Market and Welfare Effects of Renewable Portfolio Standard in the Vertically Differentiated U.S. Energy Markets

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INTRODUCTION


RPS States in the U.S.[1]

Renewable Energy Markets

Compliance Market | Voluntary Market

Renewable Portfolio Standard

- ❖ Mandate on retail electricity providers to include a certain percent of renewable in their electricity supplies
- ❖ Design varies across states (coverage, existing renewable capacity, REC trading)

Voluntary Purchases by Consumers

- ❖ Offered by utilities/marketers to residential and non-residential consumers in both regulated & deregulated states
- ❖ Green utility programs (fixed-quantity or percent-of-use products)

RESEARCH OBJECTIVES

Previous Studies[2,3,4,6,8]:

- ❖ Focus only on supply effects of state RPS
- ❖ Focus on economic effects of federal RPS but do not
  - a) consider market power among suppliers
  - b) heterogeneous consumer preference

Present Study:

- ❖ Builds an applied-theoretic RPS model that considers:
  - a) Supply-demand effects of RPS
  - b) Interaction of compliance with voluntary markets
  - c) Imperfect competition among electricity suppliers
  - d) Consumer heterogeneity
- ❖ Estimates theoretical model using mixed effect approach
- ❖ Simulates on key parameter values to analyze the economic effects of the introduction of RPS across 8 NERC regions in the U.S.

MODEL FRAMEWORK

Theoretical VPD Model[5]

RPS Effects in the Compliance Market

Cost Effect: $\gamma = C_R^{RPS} - C_R$

Utility Effect: $\delta = a_1 - a$

Inverse Demand Curves

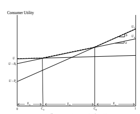
Regular Power Market

$$P_R(X_R, X_G) = \frac{a}{b}P_G - \frac{a(b-a)}{b}X_R$$

Green Power Market

$$P_G(X_R, X_G) = P_R + (b-a) - (b-a)$$

X_R, X_G – Power Quantities
P_R, P_G – Power Prices
a, b – WTP for Regular/Green Power
c_R, c_G – Power Costs
θ_R, θ_G – Market Power Parameters
$b > a, \frac{P_G}{P_R} > \frac{b}{a}, P_G - P_R < b - a$



Consumption Decisions and Welfare Under Pre-RPS Scenario

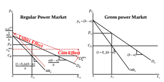
Prices-Quantities

$$P_R = \frac{a\theta_R(\theta_G(b-a)+c_G)+b(1+\theta_G)c_R}{(1+\theta_R+\theta_G)b+\theta_G\theta_R(b-a)}$$

$$X_R = \frac{b(a[\theta_G(b-a)+c_G]-[b+(b-a)\theta_G]c_R)}{a(b-a)((1+\theta_R+\theta_G)b+\theta_R\theta_G(b-a))}$$

$$P_G = \frac{b[(1+\theta_R)(\theta_G(b-a)+c_G)+\theta_G c_R]}{(1+\theta_R+\theta_G)b+\theta_G\theta_R(b-a)}$$

$$X_G = \frac{b[(b-a)(1+\theta_R)+c_R]-(b+(b-a)\theta_R)c_G}{(b-a)((1+\theta_R+\theta_G)b+\theta_R\theta_G(b-a))}$$



Market Equilibrium Conditions Under Pre-RPS Scenario

Empirical Mixed-Effects Model

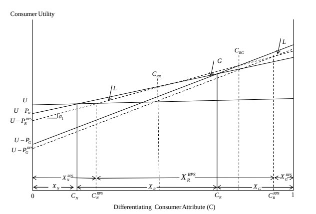
$$Y_{k_{it}} = \alpha_0 + \beta_1 X_f + \gamma_1 Z_r + \varepsilon_{it}$$

