Market Power and Renewables: The Effects of Ownership Transfers

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Introduction

Ambiguous effects of introducing renewables

In **electricity markets**

Energy portfolios are becoming greener:

- Introduction of Renewable Energy Sources (RES) through incentives or carbon penalization:
  - ⇒ Reduction of emissions
  - ⇒ **Merit-of-order effect** (MoE)

Merit-of-order effect

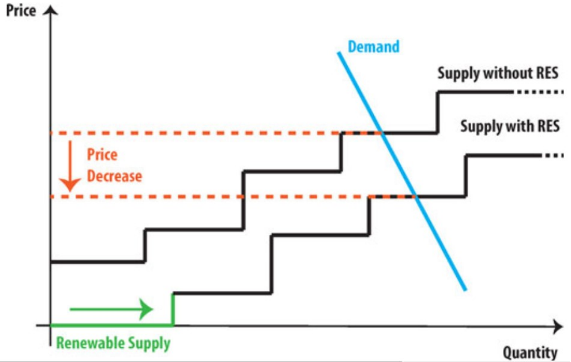


Figure: Source: Acemoglu et al. (2017)

Ambiguous effects of introducing renewables

Energy portfolios are becoming greener:

- Introduction of RES through incentives or carbon penalization
  - $\Rightarrow$ Reduction of emissions
  - $\Rightarrow$ **Merit-of-order effect** (MoE)

BUT **market power** attenuates these effects:

- Firms **internalize** this shift **and withhold** production
  - Theoretical studies on this effect (Acemoglu et al., 2017; Brown and Eckert, 2018; Genc and Reynolds, 2019)
  - What happens in an actual market?

Research question

What are the effects of **expanding or transferring renewables** capacity on electricity prices in the presence of market power?

Goals of the paper

1. To quantify the net effect on wholesale prices of the two opposite effects: market power and the MoE
   - By holding total system's capacity constant
   - By expanding net capacity
2. To bound the impact of (uniform) incentives for the adoption of RES (feed-in-tariffs, renewable portfolio standards) on wholesale prices
   - By allowing market participants to hold *y*% additional RES capacity, wholesale electricity prices would change by up to *x*%
   - This will be completely or partially passed-through to consumers

Our results

Theoretical results:

- RES transfers from small to big players:
  - Non-RES withholding
  - Wholesale price increase (= opposite of MoE)
    (but only under restrictive assumptions) $\Rightarrow$ *need for empirical analysis*

Empirical results:

- We apply our model to data from Ontario
- RES transfers from small to big players while keeping total capacity fixed:
  - Prices increase up to 24% relative to average prices
  - Prices increase more when strategic firm's new portfolio more diversified
- Expanding RES capacity by 5% as suggested by policy guidelines:
  - When biggest player gets RES = virtually no drop in prices
  - When small player gets RES = same drop as if fringe owned new capacity

Setting

Policy environment and past experiences

- We use data from Ontario
  - December 2016: final FiT (feed-in-tariff) application period
  - Ontario govt. attempts to scrap the Green Energy Act (arguing that it caused retail electricity prices to increase)
  - Mkt participants argue for the cancellation of FiT contracts

$\Rightarrow$ Possibility of a reshuffling of assets in which new entrants or large firms will acquire assets under financial distress

+

Federal policies still in effect calling for RES capacity expansions

Policy environment and past experiences

Recent cases of ownership transfers

- Denmark (= 2 zones in NordPool mkt)
  - 2017: Ørsted divested all its coal thermal plants and acquired significant amounts of wind turbine capacity
  - Its portfolio composition went from 17% in RES to 80% in RES
  - Its total market share: 49% in Denmark
- Germany
  - 2019: RWE acquired E.ON's and innogy's RES assets
  - RWE's production market share in 2018: 25% (becoming third largest firm in Europe by RES capacity)

Electricity production in Ontario

Ontario has large capacity (2x domestic demand):

- Nuclear (36%), Natural Gas (28%), Hydro (23%), Wind (11%), Rest (2%)

Most of this capacity is non-strategic:

- Regulated vs. Non-regulated assets
- Approx. 90% of production have prices set before market

More than a hundred producers:

- Big Three: OPG, Bruce, Brookfield
  - Hold $\sim$ 80% of capacity/ produce $\sim$ 92% of demand

