Cleaner but Volatile Energy? The Effect of Coal Plant Retirement on Market Competition in the Wholesale Electricity Market

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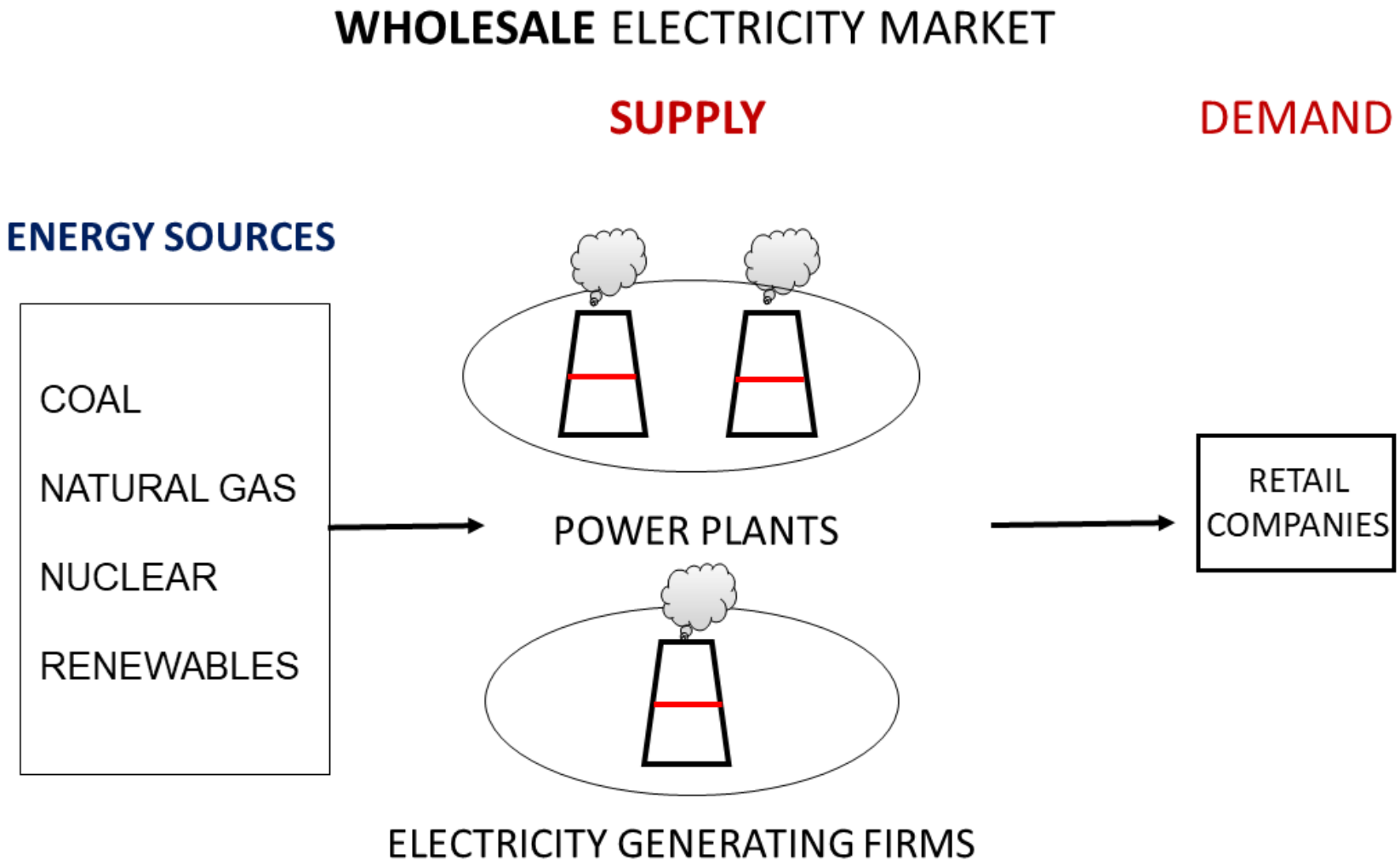
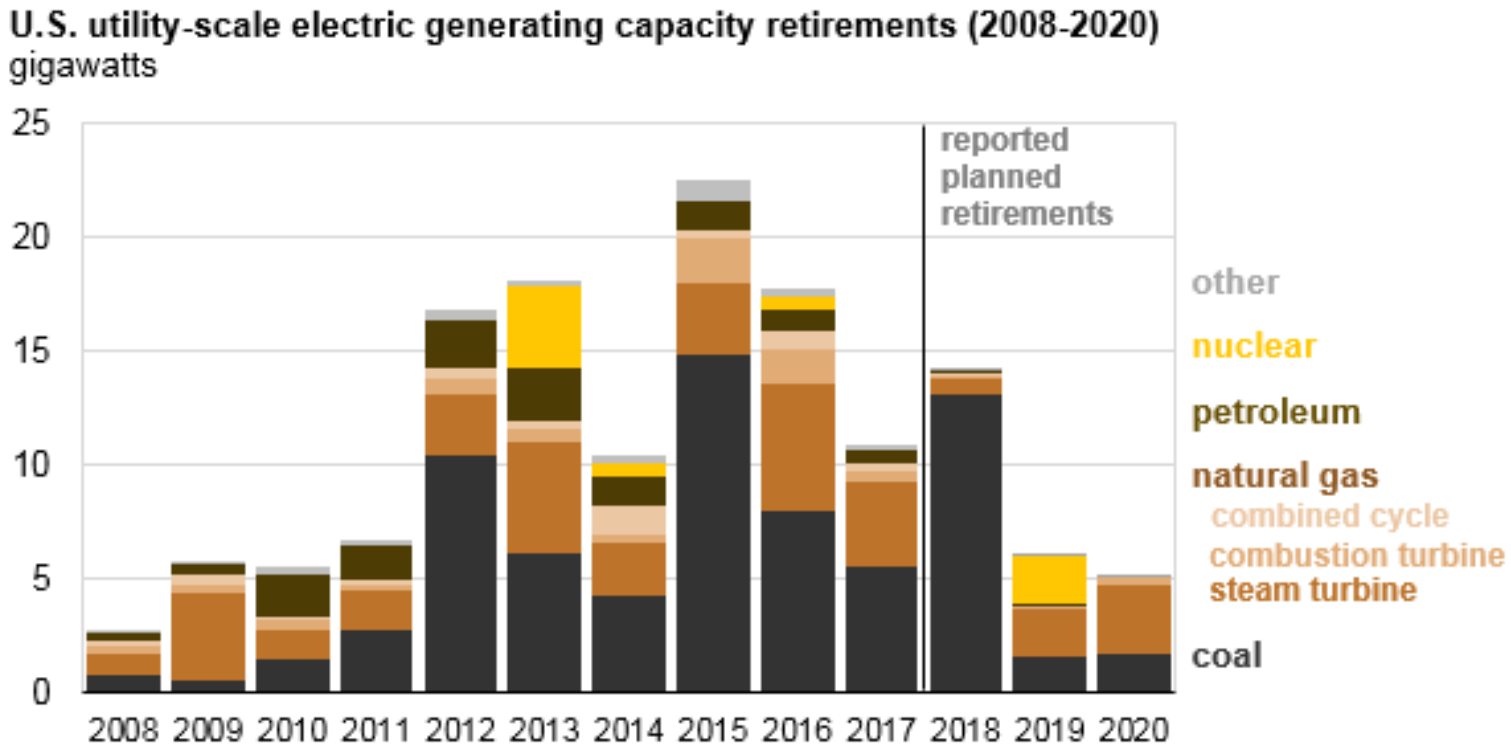
July 17, 2020

Wholesale Electricity Market



Coal power plants are retiring from the grid in the U.S.

- Almost 15% of coal generation (47 GW) retired between 2011-2016
- In 2018, 13 GW of coal generation retired



Coal power plants are retiring from the grid in the U.S.

