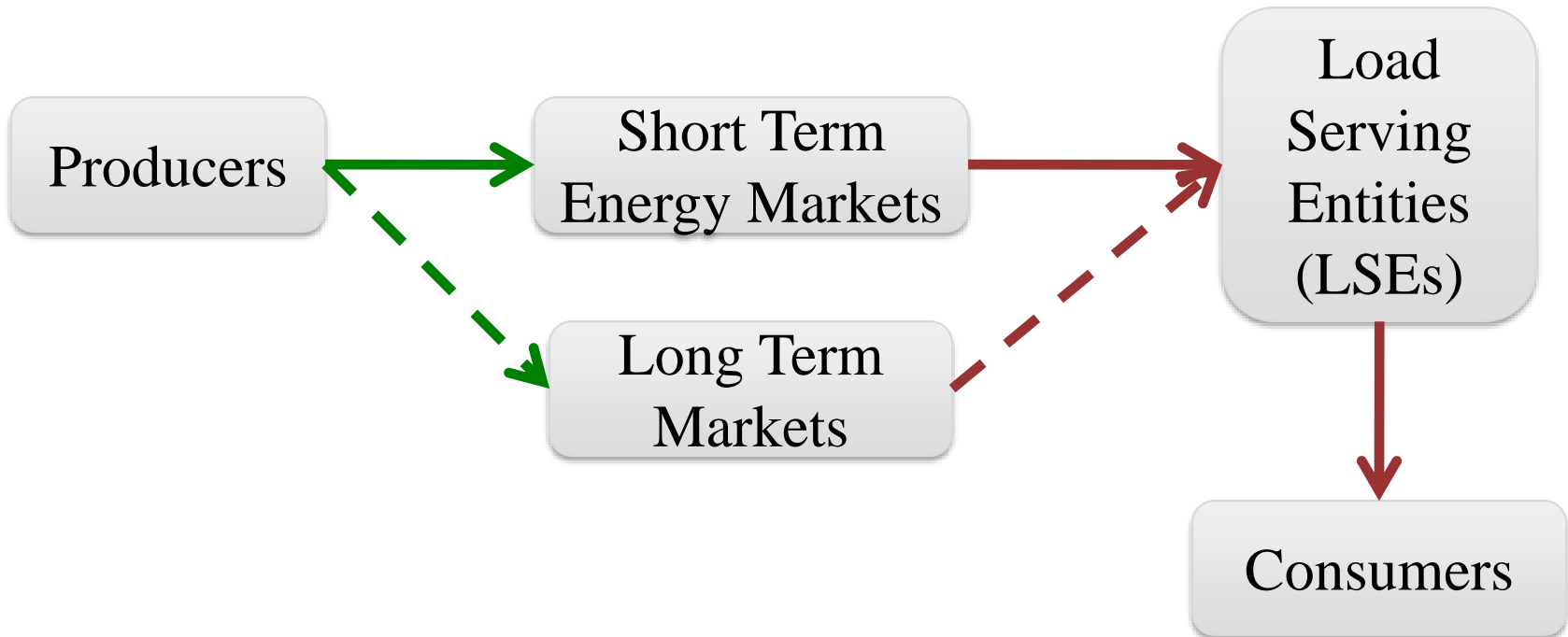

Forward Contracts and Generator Market Power: How Externalities Reduce Benefits in Equilibrium

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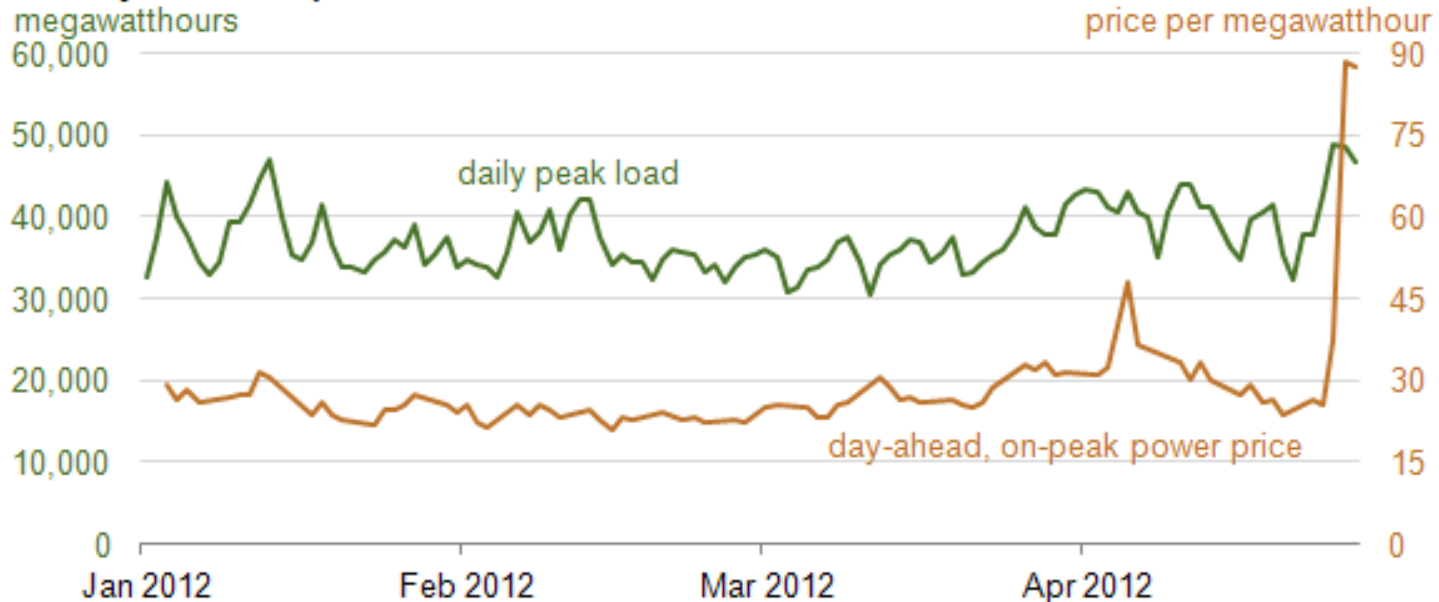
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Electricity market structure: consumers represented by LSEs



