Interaction of Oligopolistic Transmission–Constrained Power Markets with Renewable Portfolio Standards, Green Pricing Programs, & Emission Allowances

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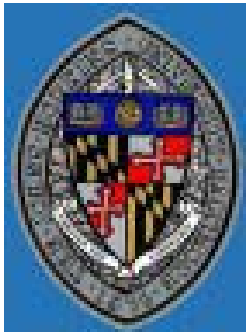

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Outline

- Questions
- Model Structure and Computation Approach
- Application
- Results

Questions of Interest

Accounting for the interactions of

- ***transmission constraints & energy markets***
- ***green power***
- ***renewable portfolio standards***
- ***NO_x markets,***

… the following questions are addressed:

- ***What is the impact of market power on prices of energy (grey, green premium), renewable energy credits (RECs), and No_x allowances?***
- ***What is the impact on social surplus?***
- ***What is the magnitude of productive inefficiency?***
- ***What is the rationale for players' behavior in markets?***

Model Structure and Computational Approach: Direct Solution of Equilibrium Conditions

Producer A

Choose gen & sales to maximize profit s.t. capacity

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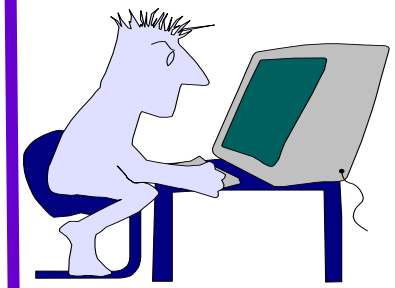
Producer B

Choose gen & sales to maximize profit s.t. capacity



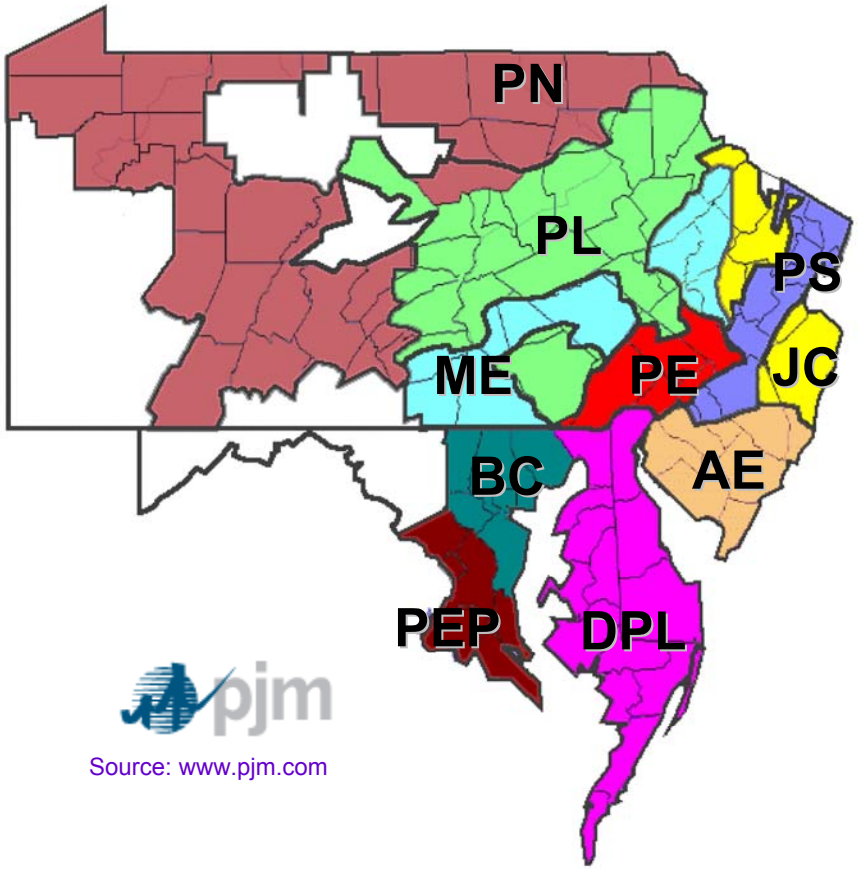
ISO: Choose Transmission Flows to Max Value of Network s.t. transmission constraints⇒ 1st order conditions