- Almost 15% of coal generation (47 GW) retired between 2011-2016
- In 2018, 13 GW of coal generation retired

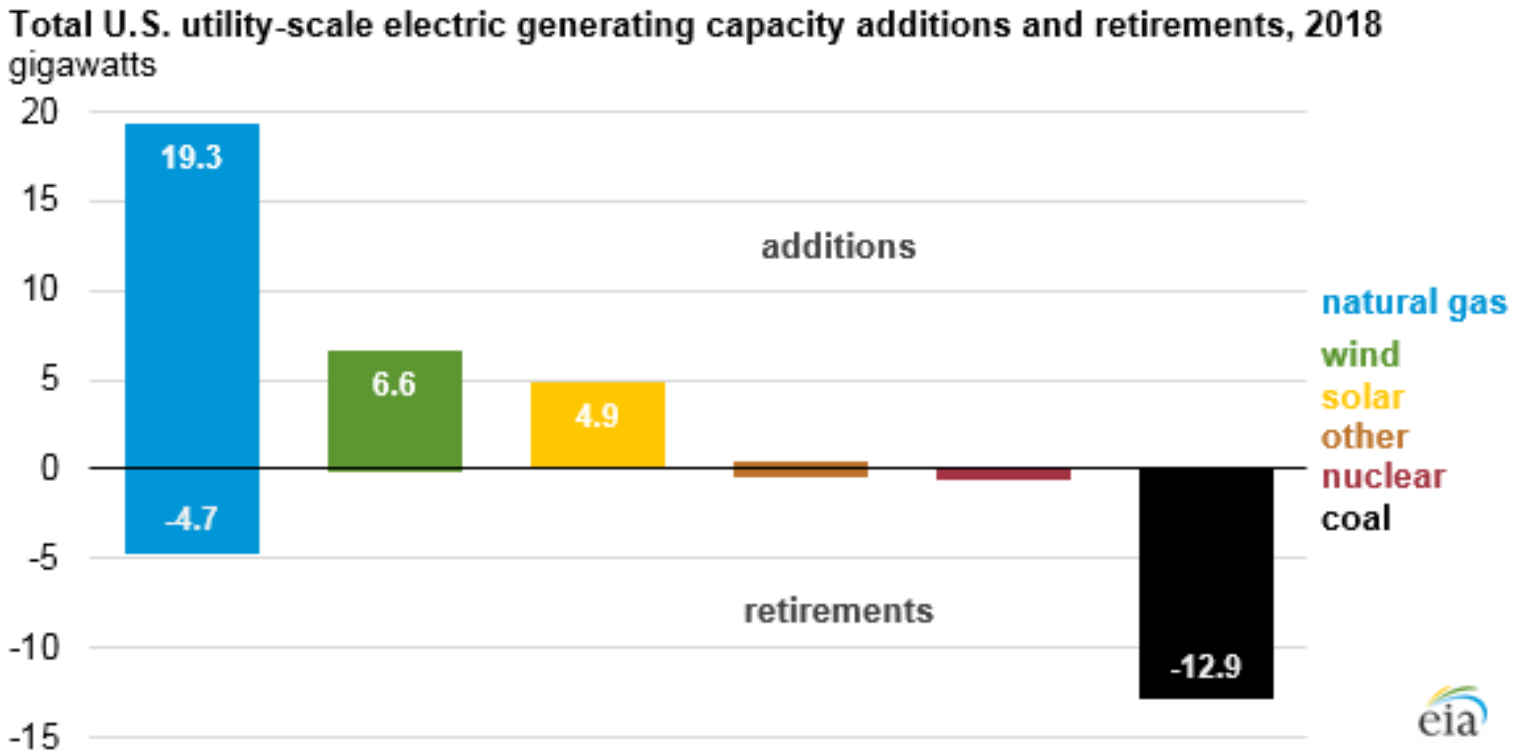
What drives the retirement of the coal power plants?

1. Environmental Regulations:
   - High compliance cost to coal plants (e.g., EPA MATS)

2. **Economic Pressure**: competing with the cheap Natural Gas (and renewable) generation

   - Low NG price (due to the shale gas boom)
     $\rightarrow$ MC of natural gas generation $\approx$ MC of coal generation

Retired coal generation will be replaced primarily by the Natural Gas generation



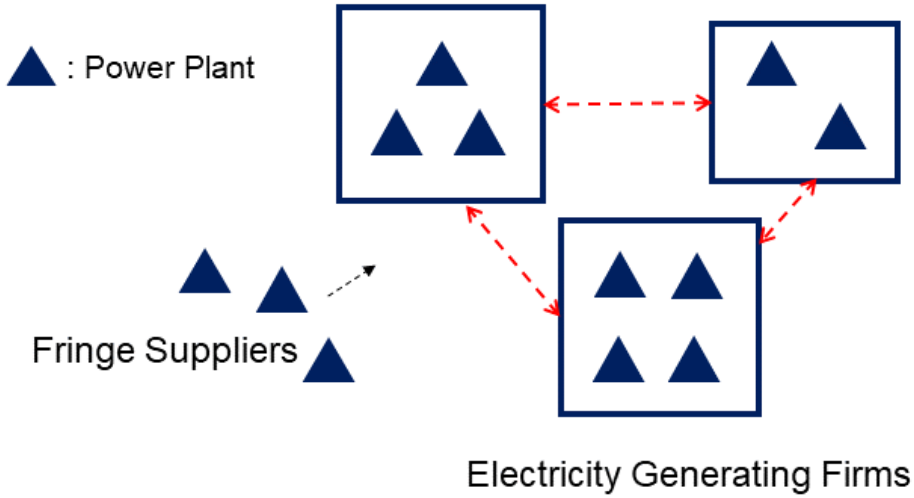
Capacity Additions by Region

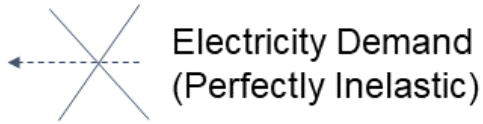
Research Question

- Generation mix is changing: dirty coal power plants are retiring and cleaner NG power plants replacing them
- This paper focuses on the **competition** side of the industry transition
- **Q**: How strategic competition between electricity generating firms affected by the industry's transition?
- This question particularly interesting when focusing on:
  1. A specific feature of the clean NG energy; volatile input costs
  2. The transition reshapes the industry structure

Literature Review

Competition in the Wholesale Electricity Market





- Several large-scale electricity generating firms: close to oligopoly (homogeneous quantity)
  - Firms make strategic decisions based on their residual demand
- Demand (from retail companies) is perfectly price inelastic
  - long-term retail price contract b/w the retail company and the customers
- Firm's strategic decision affected more by the supply responses (elasticity) of competing firms