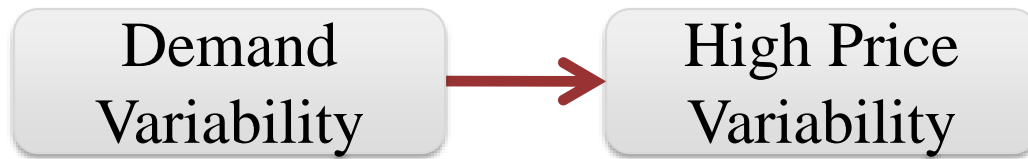
Stochastic and varying demand leads to electricity price spikes

ERCOT daily peak load and day-ahead, on-peak power price, January 1, 2012 - April 27, 2012



- Less than 10% change can easily triple the price of electricity.

Demand variability leads to high price variability



Price uncertainty has high costs on consumers



Forward contracting helps reduce price uncertainty



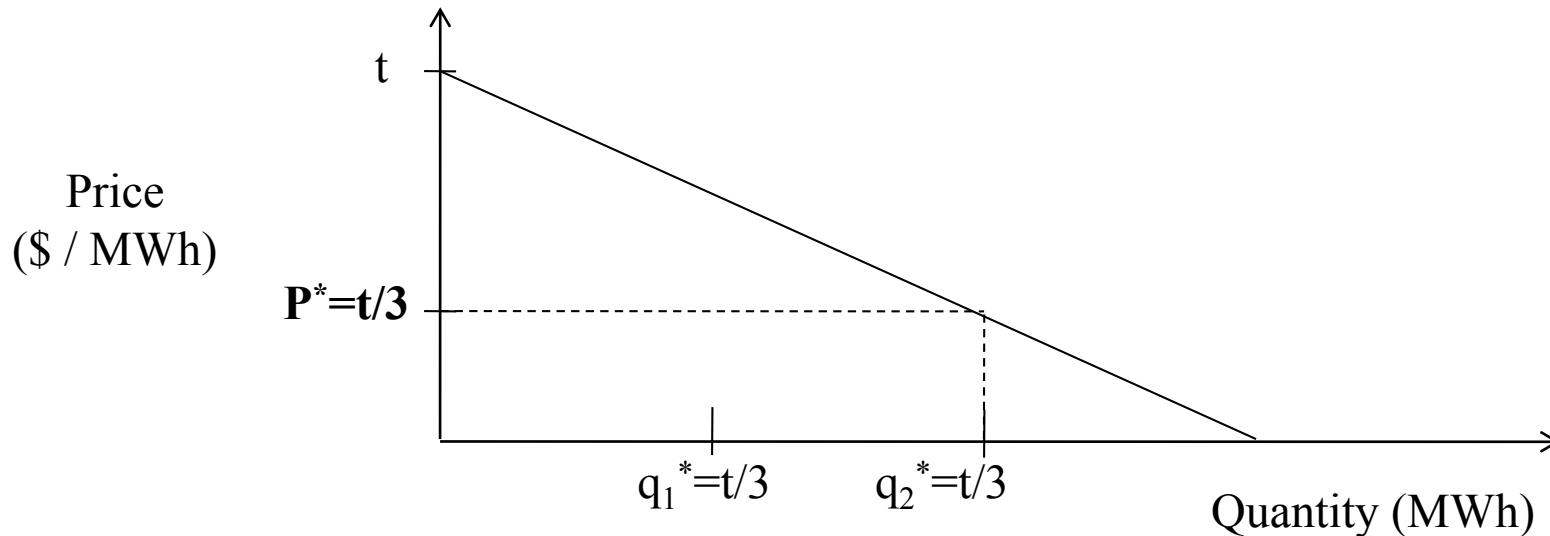
- Many types of long-term contracts can reduce price uncertainty (swaps, options)
- In electricity markets, capacity markets act as a form of forward contracting with some non-financial considerations.

