

Demand Level	Peak	150th highest	300th highest	450th highest	600th highest	744th highest
March						
Competitive Price ($/MWh)	26.69	25.95	25.95	25.25	23.97	22.96
Cournot Equilibrium Price ($/MWh)	27.45	27	26.17	25.42	24.3	23.87
Market Quantity	35658	33838	31123	26020	22688	22567
June						
Competitive Price ($/MWh)	30.44	26.18	25.23	24.41	23.16	20.84
Cournot Equilibrium Price ($/MWh)	32.07	26.24	26.07	25.18	23.87	20.83
Market Quantity	49253	39648	34918	29513	26366	21695
September						
Competitive Price ($/MWh)	124.88	33.93	32.09	26.78	24.37	22.96
Cournot Equilibrium Price ($/MWh)	186.13	58.17	58.17	28.05	25.18	23.74
Market Quantity	47163	39915	36867	33004	28228	25887
December						
Competitive Price ($/MWh)	34.01	28.73	28.82	26.98	25.76	25.16
Cournot Equilibrium Price ($/MWh)	58.35	29.28	32.38	28.06	26.81	25.18
Market Quantity	39826	35513	34159	29903	26502	23543

Table XV: Full Divestiture, elasticity = 0.4

Demand Level	Peak	150th highest	300th highest	450th highest	600th highest	744th highest
March						
Competitive Price ($/MWh)	27.5	27.06	27.01	26.18	24.37	23.47
Cournot Equilibrium Price ($/MWh)	28.17	27.45	27.45	27	25.18	24.2
Market Quantity	39146	36104	33897	28959	24718	23659
June						
Competitive Price ($/MWh)	34.74	27.3	26.18	25.43	23.89	22.18
Cournot Equilibrium Price ($/MWh)	39.79	27.46	27	26.07	24.2	22.28
Market Quantity	50752	42724	38348	32612	27997	24758
September						
Competitive Price ($/MWh)	68.62	43.44	36.71	28.2	25.43	23.56
Cournot Equilibrium Price ($/MWh)	69.34	46.27	41.34	28.19	25.42	24.2
Market Quantity	48372	40625	37798	35311	30598	27958
December						
Competitive Price ($/MWh)	38.49	30.25	30.42	28.19	26.18	25.43
Cournot Equilibrium Price ($/MWh)	43.87	32.38	33.59	28.64	27.04	25.99
Market Quantity	40832	38261	35453	32248	28876	25919

Table XVI — Market outcomes for base case with elasticity = 0.1 and Linear Demand

Demand Level	Peak	150th highest	300th highest	450th highest	600th highest	744th highest
March						
Competitive Price ($/MWh)	26.66	25.88	25.88	25.25	23.97	22.96
Cournot Equilibrium Price ($/MWh)	58.35	27.45	27	27	25.18	24.2
Market Quantity	40085	38771	36471	31079	26237	23272
June						
Competitive Price ($/MWh)	29.91	26.18	25.19	24.39	23.11	20.84
Cournot Equilibrium Price ($/MWh)	126.11	27.45	26.24	25.42	24.2	20.83
Market Quantity	48372	42480	37548	31890	26902	21819
September						
Competitive Price ($/MWh)	104.76	33.93	32.08	26.69	24.34	22.96
Cournot Equilibrium Price ($/MWh)	178.12	144.94	132.26	63.08	25.42	24.2
Market Quantity	49649	40118	37157	34728	30147	26170
December						
Competitive Price ($/MWh)	33.81	28.73	28.81	26.86	25.69	25.06
Cournot Equilibrium Price ($/MWh)	135.69	104.48	100.9	54.93	28.06	25.42
Market Quantity	40050	36241	34363	31596	27980	24235

Table XVII— Market outcomes for base case with elasticity = 0.4 and Linear Demand