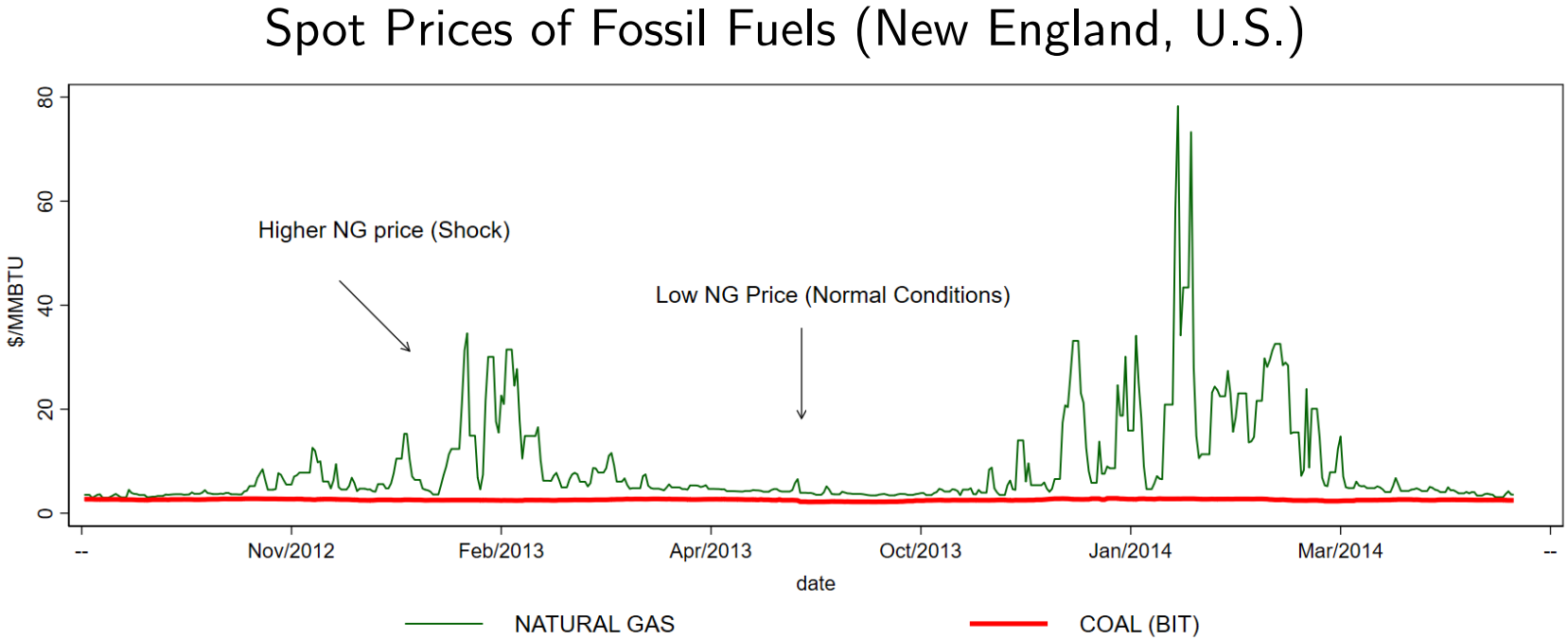
1. Coal plant retirement, volatile input costs, and competition

- Energy transition: replaces a coal power plant with a NG power plant

- Under normal conditions: **Low NG price** $\approx$ Coal price
  MC of coal $\equiv$ MC of NG $\Rightarrow$ replacement has minimal effect

- However, NG price is *volatile*: Low NG price $\leftrightarrow$ High NG price
  - Coal price stays low and stable
  - NG price could increase: exogenous shocks caused by pipeline congestion

Fuel price volatility difference: NG vs. Coal



- Low NG price (normal condition): NG price stays at \$4/MMBtu

  MC of NG generation $\approx$ MC of Coal generation

- Higher NG price (shock): NG prices $>$ \$4/MMBtu

  MC of NG generation $>>$ MC of Coal generation

Industry MC curve

1. Coal plant retirement, volatile input costs, and competition

- Energy transition: replaces a coal power plant with a NG power plant

- Under normal conditions: **Low NG price** $\approx$ Coal price
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- However, NG price is *volatile*: Low NG price $\leftrightarrow$ High NG price
  - Coal price stays low and stable
  - NG price could increase: exogenous shocks caused by pipeline congestion

- **Higher NG price**: competitive environment will be affected by the transition
  : MC of coal $<$ MC of NG $\Rightarrow$ replacement affects the distribution of MC of strategic firms
  $\rightarrow$ change in supply responses of firms $\rightarrow$ strategic competition

Q1. How will the competition/market power change due to the transition especially when the NG price rises above the normal level (cost shock)?

2. Industry structure: Installation of new NG power plants

- New NG power plants are installed to replace the retired coal power plants
- Which firms are installing them? Size of the plant?
  $\Rightarrow$ determines the industry structure (scale and the number of firms)
- Industry structure could be quite different from now once the clean energy transition is completed: more/less concentrated?
- **Q2.** Examine the effect on competition under different industry structures that are likely after the transition
  - Consider different scenarios of installation of NG generation capacity
  - Under which case the market becomes most competitive?

Description

Data: New England Wholesale Electricity Market

— Wholesale electricity market covering 6 states in the U.S. Northeast region

1. Large (baseload) coal power plants retiring (about 4,000 MW)

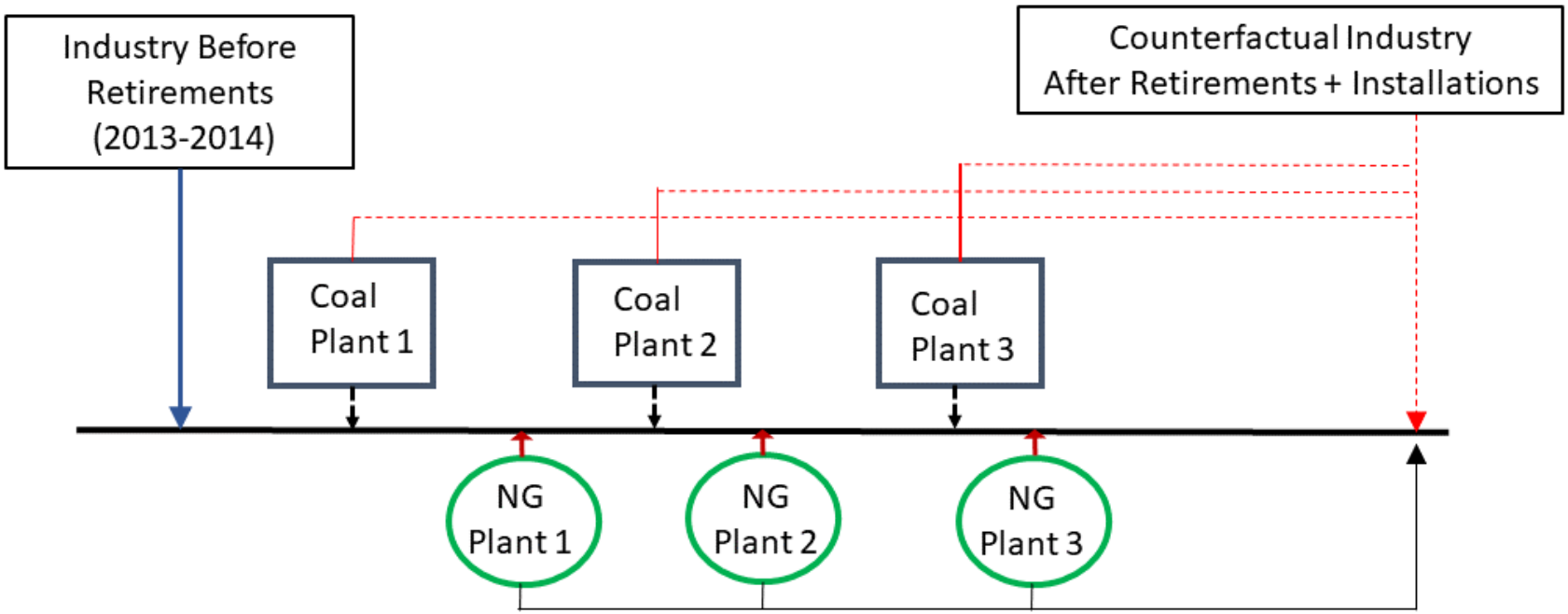
Plant Name	Capacity (MW)	Fuel type	Date of retirement
Salem Harbor Station	749	coal	June 2014
Mount Tom Station	143	coal	Oct. 2014
Vermont Yankee	604	nuclear	Dec. 2014
Brayton Point Station	1,535	coal	May 2017
Pilgrim Nuclear Station	677	nuclear	2019

2. NG Price shocks (volatility) most severe and frequent
   - Period: The winter of 2013-14 $\Rightarrow$ 30% of days affected by NG price shock NGprice table