Y_{it} - the logarithmic transformation of the response variable - levels of regular/green power sales
X_f - a vector of fixed effects (variables: utility & state characteristics, RE policies, resource potential)
Z_r - a vector of random effects (variables: interaction term of region*resource cost)
ε_{it} - idiosyncratic error term

Data – Panel data comprising of 757 utilities selling regular/green power in 48 U.S. states nested in 8 NERC regions during the period 2007-2010

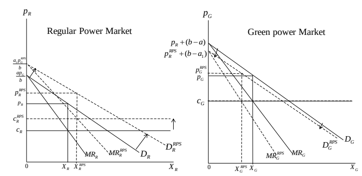
SIMULATION RESULTS

$$P_R^{RPS} \uparrow P_G^{RPS} \uparrow Q_R^{RPS} \uparrow Q_G^{RPS} \downarrow \Pi_R^{RPS} \uparrow \Pi_G^{RPS} \uparrow CW^{RPS} \uparrow CW_R^{RPS} \uparrow CW_G^{RPS} \downarrow$$



$$L = \int_{C_N}^{C_N^{RPS}}(U_R - U_N)dC + \int_{C_N^{RPS}}^{C_{RR}}(U_R - U_R^{RPS})dC + \int_{C_{RG}}^{C_R^{RPS}}(U_G - U_R^{RPS})dC + \int_{C_R^{RPS}}^{1}(U_G - U_G^{RPS})dC, G = \int_{C_{RR}}^{C_R}(U_R^{RPS} - U_R)dC + \int_{C_R}^{C_{RG}}(U_R^{RPS} - U_G)dC$$

Consumption Decisions and Welfare Under Post-RPS Scenario

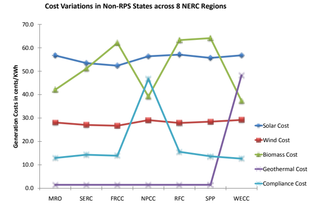


Market Equilibrium Conditions Under Post-RPS Scenario

Four Possible Market Scenarios:

Scenario I - $\Delta X_R < 0, \Delta X_G > 0, \Delta P_R > 0, \Delta P_G > 0$
Scenario II - $\Delta X_R < 0, \Delta X_G < 0, \Delta P_R > 0, \Delta P_G > 0$
Scenario III - $\Delta X_R > 0, \Delta X_G < 0, \Delta P_R > 0, \Delta P_G > 0$
Scenario IV - $\Delta X_R > 0, \Delta X_G < 0, \Delta P_R > 0, \Delta P_G < 0$

Cost Variations in Non-RPS States across 8 NERC Regions



Regions	Consumer Valuation for Regular Power				
		Wind	Solar	Biomass	Geothermal
MRO	Low Cost	$a_1/b > 0.62$	$a_1/b > 0.38$	$a_1/b > 0.35$	
	High Cost	$a_1/b > 0.82$	$a_1/b > 0.58$	$a_1/b > 0.56$	
SERC	Low Cost	$a_1/b > 0.67$	$a_1/b > 0.38$	$a_1/b > 0.52$	
	High Cost	$c_R > c_G$	$a_1/b > 0.78$	$a_1/b > 0.73$	
FRCC	Low Cost	$a_1/b > 0.67$	$a_1/b > 0.38$	$a_1/b > 0.32$	
	High Cost	$c_R > c_G$	$a_1/b > 0.67$	$a_1/b > 0.58$	
NPCC	Low Cost	$c_R > c_G$	$a_1/b > 0.88$	$c_R > c_G$	
	High Cost	$c_R > c_G$	$c_R > c_G$	$c_R > c_G$	
RFC	Low Cost	$a_1/b > 0.67$	$a_1/b > 0.35$	$a_1/b > 0.58$	
	High Cost	$c_R > c_G$	$a_1/b > 0.73$	$a_1/b > 0.75$	
SPP	Low Cost	$a_1/b > 0.62$	$a_1/b > 0.35$	$a_1/b > 0.29$	
	High Cost	$a_1/b > 0.97$	$a_1/b > 0.58$	$a_1/b > 0.58$	
WECC	Low Cost	$a_1/b > 0.55$	$a_1/b > 0.50$	$a_1/b > 0.35$	$a_1/b > 0.29$
	High Cost	$a_1/b > 0.73$	$a_1/b > 0.61$	$a_1/b > 0.53$	$a_1/b > 0.44$

