

Designing Competitive Wholesale Electricity Markets for Latin American Countries

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Outline of Talk

- Challenges Facing Electricity Supply Industries (ESIs) in Latin American Countries (LACs)
- Market Design Problem
 - Generic market design problem
 - Necessity of market design problem
- Lessons from Developed Countries for LAC Market Design
- Lessons from LACs for Market Design
- Challenges Specific to Brazil, Chile, Colombia, Honduras and Mexico
- Recommended Baseline Market Design for LACs

Challenges Facing ESIs in LACs

- **Rapid Demand Growth and Future Supply Adequacy**
 - Between 5%-7% annual load growth in LACs
 - 2%-3% annual load growth in developed countries
 - Funding new generation capacity with government revenues or backed by government guarantees leaves less funding for important social programs
- **Little experience with regulatory oversight or competition law**
 - Credibility problem for assuring private entrants they can recover sufficient revenues to justify initial investment
- **Government subsidizes electricity consumption for some or all customers**
 - Two types of subsidies because most countries are operating at the point where $MC > AC$ given rapid demand growth
 - Price charged to consumers does not equal marginal cost of last unit produced
 - Price charged to consumers may not cover average cost of all units produced

Challenges Facing ESIs in LACs

- Management of government-owned firm faces divergence set of incentives
 - Like all government-owned entities it has limited incentive to choose least-cost mode of supply for present production and new capacity investments
- Many households do not have access to electricity
 - Requires expanding distribution network
- Particularly for Central American countries, small peak demand relative to minimum efficient fossil-fuel plant size
 - Difficult to create sufficient number of suppliers for a competitive spot market
 - Difficult to justify some fixed-cost investments in market infra-structure

Market Design Problem

- Maximize market designer's payoff function (which depends on market outcomes) by setting
 - Number and size of market participants
 - Rules for determining revenues each firm receives
- Subject to constraints that *all market participants will choose their strategies to maximize payoffs given rules set by market designer* (Incentive constraints)
- Competitive market may not always maximize market designer's payoff function

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

Principal/Agent Problem

- Market Design Problem
 - Multiple Layer, Multiple Principal-Multiple Agent Problem
- $W(x,s)$ = Payoff of Principal (regulator or government)
 - $x(a,s)$ = observable market outcomes x (output produced)
 - s = state of world s (level of market demand)
- $V(a,y,s)$ = Payoff of Agent (firm)
 - a = actions (bids, maintenance, employment, fuel use decisions)
 - $y(x)$ = compensation function set by principal (how firms are paid for actions they take)
- Usually assume that Principal
 - Cannot observe all actions a or true state of world s
 - Can observe $x(a,s)$ outcome that depends on a and s

Principal-Agent Theory

- Principal's problem is to choose function, $y(x)$, to maximize $E_s[W(x,s)]$, its expected payoff, subject to
 - (1) Individual rationality of agent--agent will choose a to maximize $V(a,y(x),s)$ or its expectation given $y(x)$ and s
 - (2) Participation constraint-- $y(x)$ must allow agent to achieve reservation payoff or expected payoff V^*
- Regulator must recognize that once $y(x)$ is set, agent will choose a to maximize its payoff function
- Regulator must set $y(x)$ to allow agent to achieve at least reservation payoff V^*
 - Firms must find it in their self-interest to participate in market

Theory of Market Design

- Market Design Requires Solving Hierarchical Principal-Agent Problems at Multiple Levels
- First Level
 - Principal = Market Designer
 - Usually government and/or regulator
 - Agents = Firms and consumers in market
- Second Level within Firm
 - Principal = Owner of Firm
 - Agent = Management of Firm
- Two dimensions of market design
 - Markets versus regulation
 - Government-ownership versus private ownership

Optimal Market Design

- Proposed objective function for market designer
 - Lowest possible average annual delivered price consistent with financially viable industry
 - In economist's language--maximize consumer surplus subject to marginal firm in industry earning zero economic profit
- Minimum requirement for competitive market is lower average price than under government-owned vertically-integrated monopoly regime
 - Otherwise it is hard to rationalize industry restructuring

Major Market Design Challenge with Privately-Owned Firms = Market Power

- Electricity supply industry extremely susceptible to the exercise of market power in the spot 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 market power in a very short time
 - Ask California and New Zealand

Market Design Challenge with Government-Owned 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
- Can set prices to recover incurred cost of production
- Government-Owned firms have little incentive to raise prices above level necessary to cover average costs

Optimal Market Design for ESI

- Four segments of electricity supply industry
 - Generation
 - Transmission
 - Distribution—Wires only
 - Supply—Retailing only
- For each segment market designer has option to design a regulatory mechanism
 - Market versus regulation
 - Government versus private ownership
- Provide optimal market design rationale for this choice for each segment of industry
- Market design process in network industries--Why?

Necessity of Market Design

- Most markets do not require explicit market design process
 - Markets evolve from locations where economic agents trade
 - New York Stock Exchange (NYSE)
- Economic agents are free to trade at any market they like
 - Buyers search for markets offering lowest selling price
 - Sellers search for markets that offer highest buying price
- Why do network industries, particularly electricity, require market design process?

Necessity of Market Design

- Network required to deliver electricity
 - Despite Nikola Tesla's attempts, cannot beam electricity to final customers
 - Cost structure favors a single transmission network for a given geographic area
- How network access determined can have an enormous impact on profits of market participants
 - Without access to transmission network generation unit owners can only sell to local consumers
- This requires designing a regulatory mechanism
 - To ensure equal access to network to all market participant
 - To compensate entity that manages transmission network
 - To set prices charged for use of transmission network

Some Form of Regulation Necessary

- Choice is not de-regulation versus regulation, but how much and where to regulate
- All markets are regulated
 - Consumer safety, Environmental quality
- Re-structuring is an alternative regulatory mechanism for attaining higher value for principal's objective function than government-ownership and vertical integration
 - For market and private ownership to be superior regulatory contract it must do a better job of solving market design problem

Some Form of Regulation Necessary

- “Competitive” regime restricts regulated portion of industry to smallest entity possible
 - Transmission and distribution are only services with their prices set through a regulatory process
 - Generation and electricity retailing are open to competition
 - Economies of scope difficult to capture under this regime
- “Vertically integrated” regime imposes regulatory process on all aspects of industry
 - Final output price of vertically integrated monopoly is regulated--economies of scope possible
- Choice between regulation and competition depends which regime achieves market designers objectives

