UNIVERSIDAD PONTIFICIA
ICAI ICADE
COMILLAS
MADRID
ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA
INSTITUTO DE INVESTIGACIÓN TECNOLÓGICA (IIT)

An Iterative Algorithm for Profit Maximization by Market Equilibrium Constraints

Andrés Ramos

Mariano Ventosa Michel Rivier

Abel Santamaría

14th PSCC

Seville, 25 June 2002

Outline

Introduction

- Two main approaches to model market equilibrium:
  - Cournot (firms compete only in quantities)
  - Supply function equilibrium (in quantities and prices)
- A great number of medium and long term oligopoly market models are based on Cournot equilibrium

Outline

Model Description

- Based on a detailed production cost model
  - Detailed representation of operation constraints
  - Decision variables are generator output levels
  - Determine the cheapest commitment and operation of the hydrothermal system
- Market equilibrium among firms represented by a set of additional constraints. By these constraints each strategic agent maximizes its profit (revenues minus costs)
  - Determine the output level for each strategic firm
- Advantage:
  - use of any available production cost model (PCM)
- Drawback:
  - market equilibrium constraints depend on SMP, not directly obtained from a PCM

Production cost model with market equilibrium constraints

Minimization of:

Objective Function → Total Generation Variable Costs + + Costs of non accepted demand bids

Subject to:

Operating Constraints →

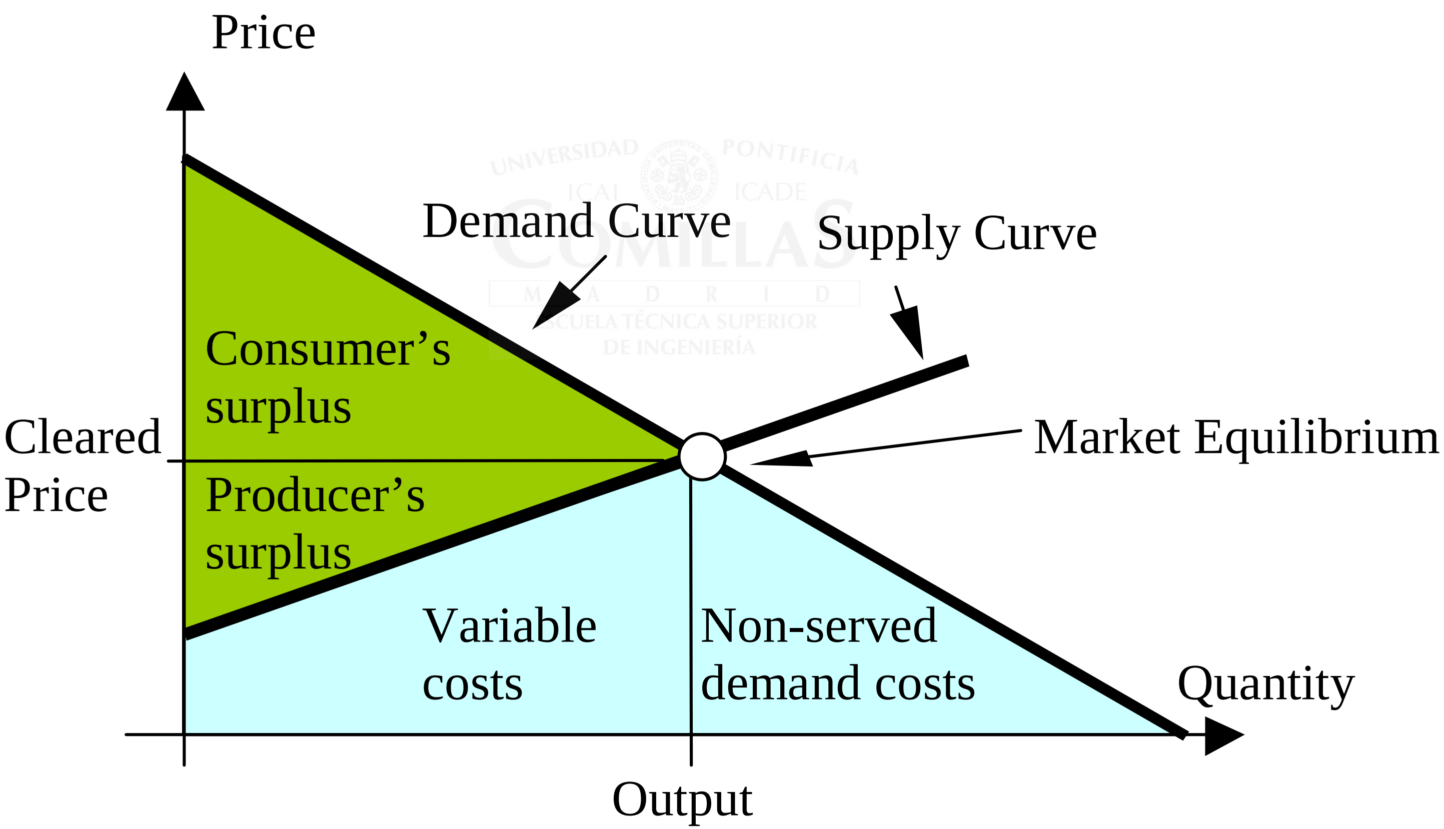
- Interperiod Constraints
  (Maintenance scheduling, fuel purchase, hydro scheduling, seasonal pumping)
- Intraperiod Constraints
  (Generation-demand balance, thermal unit commitment, generation limits)

