Market Design: Using Economics to Improve Energy Infrastructure Performance

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Market Mechanisms in Infrastructure Services

- World-wide trend to replace explicit regulation with market mechanisms to set prices and determine which firms provide service
- Distinguish between “deregulation” and “restructuring”
  - Industries typically require significant regulatory oversight so “restructuring” is appropriate term
  - Regulatory oversight can decline over time with technological change
    - Telecoms, Postal Delivery, Water, Energy

What is Restructuring Electricity Supply Industry?

- Replace explicit regulation with market mechanisms to set prices and determine how electricity is supplied
  - Price-regulated open access to
    - Inter-state transmission network
    - Local distribution network
  - Market mechanism to set prices for wholesale power and determine which generation units produce energy
  - Market mechanism to set prices for retail electricity and determine which retailers sell electricity to final consumers

North American Electricity Markets

Some Regulation Always Necessary

- Technology for delivering electricity implies
  - One transmission and distribution grid needed for a given geographic area
  - Competition among multiple networks would lead to single dominant network
    - Large fixed cost to construct network
    - Close to zero marginal cost to operate
- In all regimes, monopoly supplier of transmission and distribution services for each geographic area requires regulatory oversight
  - Unregulated monopoly can set prices for use of network that extracts all monopoly profits from electricity supply

Vertically-Integrated Monopoly Regime

- One company owns all generation, transmission network, and distribution network for geographic area
  - Can have long-term supply arrangements with neighboring areas to additional energy
- Given monopoly status, firm could raise prices far above average cost without losing customers
- State-level regulation
  - Sets retail price firm can charge
  - Determines prudency of operation and investment decisions
- Design and operation of regulatory process in vertically-integrated monopoly regime is lawyer and accountant-intensive process

Wholesale Market Regime

- Requires regulatory process to design wholesale market and monitor its performance
  - Process of continuous improvement responding to changing market conditions
- Both aspects of process must recognize that market participants behave strategically
- Market design and market monitoring process can have an enormous impact on market outcomes
- Rather than set prices that are “just and reasonable”, regulator must now implement market rules that result in market prices that are “just and reasonable”
  - Massively more complex task (economists can help!)

What is Market Design?

- Market Design
  - Set number and size of market participants
  - Set rules for determining revenues each entity receives
  - So that ***combined actions of each participant acting in its own best interest yields market outcomes as close as possible to market designer’s desired outcome***
- Many feasible market designs, each of which can yield different market outcomes
  - Research challenge to economists is to figure out market design which maximizes consumer benefits subject to long-term financial viability of industry
  - Focus of much of my research over the past 20 years

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Adam Smith on Market Design

- "It is not from the benevolence of the butcher, the brewer, or the baker, that we expect our dinner, but from their regard to their own interest. We address ourselves, not to their humanity but to their self-love, and never talk to them of our necessities but of their advantages."

  The Wealth of Nations, Book I Chapter II

Market Design Challenge with Price Regulated Firms = Productive Efficiency

- How to cause producers to supply electricity in technically and allocatively efficient manner
  - Technically efficiency = produce the maximum amount of output for a given quantity of inputs—capital, labor, input energy, and materials
  - Allocative efficiency = produce fixed amount of output at least cost given input prices
- Regulator must set prices to allow firm the opportunity to recover incurred cost of production
  - Regulator does not know least cost mode of production
- Will not summarize research on this aspect of market design process today
  - See Wolak (1992) "Econometric Analysis of Asymmetric Information Regulator-Utility Interaction"

Major Design Challenge with Market Pricing = Market Power

- Electricity supply industry extremely susceptible to the exercise of unilateral market power in the short-term market
  - Demand must equal supply at every instance of time at every location in the transmission network
  - All electricity must be delivered through transmission network
  - Non-storability of product
    - Demand varies throughout the day
  - Production subject to severe capacity constraints
  - How electricity is priced to final consumers makes real-time demand elasticity effectively equal to zero
- Implication--Firms can exercise enormous amounts of unilateral market power in a very short time
  - Periods when suppliers have exercised significant unilateral market power have occurred in virtually all wholesale markets

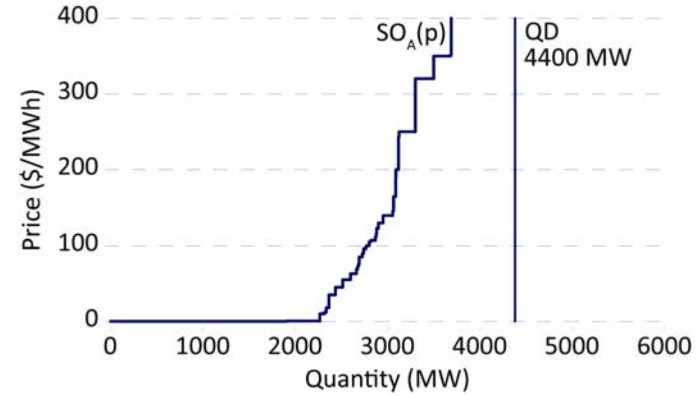
Exercising Unilateral Market Power = Maximizing Profits

- A firm exercising all available unilateral market power subject to the market rules is equivalent to
  - The firm maximizing profits, which is equivalent to
  - The firm's management serving its fiduciary responsibility to its shareholders
- Unilateral market power is like gravity, it is a force influencing outcomes on all wholesale electricity markets
  - Major goal of economic research on market design is how to best manage this force to serve the interests of consumers and maintain long-term financial viability of producers
- Research question-Measure ability and incentive of a supplier to exercise unilateral market power
  - Summarize research on how firms maximize profits in bid-based multi-unit auction markets
  - To know if it is a problem, must be able to measure it