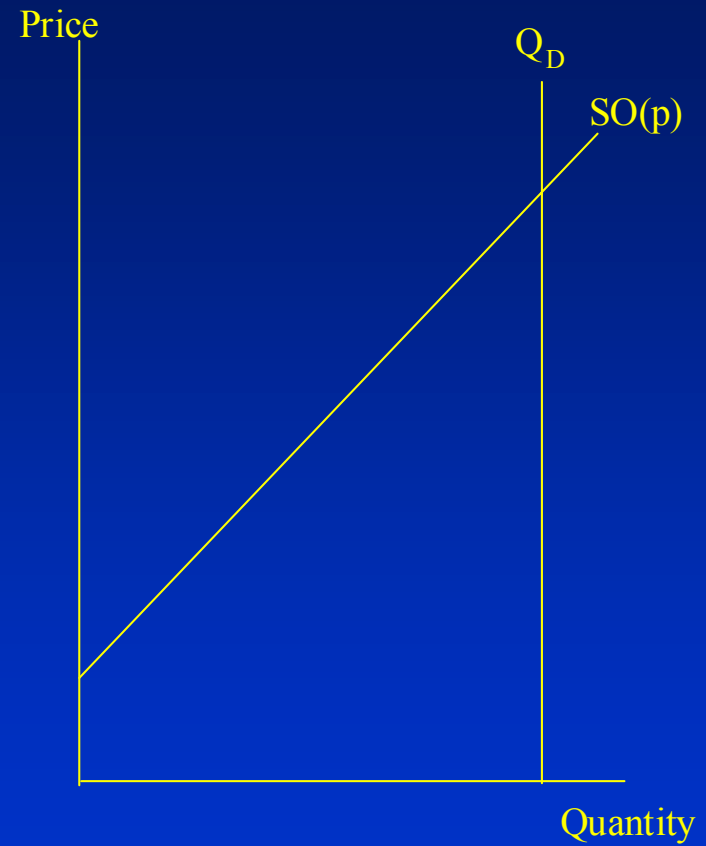
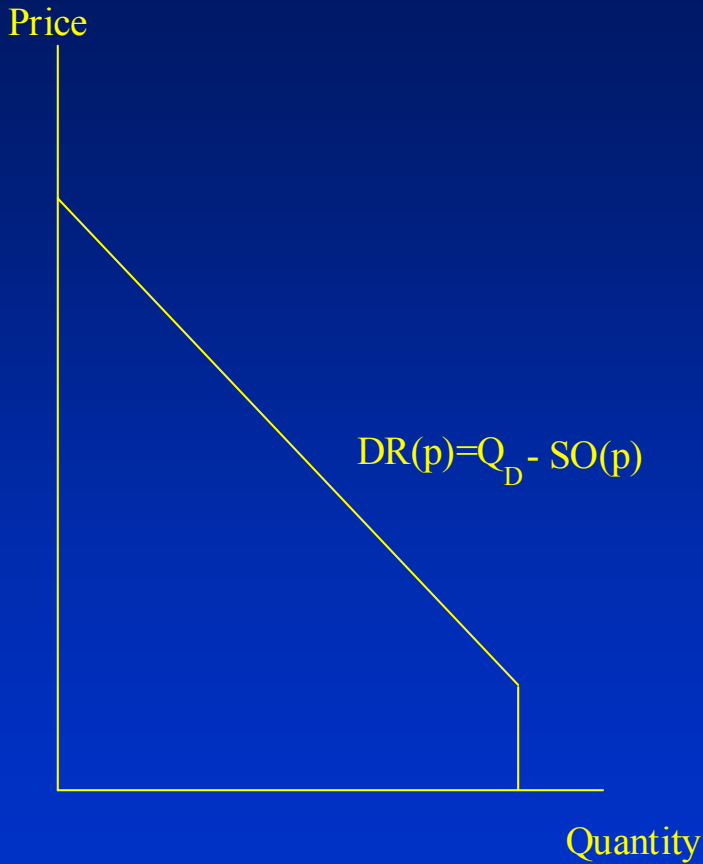
Market Design Lessons From Developed Countries

- Solving Market Power Problem--First Step in Market Design Process
 - Understanding how firms bid to maximize profits under given set of market rules, $y(x)$
 - How do firms exercise their unilateral market power
- Allows Market Designer to define constraint set it faces in maximizing its payoff function
 - Firms will maximize profits given market rules
 - Individual Rationality
 - Firm must be expect to earn return sufficient for it to participate in market
 - Participation Constraint
- How firms maximize profits in bid-based markets

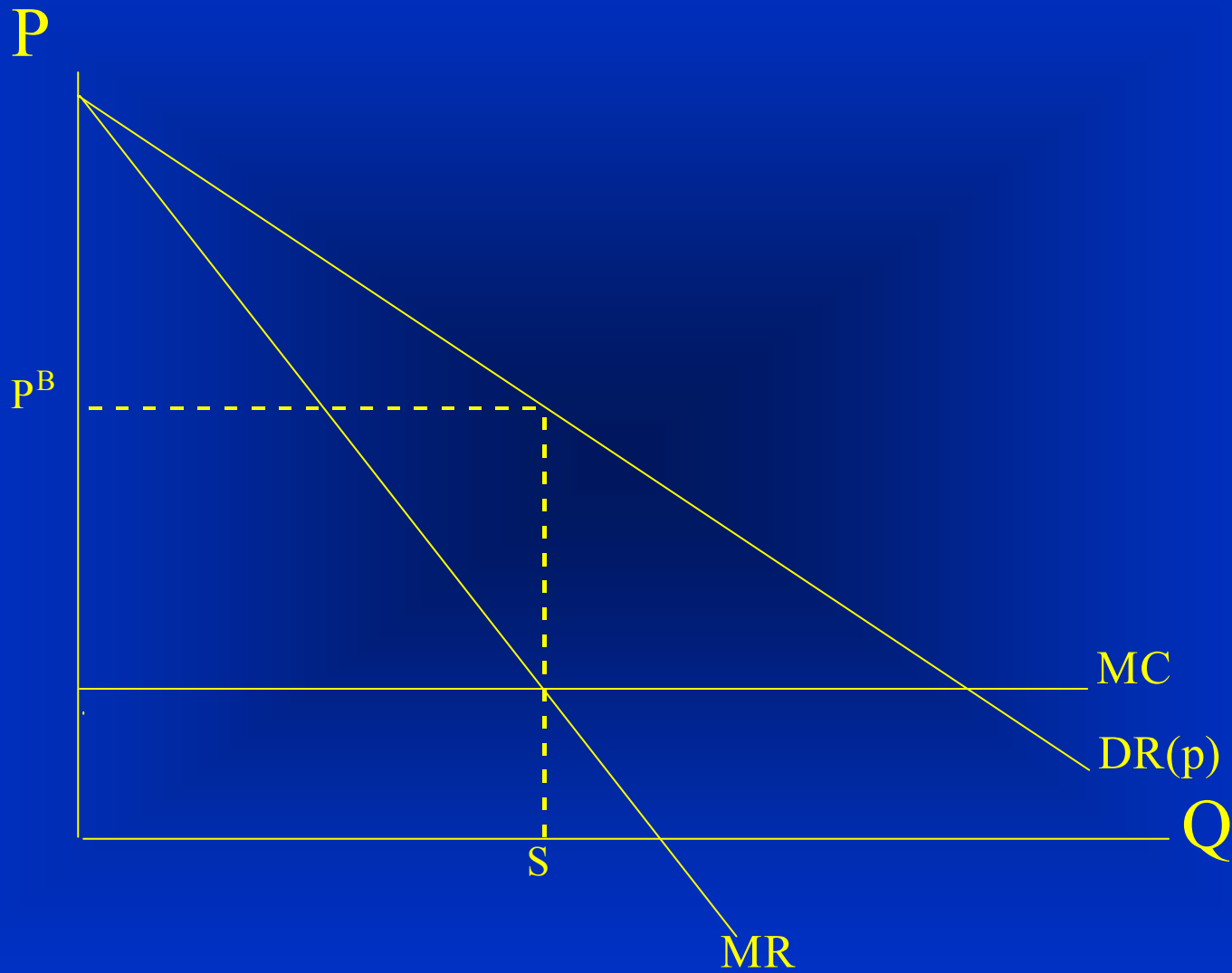
Bidding in Competitive Markets

- Simple model of profit-maximizing bidding behavior in competitive market
- Q_{id} : Total market demand in load period i of day d
- $SO_{id}(p)$: Amount of capacity bid by all other firms besides Firm A into the market in load period i of day d as a function of market price p
- $DR_{id}(p) = Q_{id} - SO_{id}(p)$: Residual demand faced by Firm A in load period i of day d , specifying the demand faced by Firm A as a function of the market price p
- $\pi_{id}(p)$: Variable profits to Firm A at price p , in load period i of day d
- MC: Marginal cost of producing a MWH by Firm A