Market Constraints →

- Market Equilibrium Constraints
- Price equation
- Market Share Constraints

Utility function

- Market equilibrium obtained by maximizing consumer's and producer's surplus



Market equilibrium constraints

Minimisation of:

Objective Function

Total Generation Variable Costs +
+ Costs of non accepted demand bids

Subject to:

Operati
Constrain

Marke
Constrain

Market
Constraints

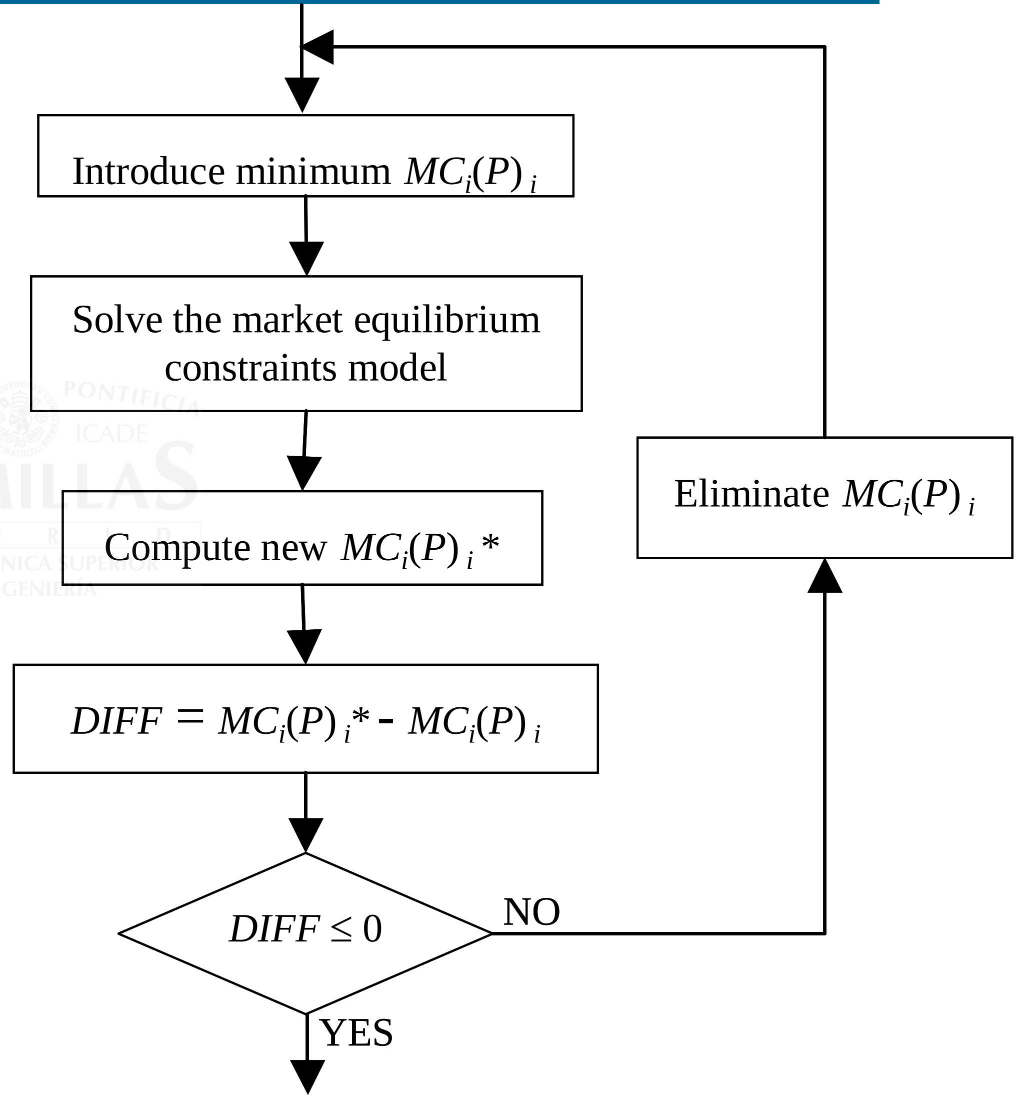
- Equilibrium Constraints
  - Marginal revenues equal marginal cost for each *strategic* firm
  - Marginal cost of each firm as a function of its committed units
- System Marginal Price equation
  - The price is a function of the served demand
- Market Share Constraints
  - The market share of each *leader in quantity* must be equal to its market share objective

Iterative computation of system marginal price (*SMP*)

