Using Environmental Emissions Permit Prices to Raise Electricity Prices: Evidence from the California Electricity Market

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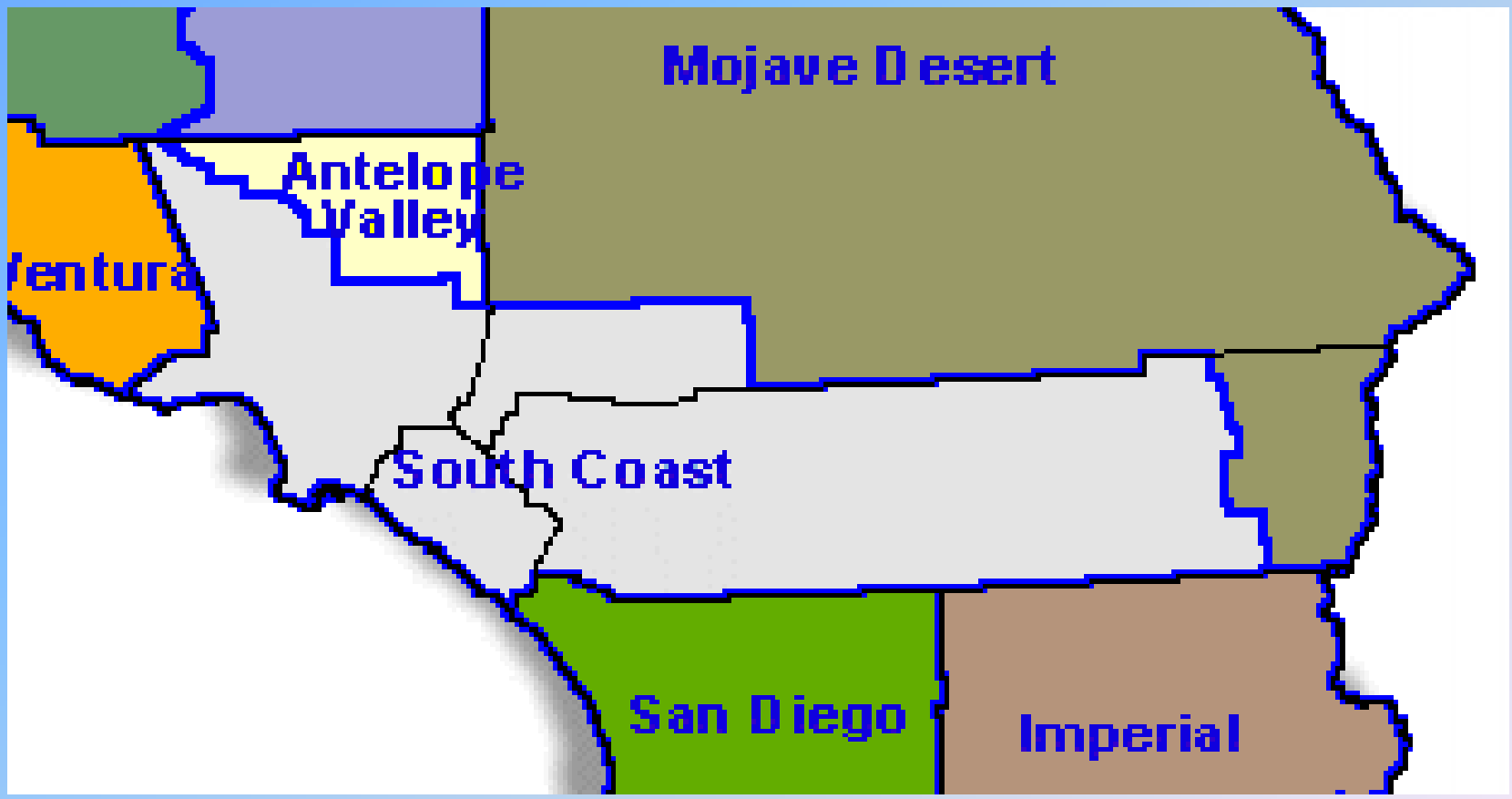
Outline of Talk

- South Coast Air Quality Management District (SCAQMD)
  - Regional Clear Air Incentive Market (RECLAIM) for NOx emissions permits
  - Compare market performance before and after electricity industry restructuring
- How to Use NOx Emissions Permit Prices to Raise Electricity Prices in California Market
- Three lines of empirical evidence in favor of this view
  - Prices paid for NOx permits and holdings of unused permits as function of type of market participant in SCAQMD market
  - Operating behavior of instate fossil fuel generation units as a function of plant location, ownership, and NOx emissions rate
  - Relationship between implied marginal cost from profit-maximizing bidding behavior and actual fuel costs and NOx emissions costs
- NOx market reforms to enhance competitiveness of electricity market

South Coast Air Quality Management District (SCAQMD)




CALIFORNIA ISO ZONE MAP
Effective Feb. 2000
OREGON
External To ISO Control
NEVADA
HUMB
(Inactive)
PGE1
RED1
LMD1
PGE3
NP15
SMD1
SF
(Inactive)
PGE2
MID1
CSC1
TID1
PGE4
ZP26
(Active Feb. 2000)
SCE1
PAS1
LDW1
ANA1
SDG1
IID1
SP15
0 50 100 150 200 mi
LEGEND
Demand Zones
PGE1
PGE2
PGE3
PGE4
SCE1
SDG1
PAS1
ANA1
Internal to ISO Control
External to ISO Control
CALIFORNIA ISO