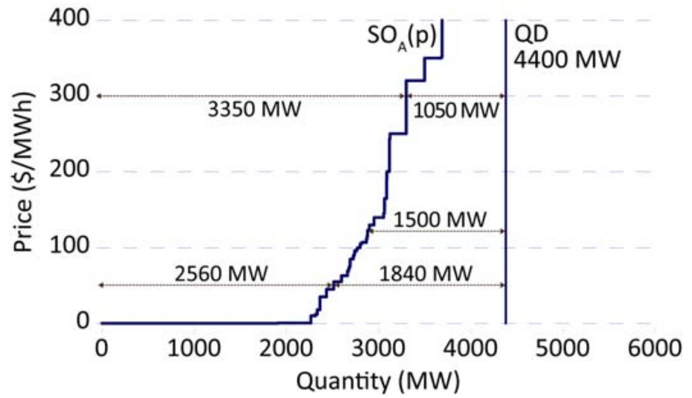
Unilateral Market Power

- A supplier exercises *unilateral market power* by maximizing profits taking the actions of others as given
  - In bid-based wholesale electricity markets, market participants submit offer curve S(p), giving the amount of energy they are willing to supply at each price level in the interval [p(min), p(max)]
    - p(min) = offer price floor
    - p(max) = offer price cap
- In bid-based market, actions of other participants create a residual demand curve that is ex post observable
  - Different from markets for other products—cars, air travel, etc.,
- Residual demand curve for supplier 1 is aggregate demand at each price level less amount all other market participants are willing to make available at that price
  - $S_k(p)$ = offer curve of supplier k, for k=2,3,…,K
  - D(p) = market demand curve
  - $DR_1(p)$ = residual demand curve facing supplier 1
  - $DR_1(p) = D(p) – [S_2(p) + S_3(p) +…+ S_K(p)]$

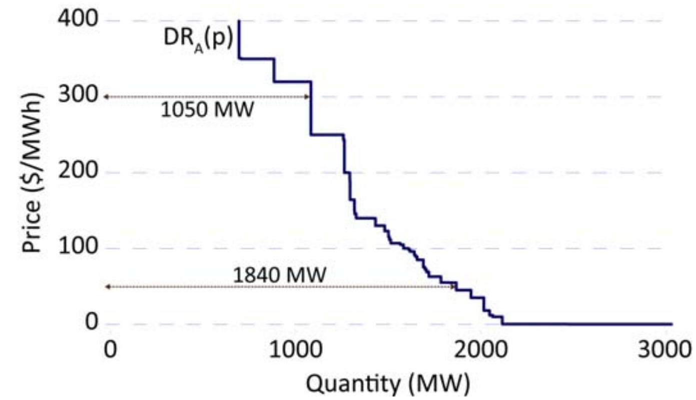
Calculation of residual demand curve: offers of all generators except Firm A



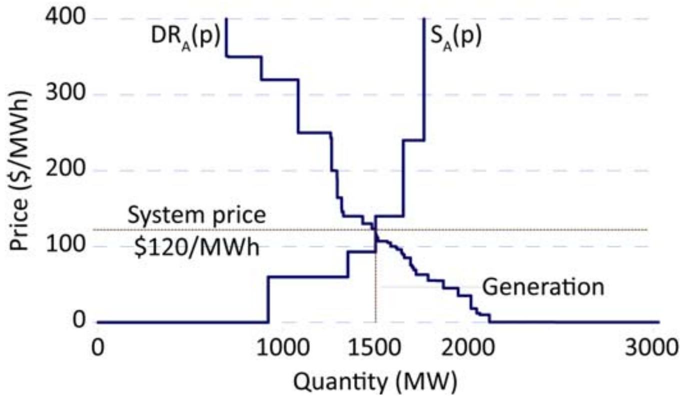
Calculation of residual demand curve for Firm A



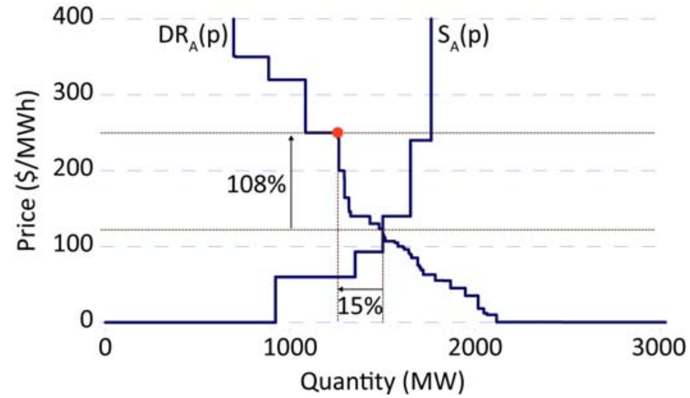
Calculation of residual demand curve for Firm A



Residual demand and offer curves for Firm A



Example showing pricing off the residual demand curve



Variable Profit for Firm A

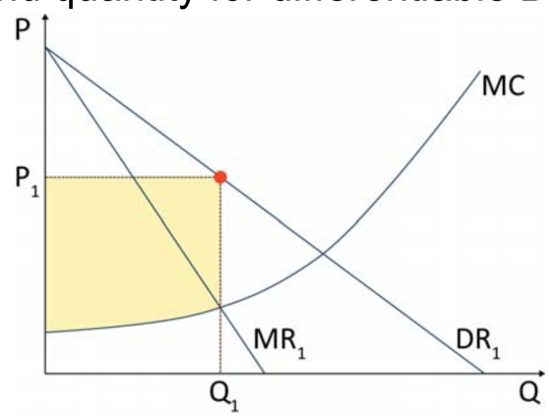
Consider a “merchant supplier” of electricity that only sells in the short-term market

Its variable profits for one period are:

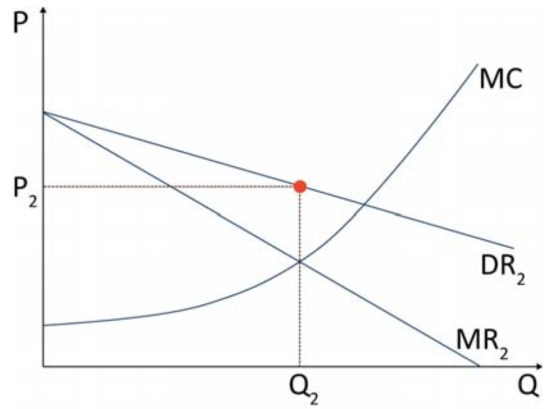
$$\Pi(p) = DR(p)p - C(DR(p)),$$

where C(q) is the variable cost of output level q

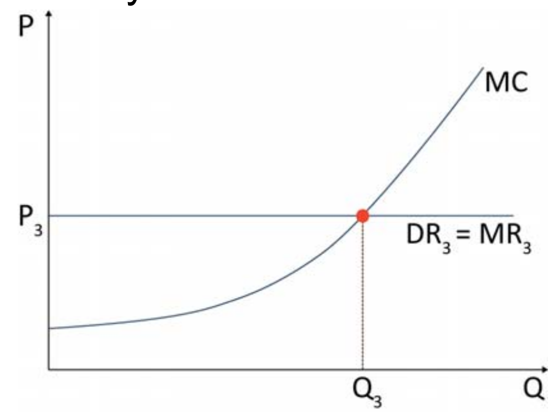
Profit-maximizing choice of price and quantity for differentiable DR



Profit-maximizing choice of price and quantity with elastic residual demand



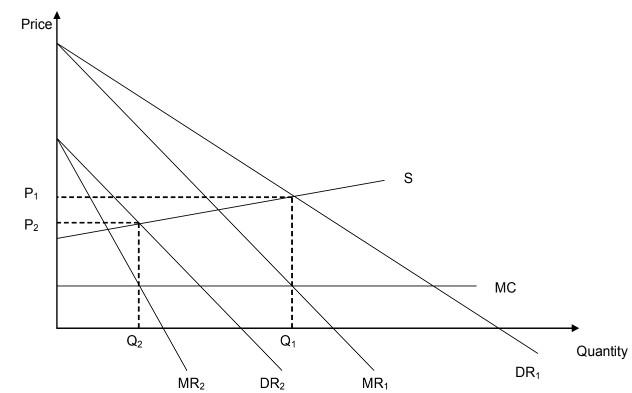
Profit-maximizing choice with perfectly elastic residual demand



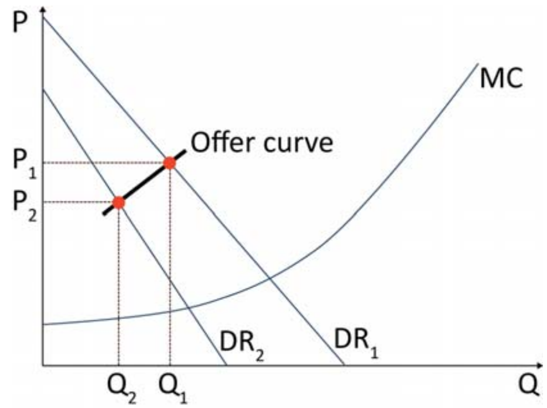
Simplified Model of Expected Profit Maximizing Offer Behavior

- Supplier does not know residual demand curve it will face when it submits offers
  - Suppliers submits offers simultaneously
- Suppliers knows distribution of residual demand curves that they face
  - Supplier submits offer curve that sets market-clearing price and quantity sold for each residual demand realization to maximize expected profits with respect to distribution of residual demand curve realizations that firm faces
  - For simplified model, but not in general, this means connecting ex post profit-maximizing price and quantity pairs for each possible residual demand realization to obtain offer curve

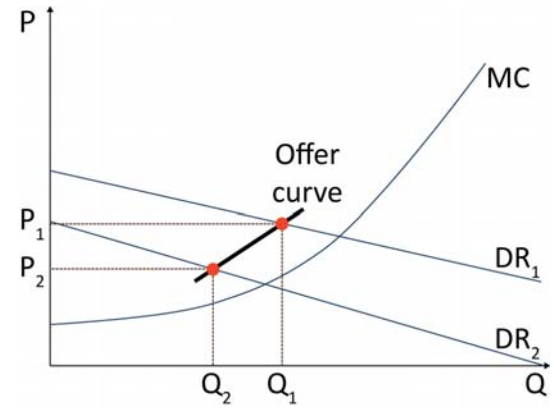
Expected profit-maximizing offer curve for two residual demand realizations



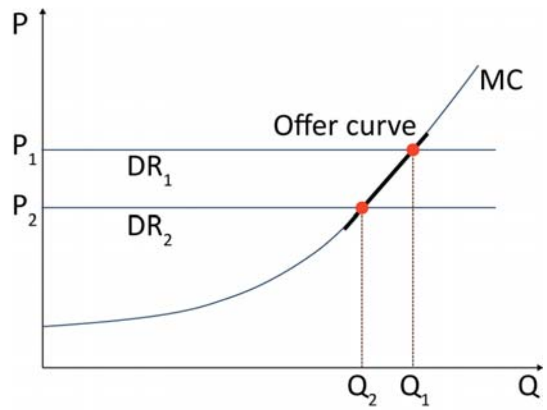
Derivation of offer curve with steeper residual demands



Derivation of offer curve with flatter residual demands



Derivation of offer curve with perfectly elastic residual demand



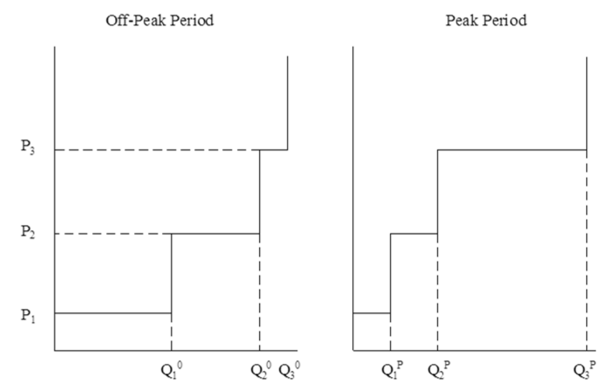
Goal of Market Design Process

- Make distribution of residual demand curves faced by all suppliers as flat as possible
  - Then all suppliers have unilateral incentive to submit offer curves into wholesale market as close as possible to minimum cost marginal cost curve
- Major market design parameters
  - Fixed-price forward contracting by suppliers
  - Active participation of final demand
  - Transmission network expansions
  - Pricing that reflects all relevant operating constraints
  - Integration of financial market for energy with physical market for energy
- Summarize research challenges in each of these areas—But first, do suppliers really behave as models predict?