  $\Rightarrow$ Cournot players
- Rest of producers modeled as competitive fringe

Regulatory Framework

Ontario market is regulated by **IESO** (Independent Electricity System Operator):

- Operate the market (bidding process)
- Distribute electricity
- Implement policies decided on prov./fed. level
- Ontario's grid is connected to five regions:
  - U.S.A.: New York, Michigan and Minnesota
  - Canada: Quebec and Manitoba

Data

Data

For demand estimation:

- Market equilibrium data (from IESO)
- Meteorological data (from NOAA (National Oceanic and Atmospheric Administration))

For supply model:

- Production costs (from reports)
- Production assets (from IESO and fin. statements)

Overview of the market

Year	Avg. hourly load *in MWh*	Avg. market price *in $/MWh*	Avg. hourly NX *Total in MWh*
2010	17,960	37.83	1,272
2011	17,616	30.13	1,146
2012	17,749	22.82	1,211

Table: Descriptive summary statistics of market equilibrium data in Ontario, from 2010 to 2012

Model

Demand Estimation

We follow the literature and assume Ontario demand is inelastic

- Then add linear net exports supply (elastic)

$\Rightarrow$ Recover elastic **residual demand**

Net exports supply estimated (for each trading region k) as:

$$
\begin{aligned}
Q_{\text{nx},k,t} = \beta_{0,k} + \beta_{1,k} \cdot p_{\text{ON},t} + \beta_{2,k} \cdot \text{CDD}_{\text{k},t} + \beta_{3,k} \cdot \text{HDD}_{\text{k},t} \\
+ \beta_{4,k} \cdot \text{Weekday}_t + \beta_{5,k} \cdot \text{Crisis}_t \\
+ \sum_{\text{years}} \psi_{y,k} \cdot \text{Year}_y + \sum_{\text{seasons}} \gamma_{s,k} \cdot \text{Season}_s \\
+ \sum_{\text{hours}} \omega_{h,k} \cdot \text{ToD}_h + \varepsilon_{k,t}
\end{aligned}
$$

As always with demand-supply estimation: endogeneity!

$\Rightarrow$ Need an instrument for price (p_{ON})

- In this case, a **demand-shifter**

Litterature suggests two sets of instruments:

- Domestic **weather** (Brown and Eckert, 2016)
- Domestic **demand** (Bushnell et al., 2008)

Both methods yield similar results with weather instruments having a slightly higher prediction power

Estimation Results

From NX supply to residual demand

Using estimated parameters, we can write NX supply as:

$$Q_{\text{nx},k}(p_{\text{ON}}) = \hat{\alpha}_k + \hat{\beta}_k p_{\text{ON}}$$

where $\hat{\alpha}_k$ is the aggregation of all variables except price.

And recover "residual" demand $Q(p_{\text{ON}})$ as:

$$Q(p_{\text{ON}}) = \bar{Q}_{\text{ON}} + \sum_{k \in \mathcal{K}} Q_{\text{nx},k}(p_{\text{ON}})$$

Competition models

Literature shows that market prices are bounded by:

$$p^{\text{PC}} \leq p^{\text{Obs.}} \leq p^{\text{C}}$$

Thus, we use two models for the Ontario market:

1. **Perfect competition** model
2. **Cournot** model with two firms and a fringe

We show the effects of ownership transfers in this setting

Set-up

- Capacities are $\bar{K}_j$ for conv. sources, $\bar{K}_R$ for RES
- Quantities are q_j for conv. sources, q_R for RES
  - At all times, $q_R = \bar{K}_R$ (= not a choice var.)
- Inverse demand function is $P(\cdot)$, cost function is $C(\cdot)$

Perfect Competition model

Perfect competition equilibrium given by intersection of $P(Q)$ and $C'(Q)$ plus capacity constraints

$$
\begin{aligned}
q_j \leq \bar{K}_j : \mu_j \quad (j \in \mathcal{J}) \\
0 \leq q_j : \lambda_j \quad (j \in \mathcal{J}),
\end{aligned}
$$

Altogether it gives system of FOC + complementarity conditions:

$$
\begin{aligned}
C'(Q) - P(Q) + \mu_j - \lambda_j = 0 \\
0 \leq \bar{K}_j - q_j \perp \mu_j \geq 0 \\
0 \leq q_j \perp \lambda_j \geq 0.
\end{aligned}
$$