- Main Data: Bidding data from the day-ahead market
  - Auction (multi-unit uniform price) used for clearing the market
  - Market clears every hour(h) of the day (t)
  - Quantity, capacity info. + **estimate parameters**

Empirical Strategy: Counterfactual Analysis

- Counterfactual analysis based on the (static) model of quantity competition
- Construct the industry that is likely in the near future, after:
  - All the planned retirements of coal power plants are completed
  - The hypothetical gas power plants replacing them are installed



- Keep all other market variables (demand, MC, fuel price) the same as before retirements

Why counterfactual

(1) Retirement and Replacement of Power Plants

Retirements

- Remove actual (baseload) coal power plants that announced plans to retire as of 2014 from firm's generation set

  $\Rightarrow$ 5 power plants, operated by 4 firms

Replacement: installation of new NG generation

- **Baseline case**: firm that operates the retired power plant (Retired firm) installs hypothetical gas power plant of the same capacity
  - Industry structure does not change, only the generation mix changes
  - (cf) MC of a hypothetical NG power plant = efficiency of the most up-to-date generator $\times$ NG price index data

Different sizes

Three additional cases of new NG generation capacity installation

0. Baseline case: Retired firms add the same-size capacity
   $\Rightarrow$ Industry structure remains unchanged

Changing the Industry Structure:

1. Capacity CF (1): Entry of fringe suppliers

2. Capacity CF (2): **Retired firms** install NG power plant 50 % larger than the retired coal plant capacity

3. Capacity CF (3): **Other incumbent firms** install NG power plants: expand their existing gas generation capacity

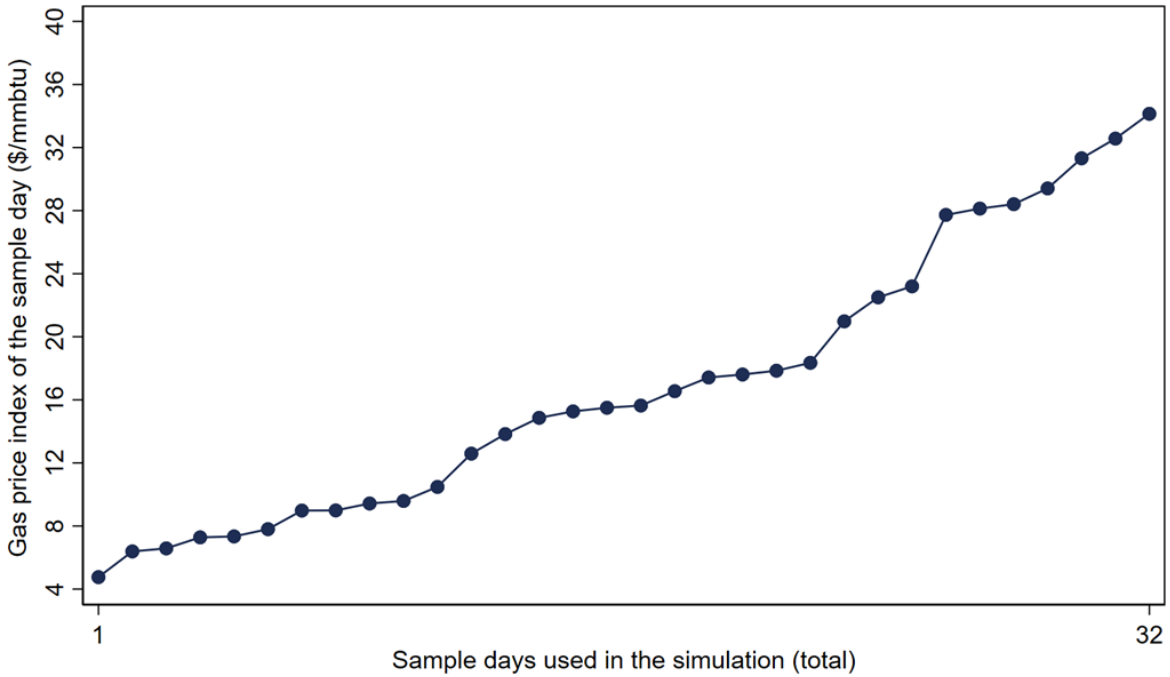
$\Rightarrow$ CF (2) and (3): based on the actual capacity installation pattern (EIA-860 data)

Description EIA-860 example

(2): Accounting for the increase in NG prices

- Pre-retirement sample: select days from 2013-2014 when NG prices were volatile
- Compute counterfactual equilibrium for each market (t, h), using the MC parameters from the pre-retirement sample

- Comparing results *across days* $\rightarrow$ shows how the impact of retirement varies with the increase in NG prices



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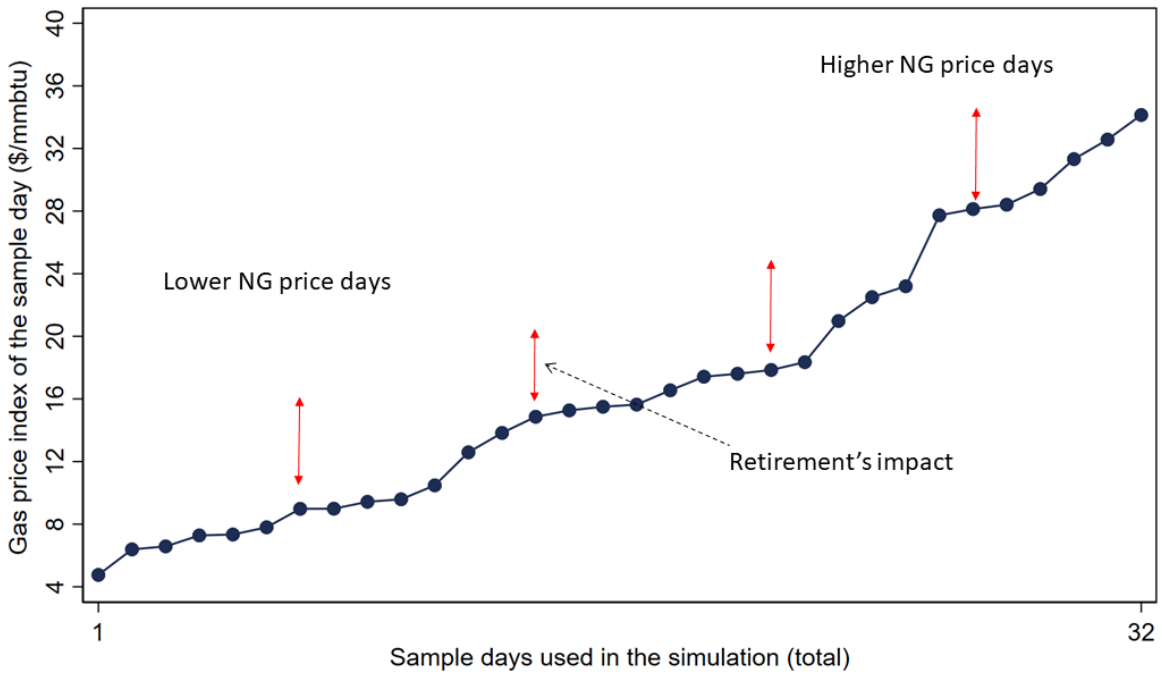
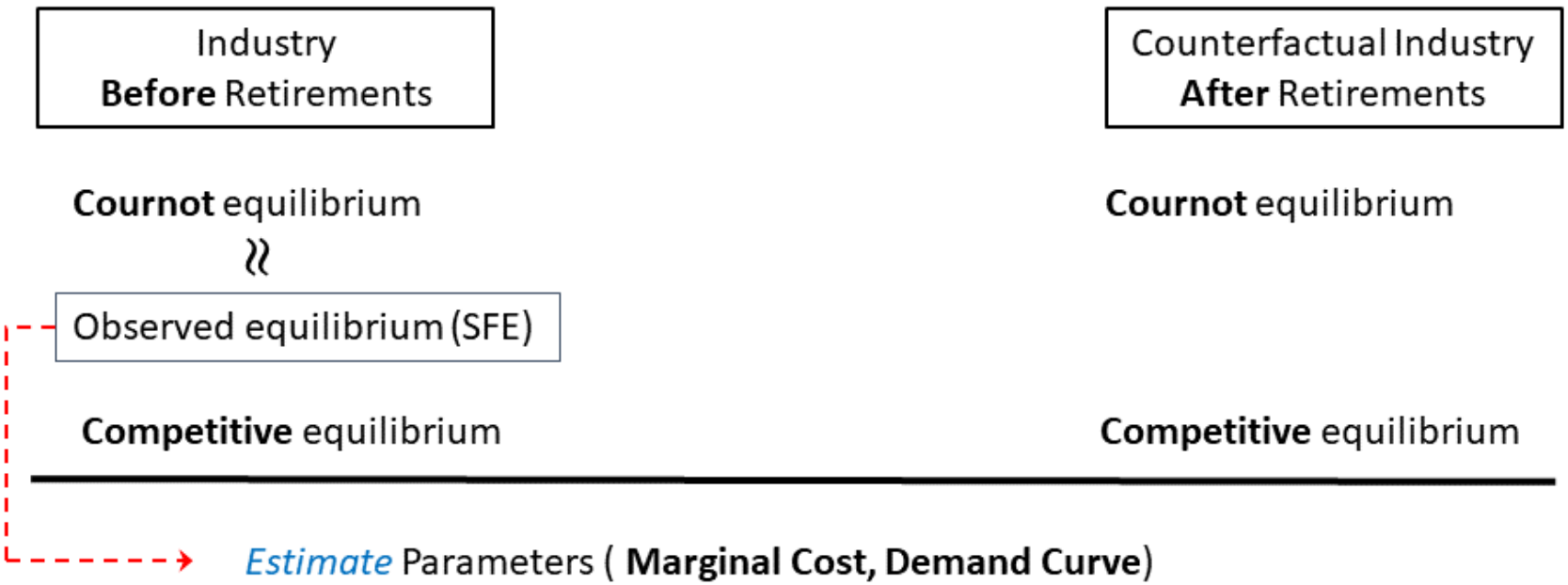