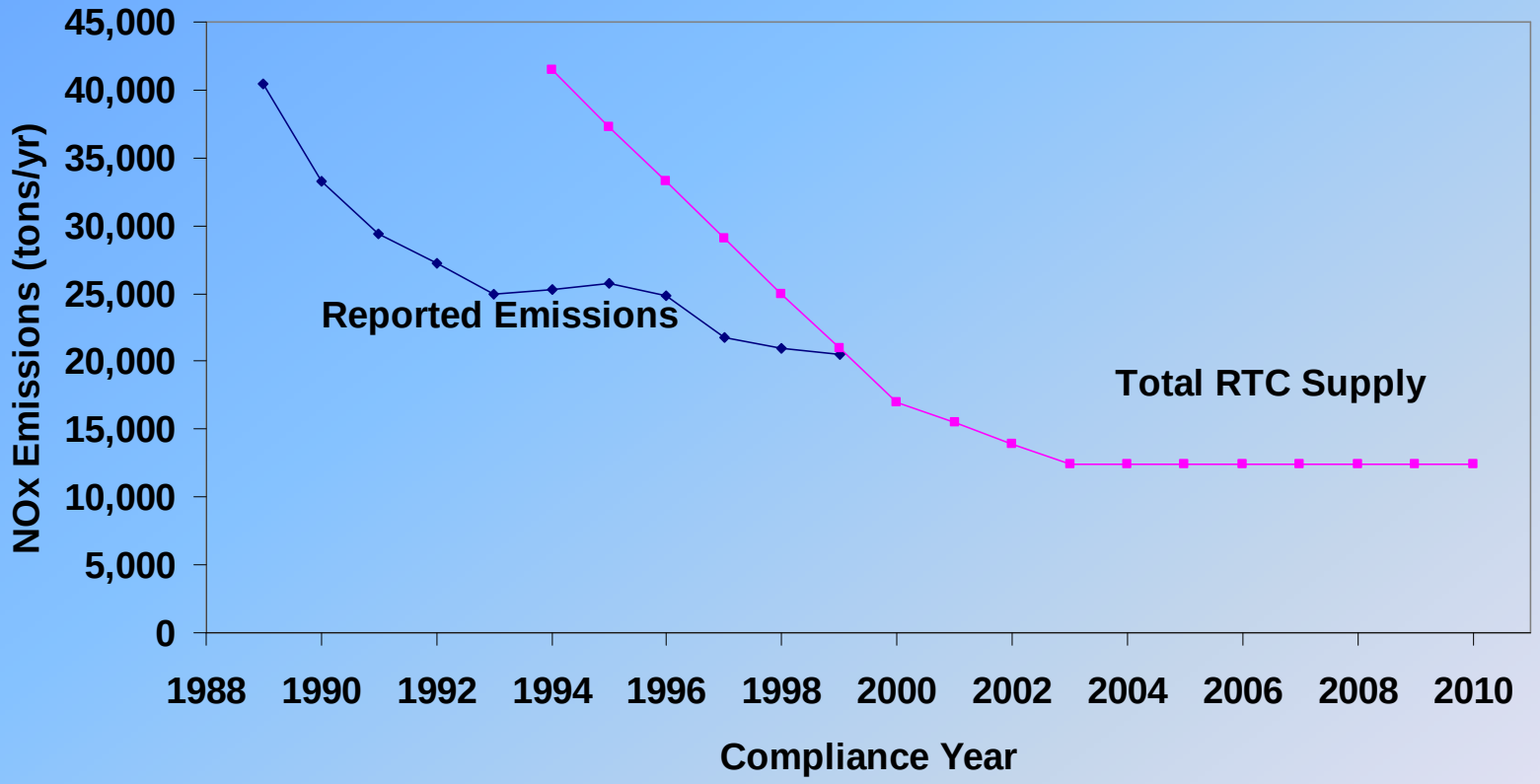
RECLAIM Market

- Began operation in 1994
  - Started with 390 market participants
  - Currently 364 market participants
- Each actor receives an allocation of RECLAIM Trading Credits (RTCs) each year
  - One RTC allows owner to emit one pound of NOx emissions during that year and compliance cycle
- RTC allocations initially set very conservatively
  - Above emissions levels that existed at the time
- Each year, two vintages of permits are issued
  - Cycle 1– January 1 to December 31 of vintage year
  - Cycle 2—July 1 of vintage year to June 30 of following year
  - Either vintage can be used to rationalize NOx emissions during period permit is valid