Consumers: Max Value - Expenditures (Demand Curve)

Market Clearing Conditions

1. Derive 1st-order conditions for each player
2. Impose market clearing conditions
3. Solve resulting system of conditions (*complementarity problem*) with **PATH**

Application Background
PJM Market and USEPA NO_x Program



Source: www.pjm.com

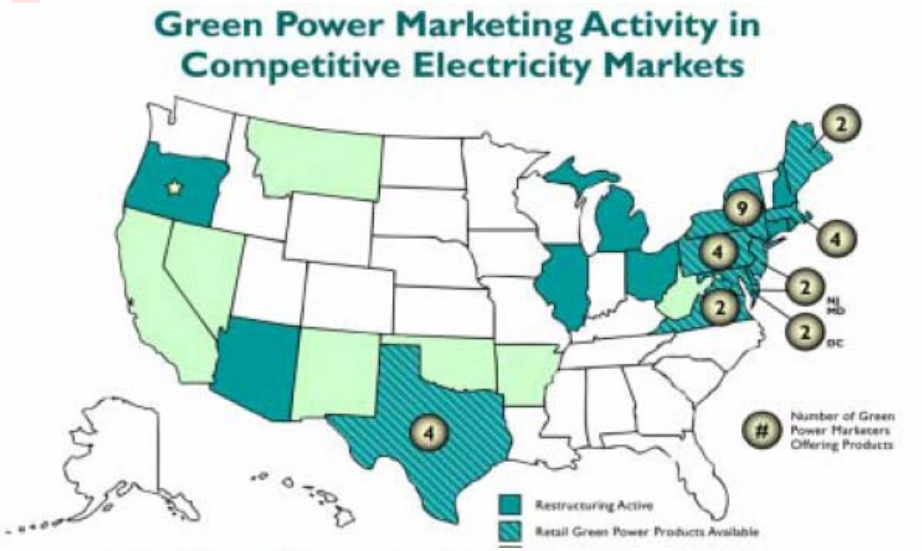
PJM Market (2000)

- *Peak: 49,000 MW*
- *Average Price: 30.7 [$/MWh]*
- *Moderate Concentrated:*
  HHI ~ 1,500
- *14 node, 18 arc system*
- *9 producers*
- *80% sales either forward contracted, or by vertically integrated firm*

USEPA *NO_x* Program

- *Cap-and-Trade*
- *May 1st – Sep. 30th (3,672 hrs)*
  - *Approximated by 5 load periods*
- *9 States in 2000*

