# WIND GENERATION SUBSIDIES

## The impact on the capacity fuel mix, welfare implications and other market consequences

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## INTRODUCTION

In the context of liberalized competitive electricity markets US policy makers have **conflicting goals** –both at the Federal and that the State level–

### Environmental Goals

- Promotion of Wind Generation Capacity
- Recent policies
  - ✓ Renewable Electricity Production Tax Credit (PTC)
  - ✓ Renewable Portfolio Standards (RPS)

### Guarantee Adequate Reliable Supply

- Increasing concern about the Resource Adequacy problem or "Missing Money" problem
- Potential solutions
  - ✓ Capacity Markets (PJM, ISO-NE, NYISO, etc.)
  - ✓ Operating Reserve Demand Curve (Texas ERCOT)

Having that in mind, we are interested in analyze: what is the tradeoff of the renewable promotion?

## GOALS

- Investigate the impact on the electricity market of subsidies to the renewable energy production
  - In particular, we focus our attention to subsidies to wind generation
- Explore the consequences for the generation capacity fuel mix
  - We challenge previous studies that argue that subsidies to wind are more likely to displace peak load generation (natural gas)
  - E.g. Cullen (2008), Wynne et al. (2009), Blossman et al. (2009)
- Putting aside the environmental gains: what are the consequences for consumers?
  - Taking into account the intermittent nature of renewables, we explore the impact on Consumer Surplus and Price Volatility

## METHODOLOGY: THE MODEL

We set up a theoretical framework with cost heterogeneous electricity generators and stochastic demand

### Demand

- Unit one continuum of risk averse consumers
- Reservation price $p^H$ (VOLL)
- Quantity demanded: $\theta$ stochastic
  - non-negative random variable
  - uniformly distributed over the interval $[\underline{\theta}, \overline{\theta}]$
  - cumulative distribution function $F(\theta)$
  - w.l.o.g. normalize this support such that $\underline{\theta} = 0$ and $\overline{\theta} = 1$

### Timing

1. Generators decide how much to invest in capacity
   - $k_i \geq 0,\ i \in \{b, p\}$
2. Demand is realized
   - $\theta \in [\underline{\theta}, \overline{\theta}]$
3. Generators compete in uniform-price auction to sell electricity
   - market-clearing price: $p^s \in [0, \min(p^H, p^{\text{cap}})]$

Solve by backward induction

### Supply

- Unit measure continuum of identical
  - wind load electricity generators
  - base load electricity generators (e.g. coal)
  - peak load electricity generators (e.g. natural gas)
- Costs
  - variable cost: wind < base < peak($c_w < c_b < c_p$)
  - per unit capacity cost: wind > base > peak($c_{k_w} > c_{k_b} > c_{k_p}$)
- Production function
  - wind generators (intermittent!): $0 \leq q_w \leq (1-\rho)k_w$
  - base and peak generators: $0 \leq q_i \leq k_i \quad i \in \{b, p\}$
- Free-entry

### Market Equilibrium

- First we find a unique equilibrium in the wholesale market
  - Equilibrium bids and productions: $p_i,\ q_i,\ i \in \{w, b, p\}$
  - Contingent on whether the wind is blowing or not
- Then we find a unique capacity investment: $k_i,\ i \in \{w, b, p\}$

## Testing the model: ERCOT data

We use the following to simulate the equilibrium capacities

- Texas ERCOT data
  - Hourly load data (in MW) from 1995 to 2014 –not available for 2001 and 2002–
- Parameters:
  - VOLL and Price Cap: $p^H$=6,000 $p^{\text{cap}}$=2,500
  - Variable cost: $c_w$=0 $c_b$=24.5 $c_p$=42
  - Per capacity cost: $c_{k_w}$=60 $c_{k_b}$=24.6 $c_{k_p}$=10
  - Wind subsidy: $s$=22 Intermittency: $\rho$=0.25

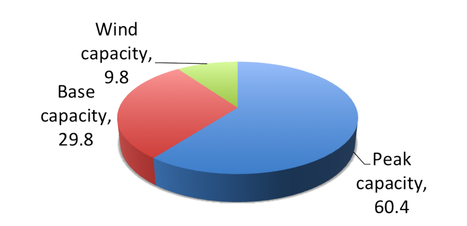
## Welfare and Market analysis

- Fuel generation mix –measured in percentage
- Price volatility –measured as the expected variance
- Consumer Surplus –measured according to the following (standard) formula

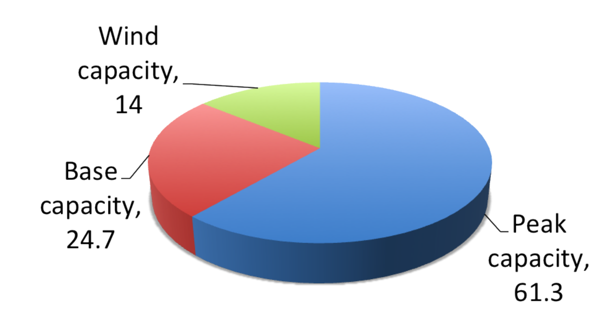
$$\text{CS} = \int_0^{k_b} (p^H - c_b)\theta dF(\theta) + \int_{k_b}^{K} (p^H - c_p)\theta dF(\theta) + \\ + \int_K^1 \left(\max\{p^H - p^{\text{cap}}, 0\}\right) K dF(\theta)$$

## MAIN PLOTS

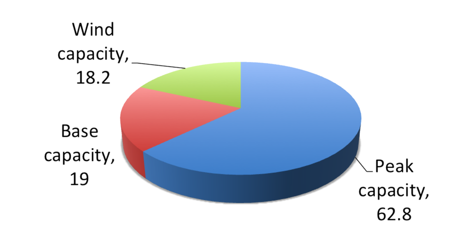
Capacity Fuel Mix with Price Cap ($p^{\text{cap}}$) at $2,500 per MWh