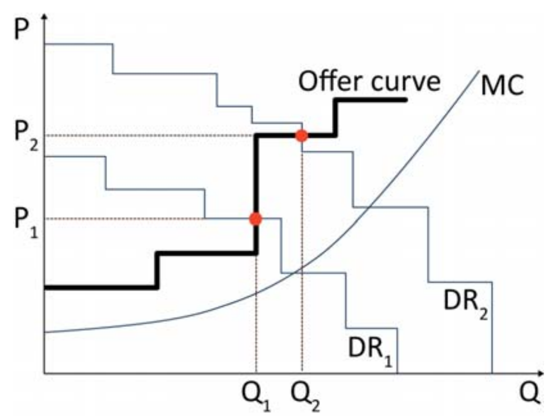
Do Suppliers Behave as Predicted by this Model?

- Wolak (2000) develops model of expected profit maximizing offer behavior that accounts for actual market rules
  - Suppliers submit step function offer curves at generation unit level
  - Suppliers face step function residual demand curves
- Suppliers choose price and quantity steps for each generation unit to maximize expected profits
  - Yields a set moment restrictions that can be constructed from offer data and market-clearing price and quantity outcomes
- Wolak (2003a) tests the validity of these moment restrictions and finds no evidence against the null hypothesis of expected profit-maximizing offer behavior
  - This model of expected profit maximizing behavior has been used by Hortascu and Puller (2008), Kastl (2011), Reguant (2011)

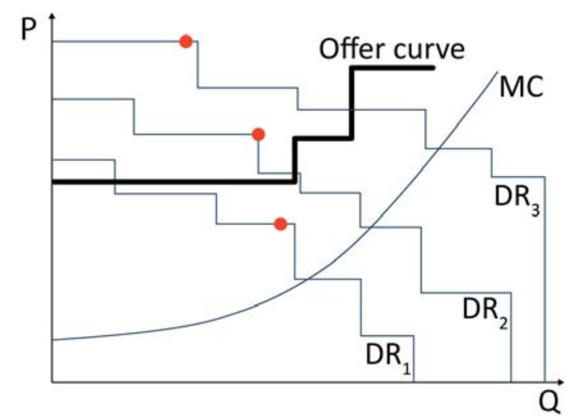
Feasible Bid Curves in Australian Electricity Market



Impact of step functions on optimal offer curve



Expected profit-maximizing offer curve



Measuring Ability and Incentive to Exercise Unilateral Market Power

- Wolak (2000) develops measures of ability to exercise unilateral market based on residual demand curve
- Wolak (2003b) computes these measures for the five large suppliers in California wholesale electricity market for summer of 1998 to 2000
  - For all five suppliers, unilateral ability measures are orders of magnitude higher for Summer 2000 relative other two summers
- Residual demand curve-based methods for measuring unilateral market power in wholesale electricity markets have been adopted by all US market monitors

Measuring Market Performance

- Borenstein, Bushnell and Wolak (2002) derive measure of market performance by comparing actual market prices to those that would exist if no firm had ability to exercise unilateral market power
  - Apply procedure to California market from 1998 to 2000 and find modest to very small deviations from competitive benchmark pricing in 1998 and 1999
  - Extremely large deviations from competitive benchmark pricing in summer and autumn of 2000
    - Results are consistent with results in Wolak (2003b) for unilateral ability to exercise market power five largest suppliers in California
- This approach to measuring market performance has been adopted by all US market monitors and Federal Energy Regulatory Commission (FERC)
  - Difference between actual and competitive benchmark price provides measure of "health" of industry
  - Many examples from actual markets of high prices consistent with competitive benchmark pricing

Market Design

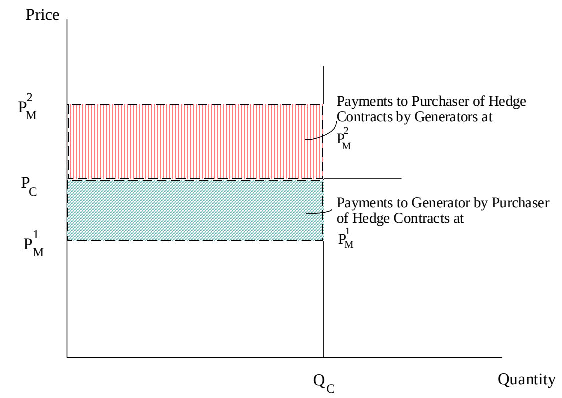
- Market performance measures are useful for determining when market power is likely to exert a substantial influence on market outcomes and for quantifying cost of exercise unilateral market power
  - Recent FERC decision of refunds to California during electricity crisis are based on Borenstein, Bushnell and Wolak (2002) approach
- For same underlying market structure, numbers of firms and relative sizes of generation capacity owned, how can market performance be improved?
  - Face suppliers with flatter distribution of residual demand curves

Fixed-Price Forward Market Obligations to Limit Incentive to Exericse Unilateral Market Power

Forward Financial Instruments

- Fixed-price forward financial contract
  - Contract that obligates seller to "deliver" to buyer a fixed quantity of MWh at an agreed-upon date in the future at an agreed upon price
- Because electrons cannot be delivered to specific locations in the network, a forward contract obligates the seller to guarantee the price at which buyer of contract can purchase agreed upon quantity of energy at that location and date
- If seller agrees to "deliver" 100 MWh at $50/MWh at node A at date T, then the seller agrees to guarantee that buyer of contract can purchase 100 MWh at node A at date T for $50/MWh, regardless of realized spot price at that node
- Swap contract is a sequence of forward contracts
  - If a supplier sells QC swap contracts at a price equal to PC, then the seller's profit or loss from this action in period t is (PC – p(t))QC, where p(t) is the spot price on during delivery period t