Residual Demand Curve faced by Firm



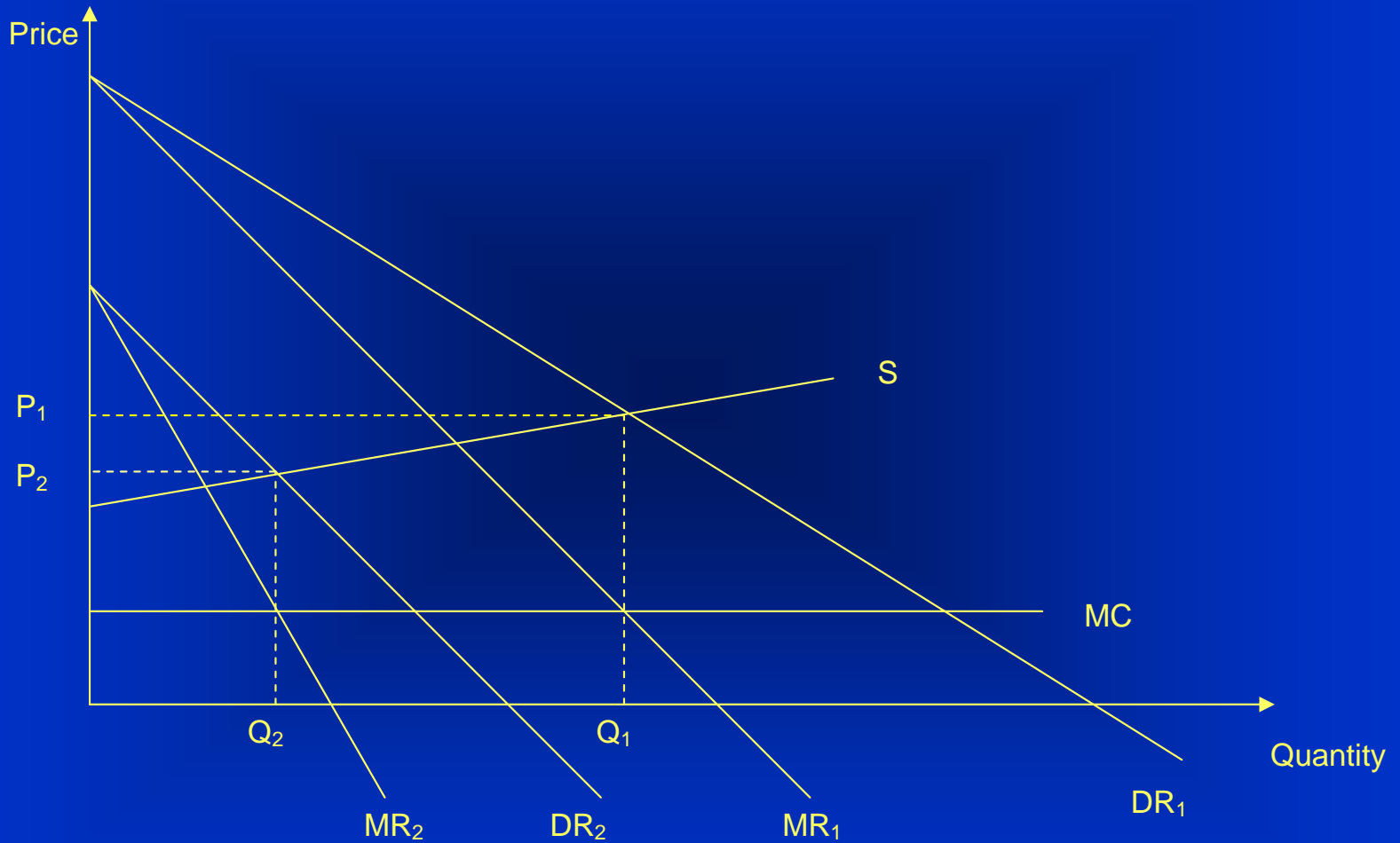
Bid to Maximize Profits Subject to Residual Demand



Profit-maximizing behavior implies a profit-maximizing price above marginal cost

- Residual Demand Curve unknown at time generator submits bids
 - Demand uncertainty
 - Uncertainty about actions of other suppliers
- Optimal bid curve depends on distribution of elasticities of residual demand function