RECLAIM Market

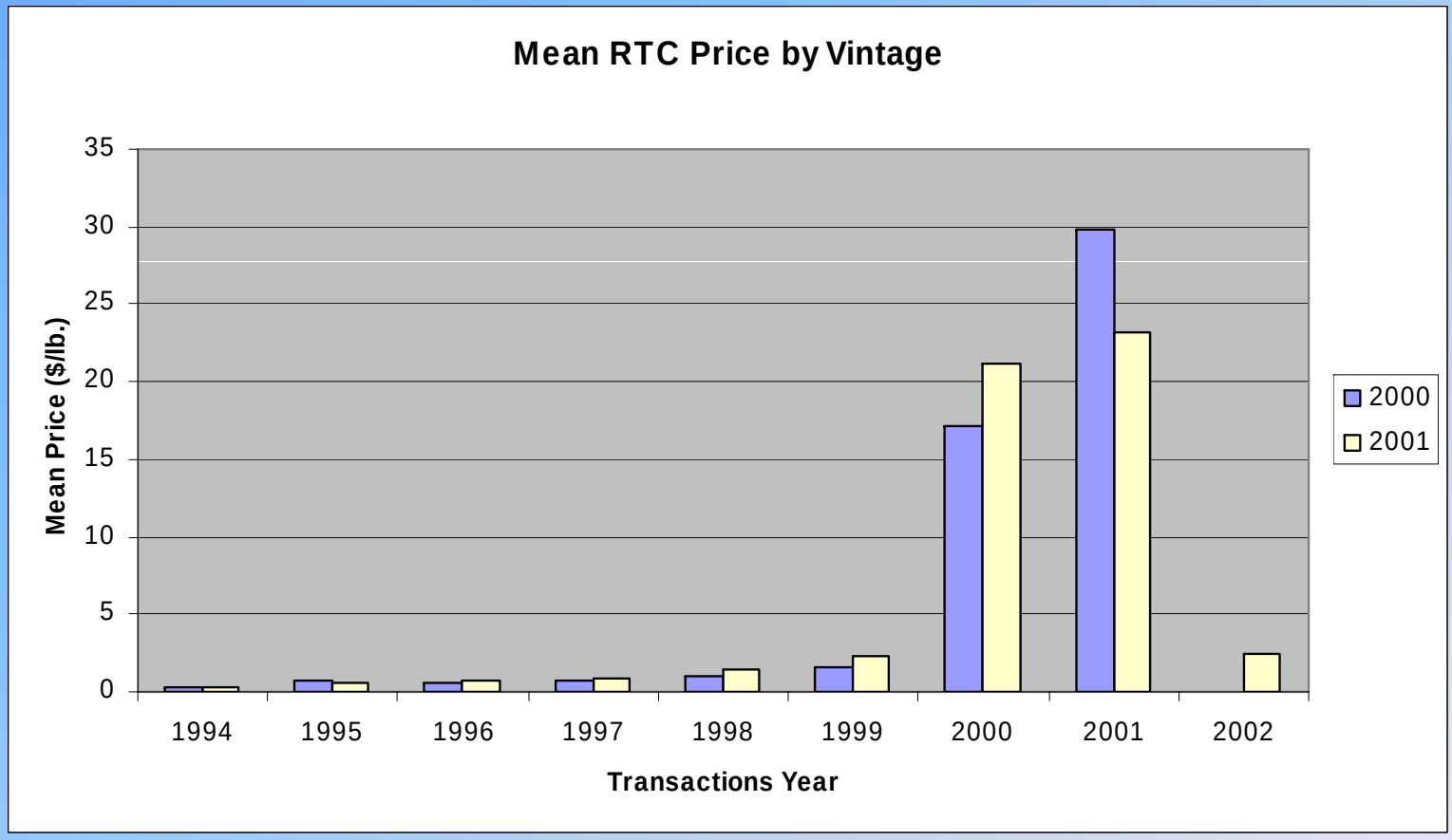
- Firms are randomly assigned to the two emissions cycles
  - Firm must rationalize its emissions with qualifying RTCs that it holds within three months of the end of its permit cycle
- Aggregate RECLAIM RTC allocations were to be reduced at 8.3% relative initial allocations until 2003
  - Larger emissions reductions were demanded from electricity generating facilities and oil refineries
- Firms can purchase RTCs through bilateral negotiations from other RECLAIM market participants to rationalize their actual emissions
  - While maintaining market-wide compliance with SCAQMD NOx emissions limits

RTC Allocations and NOx Emissions

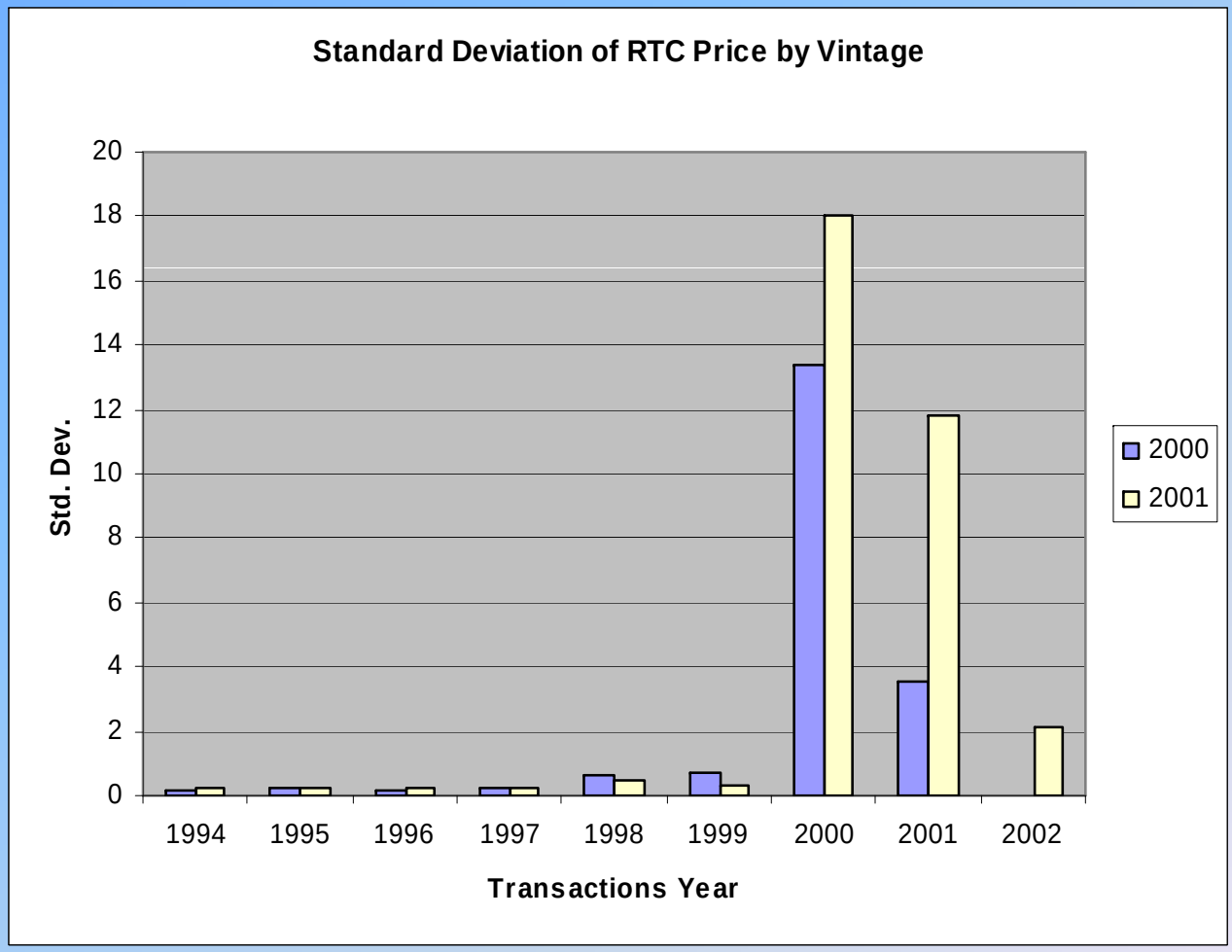


Source: Coy et al. "SCAQMD White Paper on Stabilization of NOx RTC Prices," 2001.