Solved with the PATH solver for GAMS (within Python)

Cournot model with fringe (1)

Firms in the **fringe** are price-takers

We add two **Cournot** players solving:

$$\max_{\{q_{ij}\}_{j\in\mathcal{J}_i}} P\left(\sum_{j\in\mathcal{J}_i} q_{ij} + \sum_{h\in\mathcal{I}} \bar{K}_{hR} + Q_{-i} + Q_f\right)\cdot\left(\sum_{j\in\mathcal{J}_i} q_{ij} + \bar{K}_{iR}\right)$$
$$- C_i\left(\sum_{j\in\mathcal{J}_i} q_{ij} + \bar{K}_{iR}\right)$$

Subject to:

$$\begin{aligned} q_{ij} &\leq \bar{K}_{ij} : \mu_{ij} \quad (j \in \mathcal{J}_i) \\ 0 &\leq q_{ij} : \lambda_{ij} \quad (j \in \mathcal{J}_i), \end{aligned}$$

Cournot model with fringe (2)

For each firm, we recover the system of KKT conditions:

$$C_i'\left(\sum_{j\in\mathcal{J}_i} q_{ij} + \bar{K}_{iR}\right) - P'(Q)\cdot\left(\sum_{j\in\mathcal{J}_i} q_{ij} + \bar{K}_{iR}\right) - P(Q) + \mu_{ij} - \lambda_{ij} = 0$$

$$0 \leq \bar{K}_{ij} - q_{ij} \perp \mu_{ij} \geq 0$$

$$0 \leq q_{ij} \perp \lambda_{ij} \geq 0.$$

In addition to the KKT conditions from the fringe.

Ownership transfers

Simplify the previous models:

- Only 2 energy sources: non-RES (*NR*) and RES (*R*)
- Total RES in the market is $\bar{K}_R$
  - Each strategic firm holds γ/n of $\bar{K}_R$;
  - Fringe holds $(1-\gamma)\bar{K}_R$

Proposition

With the setting described previously and

(i) a demand function $P(\cdot)$ such that $P' < 0$ and $P'' \leq 0$

(ii) a cost function that it is additively separable in non-renewable ($C_{\text{NR}}(\cdot)$) and renewable inputs ($C_{\text{R}}(\cdot)$)

(iii) $C'_{\text{NR}} > 0$ and $C''_{\text{NR}} > 0$

then:

$$\frac{\partial q_{i,\text{NR}}}{\partial \gamma} < 0, \quad \frac{\partial q_{f,\text{NR}}}{\partial \gamma} > 0, \text{ and } \frac{\partial P}{\partial \gamma} > 0$$

As the share of total RES owned by strategic players increases:

- Strategic players use less NR energy
- Fringe uses more NR energy

$\Rightarrow$ In total, price increases = opposite of MoE!

- Acemoglu et al. (2017) call this diversification effect
- Difficult to disentangle from market power

BUT lot of assumptions (on demand, costs, symmetry, etc.) $\Rightarrow$ need for empirical analysis!

Empirical results

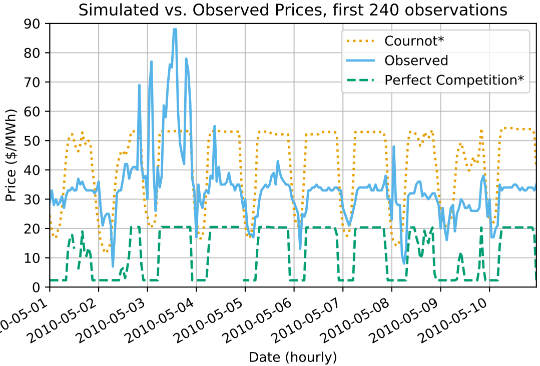
Solving the model

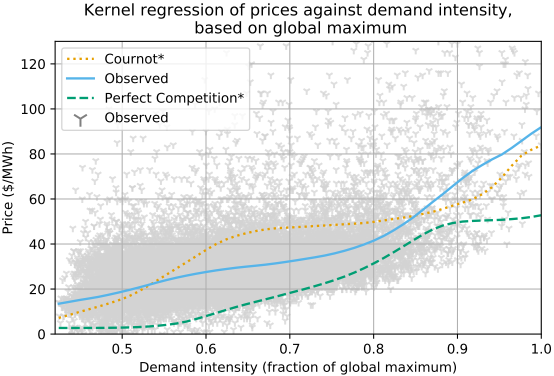
We solve for equilibrium prices in Perfect Competition and Cournot using:

a) Estimated residual demand
b) Competition model

Goal: get upper and lower bounds for market prices

Baseline results




Kernel regression of prices against demand intensity,
based on global maximum
Cournot*
Observed
Perfect Competition*
Observed
Price ($/MWh)
0
20
40
60
80
100
120
0.5
0.6
0.7
0.8
0.9
1.0
Demand intensity (fraction of global maximum)