Bid to Maximize Expected Profits



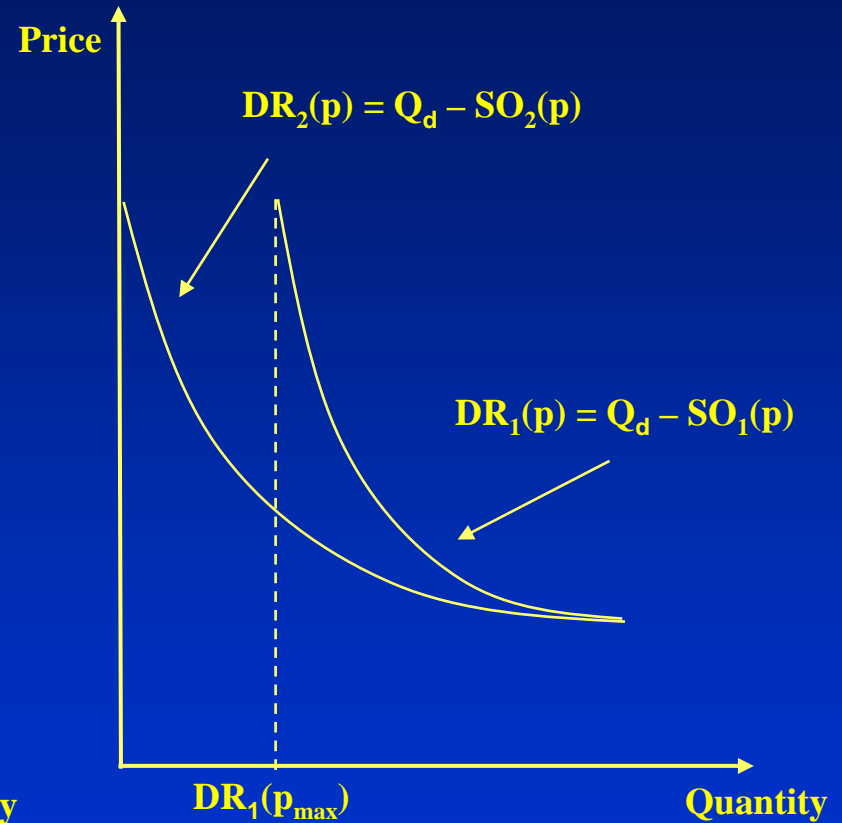
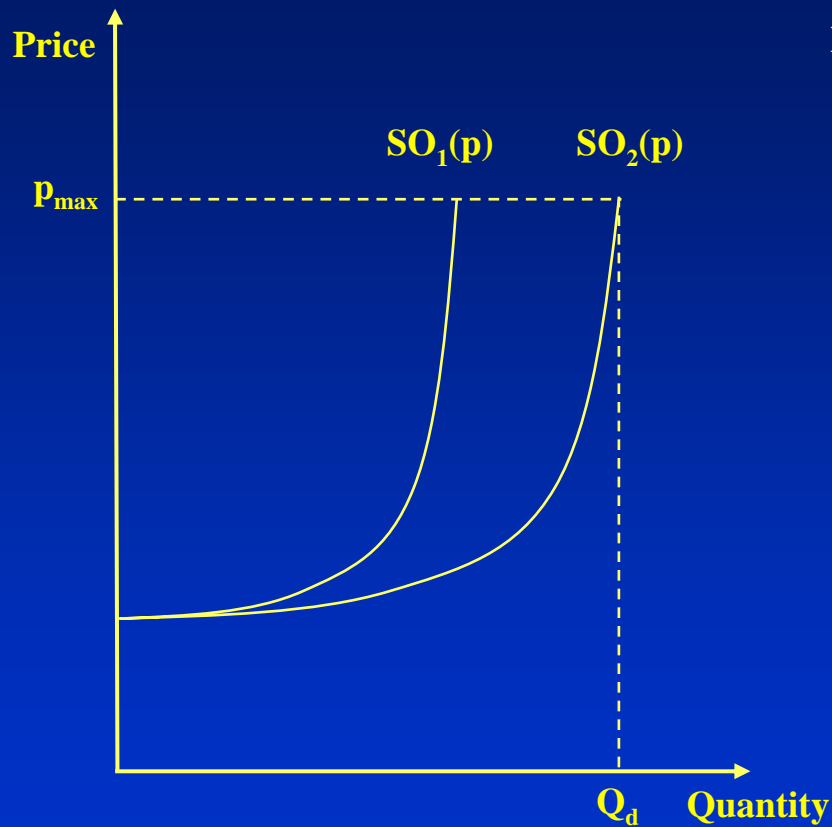
Market Design = Limiting Market Power of Firms

- Make residual demand curves perceived by all unit owners as elastic as possible
 - Generators facing infinitely elastic residual demand curve perceive themselves as being unable to impact the market price by their bids
 - Optimal strategy for generation unit owner facing infinitely elastic residual demand curve is to bid marginal cost curve (MC) as willingness to supply curve $[S(p)]$
 - This will lead to market prices as close as possible to market designer's optimum

Limiting Market Power of Firm

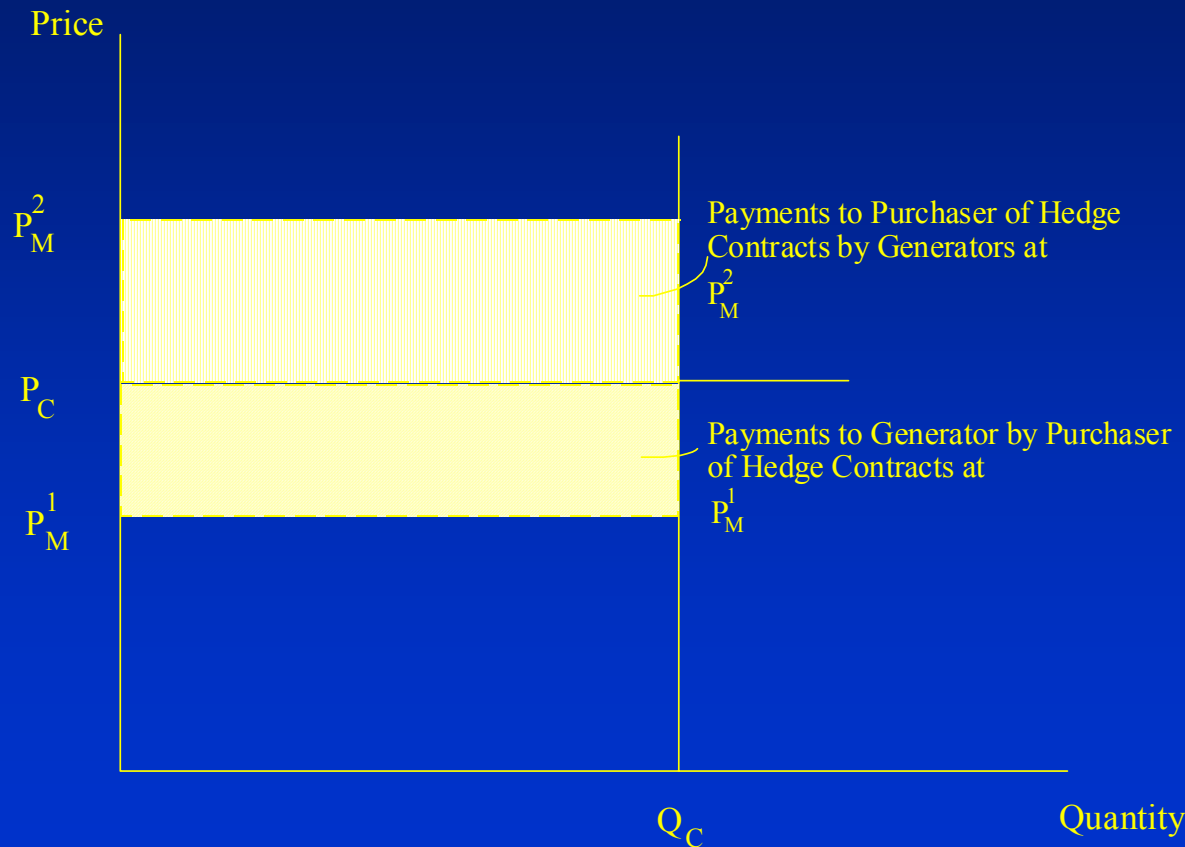
- Divestiture of Generation Capacity
- Forward Financial commitments make firms bid more aggressively in spot market
- Transmission upgrades to face all unit owners with more elastic residual demand curves
 - Economic reliability of transmission network versus Engineering reliability of transmission network
- Price Responsive Demand makes residual demand curves perceived by all unit owners more elastic
- Credible Regulatory Process
 - Firms must obey market rules