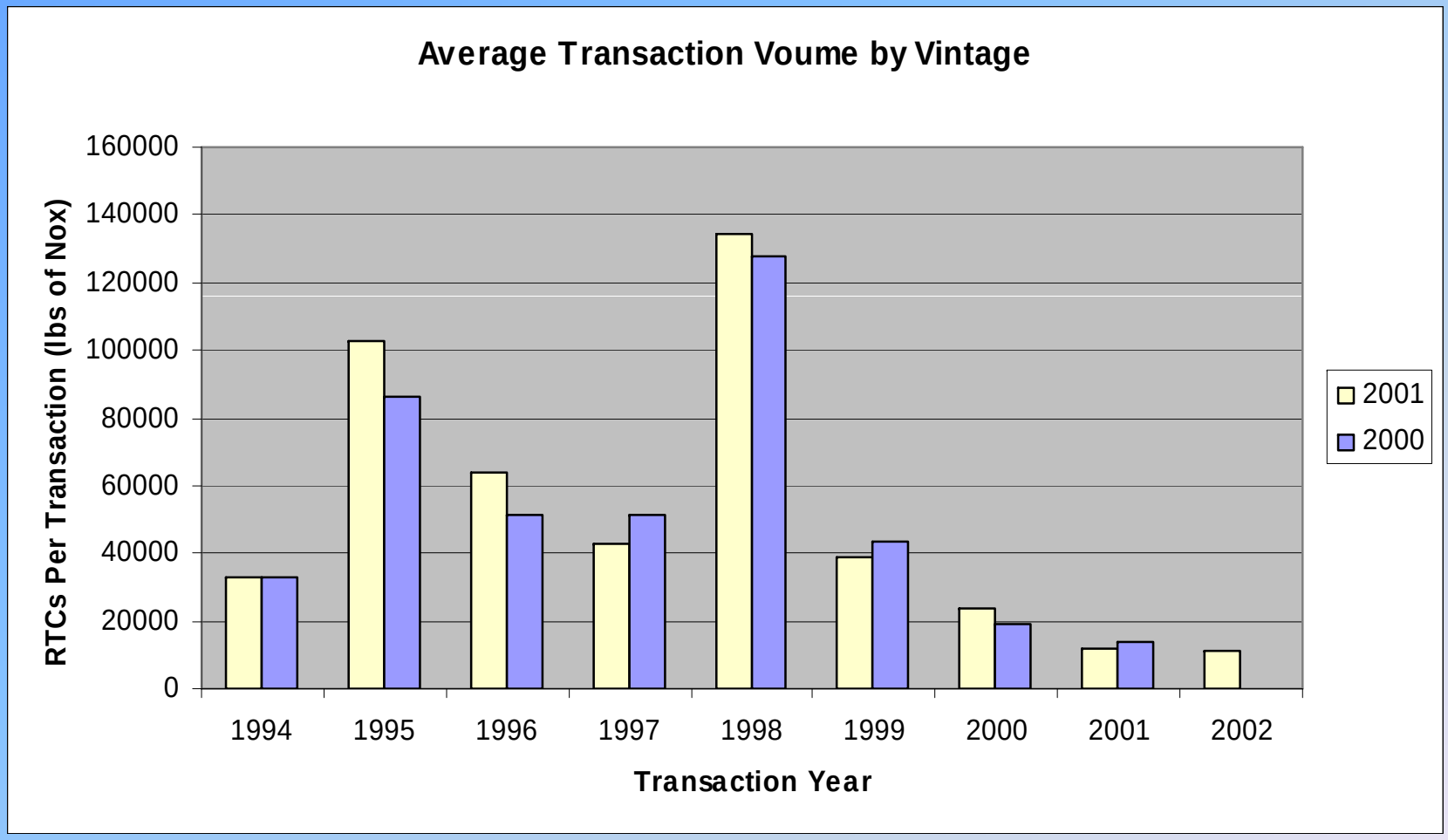
Mean RTC Prices Over Time



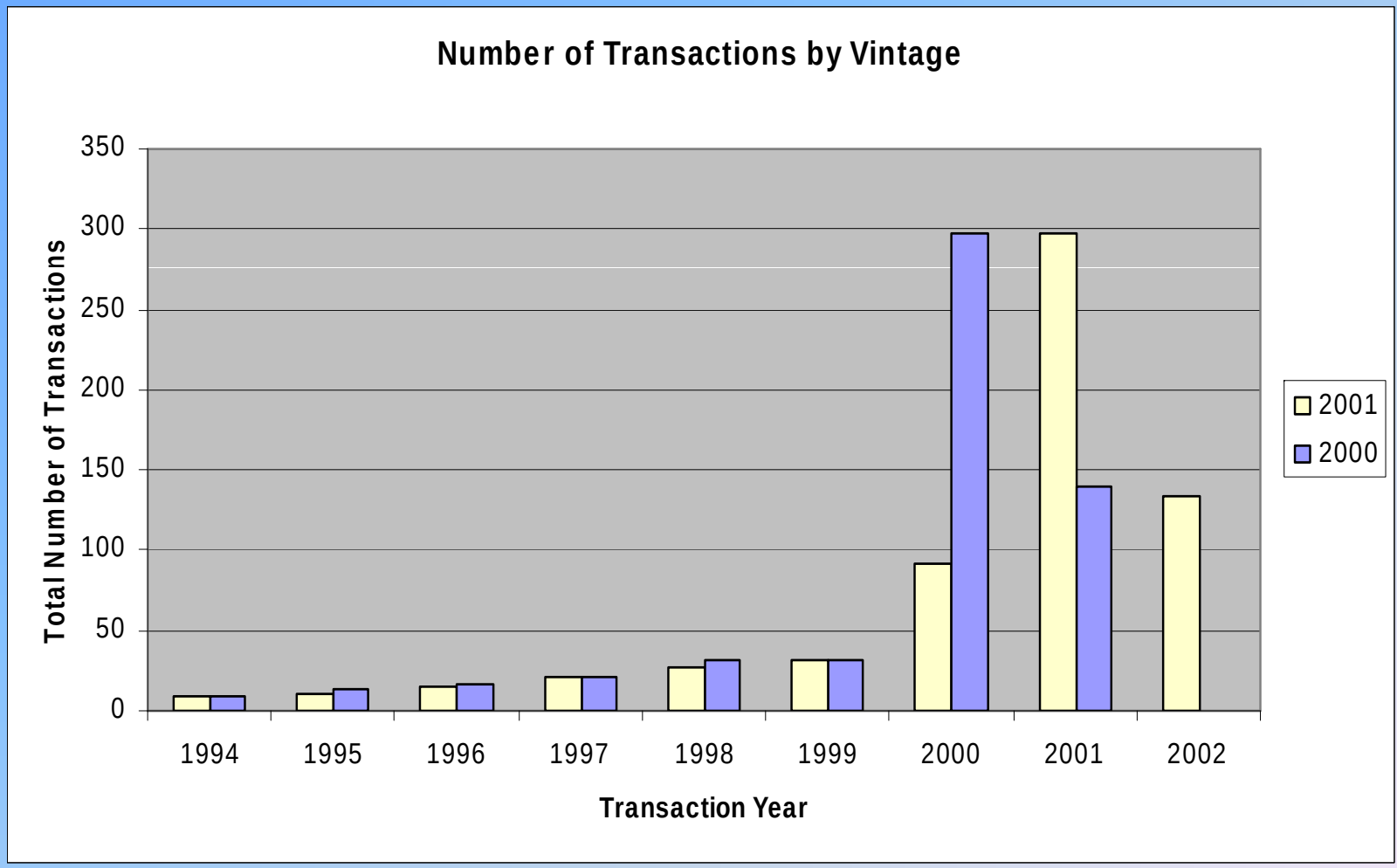
Standard Deviation of RTC Prices Over Time