Baseline results

	Mean price			Median price		
Year	PC*	Mkt	Cou*	PC*	Mkt	Cou*
2010	17.44	37.83	45.70	19.88	35.00	50.96
2011	12.76	30.14	38.06	8.71	32.00	45.09
2012	11.07	22.82	31.47	2.89	22.00	36.64

Table: Simulation statistics, by year

$\Rightarrow$ model can bound actual prices to some degree of accuracy

- Can use to bound the true outcomes for counterfactuals

Even more goodness-of-fit results

Counterfactual experiments

Market power vs MoE

1. Quantify market power effects on wholesale prices
   - by holding total capacity constant
   - by transferring RES from the fringe to the players
2. Compare previous effect to MoE:
   - by introducing RES to the market
   - by allowing different firms to own the new capacity

Simulating changes ownership changes

For each time observation we draw a random proportion of RES that gets transferred from fringe to Cournot players

- Empirical analysis of the previous theoretical results
- Potential outcome if RES payments cease to exist

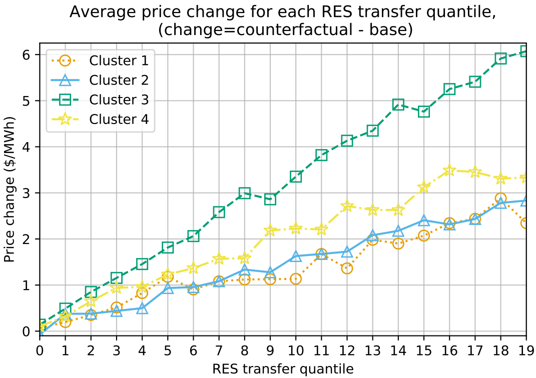
ex. $\bar{K}_{f,R} = 1000$, if we draw $prob = 0.5$:

- New $\bar{K}_{f,R} = 500$
- Each $\bar{K}_{i,R}$ gets 250 more

$\Rightarrow$ Solve for new equilibrium

This empirical analysis is more flexible than theory:

- Firms are asymmetric
- Cover many combinations of market conditions
- Fluctuations in RES availability are taken into account

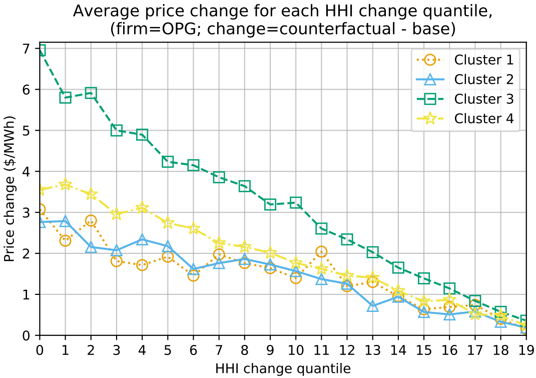


Demand clusters

Maximum price change: 6 / avg. price = 20%

	Market	Fringe	OPG	Brookfield
HHI	0.2661	0.3655	0.3529	0.9033
Total Capacity (MW)	28,432	19,414	9,462	758

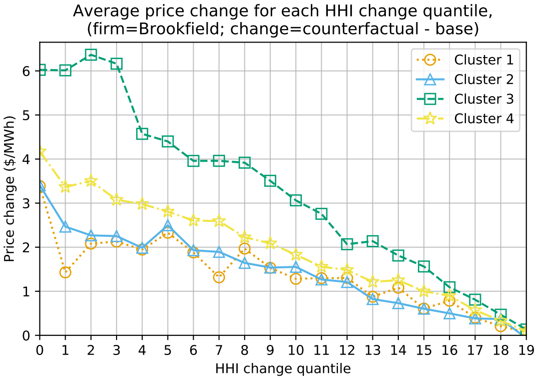
Table: Average portfolio concentrations in Ontario