Green Pricing Programs

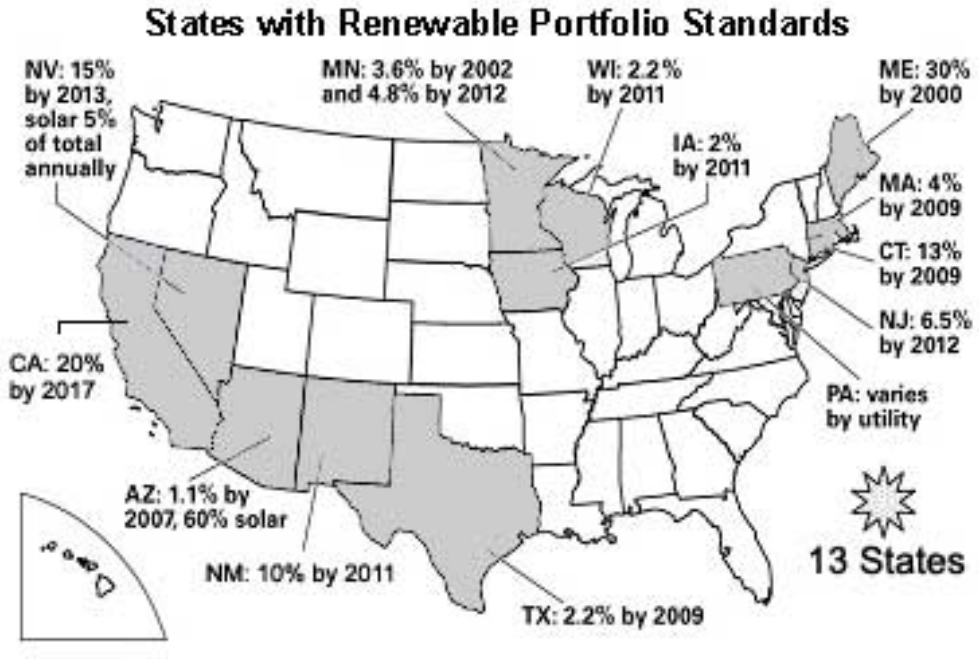


- *29 marketers offering green power (8 States and DC)*
- *Retail green premium:*
  0.5-2.5 ¢/kWh
- *0.028% of total US sales (2001)*

- *>350 utilities in 33 states offer green pricing programs*
- *Utility green premium:*
  0.7- 17.6 ¢/kWh
- *0.017% of total US sales (2001)*

Source: L. Bird and B. Swezey, "Green Power Marketing in the United States: A Status Report", Sixth Edition, NREL. Available at:

Renewable Portfolio Standards (RPS)



Source: Union of Concerned Scientists, available at

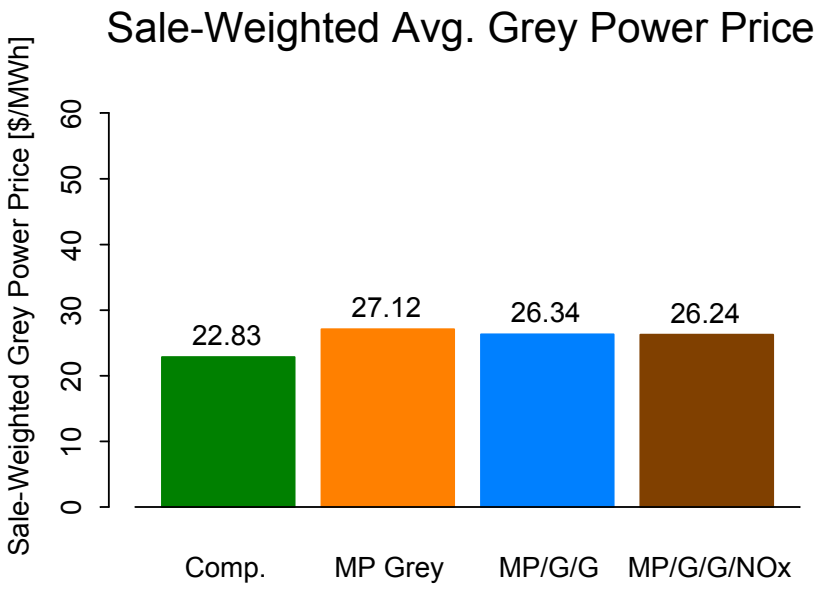
- *14 states mandate RPS*
- *RPS requirement differs by state, e.g.,*
  - *30% by 2000 in ME*
  - *1.1% by 2002 in AZ*
- *5 States allow trading in renewable energy credits (RECs)*