Two-Sided Hedge Contract Payments Streams



Impact of Fixed-Price Forward Market Obligations

Expression for the vertically-integrated firm's profits can be re-written as:

$$\Pi(p) = (P_R - \tau - c)Q_R + (P_C - c)Q_C + [DR(p) - (Q_R + Q_C)](p - c),$$

which can be re-written as

$$\Pi(p) = DR_F(p)(p-c) + F$$

where $F = (P_R - \tau - c)Q_R + (P_C - c)Q_C$

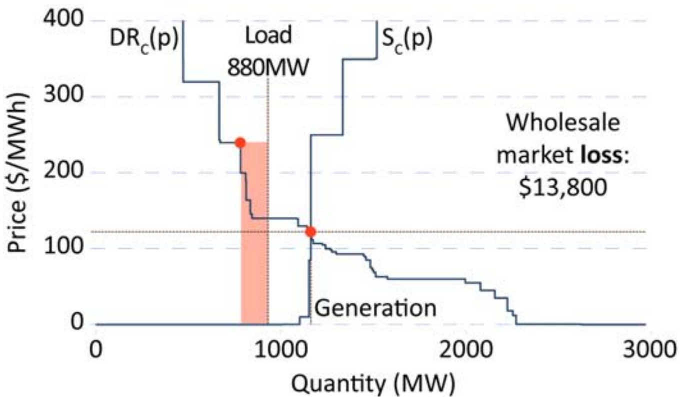
$DR_F(p) = [DR(p) - (Q_R + Q_C)]$

Note that supplier only earns or pays short-term price, p, for difference between short-term market sales and fixed-price forward market obligations

Dramatically alters firm's incentive to exercise market power

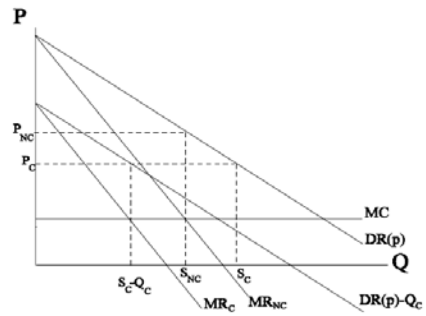
P_R = retail price, p = wholesale price, Q_R = retail load obligation, c = marginal cost, P_C = price of fixed-price forward contracts, Q_C = net forward contract quantity, τ = marginal cost of electricity retailing

Importance of contract obligations for the incentive to increase price



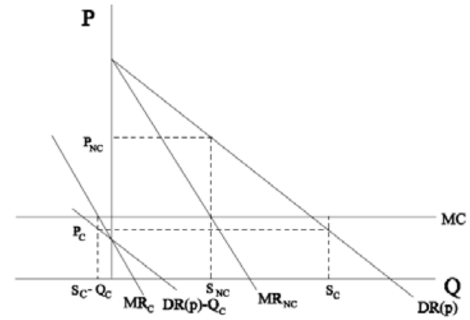
Long on Contracts and Constant MC

$\pi(p) = (DR(p) - QC)(p - MC) + (PC - MC)QC.$



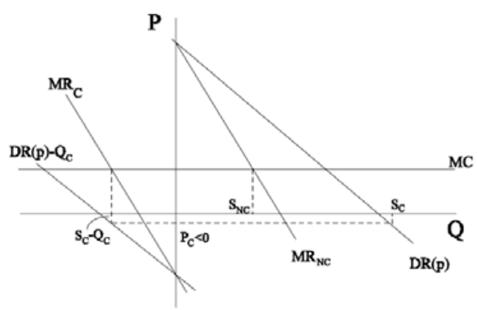
Short on Contracts and Constant MC

$\pi(p) = (DR(p) - QC)(p - MC) + (PC - MC)QC.$

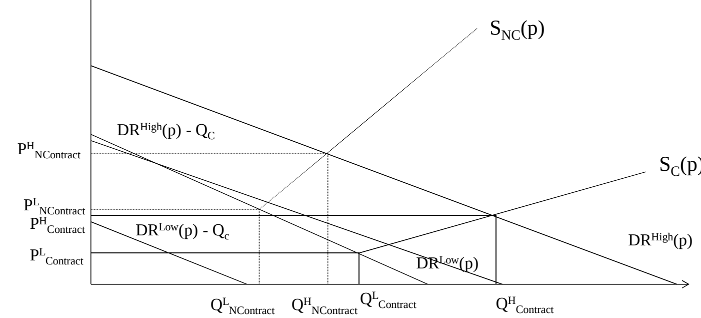


Extremely Short on Contracts

$\pi(p) = (DR(p) - QC)(p - MC) + (PC - MC)QC.$



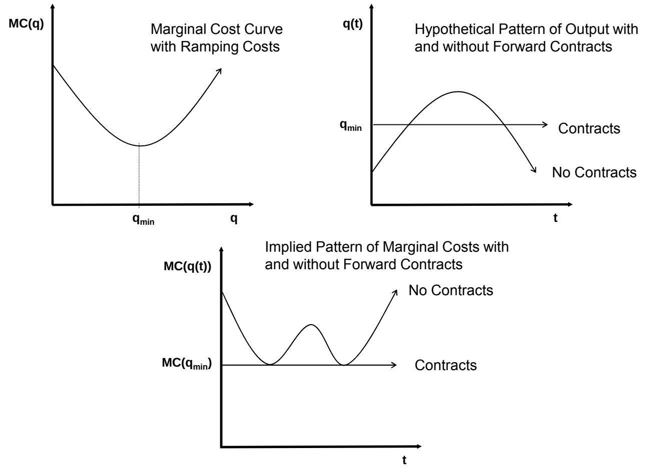
Profit-Maximizing Bidding With $Q_C > 0$ and $Q_C = 0$ (For Simplicity Assume MC = 0)