Demand Level	Peak	150th highest	300th highest	450th highest	600th highest	744th highest
March						
Competitive Price ($/MWh)	27.5	26.78	26.66	25.95	24.31	23.31
Cournot Equilibrium Price ($/MWh)	45.97	27.46	27.9	27	25.18	24.3
Market Quantity	41538	41879	39309	33614	28523	25359
June						
Competitive Price ($/MWh)	33.89	26.94	26.08	25.25	23.56	21.45
Cournot Equilibrium Price ($/MWh)	58.17	27.46	27.45	26.24	25.18	21.95
Market Quantity	51332	45886	40509	34537	29215	23905
September						
Competitive Price ($/MWh)	67	42.76	35.26	28.14	28.14	23.31
Cournot Equilibrium Price ($/MWh)	73.56	58.17	58.17	49.9	47.9	24.3
Market Quantity	52294	43529	39715	35577	32650	28517
December						
Competitive Price ($/MWh)	37.22	29.75	29.94	27.9	26.12	25.27
Cournot Equilibrium Price ($/MWh)	58.35	54.54	53.71	44.44	28.13	25.99
Market Quantity	42947	38110	36117	32827	30164	26272

Appendix B- Data Sources

Thermal Generating Plant Data

Costs of thermal generating plants were derived using the inputs from General Electric's MAPS multi-area production cost simulation model obtained from CEC staff. Plant status and capacities were cross checked with the Energy Information Administration's 1994 Inventory of US Generating plants (DOE/EIA [1995]) for plants not owned by California utilities. Generation plants owned by California utilities were also cross checked with plant capacities in appendix A of the CEC's 1994 electricity report, ER94, (California Energy Commission [1995]). "Available" plant capacities were derived using the plants rated capacity multiplied by its average forced outage rate (FOR). Forced outage rates were taken from the MAPS inputs and, for California owned plants, crossed checked with FORs provided in ER94. As explained in the text, capacities are not adjusted for maintenance requirements, because the timing of such unavailability is a strategic decision of the firm.

Thermal plant operating costs were derived using the full capacity average heat rates from MAPS, and fuel cost projections used by Deb, et. al. [1996] which were derived from ER94 and other sources. To these fuel costs we added variable operating and maintenance costs taken from the MAPS data set. There is, however, a disturbing amount of variance between data sets about the capabilities and costs of plants in some regions. Fortunately, the larger source of information available for California owned facilities is much more consistent across data sets.

Table XVIII: Forecast Delivered Gas Prices ($/Mcf)

Period	*Northwest*	*Nor. Cal.*	*So. Cal.*	*Rocky Mt. N.*	*Rocky Mt.- SW*
December	2.18	2.50	2.69	2.18	2.50
March, June, Sep	2.04	2.31	2.50	2.04	2.31

Table XIX: Incremental Costs of PG&E and SCE (using summer gas prices)

	PG&E		SCE	
Incremental $/MWh	**Total Capacity**	**Cum Capacity (GW)****	**Total Capacity**	**Cum Capacity (GW)****
0-4.90	4.26*	4.26	1.128*	1.128
5.00-9.90	0.00	4.26	0	1.128
10.00-14.99	1.90	6.16	2.629	3.757
15.00-19.90	0.00	6.16	0.734	4.491
20.00 - 24.90	4.34	10.50	5.751	10.242
25.00 - 29.90	2.51	13.01	2.208	12.45
30.00 - 34.90	0.05	13.06	1.082	13.532
35.00 - 39.90	0.04	13.11	0	13.532
40.00-44.90	0.00	13.11	0	13.532
45.00-49.90	0.00	13.11	0	13.532
50.00 - 54.90	0.38	13.48	0	13.532
55.00 and up	0.04	13.52	0.132	13.664

*Includes maximum instantaneous flow capacity of pondage hydro

****thermal unit capacities derated by forced outage rates**

Divestiture of Gas-fired Generation Capacity

The partial divestiture scenario involved creating 3 new Cournot firms, one that owned 1/2 of PG&E's gas resources, and two that each owned 1/2 of SCE's gas resources. The full divestiture scenario was based upon 1998 announcements of the actual sales agreements that have been reached. Table XX shows the allocation of thermal capacity before and after these announced transfers are completed.