Average Transactions Volume



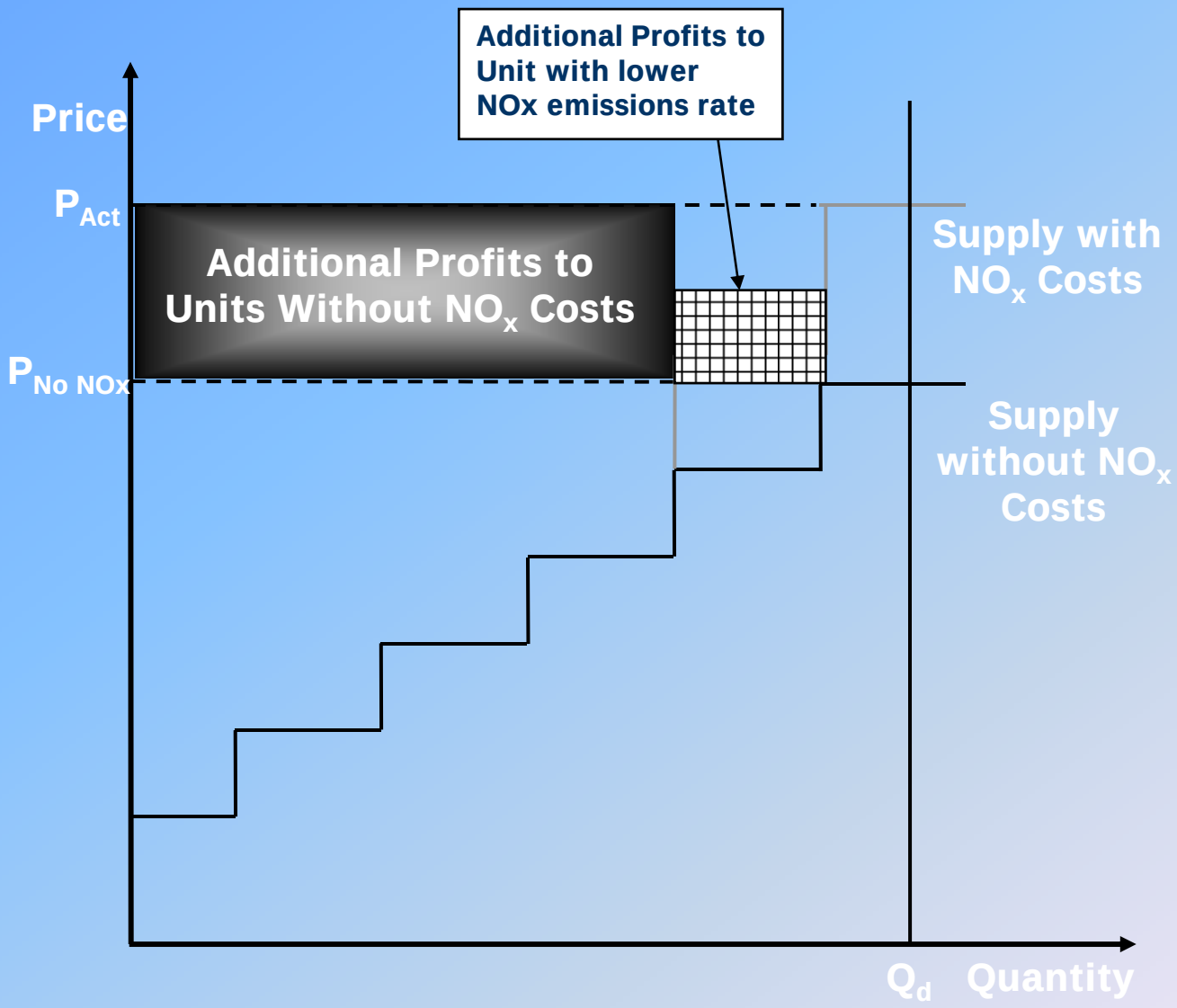
Number of Transactions



Summary of Figures

- For 2000 and 2001 vintage RTCs
  - Dramatic increase in average transactions prices for 2000 and 2001 vintages
  - Enormous increase in standard deviation of transactions prices for 2000 and 2001 vintages
  - Reduction in average transactions volume in for 2000 and 2001 vintages
  - Substantial increase in number of transactions for 2000 and 2001 vintages
- Many small RTC purchases at very high prices (and low prices) in 2000 and 2001
  - Figures are consistent with use of RTCs permits prices to raise electricity prices

Using NOx Permits To Raise Electricity Prices



Two Benefits from Raising NOx Emissions Permit Prices

- Generation units that do not require NOx emissions permits will earn higher profits
  - If market price set by bid from a unit requiring NOx permits
- Generation units that require NOx emissions permits will earn higher profits
  - If market price set by bid from a unit requiring NOx permits with a higher NOx emission rate

Did Generation Unit Owners Requiring NOx Permit Pay More For Permits?