Long-term contracting has additional benefits

- 1 Besides reducing risk, forward contracting can also help reduce market power (Allaz and Vila, 1993).
- 2 Producers sign forward contracts to take up a larger market share versus competitors
- 3 But prisoner's dilemma causes them to all over-produce.

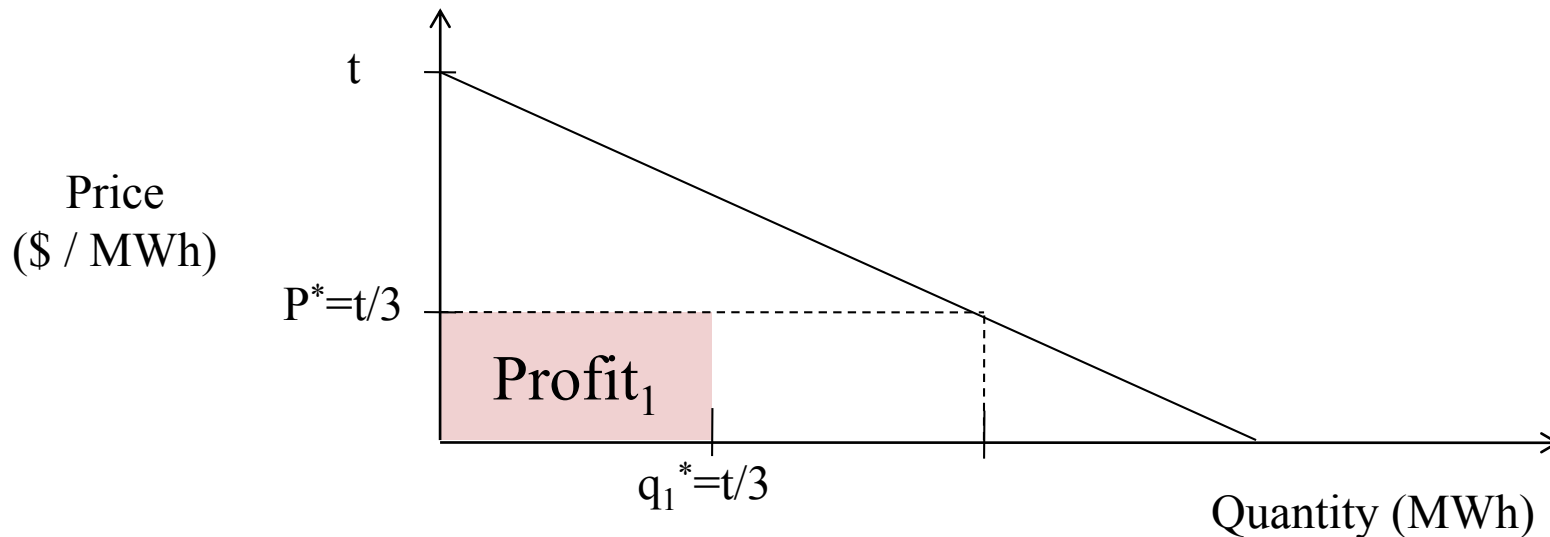
Example: long-term contracting has additional benefits

- Assume two producers, no costs, linear inverse demand $P(Q) = t - Q$.
- Cournot Equilibrium:



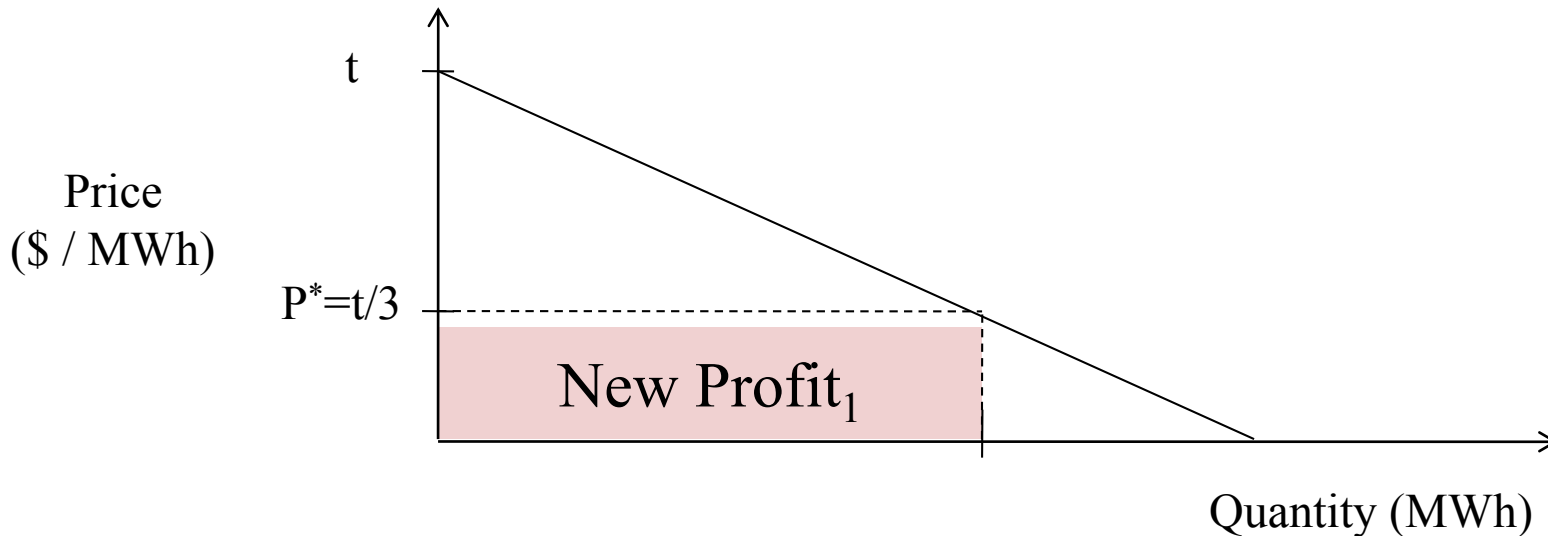
Example: long-term contracting has additional benefits

- But producer 1 could make more money through forward contracting!



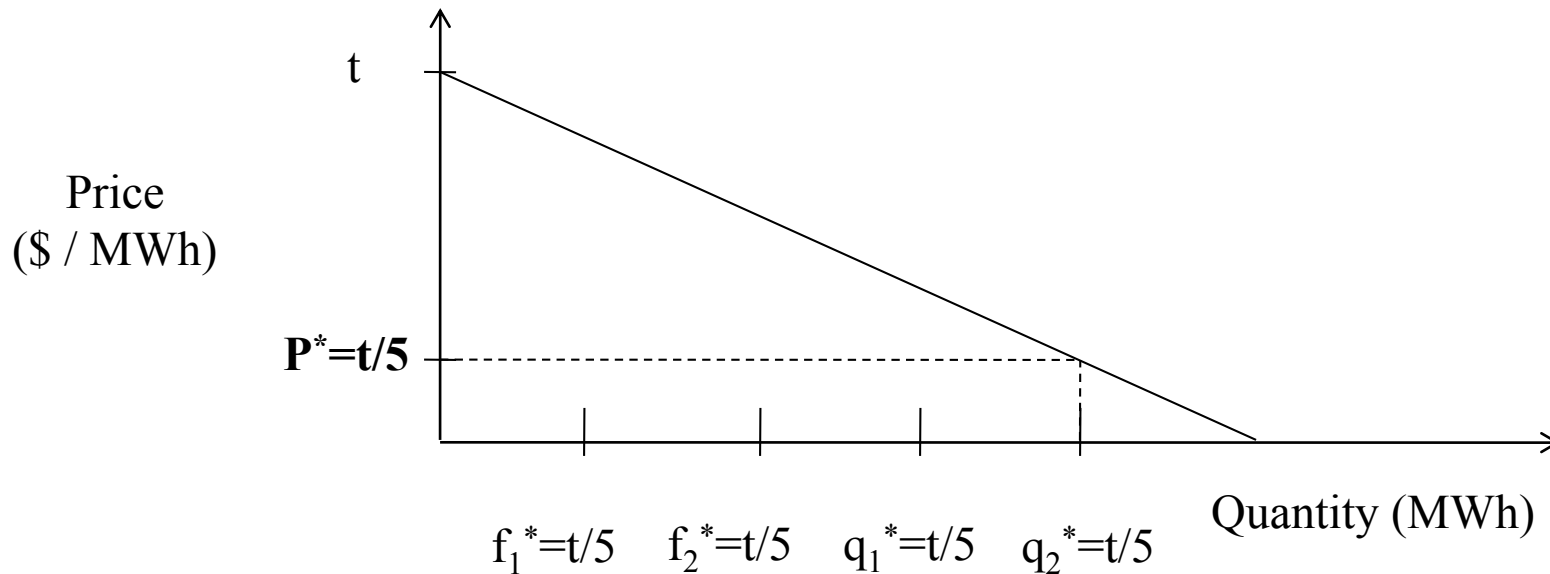
Example: long-term contracting has additional benefits