Maximum price change: 7 / avg. price = 24%

Ownership changes

Results, by firm: Brookfield



Maximum price change: 6.8 / avg. price = 23%

Following forecast from IESO for 2022:

- Additional 5,000 MW of RES capacity (wind)
- Annual demand growth rate of 1%
- Capacity factor of 30% (effective capacity of 1,500 MW)

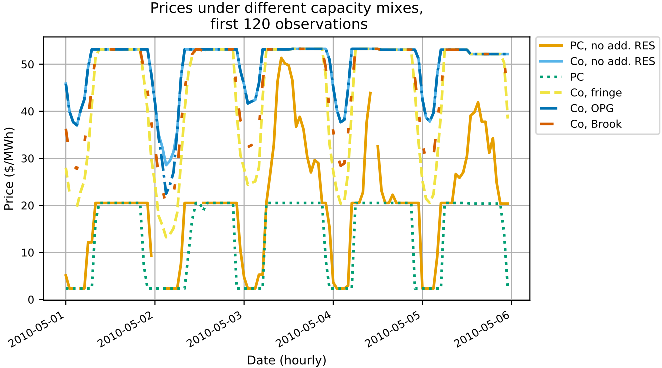
$\Rightarrow$ perfect setting for looking at market power and MoE

- Diversification and market power depends on who gets the RES
- MoE from increasing total RES capacity

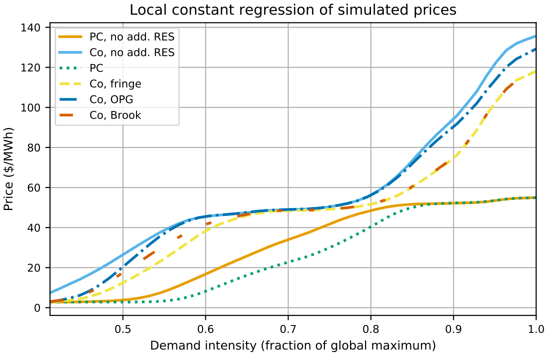
	Market	Fringe	OPG	Brookfield
HHI before adding RES	0.2661	0.3655	0.3529	0.9033
HHI after adding RES	0.2471	0.3294	0.2817	0.5431
Total Capacity Before (MW)	28,432	19,414	9,462	758

Table: Average portfolio concentrations in Ontario

Equilibrium prices at the hourly level



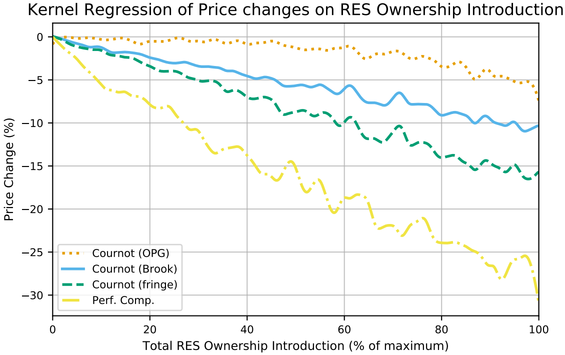
Counterfactual prices for each ownership type and by demand intensity



Max. savings = Cournot OPG − Cournot fringe

Bounds on price savings

What are the % price savings for each % increase in RES and for each type of ownership?



Conclusion

Conclusion

Market power effect

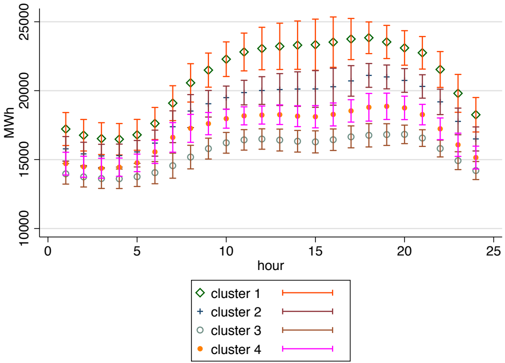
- Transferring RES from fringe to strategic players leads to price increases
  - Shown theoretically (under conditions) and empirically
- The more RES is transferred the more prices increase
  - Conjunction of increased diversification and market power

And it can **mitigate** the merit-of-order effect

- Expanding RES through strategic firms reduces the MoE:
  - Giving capacity to the biggest player might not even change prices
- This suggests discretion on who gets RES incentives as consumers could end up paying fraction of price increases