- All RTC transactions of vintages 1997 to 2000 that occurred before June 1, 2001
  - ln(P) = natural log of transaction price in $/lb of NOx
  - Wholesale = 1 if parent company is wholesaler
  - Utility = 1 if parent company is utility
  - AQMD = 1 if parent company owns units only in SCAQMD
  - InOut = 1 if parent owns units in and out of SCAQMD
  - Out = 1 if parent company owns units only outside of SCAQMD
  - Vintage indicator variables and transaction year indicator variables

Dependent Variable = Natural Logarithm of Transaction Price for RTC NOx Emissions Permit		
Variable	Parameter Estimate	Standard Error
Intercept	-1.378	0.044
Wholesale*AQMD	0.099	0.111
Wholesale*InOut	0.104	0.107
Wholesale*Out	0.230	0.280
Utility	-0.437	0.059
Year98	0.489	0.057
Year99	1.097	0.054
Year00	2.171	0.054
Year01	2.281	0.057
Wholesale*AQMD*Year00	0.172	0.136
Wholesale*AQMD*Year01	0.310	0.144
Wholesale*InOut*Year00	0.271	0.120
Wholesale*InOut*Year01	0.298	0.129
Wholesale*Out*Year01	0.091	0.376
Utility*Year00	-0.149	0.092
Utility*Year01	-0.203	0.096
Number of Observations = 1,792		$R^2 = 0.71$

Dependent Variable = Natural Logarithm of Transaction Price for RTC NOx Emissions Permit		
Variable	Parameter Estimate	Standard Error
Intercept	-1.407	0.066
Wholesale*AQMD	-0.036	0.076
Wholesale*InOut	-0.018	0.074
Wholesale*Out	0.017	0.192
Year98	0.347	0.043
Year99	0.696	0.043
Year00	1.264	0.045
Year01	1.286	0.046
TransYear95	0.313	0.077
TransYear96	0.010	0.077
TransYear97	-0.093	0.067
TransYear98	0.176	0.064
TransYear99	0.314	0.064
TransYear00	1.031	0.063
TransYear01	1.501	0.065
Wholesale*AQMD*Year00	0.115	0.093
Wholesale*AQMD*Year01	0.126	0.099
Wholesale*InOut*Year00	0.211	0.082
Wholesale*InOut*Year01	0.250	0.089
Wholesale*Out*Year01	0.015	0.258
Utility*Year00	0.130	0.063
Utility*Year01	0.035	0.066
Utility	-0.028	0.040
Number of Observations = 1,792		$R^2 = 0.87$

Owners With Units in SCAQMD Paid More

- Results in Tables 1 and 2 show that
  - InOut wholesale suppliers paid approximately
    - 20%-30% more for vintage 2000 RTCs
    - 25%-30% more for vintage 2001 RTCs
    - Estimates for 2000 and 2001 vintages very precise in both Tables 1 and 2
  - AMQD wholesale suppliers paid approximately
    - 11%-17% more for vintage 2000 RTCs
    - 12%-30% more for vintage 2001 RTC
    - Estimate for vintage 2000 results in Table 1 precise
  - Table 1 controls for vintage fixed-effects
  - Table 2 adds transaction year fixed-effects

Did Owners With Units in SCAQMD Withhold Permits?

- Surplus of permits versus emissions for all compliance cycles in 1998, 1999, and 2000
  - Despite very high RTC prices in 2000, a number of SCAQMD participants held unused permits at end of each compliance cycle
  - Unused permits held by suppliers with generation units in SCAQMD is evidence consistent with them using RTC prices to raise electricity prices
  - Energy traders also had an interest in using permits to raise wholesale electricity prices

Did Owners With Units in SCAQMD Withhold Permits?

- Compute share of unused permits owned by firm k in year t
  - Total unused permits for cycle 1 and cycle 2 facilities for firm k divided by total across all firms (k=1,2,…K)
- Regress this on year, compliance cycle and year*cycle dummies
  - Raise = 1 if firm owns generation unit in SCAQMD or is an energy trader
  - Include Raise interacted with cycle2*yr1999 and yr2000
  - Include firm dummies

Dependent Variable = Share of Market Wide Unused RTC NOx Emissions Permit		
Variable	Parameter Estimate	Standard Error
Cycle2*Year98	-0.004	0.002
Cycle2*Year99	0.001	0.003
Cycle2*Year00	-0.004	0.002
Year99	-0.008	0.002
Year00	-0.002	0.002
[Cycle2*Year99+Year00]*Raise	0.025	0.007

Dependent Variable = Share of Market Wide Unused RTC NOx Emissions Permit		
Variable	Parameter Estimate	Standard Error
Cycle2*Year98	-0.004	0.002
Cycle2*Year99	0.001	0.003
Cycle2*Year00	-0.004	0.002
Year99	-0.008	0.002
Year00	-0.001	0.001
Cycle2*Year99*Raise	0.028	0.009
Year00*Raise	0.022	0.008

Evidence that Owners and Traders SCAQMD Withheld Permits

- Share of unused permits is 0.024 higher for cycle2 of 1999 and both cycles of 2000 for market participants with units in SCAQMD and energy traders
- Separate coefficients for cycle2*yr1999*Raise and yr2000*Raise yield similar results
  - 0.028 and 0.022, respectively
- Evidence consistent with desire to create artificial scarcity of emissions permits for cycle 2 of 1999 and both cycles of 2000

Were Plants Operated in Manner Consistent with NOx Permit Costs?