Divestiture of Generation Capacity



Impact of Forward Contracts on Bidding Behavior

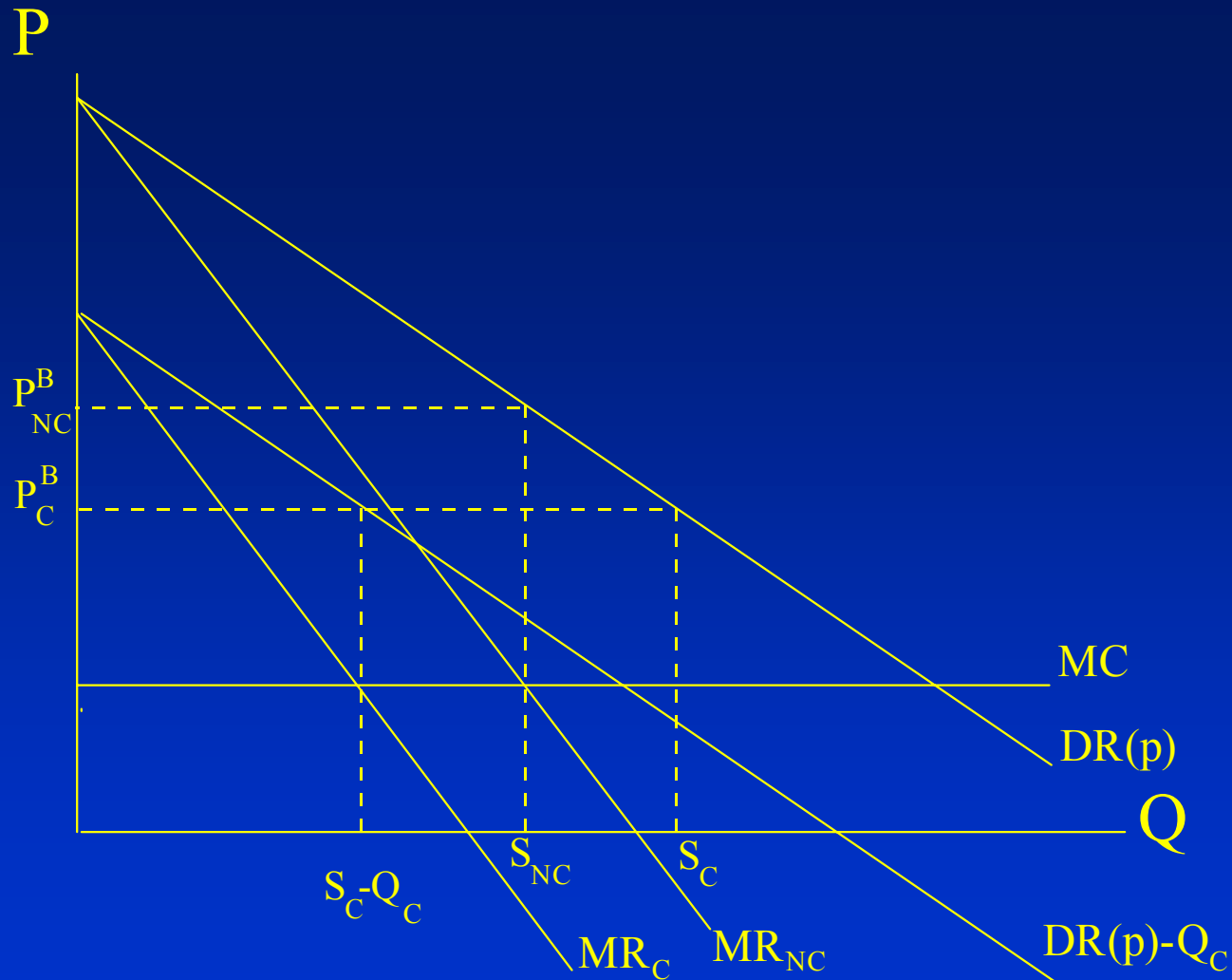
- QC_{id} : Contract quantity for load period i of day d for Firm A
- PC_{id} : Quantity-weighted average (over all hedge contract signed for that load period and day) contract price for load period i of day d



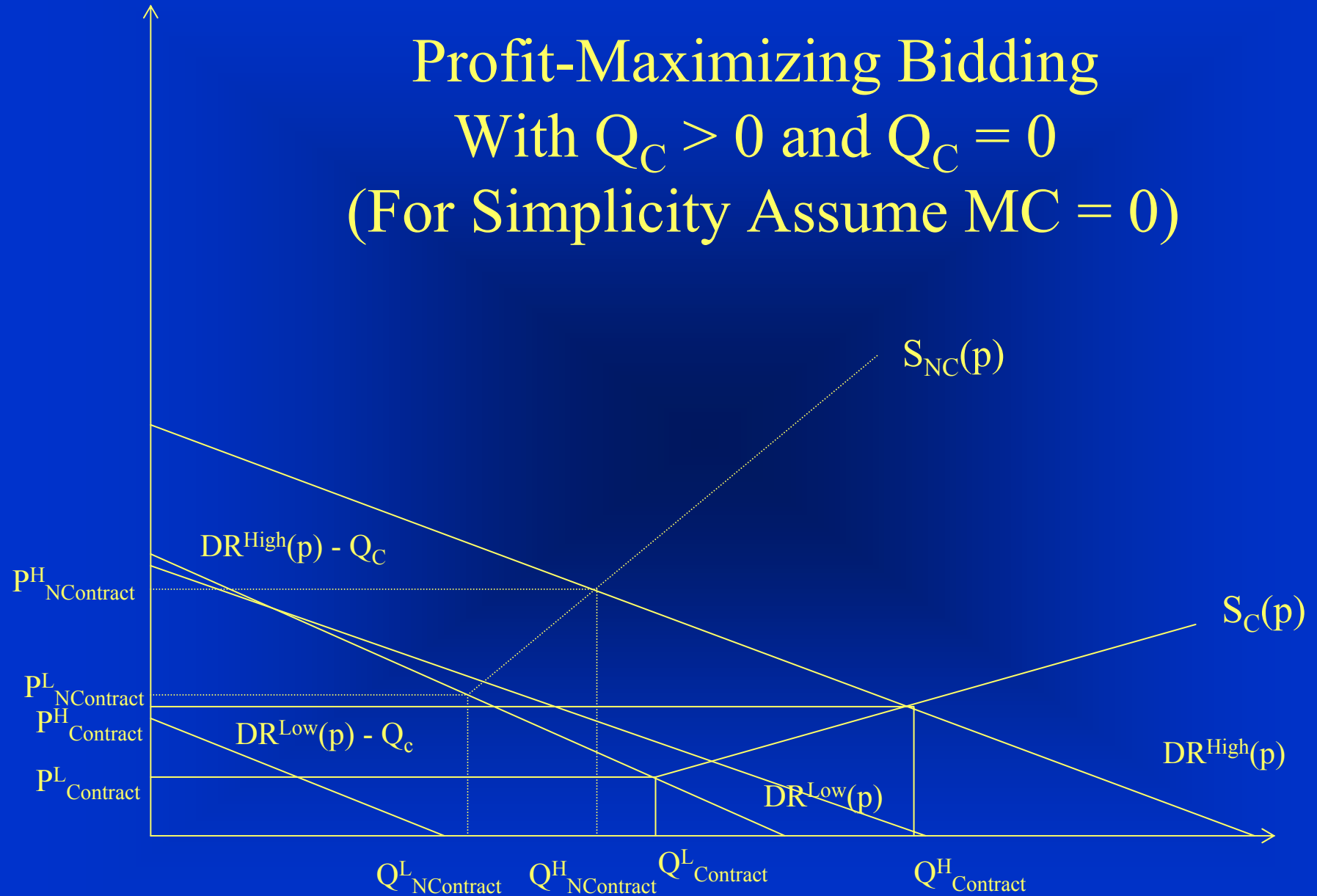
Spot Market Bidding With Forward Contracts