Appendix

Demand clusters



Back

NX supply estimation results

Weather instruments

		First stage		Second stage			
	N	F-stat.	Adj. R^2	Wald-χ^2	R^2	ρ_{ON}	SE
MB	23,015	210 ***	0.216	5,700 ***	0.162	0.382 ***	0.088
MI	23,015	221 ***	0.222	12,906 ***	0.340	6.683 ***	0.889
MN	23,015	211 ***	0.219	3,069 ***	0.123	0.116 *	0.060
NY	23,015	215 ***	0.216	4,895 ***	-	-18.537 ***	0.832
QC1	23,015	269 ***	0.219	12,956 ***	0.100	-25.001 ***	0.730
QC2	23,015	-	-	11,613 ***	0.298	-3.864 ***	0.214
QC3	23,015	-	-	3,355 ***	0.024	-0.429 ***	0.027
QC4	23,015	-	-	3,856 ***	0.119	-0.455 ***	0.039
QC5	23,015	-	-	8,628 ***	0.234	-0.553 ***	0.042
QC6	23,015	205 ***	0.221	2707 ***	-	-0.219 ***	0.014
QC7	23,015	-	-	2,619 ***	0.104	-0.015 ***	0.009
QC8	23,015	-	-	11,342 ***	0.320	-0.108 ***	0.013

Implied inverse demand slope: $\beta = -0.0238$

Table: Net exports supply function estimation, using weather-type instruments

Back

NX supply estimation results

Market demand instruments

Implied inverse demand slope: $\beta = -0.0307$							
		First stage		Second stage			
	N	*F*-stat.	Adj. R^2	Wald-χ^2	R^2	p_{ON}	SE
MB	23,015	323 ***	0.289	5,449 ***	0.087	1.035 ***	0.063
MI	23,015	348 ***	0.288	8,099 ***	-	24.260 ***	0.717
MN	23,015	329 ***	0.290	2,821 ***	-	0.964 ***	0.044
NY	23,015	341 ***	0.287	5,625 ***	-	-18.867 ***	0.522
QC1	23,015	587 ***	0.289	12,705 ***	-	-29.006 ***	0.545
QC2	23,015	-	-	8,962 ***	-	-8.934 ***	0.189
QC3	23,015	-	-	3,521 ***	0.134	-0.086 ***	0.018
QC4	23,015	-	-	4101 ***	-	-0.882 ***	0.029
QC5	23,015	-	-	8,517 ***	0.176	-0.757 ***	0.029
QC6	23,015	402 ***	0.295	2,904 ***	0.104	-0.056 ***	0.009
QC7	23,015	-	-	2,781 ***	0.027	-0.121 ***	0.006
QC8	23,015	-	-	11,377 ***	0.313	-0.122 ***	0.008

Table: Net Exports supply function estimation, using market demand instruments.

Back

A good check is to see if:

$$p^{PC} \leq p^{Obs.} \leq p^{C}$$

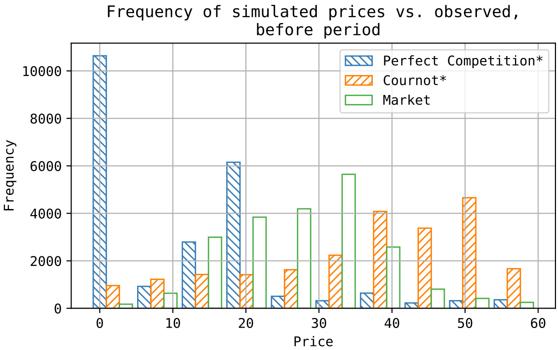
year	#obs. within bounds	#obs. in year	%
2010	4,117	5,880	70%
2011	5,612	8,471	66%
2012	5,658	8,688	65%

Table: Frequencies of observed prices within simulated prices

Back

Goodness-of-fit results

Simulation results distribution



Back

	Mean	Median	SD	Min	Max	Decile 1	Decile 10
Before period							
PC*	13.28	10.95	12.47	0.00	60.98	2.56	25.30
Mkt	29.34	29.00	20.87	-139.00	558.00	15.00	42.00
Cou*	37.51	40.12	15.75	0.00	106.75	12.63	54.32

Table: Predicted and actual prices distributions

Back