- Example: sign a forward contract for $2t/3$ units for just a little bit less than P^*



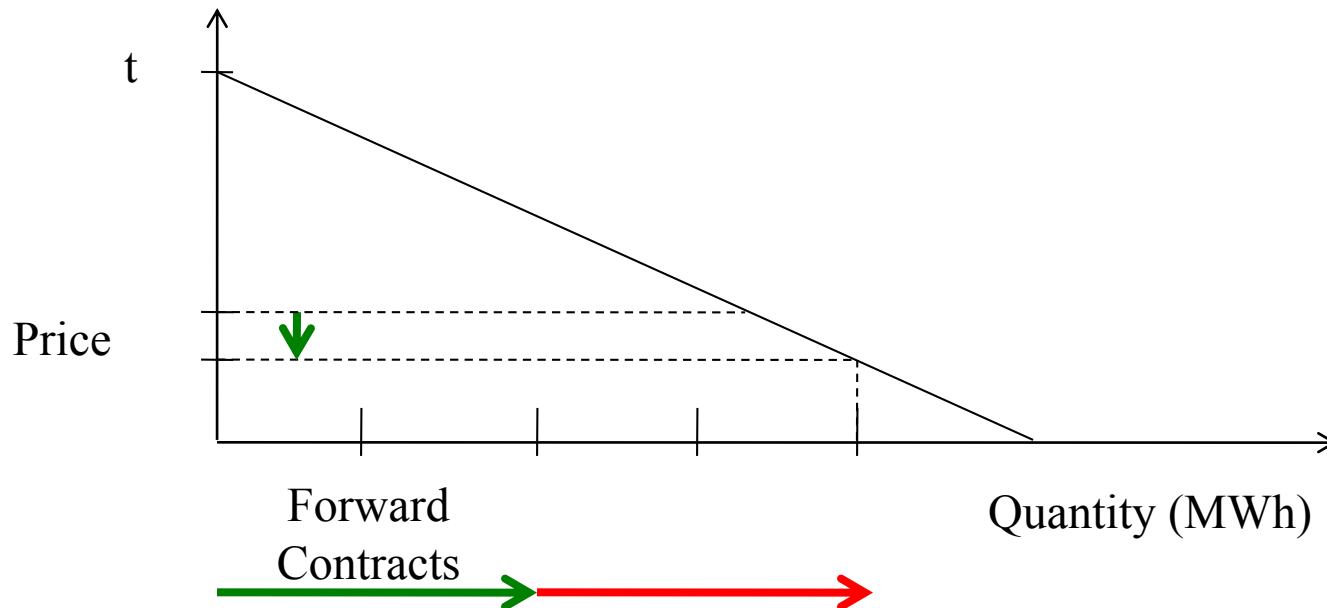
Example: long-term contracting has additional benefits

- Resulting Cournot equilibrium with one forward period:

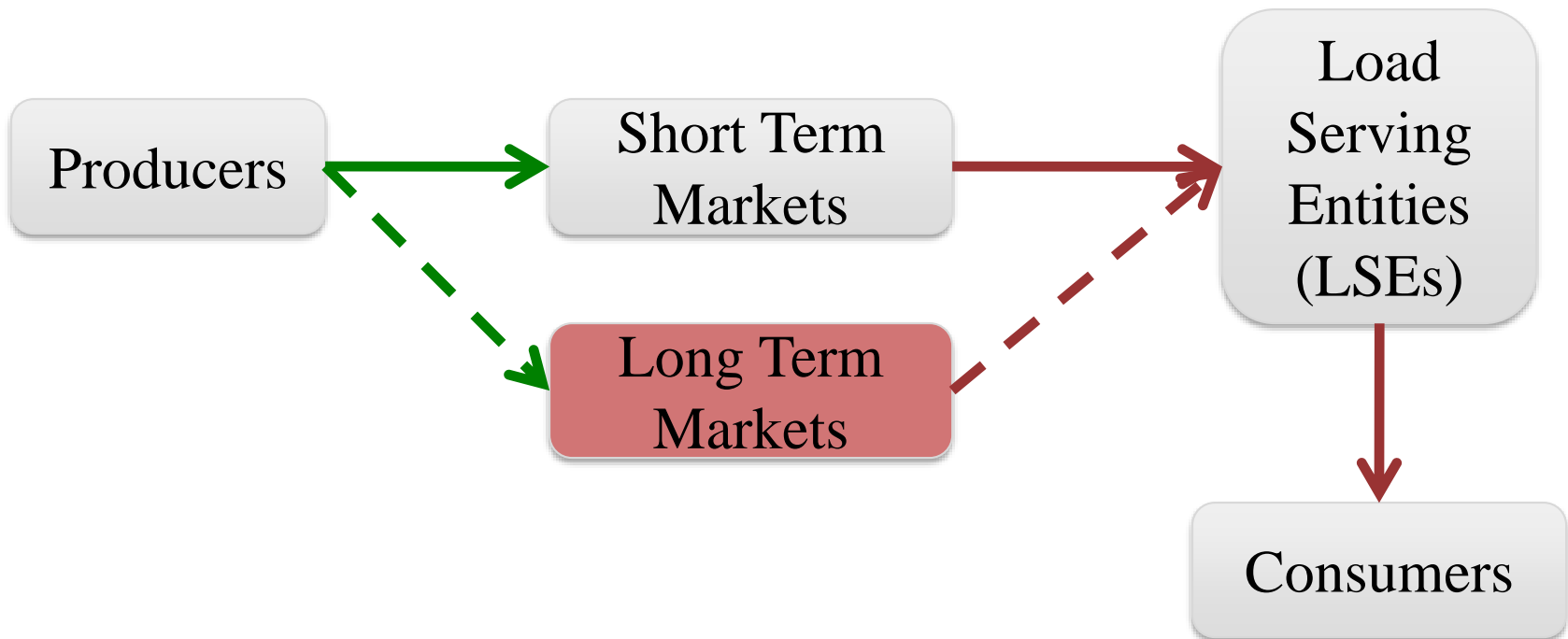


Example: long-term contracting has additional benefits

- Result: Generators produce more, exercise market power less effectively, and the price drops.

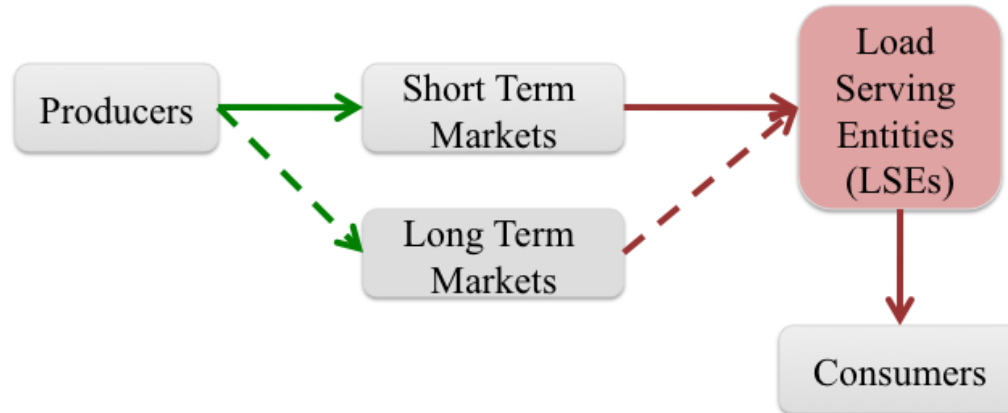


Long-term markets can help reduce market power



How does demand concentration impact forward contracting?

- We understand how supply concentration impacts forward contracting.
- How do the characteristics of the demand side of the market impact forward contracting?



Relevance: Deregulation of electricity providers

Load Serving Entities (LSEs)