Research Question

- If suppliers know that signing fixed-price forward contracts limits their incentive to exercise unilateral market power why do they sign them?
  - 1) Manage short-term price risk—In a hydro dominates system with there is too much water prices could be low for an entire year
  - 2) Because of fear that competitors will sign contracts and become more aggressive bidders in short-term market
  - 3) Because it pre-commits supplier to a lower cost pattern of output due to non-constant marginal cost of production during the day
- Wolak (2007) quantifies production cost saving from pre-commitment it to a less volatile pattern of output
  - Estimates daily multi-output cost function from expected profit-maximizing offer behavior that includes potential for ramping costs and finds evidence in favor of the existence of these costs
    - Output in period t impacts cost of production in other periods of day
  - Compares daily cost from expected profit-maximizing pattern of output with no fixed price forward contracting to actual cost with contracting

Benefits of Smooth Output Patterns



Transmission Expansions to Limit Ability of Suppliers to Exercise Unilateral Market Power

Transmission Expansions

- Re-structuring and role of transmission network
  - Before—Transmission network improves performance of *imperfectly regulated vertically-integrated utility*
  - After—Transmission network improves performance of *imperfectly competitive wholesale market*
- Least-delivered-cost-to-consumers transmission network is not the same under both regimes
  - Transmission network configuration impacts ability of expected profit-maximizing suppliers to impact wholesale prices to increase their profits
- Additional transmission capacity can increase number of hours per year that a strategic supplier faces competition from all suppliers in market
  - This causes more competitive behavior by strategic suppliers (offer curve closer to marginal cost curve)

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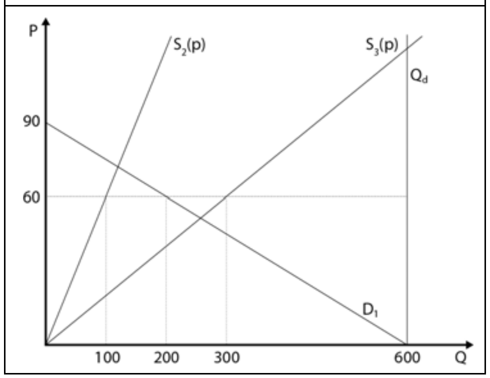
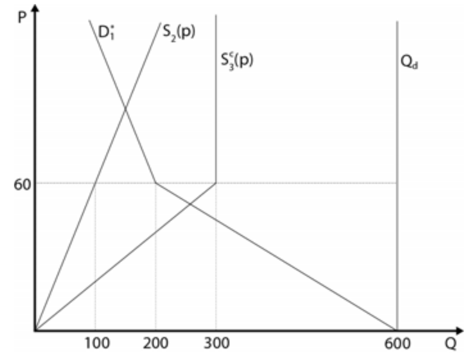
Construction of Residual Demand Curve of Firm 1



Residual Demand of Firm 1 with Transmission Constraints



Transmission Constraints and Residual Demands

- Transmission constraints causes the offers of some generation units to be eliminated from the actual residual demand curve
  - Increases slope of residual demand curve
  - Increases value of residual demand for a given price level
- Increases ability of supplier to exercise unilateral market power
- Conclusion—One benefit of a transmission expansion is facing suppliers with distribution of flatter residual demand curves
  - Suppliers face greater competition and therefore have less ability to exercise unilateral market power
- Research Question—How will offer curves of a strategic supplier change if it faces a flatter distribution of residual demand curves caused by transmission expansion and how much lower will market prices be as a result of the resulting change in offer behavior by suppliers?
  - Wolak (2012) calls this the “competitiveness benefits” of a transmission expansion

Measuring Competitiveness Benefits of Upgrades

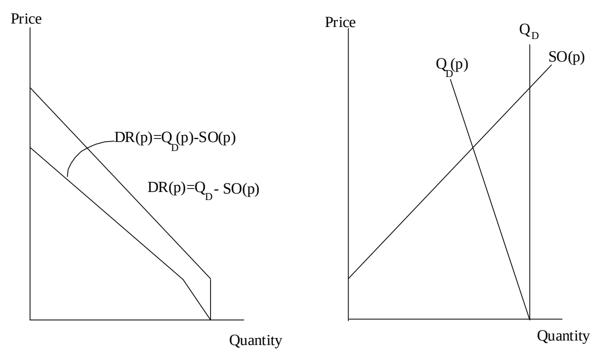
- Wolak (2012) quantifies magnitude of competitiveness benefit for actual wholesale electricity market
  - Alberta wholesale electricity market
  - Sample period January 1, 2009 to December 31, 2011
- Empirical results find sizeable competitiveness benefits of transmission investments that eliminate perception of transmission congestion by strategic suppliers
  - Results point to benefits being larger as share of intermittent renewable resources grows
  - Competitiveness benefits are specific to concentration of generation ownership, pricing mechanism, and configuration of existing transmission network in market
- Methodology can be applied to any ownership structure, pricing mechanism, existing network, configuration, and proposed upgrade
  - Goal is to incorporate this source of benefits into transmission planning processes

Symmetric Treatment of Load and Generation to Manage Intermittency and Limit Ability of Suppliers to Exercise Unilateral Market Power

Retail and Wholesale Market Interactions

- Symmetric treatment of producers and consumers of electricity
  - From perspective of grid reliability, a consumer is a supplier of "negawatts"--SN(p) = D(0) - D(p)
- Default price for all consumers should be hourly wholesale price
  - Consumer is not required to pay this price for any of its consumption, just as generator is not required to sell any output at spot price
  - To receive fixed price, consumer must sign a hedging arrangement with load-serving entity or electricity supplier
- There is nothing unusual about hedging spot price risk
  - Health, automobile and home insurance, cellular telephone

Benefits of Symmetric Treatment



Benefits of Active Participation

- Why active participation of consumers is essential
  - Managing intermittency
  - Managing unilateral market power
- Three necessary conditions for active participation
  - Interval meters, adequate information, dynamic pricing
- The role of information in active participation
  - Information experiment—Kahn and Wolak (2013)
- The role of dynamic pricing in active participation
  - **Dynamic Pricing** versus **Time-of-Use Pricing**
  - Symmetric treatment of load and generation
  - PowerCentsDC Dynamic Pricing Experiment
    - Hourly Pricing (HP)
    - Critical Peak Pricing (CPP)
    - Critical Peak Pricing with Rebate (CPP-R)
  - Day-ahead versus real-time dynamic pricing
    - Automated dynamic demand response
    - The role of symmetric treatment of load and generation