For period June 1, 1998 to December 1, 2000, compare actual operation to least-cost operation

- OUT_ACT_{hj} = hourly output of unit j in hour h
- OUT_BBW_{hj} = predicted hourly output of unit j in hour h from Borenstein, Bushnell and Wolak (BBW) competitive benchmark pricing
  - Least-cost dispatch of system each hour with generation unit-level marginal cost as sum of fuel cost, variable operating and maintenance cost and NOx emissions permit cost using actual permit prices
- $y_{hj} = OUT\_ACT_{hj} - OUT\_BBW_{hj}$
  - Dependent variable in regression

Were Plants Operated in Manner Consistent with NOx Permit Costs?

- $InGen_{hj}$ = 1 if unit owned by supplier with units in SCAQMD only
- $InOutGen_{hj}$ = 1 if unit owned by supplier with units in and out of SCAQMD and unit is located in SCAQMD
- $OutGen_{hj}$ = 1 if unit owned by supplier with units in and out of SCAQMD and unit is located out of SCAQMD
- $NOxPrice_h$ = NOx emissions price for hour h
- $NOxRate_j$ = NOx emission rate for unit j
- Year and Month indicator variables

Actual Hourly Output Versus Least-Cost Hourly Output Deviation Predictions Given Unit-Owner Characteristics and Location

(Regression includes generation unit-level, monthly, and yearly dummy variables)

Dependent Variable = (Actual Hourly Generation Unit Level Output) - (Expected Hourly Generation Unit Level Output from BBW Competitive Benchmark Pricing)		
Variable	Parameter Estimate	Standard Error
OutGen*Year99	23.656	0.463
OutGen*Year00	47.058	0.446
InGen*Year99	19.215	0.478
InGen*Year00	56.034	0.46
InOutGen*Year99	35.032	0.593
InOutGen*Year00	66.69	0.571
Number of Observations = $2{,}29 \times 10^6$		$R^2 = 0.319$

By Year Actual Hourly Output Versus Least-Cost Hourly Output Deviation Predictions Given Unit-Owner Characteristics, NOx Emissions Rate, and Location

Year 1998–Table 5 Results (N= 472,603, R^2= 0.0244)		
OutGen	-51.067	0.478
InGen	-23.802	0.540
InOutGen	-28.460	0.665
InGen*NOxPrice*NOxRate	3.489	0.327
InOutGen*NOxPrice*NOxRate	5.626	0.601

Year 1999–Table 5 Results (N= 805,919, R^2= 0.0127)		
Variable	Parameter Estimate	Standard Error
OutGen	-27.411	0.332
InGen	-8.183	0.430
InOutGen	7.083	0.527
InGen*NOxPrice*NOxRate	5.533	0.243
InOutGen*NOxPrice*NOxRate	2.716	0.440

Year 2000–Table 5 Results (N= 1.101×10^6, R^2= 0.0267)		
Variable	Parameter Estimate	Standard Error
OutGen	-4.009	0.294
InGen	33.172	0.337
InOutGen	39.819	0.426
InGen*NOxPrice*NOxRate	0.056	0.006
InOutGen*NOxPrice*NOxRate	0.041	0.010

Plants in SCAQMD with Higher NOx Permit Costs Operated More Intensively

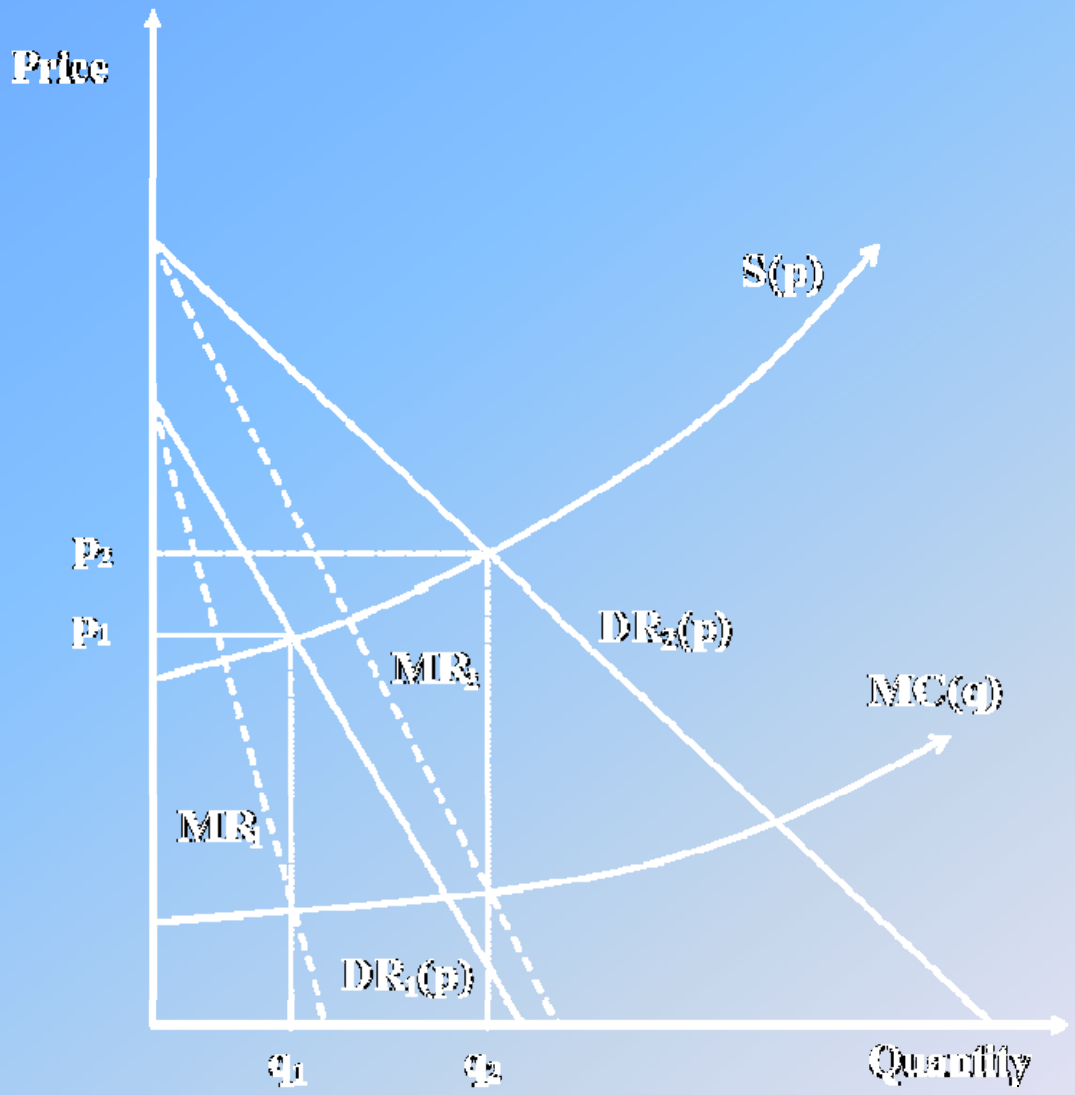
- Table 3 shows $InGen_{hj}$, $InOutGen_{hj}$ and $OutGen_{hj}$ units operated more intensively relative to output of BBW benchmark pricing in 2000
- Table 4 shows that higher InGen*NOxRate*NOxPrice and InOutGen*NOxRate*NOxPrice predicts more intensive operation of unit relative to BBW benchmark pricing level in 2000
- Even though BBW benchmark pricing algorithm accounts for NOxRate*NOxPrice in unit-level marginal cost, these units were operated more intensively
  - Consistent with logic that unit owners did not perceive these NOx costs as true in same sense as fuel costs