- Assume market clearing price p is determined by solving for the smallest price such that the equation $SA_{id}(p) = DR_{id}(p)$ holds.
- The magnitudes QC_{id} and PC_{id} are set far in advance of the actual day-ahead bidding process
- Generators sign hedge contracts with electricity suppliers or large consumers for a pattern of prices throughout the day, week, or month, for an entire or fiscal year
- Variable profits (profits excluding fixed costs) to Firm A for load period i during the day d at price p as:
 - $\pi_{id}(p) = DR_{id}(p)(p - MC) - (p - PC_{id})QC_{id}$
- This can be re-written as:
 - $\pi(p) = (DR(p) - QC)(p - MC) + (PC - MC)QC = DR_C(p)(p - MC) + F$
- Note that second part of expression is fixed from a day-ahead perspective.

Bidding With Hedge Contracts



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



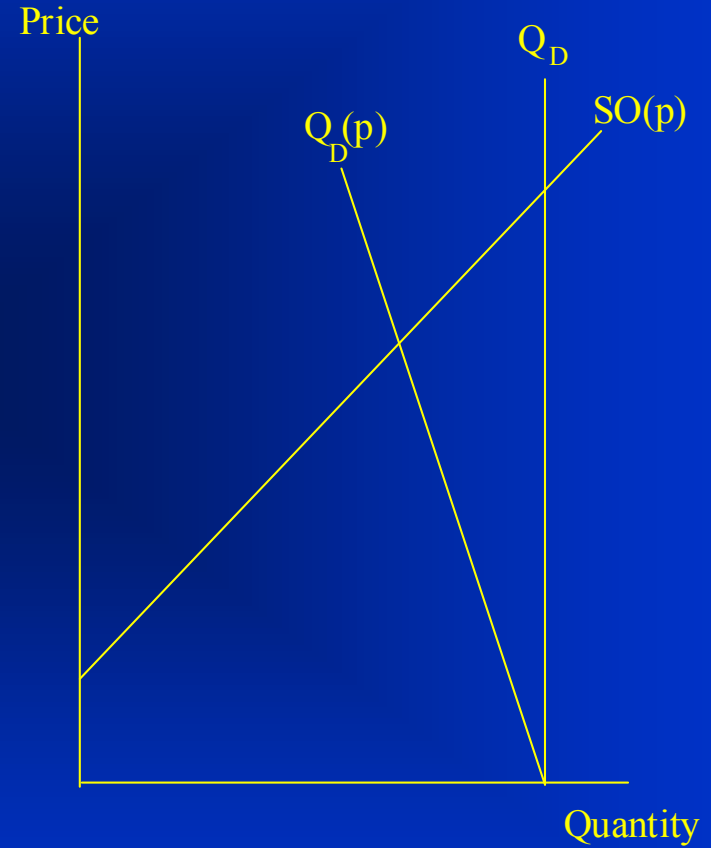
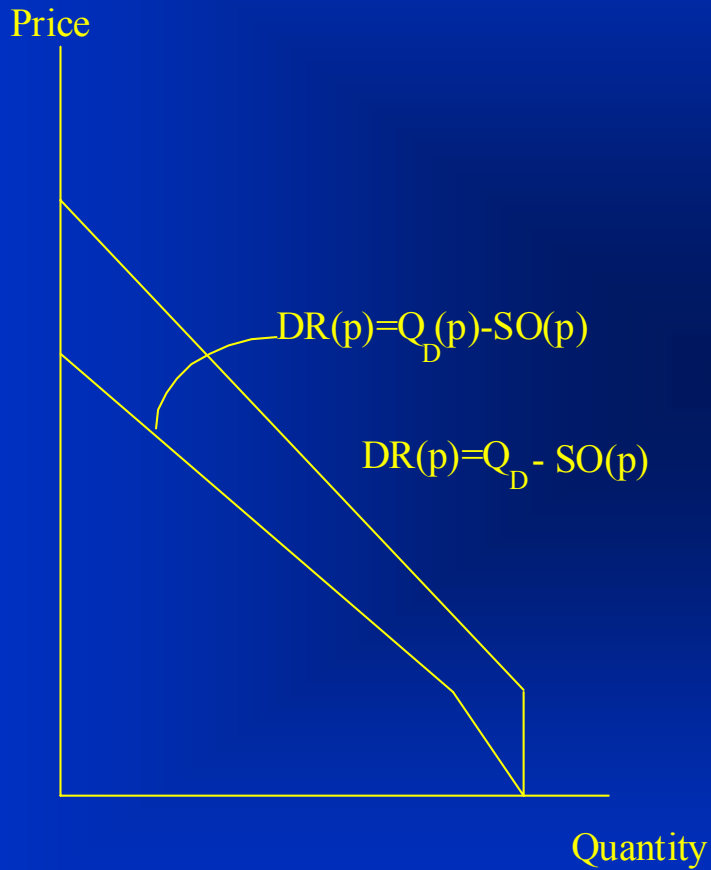
Transmission Network and Market Power

- “Over-investment” in transmission capacity relative to engineering reliability concerns can benefit market
 - Economically reliable transmission network requires far greater inter-connection capacity than technologically reliable network
 - Economic reliability--All locations in transmission network can be supplied by number of different firms a large fraction of the time—All locations face sufficient competition
- Consider case that “over-invest” in transmission capacity to increase prices by \$1/MWh
 - If increased capacity of transmission network results in more competitive wholesale market and average prices fall by \$2/MWh, consumers benefit from upgrade

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 a Price Responsive Demand



Credible Regulatory Process

- Regulator charged with protecting consumers “unjust and unreasonable prices”
 - For monopoly services this is primarily an accounting and legal exercise
 - Allow firm to recover prudently incurred costs
 - For competitively provided services this means setting “just and reasonable” market rules
 - Rules that yield “just and reasonable prices”
 - For privately-owned firms must be confident they will have opportunity to earn return on investment
 - Regulator protects against ex post opportunism of government
 - Non-discriminatory or preferential application of regulatory rules

Dimensions of Regulatory Process

Regulator must set standard for

Market outcomes and firm behavior that is consistent with workably competitive market outcomes

ISO system and market operator behavior that is consistent with prudent management techniques

Market monitor must know what to look for in order to report it to regulator

Effective market monitoring requires clearly defined protocols for acceptable and unacceptable behavior that are known to all market participants

Information on market participant characteristics and market outcomes essential to effective regulation

Regulator must have legal right to receive all necessary information

Sunshine regulation is most effective route to establishing credibility

Abuse of Market Rules versus Exercise of Market Power

- Exercise of market power is raising market price through actions that do not violate market rules
- Abuse of market rules is violating market rules to increase profits or otherwise benefit firm
- Factual nature of rules violation
 - Going 70 miles per hour in a 55 miles per hour zone
 - Violation of terms of a contractual obligation
 - Providing energy with capacity sold for reserve
- A rules violation typically has adverse system reliability consequences