$c_G > c_R$
c_G = generation costs from wind, solar, biomass, & geothermal resources
c_R = generation costs from natural gas and coal
High Cost : c_R + 6 cents/KWh, Low Cost : c_R + 1 cents/KWh

CONCLUSIONS

- ❖ This research provides a new framework of analysis of the economic effects of RPS in the U.S. electricity market that considers:
  - a) the interaction of compliance with voluntary markets
  - b) heterogeneous consumer preferences
  - c) suppliers' market power
- ❖ Market and welfare effects of RPS depend on
  - a) region- and resource- specific renewable cost increase associated with the mandate
  - b) consumer valuation for mandated-regular power (i.e. regular power containing more renewables)
  - c) relative costs of the power products
  - d) suppliers' market power
- ❖ Regular and green power prices increase
- ❖ Regular (green) power sales increase (decrease)
- ❖ Consumers of regular power and both regular and green power suppliers (IOUs) are most likely beneficiaries of RPS, while consumers of green power lose
- ❖ Being unable to exercise market power, POUs selling regular power will always lose if RPS entails fixed costs
- ❖ Threshold values of (a_1/b) that cause prices, quantities and welfare to increase after RPS:
  - a) increase with an increase in the compliance costs of RPS
  - b) are relatively lower when $c_G = Solar\ cost$ in most regions, thus, indicating that consumer support for solar power through voluntary purchases is more likely to decline with RPS

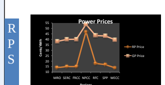
REFERENCES

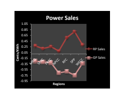
1) Database of State Incentives for Renewables and Efficiency (DSIRE), 2012. North Carolina Solar Center. available at <http://www.dsireusa.org>. Access date: July 1, 2012.
2) Delmas, M., and M. J. Montes-Sancho. "U.S. State Policies for Renewable Energy; Context and effectiveness."*Energy Policy* 39 (2011):2273-2288.
3) Fischer, C. "How Can Renewable Portfolio Standards Lower Electricity Prices?." *Resources for the Future Discussion Paper 06-20-REV* (2006).
4) Fredric, M., and S.Vachon. "The Effectiveness of Different Policy Regimes for Promoting Wind Power: Experiences from the States."*Energy Policy* 34 (2006):1786-1796.
5) Giannakas, K. "Consumer Demand in Vertically Differentiated Markets." Chapter 9 in Lusk J., J. Roosen, and J. Shogren (eds.) Oxford Handbook on the Economics of Food Consumption and Policy, Oxford University Press, September 2011, 243-259.
6) Haitao, Y., and N. Powers. "Do State Renewable Portfolio Standards Promote In-State Renewable Generation?"*Energy Policy* 38 (2010):1140-1149.
7) Heeter, J., and L. Bird. "Status and Trends in U.S. Compliance and Voluntary Renewable energy Certificate Markets (2010 Data)" *Technical Report NREL/TP-6A20-52925*. National Renewable Energy Laboratory (2011).
8) Palmer. K., and D. Burtraw."Cost-Effectiveness of Renewable Electricity Policies."*Resources for the Future* (2005).
9) Sanya, C., "State Renewable Energy Electricity Policies: An Empirical Evaluation of Effectiveness." *Energy Policy* 37 (2009):3071-3081.

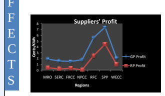
GRAPHS

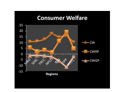
Low Cost Scenario

RPS EFFECTS









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