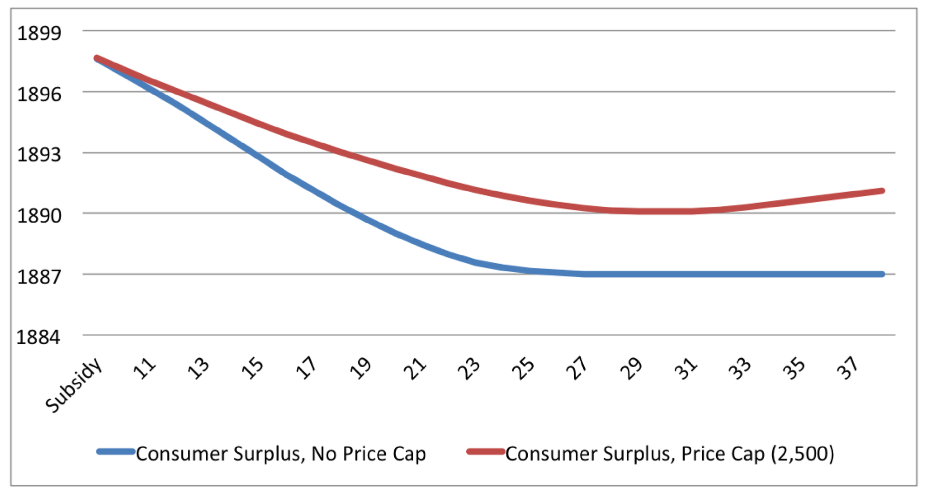

Wind subsidy = $15 per MWh



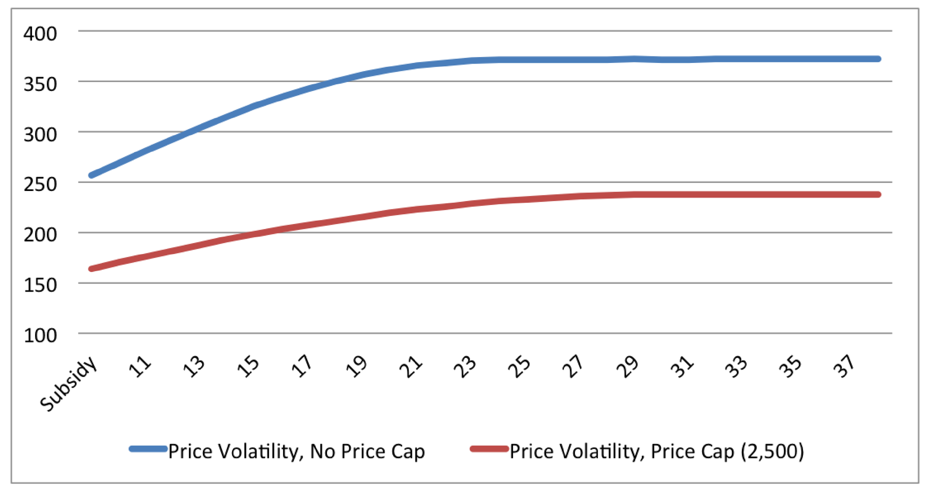

Base case: wind subsidy = $22 per MWh




Wind subsidy = $30 per MWh

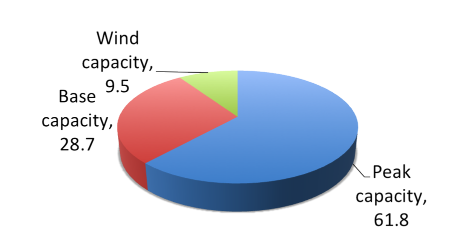



Impact of Wind Subsidies on Consumer Surplus

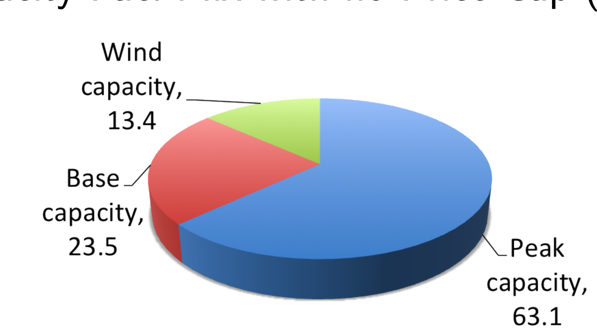



Impact of Wind Subsidies on Price Volatility

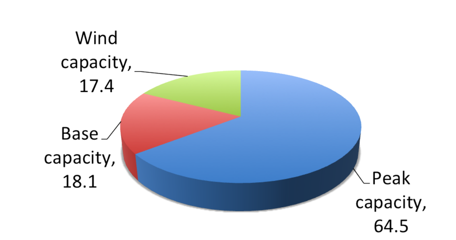
Capacity Fuel Mix with no Price Cap ($p^{\text{cap}}$)




Wind subsidy = $15 per MWh




Base case: wind subsidy = $22 per MWh




Wind subsidy = $30 per MWh

## MAIN FINDINGS

- Contrary to the aforementioned authors, we find that an increase of the wind capacity tends to displace base load facilities (coal)
  - Therefore, subsidies to wind will promote Natural Gas facilities while displacing Coal generation
- On the other hand, and putting aside the environmental gains, the promotion of wind capacity has negative impact on consumers
  - An increase in the expected price reduces ex-ante Consumer Surplus
  - Due to the intermittency nature of wind, Natural Gas (which is more expensive than coal) is the back up technology
- These consequences may be mitigated with the introduction of a Capacity Market

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