Abuse of Market Rules versus Exercise of Market Power

- Penalties are necessary to enforce market rules
- Recall that firms respond to incentives
 - Unless the cost to violating rules exceeds benefits firms will not follow the market rules
- Not advisable to rely on good intentions of market participants when system reliability is at stake
- Contracts in all markets have penalties for non-performance
- In regulated world firm and regulator had common interest in high levels of system reliability
 - Under wholesale market regime this is not necessarily the case
- If market rules are obeyed, this will prevent many problems

Coordinating Regulatory Policies

- In US, FERC sets wholesale market policies
- State Public Utilities Commissions (PUCs) set retail market policies
- Wholesale and retail market policies must be coordinated or enormous consumer harm is possible
 - Designing a wholesale market assuming active participation by retail demand can be a disaster if retail market policies do not allow this
 - Designing retail market policies ignoring need of retailers to manage spot price risk can be a disaster wholesale market policies allow spot prices to fluctuate hourly or on a shorter time horizon

Market Design Lessons from LACs

- Gambling with weather problem
- Participation by government-owned firms
 - Competitive and monopoly sectors
- Fostering an active forward market
- Bid-based versus cost-based pricing
- Regulating retail electricity prices
- Government versus private participation in ESI
- Country-specific challenges
 - Brazil, Chile, Colombia, Honduras, and Mexico

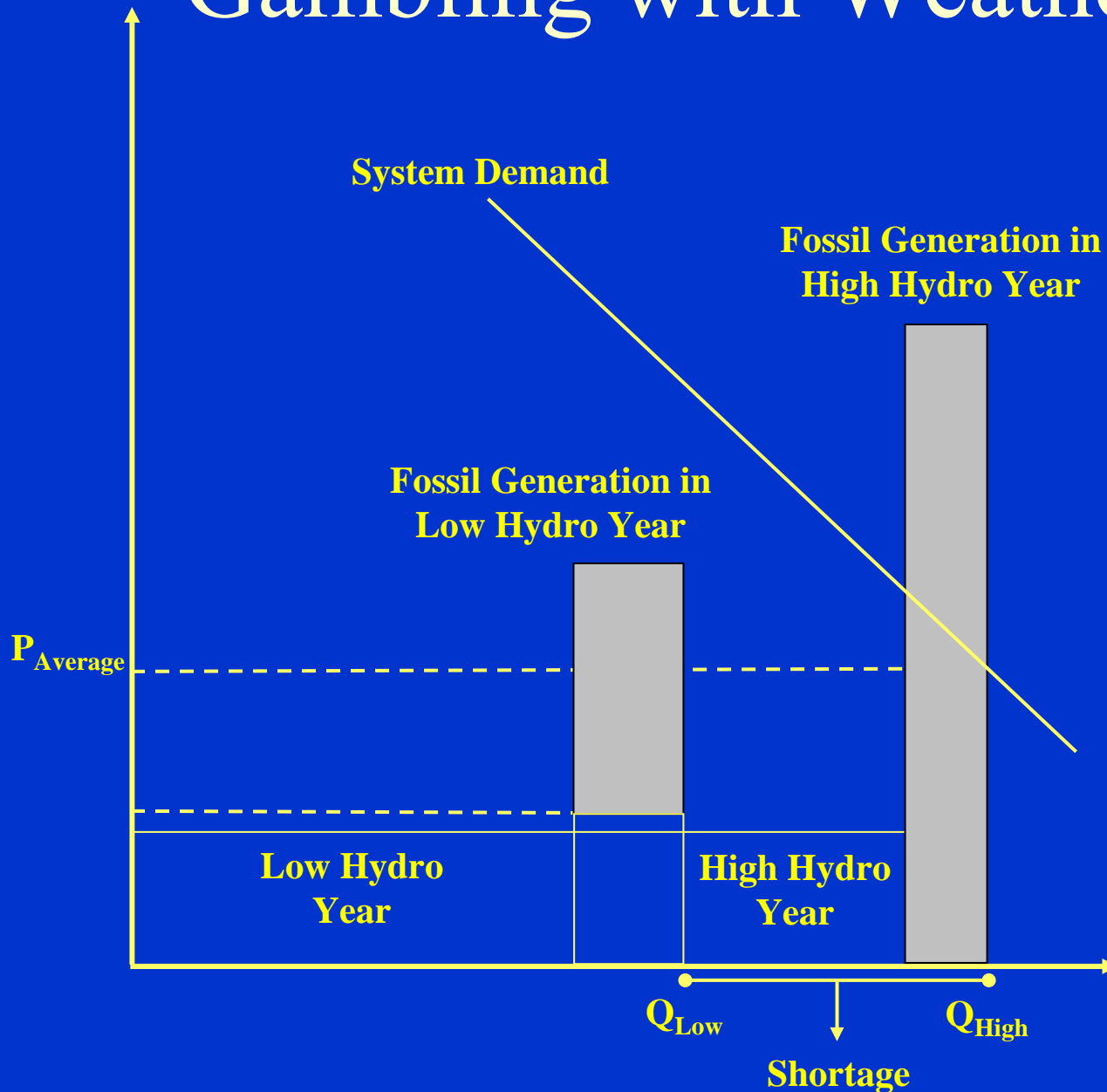
Gambling with Weather

- Hydroelectric capacity has close to zero incurred marginal cost of production
 - Very tempting for government to use this fact to keep price of wholesale electricity low
- How is this accomplished in LACs
 - ISO dispatches generation units using stochastic discrete dynamic programming (SDDP) model using operating cost of fossil-fuel units and cost of deficit
 - Current spot price reflects opportunity cost of operating fossil fuel units and cost of deficit
- Current cost of deficit in Brazil is 350 \$R/MWh, which is approximately \$100/MWh at current exchange rates
 - Chile only slightly higher
- Problems with low cost of deficit parameter
 - Sets very low average spot price—approximately \$22/MWh in Brazil at current exchange rates
 - Encourages over-consumption of electricity—average retail rate \$55/MWh in Brazil at current exchange rates

Gambling with Weather

- Problems with low cost of deficit parameter
 - Fossil fuel units may not be used until water levels get too low—Rationing periods occur
 - Lower cost of deficit implies deficits will occur with higher probability
- As long as rain comes this strategy can be a very effective way to keep wholesale electricity prices low
- Discourages fossil fuel entry
 - Extremely volatile revenue stream for fossil-fuel units

Gambling with Weather



Involving Final Demand

- Final demand can be involved in wholesale market without sophisticated metering in hydroelectric dominated system
 - Very little price volatility within day relative to fossil-fuel based system
 - Price volatility is primarily across seasons of the year
 - Wolak (1999) “Market Design and the Behavior of Prices in Restructured Electricity Markets: An International Comparison” provide evidence for this in Nordpool and New Zealand markets
- No need for hourly meters to involve final demand
 - Real-time pricing of electricity on monthly basis
 - High cost of water implies high price of electricity for coming month or billing period