(3): Models used for solving the counterfactual equilibrium

- Numerically solve counterfactual equilibrium under two different models
  1. Cournot model: strategic interaction
  2. Competitive model: no strategic interaction



- Market power: how much the strategic price departs from the "competitive benchmark"
  - counterfactual competitive equilibrium computed as well

Model | SFE counterfactual

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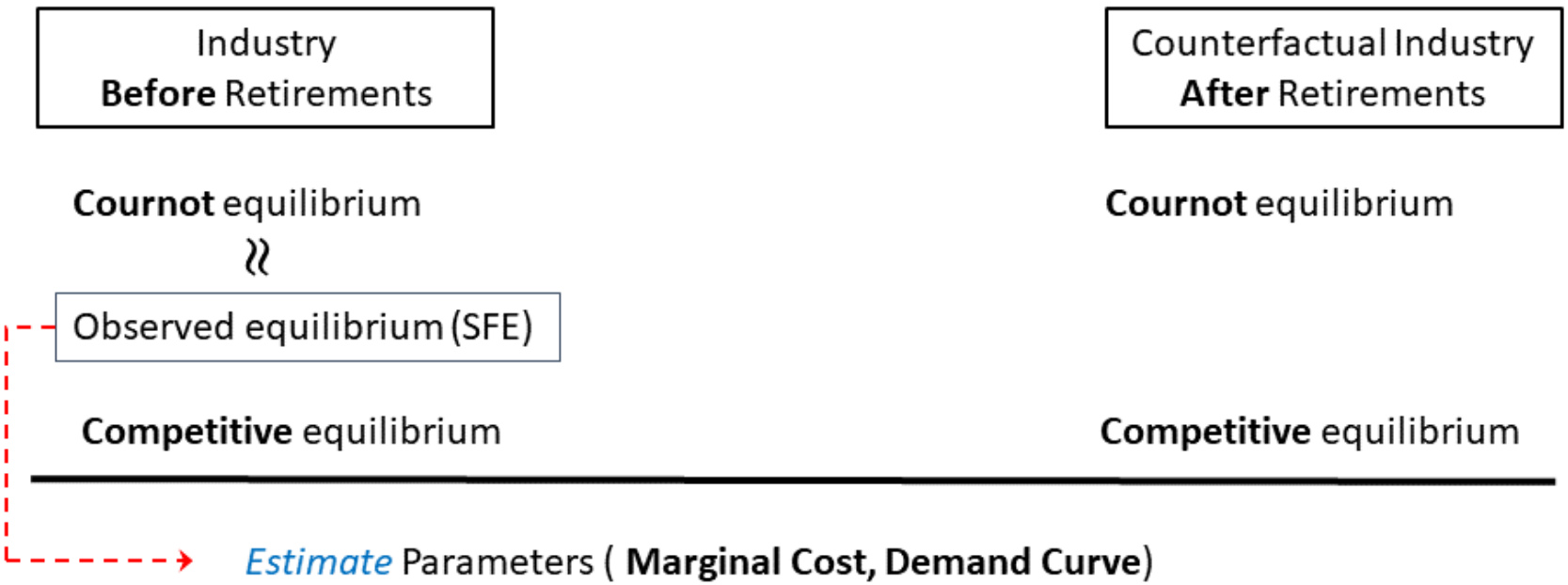
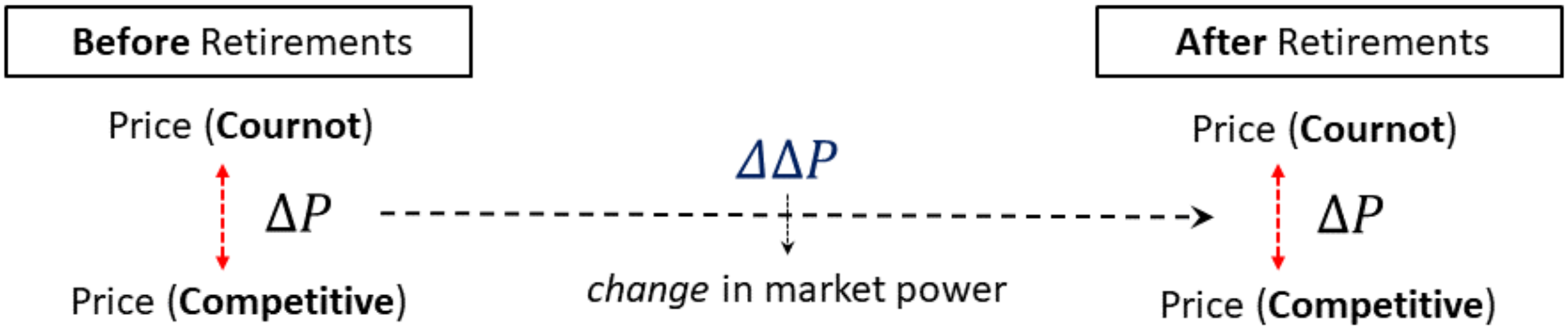


- Estimating Parameters: based on the auction model using bidding data
  - Marginal cost: generator level (Wolak, 2003; Reguant, 2014)
  - Residual demand curve: market level (Ito and Reguant, 2016)

Model SFE counterfactual

Measuring the change in unilateral market power, $\Delta\Delta P$



- For each market (t,h), measure how much the strategic Cournot price departs from the competitive price, $\Delta P = P_{\text{strategic},T} - P_{com,T}$

- $\Delta\Delta P$: measure of the *change* in market power due to retirement

$$\Delta\Delta P = \Delta P_{after} - \Delta P_{before}$$

Results (baseline case): summarized by NG price and demand levels

- We first show results of the **baseline case** (no change in the industry structure)