Table XX — Pre and Post Divestiture California Thermal Capacity

Incumbent Firms	Pre Divestiture	'Full' Divestiture
PGE	8083 MWs	782 MWs
SCE	12314	1378
New Firms		
Duke		2306
AES/Williams		3705
Houston Ind.		3554
Destec		1445
Thermo Ecotek		249
TBD*		3093

*To be divested – purchasing firm not yet identified.

Hydro Generation Data

Hydro plant data were taken from the data set used by Southern California Gas Company in its 1995 performance-based ratemaking simulation studies (Pando [1995]). This data set was also used by Kahn, et. al [1996] in their simulation analysis of the WSCC. The minimum and maximum flow capacities of the hydro resources shown in Table II are taken from this data set. Monthly hydro energy production values were primarily derived from the Energy Information Agency's *Electric Power Monthly* (EIA). The values used for U.S. production are four-year averages of the production in each respective month. The production by the Canadian members of the WSCC was taken from the 2001 production forecast given in the WSCC report *Summary of Expected Loads and Resources* (WSCC [1996]).

The data provide instantaneous maximum and minimum MW outputs for hydro-systems in the WSCC as well as monthly energy (MWH) quotas for each facility or set of facilities. Hydro facilities fall into three categories - pondage, run-of-river, and pumped storage. Run-of-river capacity is derived from the minimum flow rates of each of these facilities and the respective energy used through run-of-river was deducted from each system's monthly energy quotas. In order to derive the amount of standard pondage capacity that would be available in any given hour, we allocated the remaining monthly energy across the hours of a month in a process known as "peak-shaving." Such an allocation of hydro energy assumes that the highest output will occur in the highest demand hour and respectively less capacity would be available for lower demand hours. As long as the instantaneous flow capacity of hydro facilities were not violated, the peak shaving process would leave a constant level of demand to be served by non-hydro sources over the hours to which pondage hydro generation was applied. If the maximum flow capacity was a binding constraint, the peaks would be shaved as much as possible, but still be left with a higher level of demand than other near-peak hours. Peak-shaving was performed regionally – California hydro energy was applied to aggregate California load shapes, and likewise for the Northwest and Southwest regions. Peak-shaving is an approximation to the marginal revenue equalization that an optimizing firm would actually pursue, as described in the text.

Pump-storage units were assumed to be available in the two highest demand runs and assumed to be unavailable during the four low-demand hours. There were three pumped storage units represented: 1188 MW owned by PG&E, 217 MW owned by SCE, and 1287 MW owned by LADWP. These figures are taken from ER94. Demand in the off-peak hours was adjusted upwards to account for the additional storage into these units. The energy price of the PG&E and LADWP units was set at an estimate of the low-demand energy marginal cost, $22.50/MWH, and revised upwards to $27.50/MWH to account for energy losses in the pumping process. SCE was expected to have lower off-peak marginal costs of around $15.50/MWh which was revised upwards to $20/MWh to account for pumping losses.

Transmission Capacities

The capacities of the major transmission paths into California were taken from the non-simultaneous path-ratings of the Western Systems Coordinating Council (WSCC [1996b]) and from the most recent Southern California Instantaneous Transmission agreements (SCIT [1996]). These included a non-simultaneous capability of 4880 MW from the NW region into northern California, 2900 MW from the NW into southern California, and a total of 11326 MW from Nevada, Utah, and Arizona into Southern California. There are several path constraints that appear to be relevant when considering import capacities into southern California. These are the SCIT constraint, which includes flows from northern California, and two paths in the desert southwest - the West-of-River constraint of 9406 MW, which includes flows from Nevada, Utah, and Arizona - and the East-of-River constraint, which deals only with flows from Arizona. Because of the aggregation of States that we chose to include in our Southwest region, we used the West-of-River simultaneous import constraint to represent the limit of supply from that region. Transmission capacity into southern California is further augmented by the Intermountain DC link, which has a WSCC rated capacity of 1920 MW into California.