Fostering Forward Market

- Regulator periodically runs anonymous auctions for standardized products
 - Baseload power (1 MWh—24x7)
 - Peaking-power (1 MWh—16x6)
 - Delivery to specific location in network
 - Date in far advance of delivery
 - Start as financial and then turn “physical” as delivery nears
- Suppliers bid for right to provide power
 - Provides vehicle for supplier to sell forward obligations to finance new investment
 - Prices can used to regulate retail prices
- Default provider auctions in many parts of US can provide model for these types of auctions
 - Standardized rules, restrictions on actions of bidders
 - Eliminate barriers to participation to greatest extent possible

Single Buyer = Gov't-Owned Monopolist

- Single Buyer is another government-owned monopolist
 - Could be even worse for consumers than vertically integrated monopolist
- Single buyer option was available to state-owned monopolist but it did choose this option
 - Vertically integrated monopolist could have contracted out for all power
- Recall principal-agent framework
 - Single buyer has little incentive to minimize wholesale energy costs due to ownership structure
 - Single buyer may favor political ends over economic ends
- Behavior must change for consumers to benefit
 - Incentives must be different for behavior to change
 - Little difference in incentives for wholesale power supply
 - Market power in forward market due to entry barriers could raise wholesale energy costs if energy is contracted for by a single buyer

Bid-Based versus Cost-Based Dispatch

- Net benefits of bid-based spot markets in developed countries unclear
 - Few markets actually operate bid-based system
- ISO needs to operate system in real-time
 - Cost-based market with realistic cost-of-deficit parameter allow this to happen
 - Little advantage to bid-based system with active demand side participation
- In hydro-based system, demand must be marginal supplier of electricity (negawatts) to manage water shortfalls
 - True in bid-based and cost-based system
 - Cost-based system avoids market power problems
- Cost-based system provides more certainty on imbalance charges loads and generators will be liable for relative to their forward contracts
 - Reduces cost of new investment
 - Makes it easier to sell standardized forward contracts for energy

Regulated Retail Suppliers

- Create two customer classes
 - Negawatt suppliers
 - Regulated customers
- No need to regulate retail prices for negawatt suppliers
- Use results of periodic anonymous wholesale procurement auctions to set regulated wholesale price contained in retail price
 - Use fixed portfolio of forward prices and real-time prices

State-Owned Hydroelectric Supplier

- New entrants recognize that large government-owned hydroelectric supplier may want to keep wholesale prices low for political reasons
- This is most likely to occur during periods when private supplier could recover much of its investment costs
- Norway experience is instructive
 - In fall of 1992, Statkraft—state-owned money hydroelectric owned announced policy to maintain prices above 100 NOK/MWh
 - Although plan was initially successful, prices have subsequently fallen below this level
- Norway has not had any new investment in generation capacity since restructuring took place in early 1990s
- Significant government presence in market underscores importance of fostering forward market through periodic anonymous auctions
- Argues in favor of cost-based dispatch of all units based on transparent model with reasonable cost-of-deficit parameter

Regulatory Oversight

- Countries with former government-owned monopolies face two transition problems
 - Establishing and enforcing market rules
 - Setting prices for monopoly services
- US has had almost 100 years of experience and they still have not gotten it right—California crisis
 - Process must account for continual improvement
- Simple rules that are easy to enforce (that may not get things exactly right) may be preferable, at least during initial stages of re-structuring process
- Credibility is regulator's most powerful tool
 - Successfully enforced decisions increase credibility

Regulatory Credibility

- Advisory Committee approach to regulatory credibility
 - Establish committee of international experts to provide advise regulatory body
 - Committee has no power to issue order or impose penalties on market participants
 - Provide advice on best regulatory practices
 - Has right to access information to prepare reports
 - Can issue public opinions on periodic basis
 - Provide cover for regulator
 - Prevent opportunistic behavior by government

Brazil

- Brazilian Energy Reallocation Mechanism (MRE) pays hydroelectric suppliers according to their assured energy certificates (CEA), not their actual hourly production
- Each hour total amount of hydroelectric energy produced in Brazil is measured and this production is allocated to each hydroelectric supplier according to quantity-weight share of CEAs they own
 - Firm is paid market price times its share of total hydroelectric output
 - Payment to firm is does not depend on whether or not firm supplied any energy during hour or was available to operate in that hour
- Fossil-fuel units paid hourly price based on actual production
- New hydroelectric entrant makes profit on how many CEAs they are able to obtain, not based on hourly operating characteristics of unit
- MRE provides little incentive to build new capacity or choose fuel mix that provides maximum benefits to system reliability

Brazil

- Gambling with weather problem
- Transmission expansion essential to serve Brazilian Market given geographic size of country
 - Regulator must take forward-looking approach to fostering transmission expansion
 - Design funding mechanism to allocate causal costs to those who benefit and share common costs of upgrades
- Establishing credible regulatory process
 - Independent market monitoring committee

Chile

- Managing risk of water shortage
 - Increase cost-of-deficit parameter
- Pricing transmission expansion
 - Given structure of country network is primarily radial
 - Interconnecting northern and southern control areas could yield substantial benefits given large amount of excess capacity in north
- Because of radial nature of transmission network and relatively small peak demand Chilean approach to system operation may not scale to other LACs

Colombia

- Managing risk of water shortage
 - Bid-based approach did not prevent shortage
 - Cost-based with high cost of deficit preferred
- Transmission expansion and congestion
 - Transmission network subject to frequent de-ratings
 - Argues against bid-based dispatch
 - Argues in favor of cost-based locational marginal pricing
- Regulatory credibility problem common to all LACs

Honduras

- Small country problem
 - Peak demand small relative to minimum efficient scale of generating facilities
- Encouraging fuel diversity
 - All fossil fuel must be imported
- Inter-connections with neighboring countries primarily for reliability not economic reliability
- Regulatory credibility problem common to all LACs

Mexico

- Rapid demand growth
- Legal barriers to re-structuring
 - Constitutional requirement for electricity for public service to be provided by government
- Encouraging fuel diversity
 - Domestic natural gas may be insufficient to meet demand growth
- Substantial opportunities for trade with US
- Regulatory credibility problem common to all LACs

Recommended Market Design for LACs

- Generation sector
 - Competition and Private Ownership
 - Focus on development of forward market for energy
 - Cost-based short-term energy market
- Transmission sector
 - Government-owned and regulated
 - Focus on expanding interconnection with other countries
- Distribution sector
 - Regulation and Private Ownership
 - Focus on expanding access to network
- Retailing Sector
 - Competition and Private Ownership
 - Focus on preventing cross-subsidies between free consumers and regulated consumers
 - Focus of involving all consumers (free and non-free) in wholesale market to extent it is cost-effective

Conclusions for ESIs in LACs

- Benefits from re-structuring must come from a change in behavior of market participants
 - Behavioral change does come about unless agents have strongest possible incentive to change
- Firm operate more efficiently
 - Short-term operation at least cost
 - Investment decisions based on market signals
- Consumers make greater effort to use existing capacity more efficiently
 - Get by with less capacity to serve same number of consumers
 - Holding excess capacity is costly, because capital costs of unused capacity must be paid for whether or not it is used

Questions or Comments