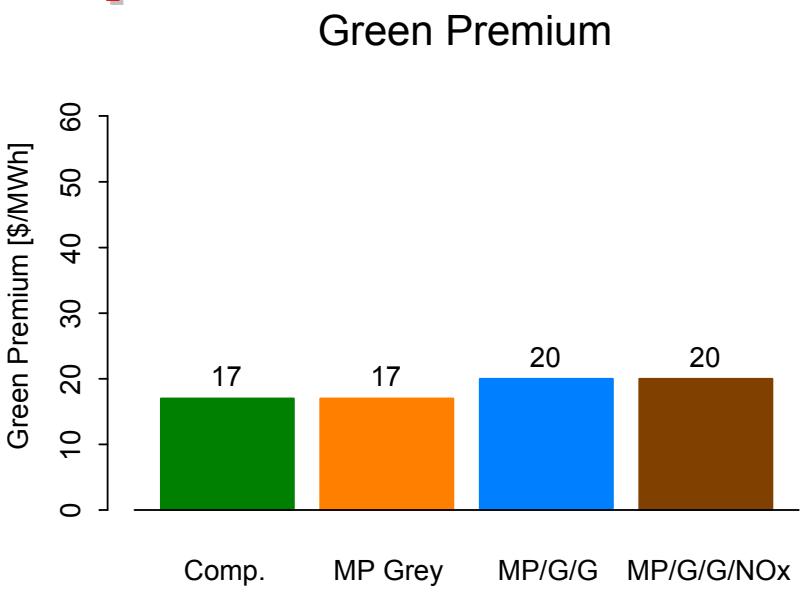
Scenarios Investigated for PJM

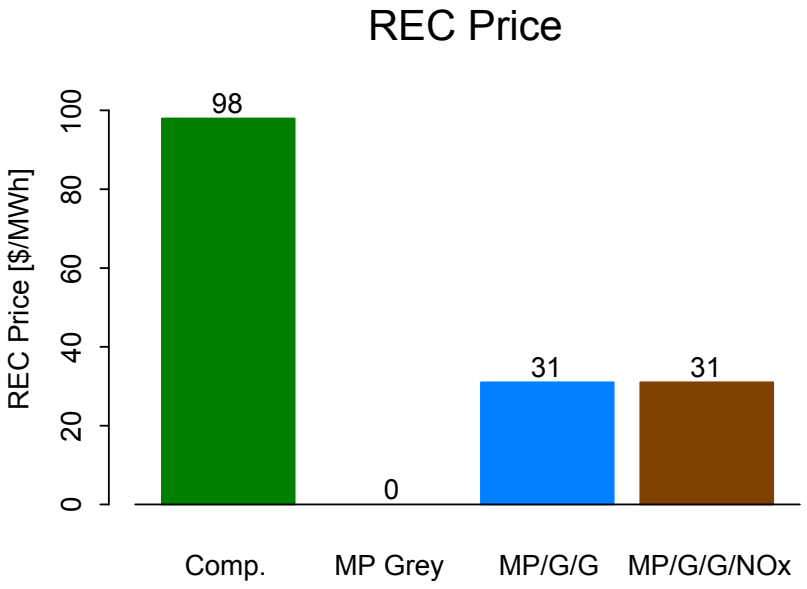
We assume a RPS of 5.5% under four competition scenarios:

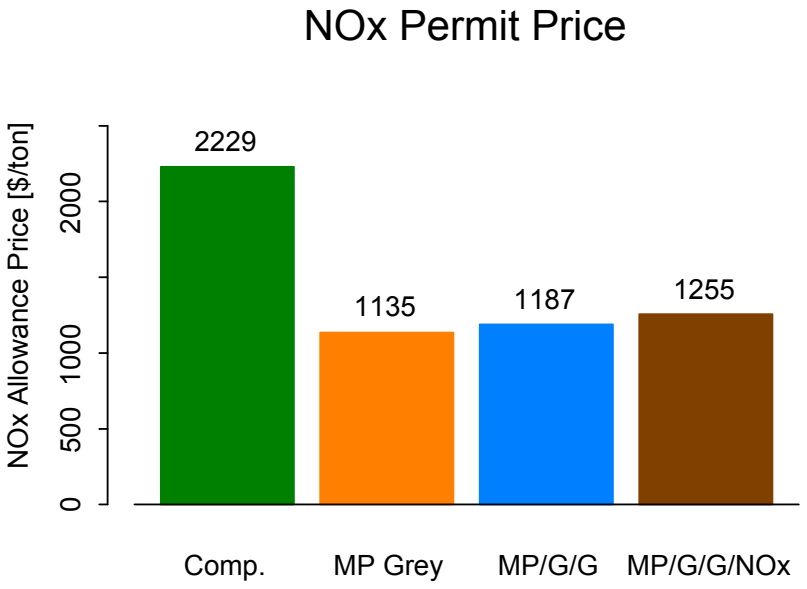
Scenario\Market	Grey Power Market	Green Power Market	NO_x Permits Market
Comp.	*Price-Taking*	*Price-Taking*	*Price-Taking*
MP Grey	*Cournot*	*Price-Taking*	*Price-Taking*
MP/G/G	*Cournot*	*Cournot*	*Price-Taking*
MP/G/G/NO_x	*Cournot*	*Cournot*	*Conjectured Response*