  $\Rightarrow$ change in market power, $\Delta\Delta P$, for each market (t, h)

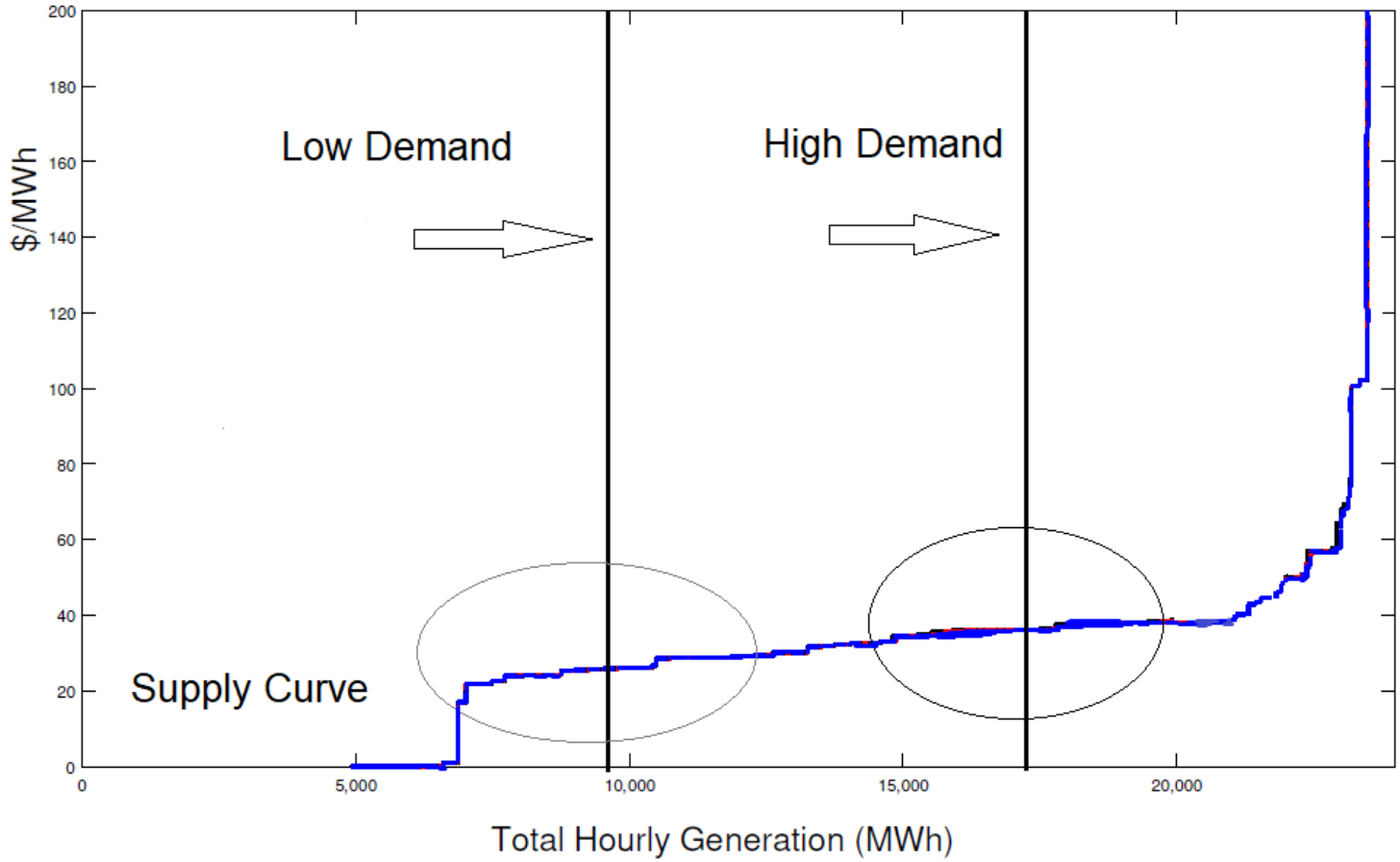
- Summarize results by NG price (G1- G3) and demand (D1-D4) that vary across markets (N = 330)

- In electricity market studies: report results by demand

  - Demand is an important determinant of strategic environment
  - Low-demand (off peak): coal plants are marginal / low market power
  - High-demand (peak): higher-cost plants are marginal / market power higher than in low demand

How we choose D and G bins

Results (baseline case): summarized by NG price and demand levels



- Set of strategic firms/non-strategic firms change with demand

Results (Baseline case): change in market power, $\Delta\Delta P$

1. Total: market power increases, on average, to raise the strategic price by \$9/MWh more relative to the competitive price

	$\Delta\Delta P = \Delta P_{af} - \Delta P_{bf}$				
		Low Demand	$\Rightarrow$	High Demand	
	Total	(D1)	(D2)	(D3)	(D4)
$\Delta\Delta P$	9.1	10.3	11.2	9.3	5.3
Further Controlling for the Daily Gas Prices					
(G1) Low Gas Price					
$\Delta\Delta P$	5.5	6.9	7.1	2.7	4.9
(G2) Med Gas Price					
$\Delta\Delta P$	9.6	9.5	6.8	14.4	5.8
(G3) High Gas Price					
$\Delta\Delta P$	16.4	18.1	18.9	25.7	5.7

Market power increases more in the low-demand sample

2. Market power increases more in low-demand than in high-demand

		$\Delta\Delta P = \Delta P_{af} - \Delta P_{bf}$			
		Low Demand		$\Rightarrow$	High Demand
	Total	(D1)	(D2)	(D3)	(D4)
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Market power increases more on higher NG price days

3. Market power increases more on days with higher natural gas prices

	$\Delta\Delta P = \Delta P_{af} - \Delta P_{bf}$				
		Low Demand	$\Rightarrow$	High Demand	
	Total	(D1)	(D2)	(D3)	(D4)
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(G3) High Gas Price					
$\Delta\Delta P$	16.4	18.1	18.9	25.7	5.7

After the transition, wholesale electricity price increase more than before – due to market power – and this effect stronger with higher NG prices

Market power increase: interaction between strategic firms

- Which type of firm more actively exercises market power?
  - Examine the *quantity withholding* behavior at the firm level
  - Find firms that withholds quantity more after retirements occur
  - Summarize by firm type (grouped by generation mix)

- **Gas-intensive firms** (more than 90% of generation is NG-fired, and do not operate retired plants) are the major withholders: 60% of cases

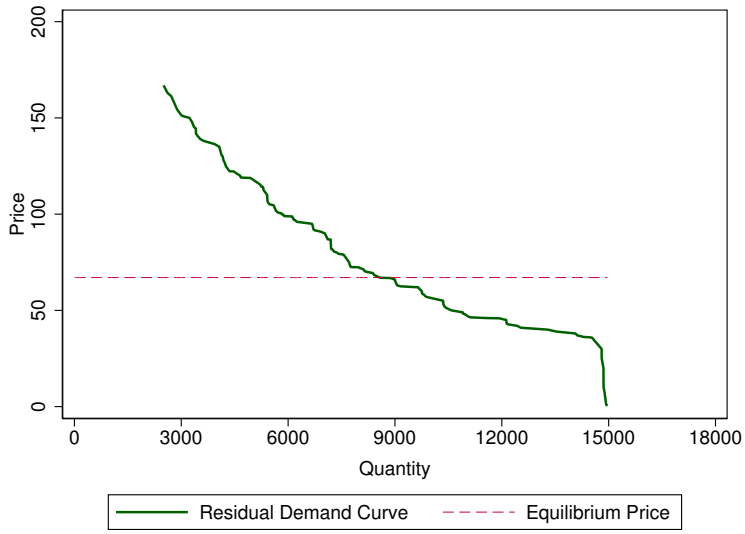
- They face lesser competitive pressure from both strategic and non-strategic competitors
  - They become relatively *low-cost* strategic firms after the coal plants retire: especially in low demand and high NG price
  - Non-strategic (fringe) supply is price inelastic