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Regulatory Barriers

- Substantial state-level regulatory barriers to active participation
  - "Consumers must be protected from short-term price risk"
  - "Electricity is a right, not a commodity"
    - Wolak, Frank (2007) "Managing Demand-Side Economic and Political Constraints on Electricity Industry Re-structuring Processes," on web-site.
- Stakeholders in regulatory process realize few, if any, benefits from active participation
  - Most lose--Regulatory staff, Generation unit owners, Distribution utilities
- Only consumers realize benefits
  - Wolak, Frank (2010) "An Experimental Comparison of Critical Peak and Hourly Pricing: The PowerCentsDC Program," on web-site
  - Wolak, Frank (2006) "Residential Customer Response to Real-Time Pricing: The Anaheim Critical-Peak Pricing Experiment," on web-site

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Politically Acceptable Dynamic Pricing

- Major complaint with dynamic retail pricing is that customers cannot respond to hourly wholesale prices
  - Difficult to determine when is best time to take action
- If taking action is costly and price increase is one hour in duration, a very large price spike is needed to cause most customers to respond
  - For residential customer with (2.5 KW) flat load shape, a large price spike is needed to overcome $5 cost of taking action to reduce demand by 20 percent
    - $10,000/MWh for a 0.5 KWh demand reduction for 1 hour
  - Longer duration of high prices requires smaller increase in prices
    - $5,000/MWh average price for 0.5 KWh demand reduction for 2 hours
- Mechanisms that address cost-of-taking-action problem can increase willingness of consumers to participate
  - Critical Peak Pricing (CPP) is a popular way to do this

Politically Acceptable Real-Time Pricing

- Critical Peak Pricing—Customer purchases according to usual fixed-price tariff or nonlinear price tariff during all hours of each day
- Customers face risk of Critical Peak Pricing (CPP) day
  - Retailer commits to no more than N (N ≈ 10) CPP days in a pre-specified time interval
  - During peak-period of a CPP day, customer pays a much higher price for electricity
    - Strong incentive reduce demand during this time period
    - Peak period is typically 4 to 6 hours during day
    - *Overcomes cost of taking action problem by committing to a sustained period of high prices*
- Potential "moral hazard" problem for retailer
  - Can declare CPP day to manage short-term wholesale energy purchase costs due to inadequate forward market procurement
  - Retailer has incentive to use all available CPP days because these are high profit days for retailer
    - CPP price much higher than average retail price

Politically Acceptable Real-Time Pricing

- CPP with rebate is more popular with consumers because it addresses this moral hazard problem
  - Consumption during peak hours of CPP days receives a rebate relative to household's reference consumption, if its actual consumption is less than reference consumption
  - Retailer faces risk that total rebates paid will be more than wholesale energy procurement cost savings
    - If CPP period wholesale price is $300/MWh (implicit in retail price), then if wholesale price is below $300/MWh, retailer loses money paying for rebate
    - Retailer only wants to declare CPP days when rebates paid are less than wholesale cost savings

Politically Acceptable Real-Time Pricing

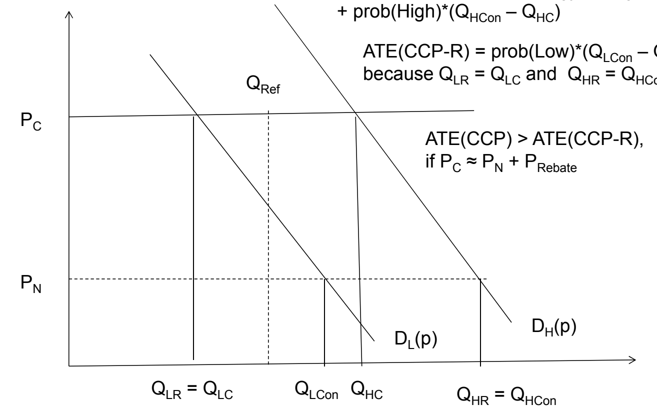
- CPP with rebate (CPP-R) implies that customers *guaranteed not to pay more* than they would have under baseline tariff
  - "You can't lose from rebate mechanism"
- Customers have *the option to quit* with no cost implications if it is too difficult to reduce their consumption
  - Pay for consumption above reference level during CPP period at fixed retail price
- Under CPP-R, marginal price of fixed retail price plus rebate is only relevant if consumption is less than reference level
  - Only "carrot" of rebate is used under CPP-R
- Under CPP, both "carrot" and "stick" used
  - Higher price for all consumption during CPP period

Option to Quit and Average Treatment Effect

$ATE(CCP) = prob(Low)*(Q_{LCon} – Q_{LC})$
$+ prob(High)*(Q_{HCon} – Q_{HC})$

$ATE(CCP\text{-}R) = prob(Low)*(Q_{LCon} – Q_{LC})$,
because $Q_{LR} = Q_{LC}$ and $Q_{HR} = Q_{HCon}$

$ATE(CCP) > ATE(CCP\text{-}R)$,
if $P_C \approx P_N + P_{Rebate}$



PowerCentsDC Experiment--Wolak (2010)

- Do customers respond to high real-time price warnings and CPP events?
  - Treatment effect of discrete event (price elasticities will come later)
- How do these price responses differ across customer classes?
  - Regular (R) versus All Electric (AE) customers
  - Low-income (RAD) versus regular (R) customers
  - Summer versus winter
- Does "cost of taking action" limit demand response of HP customers versus CPP customers?
- Does "option to quit" result in CPP response greater than CRR with rebate (CPP-R) response?
- Do Smart thermostats boost demand response?