Regulated Utilities



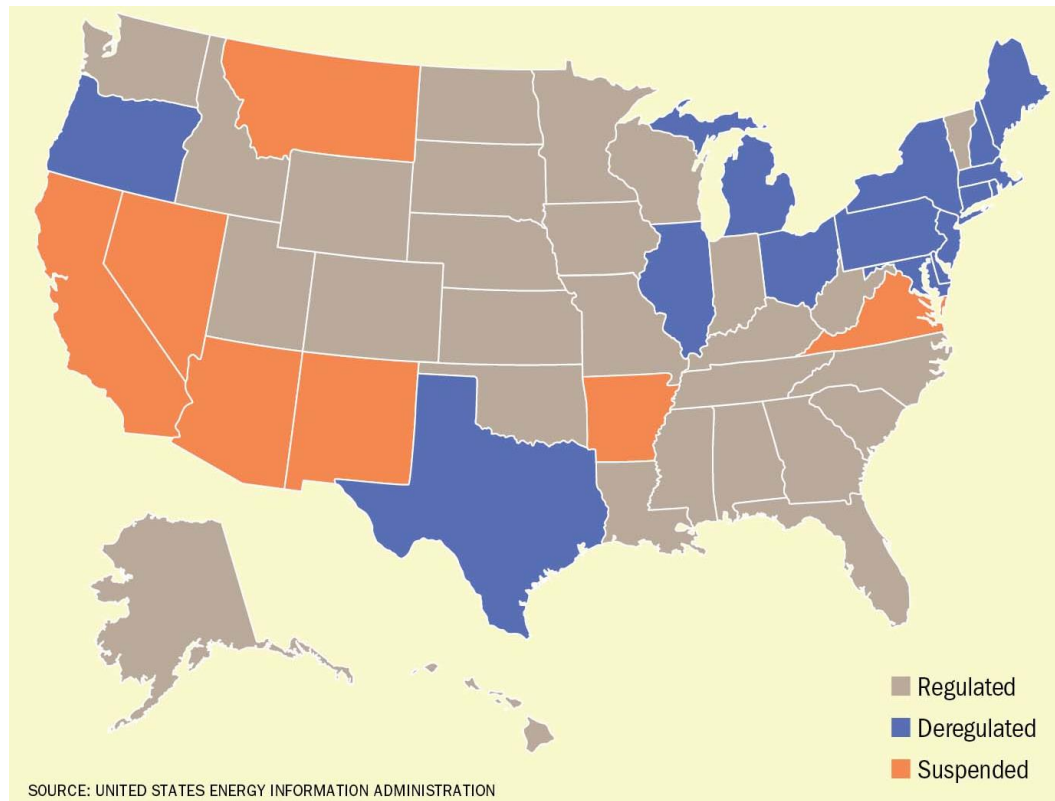
nationalgrid

EVERSOURCE
ENERGY

(New) Competitive Retail
Electric Providers



Relevance: Deregulation of electricity providers



How does demand competition impact forward contracting?

- For a long time, we have known that supply-side competition can impact the level of forward contracting.
 - This impacts market power and prices
- Deregulated retail is increasing the number of LSEs and increasing demand competition.
 - Does this also have an impact?

The model:

- i in $\{1, 2, \dots, N\}$ producers
 - Each has cost of production c_i
- j in $\{1, 2, \dots, M\}$ “consumers” or load-serving entities
 - Each with load share α_j
- Linear inverse demand $P(Q) = t - b Q$

The model: two stage equilibrium

- In the first stage, producers offer forward contracts at the forward contract price p_F .
 - Consumers choose the level of forward contracts they prefer.
- In the second stage, producers sell energy in real-time at the endogenous market price.
- We solve a two-stage subgame perfect equilibrium.



The model: how do we deal with risk aversion?

- We don't explicitly model risk aversion, but rather allow the forward price p_F to vary from the real-time price.
- With no uncertainty / risk aversion, this would allow for unlimited arbitrage opportunities.
- But we treat the forward price as a parameters whose true value is based on risk preferences.

Equilibrium: Second Stage

- Assume producers have equal costs c .
- Assume producers have signed forward contracts with total quantity:

$$Q = \sum_{i=1}^N q_i$$

- Equilibrium production level s_i :

$$s_i = \frac{t - bQ - c}{b(N + 1)}$$



Equilibrium: Second Stage

Demand parameter / max WTP

Quantity of forward contracts signed

Marginal cost of energy production

Equilibrium energy production by producer i

$$s_i = \frac{t - bQ - c}{b(N + 1)}$$

Demand curve slope

Number of producers

The diagram illustrates the equilibrium energy production for a producer i . The equation is $s_i = \frac{t - bQ - c}{b(N + 1)}$. Red arrows point from the following text to the corresponding parts of the equation: 'Demand parameter / max WTP' points to t ; 'Quantity of forward contracts signed' points to Q ; 'Marginal cost of energy production' points to c ; 'Demand curve slope' points to b ; and 'Number of producers' points to N . The text 'Equilibrium energy production by producer i ' has an arrow pointing to the entire equation.

Equilibrium: First Stage

- Assume all consumers are “big enough” to participate.
 - Each have $\sim 1/9$ of market when forward price and average spot price differ by 10%.
- Equilibrium forward contracting:

$$Q = \frac{\mathbb{E}[T]}{b} + \frac{(MN(N+1) - N)c - M(N+1)^2 p_F}{b(MN + M + N)}$$



Equilibrium: First Stage

Average demand (WTP) Marginal cost of energy production Forward contract price

$$Q = \frac{\mathbb{E}[T]}{b} + \frac{(MN(N+1) - N)c - M(N+1)^2 p_F}{b(MN + M + N)}$$