Did Suppliers Bid as if NOx Emissions Costs Were Part of Marginal Costs?

Wolak (2003) "Identification and Estimation of Cost Functions Using Observed Bid Data: An Application to Electricity Markets," (on web-site) shows how to recover generation unit-level variable cost function implied by expected that profit-maximizing bidding

- Apply this methodology for price bids into CAISO real-time market by five large fossil fuel suppliers
  - Each owns capacity equal to 10 percent peak demand
- Actual MC_{hk} based on input cost
  - $Gas\_Price_h * Heat\_Rate_k + NOxRate_k * NOxPrice_h$ + Variable Operating and Maintence $Costs_k$
- Implied $MC_{hk} = \beta_0 + \beta_1 Gas\_Price_h * Heat\_Rate_k + \beta_2 NOxRate_k * NOxPrice_h$

Bidding to Maximize Expected Profits



Inferring Marginal Costs from Bidding Behavior

- For five large fossil fuel suppliers in California
  - AES/Williams, Duke, Dynegy, Reliant and Mirant
  - Only three of these suppliers have units in SCAQMD
- For June 1 to September 30 for 1998, 1999 and 2000 estimate IMC_{hk} using Wolak (2003) procedure with price bids
  - Under null hypothesis that suppliers behave as if fuel costs and NOx emission permit costs enter marginal cost
    - Coefficients on both of these variables for all firms should equal to one
    - For units not located in SCAQMD, NO_x emissions permit costs are zero

Implied Marginal Cost for Highest Cost Unit Operating During Hour h Owned Buy Supplier k (Derived from Assumption of Expected Profit-Maximizing Bidding Behavior)		
Variable	Parameter Estimate	Standard Error
Intercept	4.290	0.922
Gas*HR1	0.944	0.062
Gas*HR2	0.871	0.076
Gas*HR3	0.935	0.042
Gas*HR4	1.012	0.049
Gas*HR5	0.893	0.084
NOxPrice*NOxRate1	0.347	0.113
NOxPrice*NOxRate2	0.319	0.115
NOxPrice*NOxRate3	0.292	0.132
Estimation Constraining All Gas*HR and NOxPrice*NOxRate Coefficient To Be Equal		
Intercept	3.106	0.198
Gas	0.972	0.041
NOxPrice*NOxRate	0.344	0.083

Suppliers Do Not Bid as if NOx Costs Have Coefficient of 1 in MC_{hk}

- Table shows that
  - Coefficients on fuel costs are not jointly statistically significantly different from one for all suppliers
  - Coefficients on NOx emissions costs are jointly statistically significantly less than one for all suppliers
- Estimates that assume same coefficients for each variable for all firms finds
  - Coefficient on fuel cost has point estimate of 0.97, and is not statistically significantly different from 1
  - Coefficient on NOx emissions cost has point estimate of 0.34, and is statistically significantly less than 1

Conclusions from Empirical Analysis

- Suppliers with units located in SCAQMD paid substantially more for same permits than other RECLAIM market participants and held larger fraction of unused permits for cycle2 of 1999 and both cycles of 2000
- Suppliers with units located in SCAQMD operated units with high emissions rates more intensively than would be the case under competitive benchmark pricing dispatch treating NOx as actual costs
- Suppliers with units located in SCAQMD did not behave as if NOx emission costs entered marginal costs in same manner as fuel costs
  - Marginal cost implied by expected profit-maximizing bidding behavior was much less sensitive to NOx emissions costs than fuel costs

Conclusions from Empirical Analysis

- Design of emissions market must be consistent with design of energy market or emissions market can be used to enhance market power in electricity market
- Decision of Federal Energy Regulatory Commission (FERC) to allow suppliers to pass-through prices of RTC permits (purchased in bilateral market) in bid prices in CAISO real-time market appears to have allowed suppliers with units located in SQAQMD to raise wholesale electricity prices

Postscript on SCAQMD Market

- Effective February 8, 2001, Rule 118 of Executive Order #01-03 exempted all generating units above 50 MW from SCAQMD market
- In May 2001, SCAQMD rules modified to include this exemption
- Generation unit owners that used more than their annual allocation were penalized $7.50/lb of NOx
- SCAQMD market still operates with these units exempted from trading process
- Events of 2000 and 2001 in RECLAIM market argue in favor of periodic trading of emissions permits through anonymous multi-unit auction mechanism rather than through bilateral negotiation