Answers to Research Questions

- Price responsiveness
  - Both R and AE customers reduce their consumption in response to CPP and HP hours
  - Effect (% reduction in consumption from CPP or HP event) larger for AE customers relative to R customers in both summer and winter
  - For R customers effect primarily confined to summer periods
- RAD customers (Low Income)
  - RAD-R and RAD-AE customers reduce their consumption in response to CPP event
    - Treatment effects are larger than CPR treatment effect for R and AE customers
- Difficult to see evidence of "cost-of-taking action" for hourly pricing
  - Hourly pricing effect is between 1/3 to ¼ of size of CPP effect consistent with HP warning being for energy prices that are 1/3 to ¼ the size of CPP energy price
  - For AE customers large full-sample and winter HP warning effect

Answers to Research Questions

- Strong evidence in favor of option-to-quit effect
  - For both R and AE customers CPR effects is ½ to ¼ of CPP effect
  - For RAD customers not possible to examine this hypothesis because only CPR treatment was applied to RAD-R and RAD-AE
- Smart thermostat significantly enhances treatment effect
  - Almost doubles effect for CPP treatment for AE customers
  - Also increases treatment effects for for R customers
  - Emphasizes importance of providing information with technology

Locational Marginal Pricing to Improve Fit Between Financial Market and Physical Realities of Grid to Limit Ability of Suppliers to Exercise Unilateral Market Power

Physical Realities of Transmission Network Operation

- If suppliers know that model used to set prices is inconsistent with actual reality of how grid operates they will take actions to exploit this divergence
- Classic example—Financial market assumes no transmission constraints in network in determining market price
  - Realities of network operation imply unrestricted merit order is not feasible with actual network configuration
  - Typically use non-market mechanism to
    - Pay suppliers above market price to supply more
    - Buy power from constrained suppliers to produce less
  - Suppliers quickly figure out how to take advantage of this divergence between financial market and physical realities of system operation for their financial gain

Locational Marginal Pricing

- Prices all relevant network and other operating constraints
  - Minimize as-bid cost to meet demand at all locations in network subject to all relevant network and other operating constraints
  - Limits divergence between financial market and physical realities of grid operation
  - Locational marginal price (LMP) is increase in optimized value of objective function associated with increase withdrawal of energy at that location by 1 unit
- All US markets currently operate LMP markets
- Wolak (2011) takes advantage of switch from zonal pricing market in California to nodal pricing market in April of 2009 to measure change in cost of meeting demand under zonal versus LMP market

Locational Marginal Pricing

- Wolak (2011) finds
  - 2.1 percent reduction in total variable cost of associated with supplying same amount of energy under LMP versus zonal market
  - 2.5 percent reduction in total BTUs of fossil fuels associated with supplying same amount of electrical energy under LMP versus zonal market
- Annual variable cost savings associated with switch to LMP market estimated to be on the order of $105 million
- Major factor in explaining savings is fewer opportunities for suppliers to exploit divergence between how financial market set prices and how physical network is operated in terms which units are dispatched at what levels

Properly Designed Purely Financial Transactions in Wholesale Market Can Improve Operation of Electricity Grid

Convergence Bidding

- All US wholesale electricity markets operate a day-ahead forward market and real-time spot market (called multi-settlement market)
  – Both markets trade "megawatt-hours (MWhs) of energy delivered in hour h of day d".
- Day-ahead and real-time prices are set at thousands of locations (nodes) in the transmission network using locational marginal pricing market mechanism
  – Prices all relevant transmission network and other operating constraints
- Jha and Wolak (2013) examine the impact of introducing a purely financial product that allows trading of differences between day-ahead and real-time prices
  – Virtual Bidding (EVB) or Convergence Bidding
  – Allows all market participants to take a financial position on state of transmission network and generation units in real-time

Convergence Bidding

- Virtual bids are identified as such to system and market operator
- Incremental (INC) virtual bid is a purely financial transaction that is treated just like an energy offer curve in the day-ahead market.
  – Amount sold in day-ahead market must be purchased in the real-time market as a price-taker
  – Profit from day-ahead sale of 1 MWh INC bid is ($P_{DA} – P_{RT}$)
- Decremental (DEC) virtual bid is a purely financial transaction that is treated just like an demand bid curve in day-ahead market.
  – Amount purchased in day-ahead market must be sold in real-time market as a price-taker
  – Profit from accepted 1 MWh DEC bid is ($P_{DA} – P_{RT}$)
- Market participants can now use these products to take advantage of expected differences between day-ahead and real-time prices
  – Virtual bids impact mix of generation units committed in day-ahead market
  – Virtual bids are submitted at nodal level in California and most US markets

Convergence Bidding

- Jha and Wolak (2013) find that introduction of nodal-level convergence bidding significantly
  - Reduced average price differences between day-ahead and real-time
  - Reduced volatility of difference between day-ahead and real-time prices
- Convergence bidding also reduced cost of serving load in California ISO control area
  - Approximately 2 percent reduction in cost of serving load
- Purely financial transactions that impact physical configuration of generation units scheduled in day-ahead market reduces total cost of serving load
  - Profit-maxmizing actions of purely financial participants can improve efficiency of system operation!

Conclusions

- Introduction of market mechanisms first step in market design process, because details of market rules matter
  - New regulatory paradigm where focus is on setting market rules that provide incentives for least cost production and prices that only recover least cost mode of production
  - Economist and engineer-dominated process versus former lawyer and accountant-dominated process
- Market design is a process of continuous improvement
  - Continuous market-monitoring process based on market outcome data key to identifying design flaws and quickly correcting them
- Re-structuring does not eliminate need for regulatory oversight, just a change in form
  - In all aspects of industry, regulator must become more sophisticated (and perhaps more intrusive)
  - Understand what incentives are created by each aspect of market design

Conclusions

- Theoretical and empirical economic research can contribute to all aspects of market design process
  - Forward market and short-term market interactions
  - Transmission expansion and planning policies
  - Design of retail pricing policies
  - Pricing congestion and other relevant operating constraints
    - Particularly important in a world with a growing share of intermittent renewable resources
  - Financial and physical market interactions
  - Carbon and energy market interactions
- Technology of electricity production and delivery continually changing and environmental constraints are increasingly relevant, so market design must adapt
  - Long-term employments for energy economists!

All papers cited are on web-site

http://www.stanford.edu/~wolak