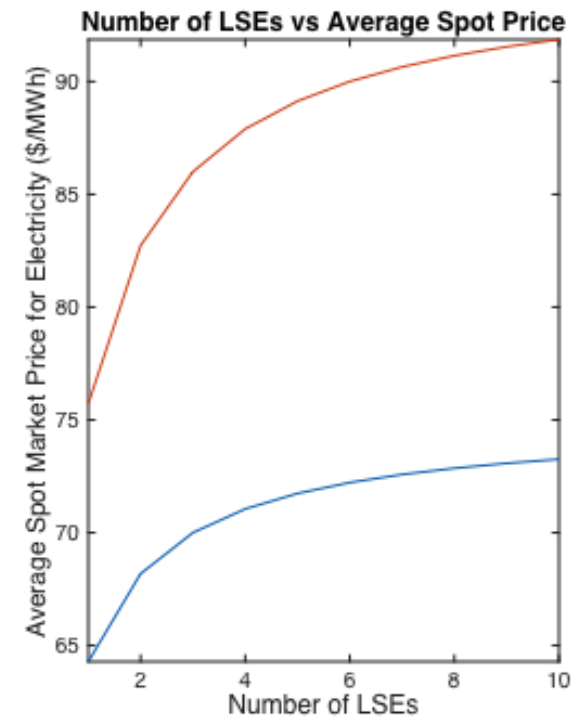
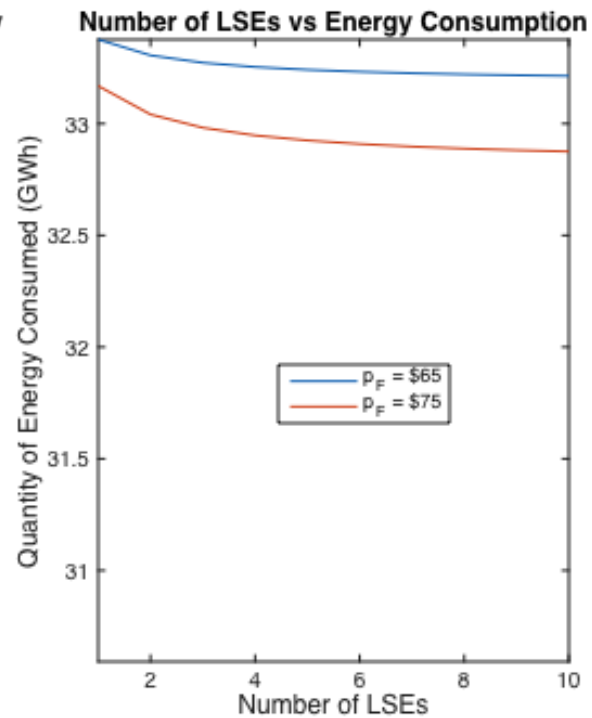
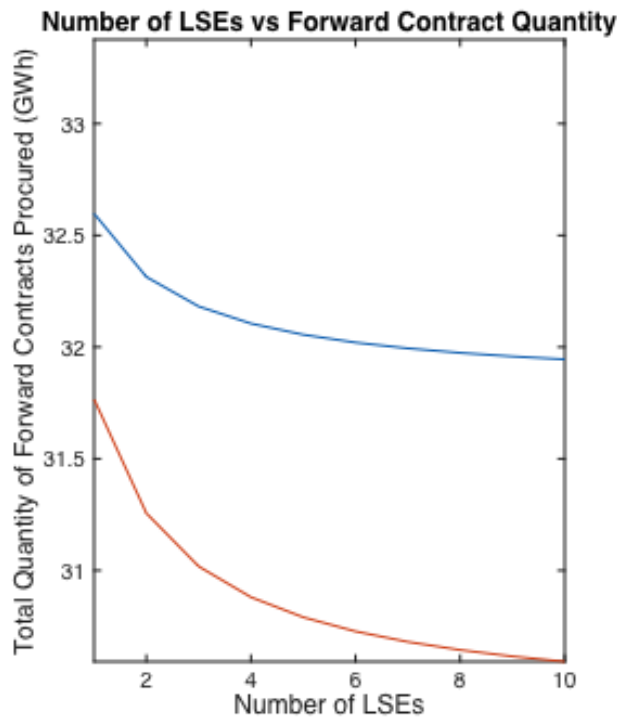
Equilibrium level of forward contracting Demand curve slope Function of number of producers N and LSEs M



Equilibrium: Effects of number of LSEs (M)

- Key Result:
- Assume that the market doesn't entice exit:
 - Either forward or market price is greater than generators' costs
- **Then both the total number of forward contracts and welfare are decreasing in the number of load serving entities.**
 - Simply use derivatives for comparative statics of equilibrium.

Effects of number of LSEs



The idea is simple and intuitive, but perhaps surprising

- LSEs pay to reduce market power in spot markets.
- But, they cannot capture all of the benefits.
 - When they sign forward contracts, it helps reduce market prices in the spot market.
 - Reduced market prices benefit everyone, not just their consumers.
 - When there are more LSEs, they sign less forward contracts and there is more market power.

This an example of theory of the second best

- There is a market distortion
 - Generators have market power
- Therefore, improving competition in retail sector does not necessarily improve the efficiency of the energy market.

A conservative interpretation of these results is meaningful

- It is hard to understand the magnitude of these effects given the challenge of measuring:
 - Risk-aversion
 - Alternative benefits of retail competition
 - Exercise of market power
- Even if small, this suggests potential:
 - Downside of retail competition
 - Benefits of required participation in capacity markets

Thank you

- Questions?