Results: Price Comparison



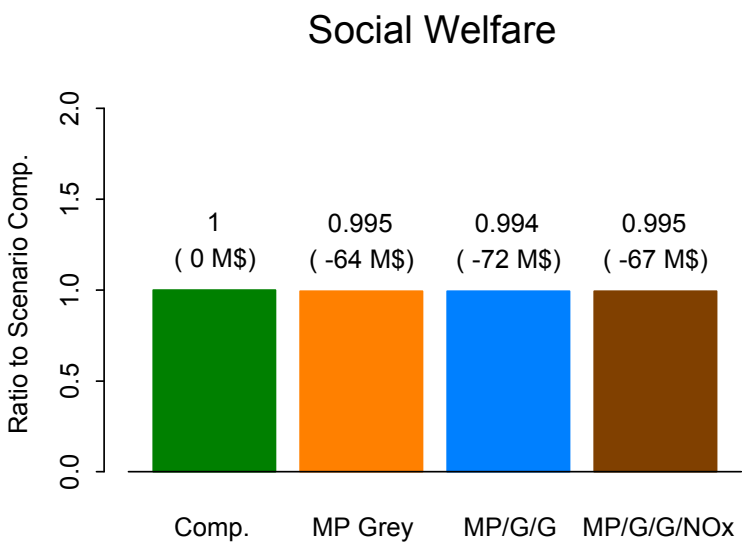


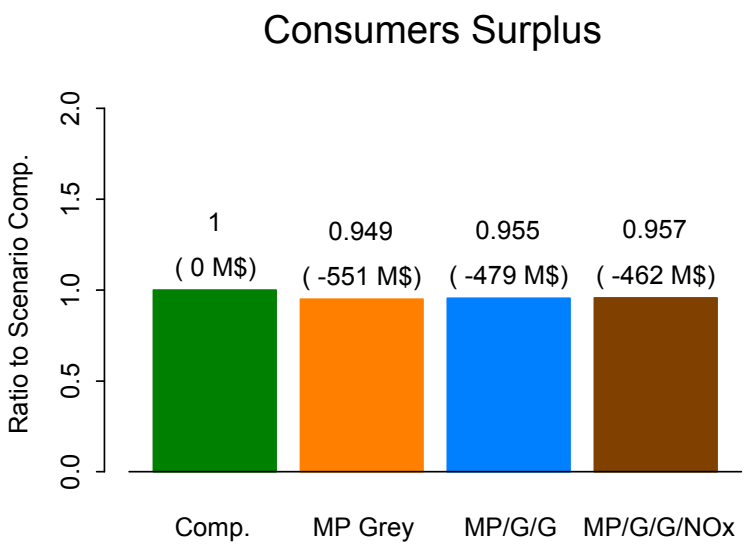


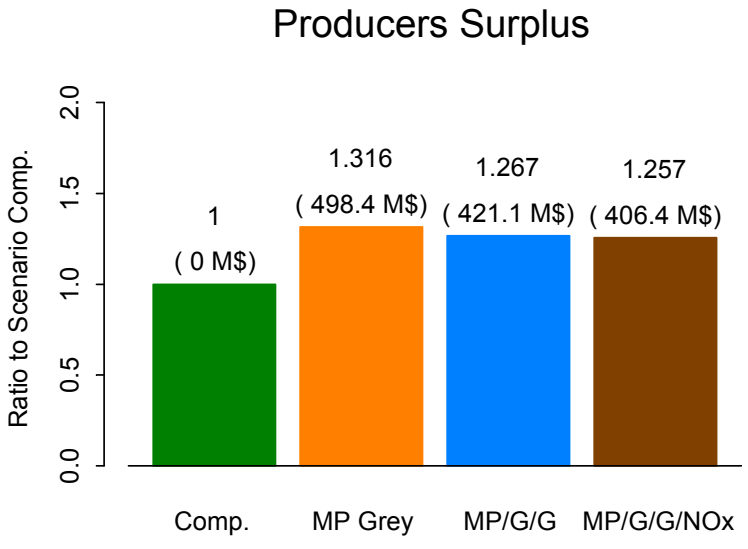


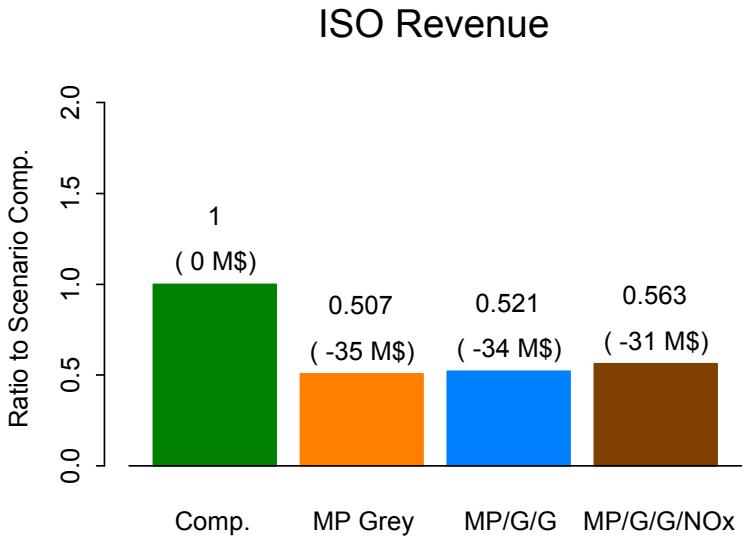
Welfare Analysis

Compared to Competitive Scenario



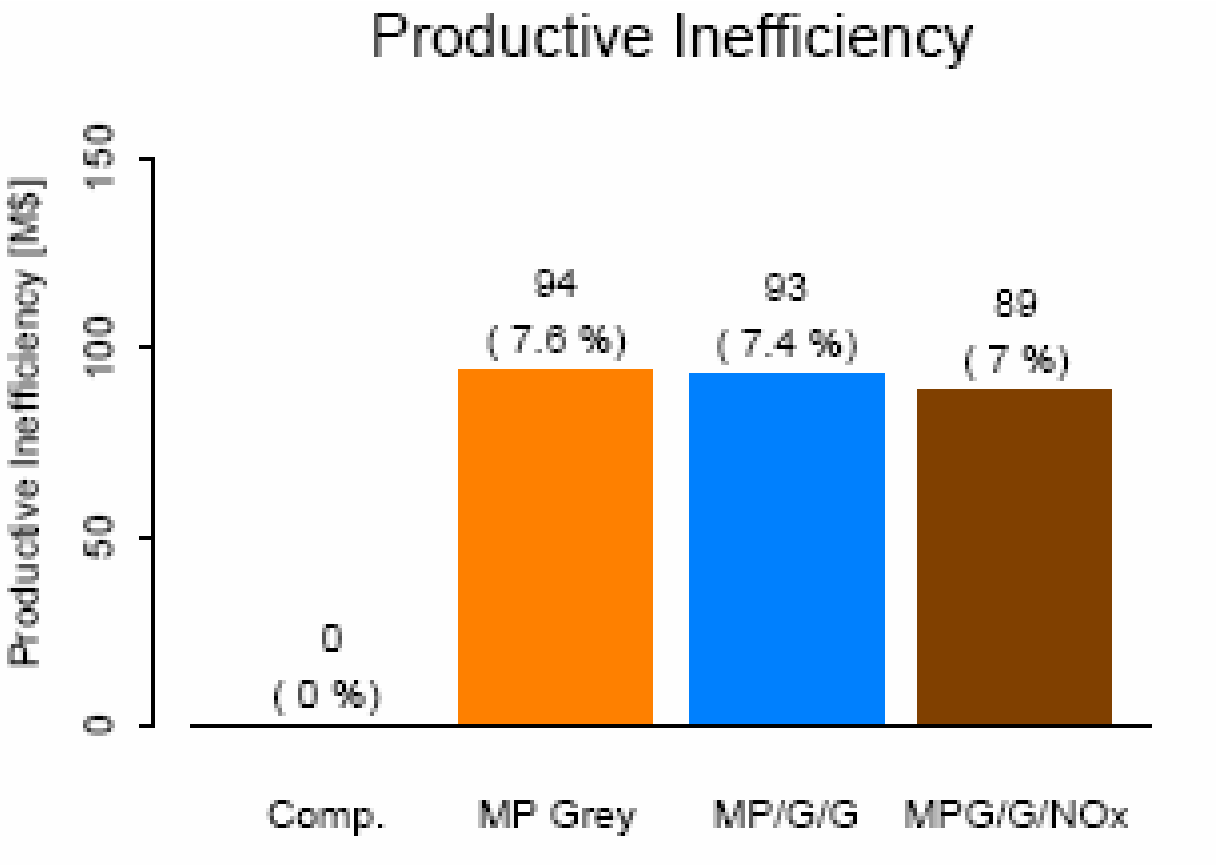






Efficiency Comparison

Compared to Competitive Scenario



Productive Inefficiency

Increase in cost relative t least-cost means of serving MW demands for green & grey energy

Market power leads to:

7.0%-7.6% productive inefficiency

Player's Strategies

***PECO* largest in power, longest in permit and RECs Markets (modeled with Cournot and NO_x conjectured price response)**

MP Grey → MP/G/G (Add MP in Green)

PECO restrains green output and increases grey output

$p^{REC} \uparrow (0 \rightarrow 31\$/MWh)$

$p^{E} \downarrow (27.1 \rightarrow 26.3\$/MWh)$

PECO worse off
CS goes up (lower p^E)
PS goes down
SW goes up

MP/G/G → MP/G/G/NO_x (Add MP in NO_x)

PECO expands output, sells fewer NO_x permits

$p^{NO_x} \uparrow (1{,}187 \rightarrow 1{,}255\$/ton)$

$p^{E} \downarrow (26.3 \rightarrow 26.2\$/MWh)$

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Conclusion

- *Interactions of electric (grey and green), RECs, and NO_x markets can be investigated by Cournot and conjectured NO_x pricing assumptions in a large-scale model (20,000 variables)*

- *Detailed market representation allows a variety of welfare and efficiency analyses, and insights on players' strategies*

- ***Next:***
  - *variable wind outputs*
  - *suppliers' long-term investment decisions under various oligopoly scenarios*

QUESTIONS AND COMMENTS?