Firm type summary

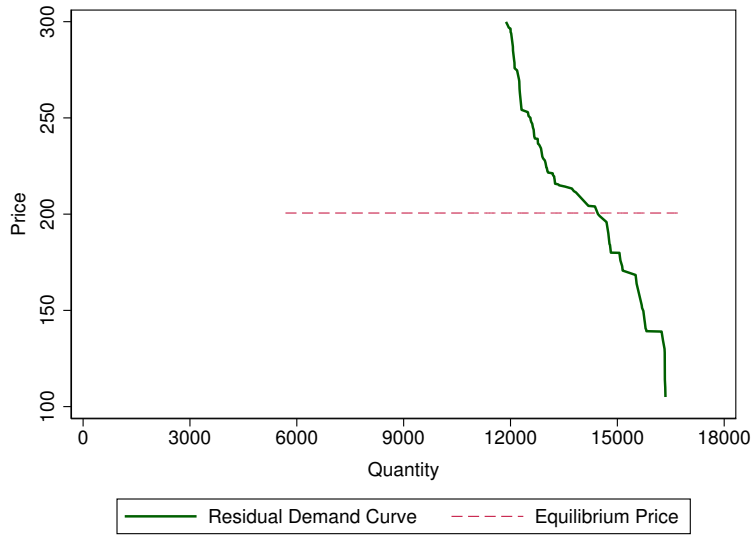
Non-strategic supply (residual demand curve) elasticity

- Non-strategic (fringe) supply, if elastic, also constrains a strategic firm's ability to exercise market power

- However, non-strategic supply (residual demand of strategic firms) is relatively more *inelastic* (smaller $\hat{\beta}_{th}$) when NG prices are higher



(a) Low NG price day

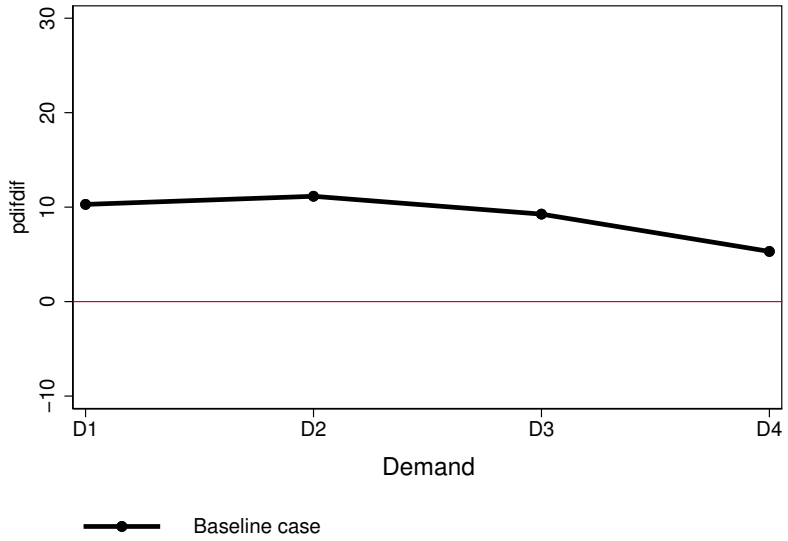


(b) High NG price day

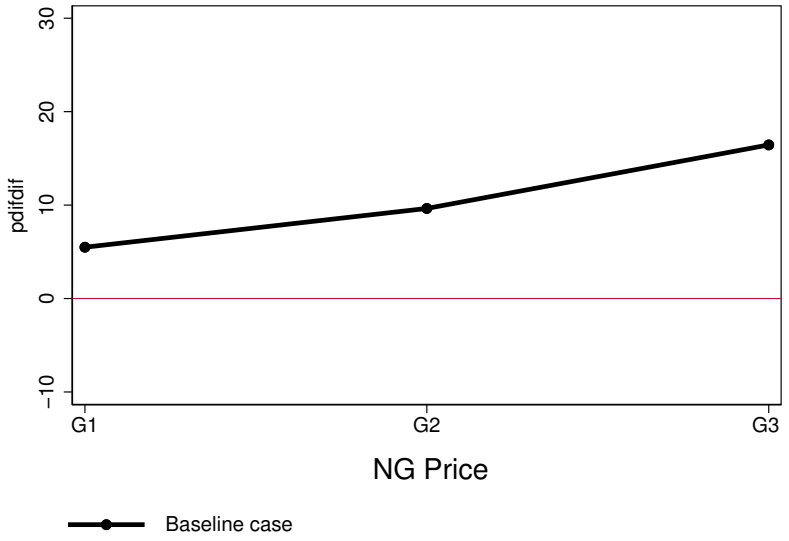
Sum of beta estimates RD dispersion

Results: $\Delta\Delta P$ – Changing industry structures

- Extend the baseline case to allow for changes in industry structures
- Plot $\Delta\Delta P$ (change in market power) of all four cases together



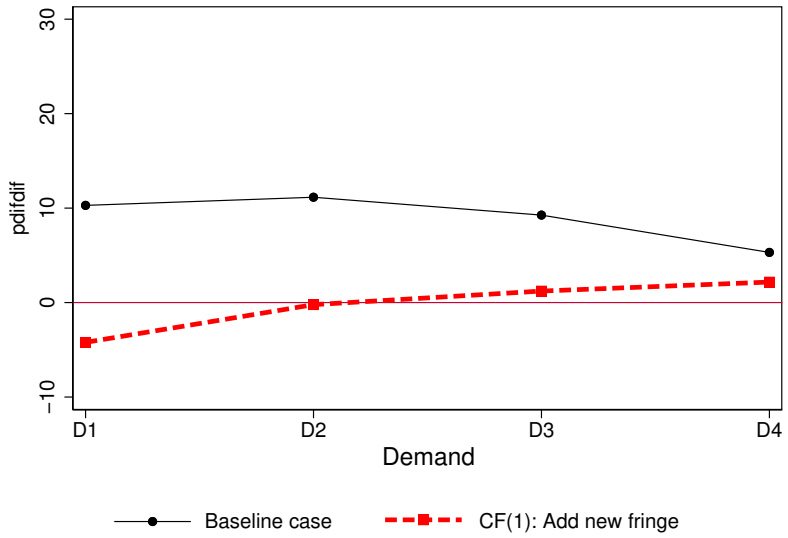
(a) By Demand



(b) By NG Price

Figure 2: Summary of $\Delta\Delta P$: Baseline case

$\Delta\Delta P$: CF(1) – Small fringe suppliers enter with NG generation capacity