Demand Data

Monthly loads and load shapes were provided from the MAPS data set for a base year of 1995. These load shapes were scaled according to the summer peak forecast for the year 2001 for each region. Annual peaks for the California utilities were taken from ER94. Monthly peaks for each utility was derived by multiplying the annual peak by monthly peak factors derived from the MAPS data. The 2001 demand peak for out-of-state utilities was derived by escalating the 1995 peaks provided by the MAPS data set by the regional summer peak growth forecasts of the WSCC.

Qualifying Facilities

For our base cases, we used ER94 estimate of reliable QF capacity, 8279 MW. The capacity was derated according to the peak and off-peak capacity factor estimates given in Kito [1992]. It was assumed that this capacity would be available during all hours. This assumption is consistent with those used in other studies of the California market (See Kahn et. al. [1996], Joskow et. al. [1996]). It is widely acknowledged that this figure most likely overstates the actual effective capacity of QF generation. The ER94 capacity estimate does not consider the fact that the majority of QFs will be receiving considerably lower payments due to the expiration of the fixed energy price period of their contracts.

Appendix C – Hydro Sensitivity Analysis

Table XXI: Effect of increased hydro production on base case prices

Demand Level	Base case Energy Price at Cournot Equilibrium - Elasticity = .1 ($/MWh)							
	September				December			
	Average Hydro		95-96 Hydro		Average Hydro		95-96 Hydro	
	Perfect Compet.	Cournot	Perfect Compet.	Cournot	Perfect Compet.	Cournot	Perfect Compet.	Cournot
Peak	**124.88**	**4829.24**	**91.95**	**3289.16**	**34.01**	**421.22**	**26.62**	**156.62**
150th highest	**33.93**	**932.18**	**28.20**	**290.83**	**28.73**	**150.88**	**27.91**	**54.93**
300th highest	**32.09**	**555.08**	**29.08**	**304.96**	**28.82**	**137.58**	**27.93**	**32.38**
450th highest	**26.78**	**63.08**	**26.78**	**58.35**	**25.59**	**28.13**	**26.21**	**27.90**
600th highest	**24.37**	**25.42**	**24.37**	**25.42**	**25.76**	**28.06**	**25.43**	**27.04**
720/744 highest	**22.96**	**24.2**	**22.96**	**24.2**	**25.16**	**25.42**	**24.76**	**25.18**

Table XXII: Effect of increased hydro production on partial divestiture prices

Demand Level	Divestiture Energy Price at Cournot Equilibrium - Elasticity = .1 ($/MWh)							
	September				December			
	Average Hydro		95-96 Hydro		Average Hydro		95-96 Hydro	
	Perfect Compet.	Cournot	Perfect Compet.	Cournot	Perfect Compet.	Cournot	Perfect Compet.	Cournot
Peak	**124.88**	**427.83**	**91.95**	**337.96**	**34.01**	**129.62**	**26.62**	**58.35**
150th highest	**33.93**	**159.13**	**28.20**	**58.17**	**28.73**	**54.93**	**27.91**	**28.18**
300th highest	**32.09**	**121.20**	**29.08**	**58.35**	**28.82**	**54.93**	**27.93**	**28.01**
450th highest	**26.78**	**28.05**	**26.78**	**27.90**	**25.59**	**28.13**	**26.21**	**27.83**
600th highest	**24.37**	**25.18**	**24.37**	**25.18**	**25.76**	**27.04**	**25.43**	**25.99**
720/744 highest	**22.96**	**23.87**	**22.96**	**23.87**	**25.16**	**25.42**	**24.76**	**25.18**