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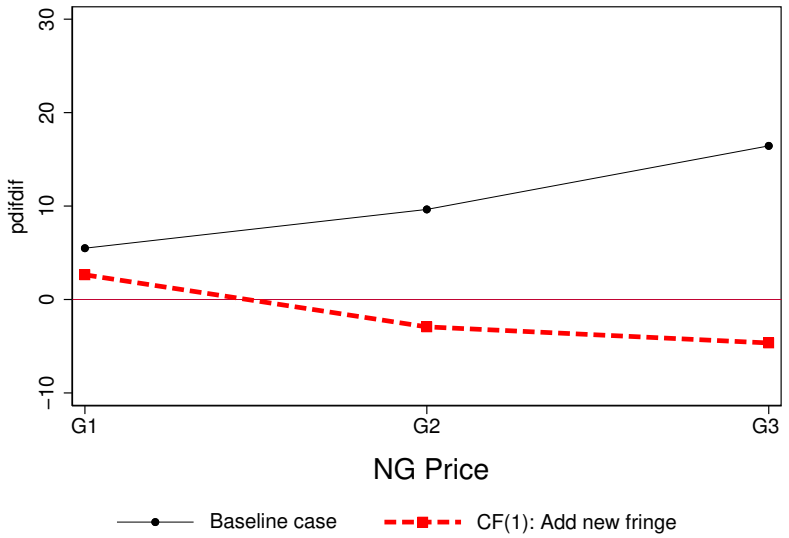
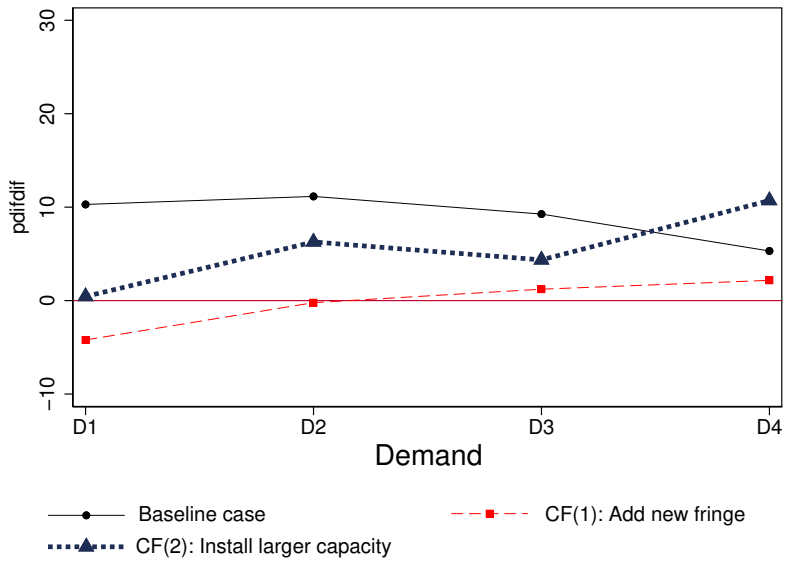


(b) By NG Price

- The most pro-competitive scenario: CF (1) – entry of fringe suppliers
  - Overall increase in market power is the smallest
  - Market power *decreases* in low-demand / higher gas prices
  - Why? residual demand becomes almost two times more price elastic

$\Delta\Delta P$: CF(2) – Retired firms install NG capacity larger than the retired capacity



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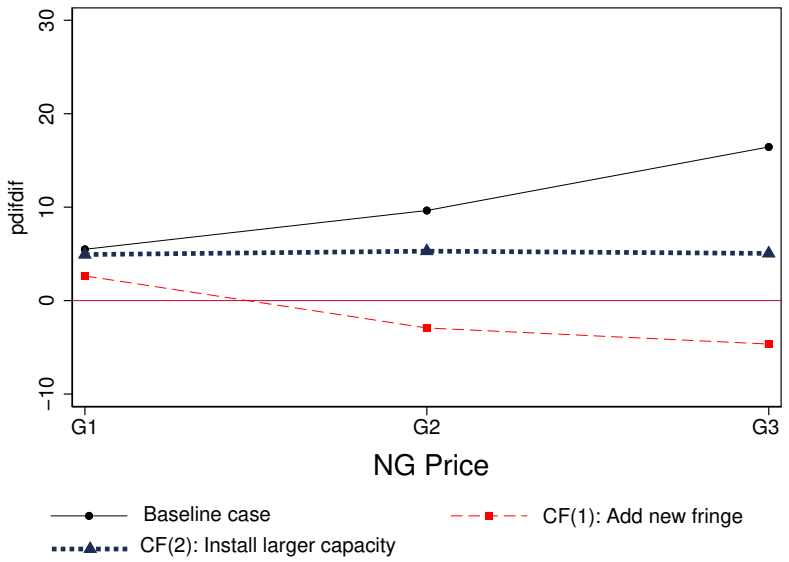
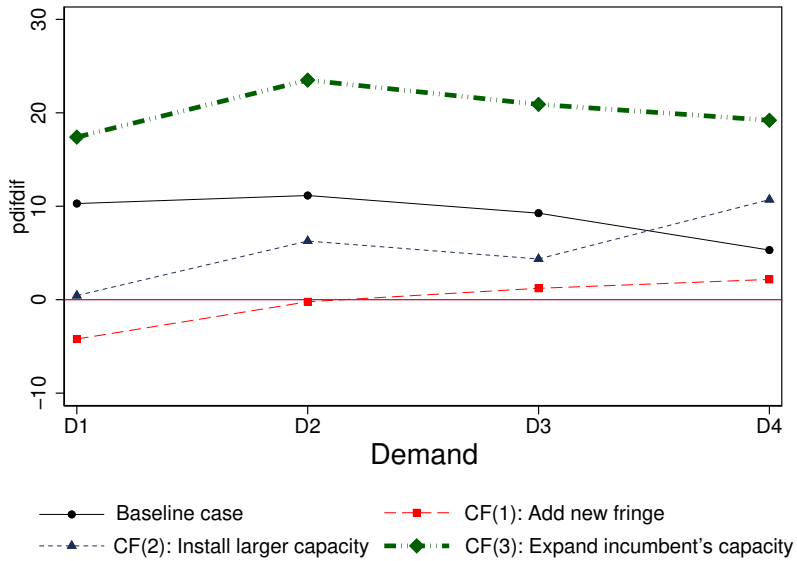


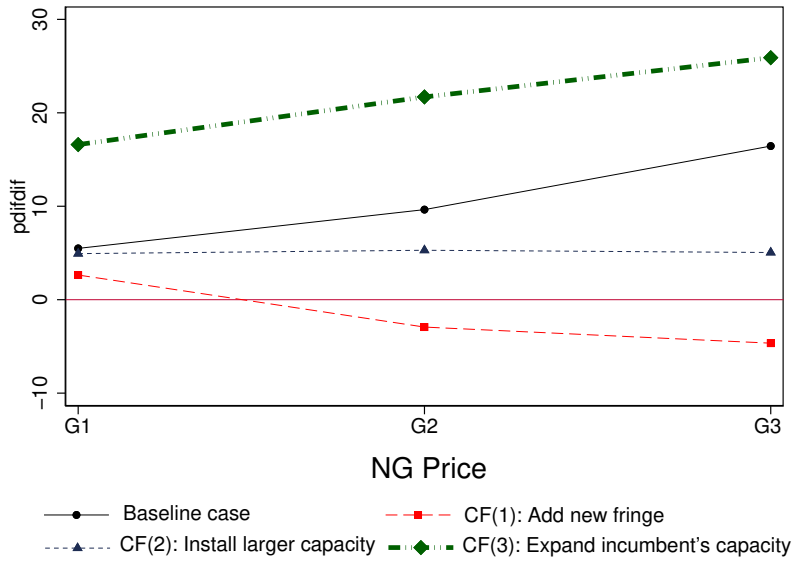
(b) By NG Price

- CF (2) – *Retired firms* install NG plant 50 % larger than the retired plant
  - Market power increases less than in our baseline case
  - Why? adding larger capacity $\rightarrow$ supply from *Retired firms* more elastic $\rightarrow$ RD of *Gas-intensive firms* more elastic $\rightarrow$ constrains the ability to exercise market power

$\Delta\Delta P$: CF(3) – Incumbents add NG generation capacity



(a) By Demand



(b) By NG Price

- The worst case is CF (3) – Incumbents (mostly gas-intensive firms) expand generation capacity
  - These firms are most capable of exercising market power in this situation
  - Allowing them to expand capacity $\rightarrow$ increasing the scale of firms with high market power

Conclusion

- Industry transition caused by the retirements of coal plants can change the competitiveness of the industry
  - Two important aspects considered: volatile cost of the NG energy, restructuring of the industry
  - Market power increases after the transition especially more when the MC of NG energy is higher, but can be mitigated by a well-planned installation of new gas generation capacities
- Can be applied to renewable generation:
  - Intermittency $\Rightarrow$ replaced with high-cost (reserve) generation
- How can we deal with the volatile cost of the cleaner NG and renewable energy?
- How can we better incentivize the installation of new generation capacity ?

Thank you!