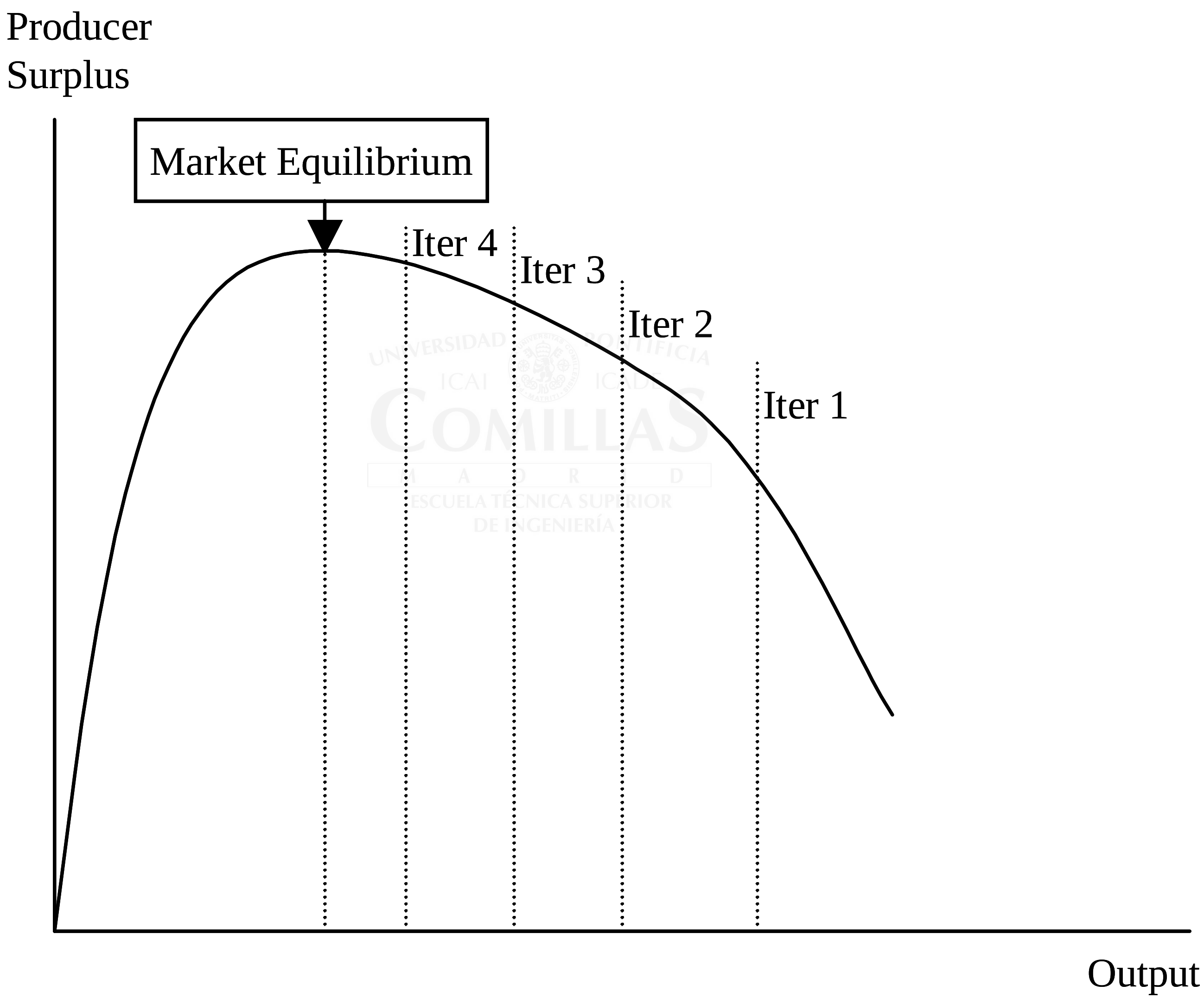
- Marginal cost (*MC*) of each firm *i* not directly calculated by the PCM due to discrete commitment decisions

- P_i output of firm *i*

$$P_i \leq \frac{SMP - MC_i(P_i)}{-\text{demand slope}}$$



Producer surplus



Iterative algorithm for hydro scheduling of strategic firms

1. Obtain an initial market equilibrium by solving the optimization problem
2. Select a load level L1 with high SMP where the market equilibrium constraints are not binding for some strategic company
3. Select a load level L2 with lower SMP where the same company can decrease its production
4. Find a fringe company that can decrease its production in load level L1 and simultaneously increase in load level L2
5. Exchange the hydro generation of the strategic and fringe companies among load levels taking into account the technical hydro constraints (i.e., maximum and minimum output, maximum and minimum reserve levels, etc.) and any other constraint (i.e, firm market share)
6. If two load levels with different SMP can be selected go to step 2. In other case go to end

Outline

1. Introduction
2. Model Description
3. Comparison with an MCP Approach
4. Case Study
5. Conclusions

Comparison with a MCP approach

- Advantages of PCM with MEC approach
  - Realistic modeling of the electric system (e.g., binary unit commitment variables)
  - Robust and efficient solution methods (e.g., Branch and bound for MIP)
  - Constraints must be linear
  - Convergence not guaranteed but obtained in practice
- Advantages of MCP approach
  - Compact problem formulation
  - Only continuous variables
  - Possibility of introducing nonlinear constraints
  - Optimality guaranteed and solution uniqueness with linear constraints
  - Slow solution method and depending of the initial value

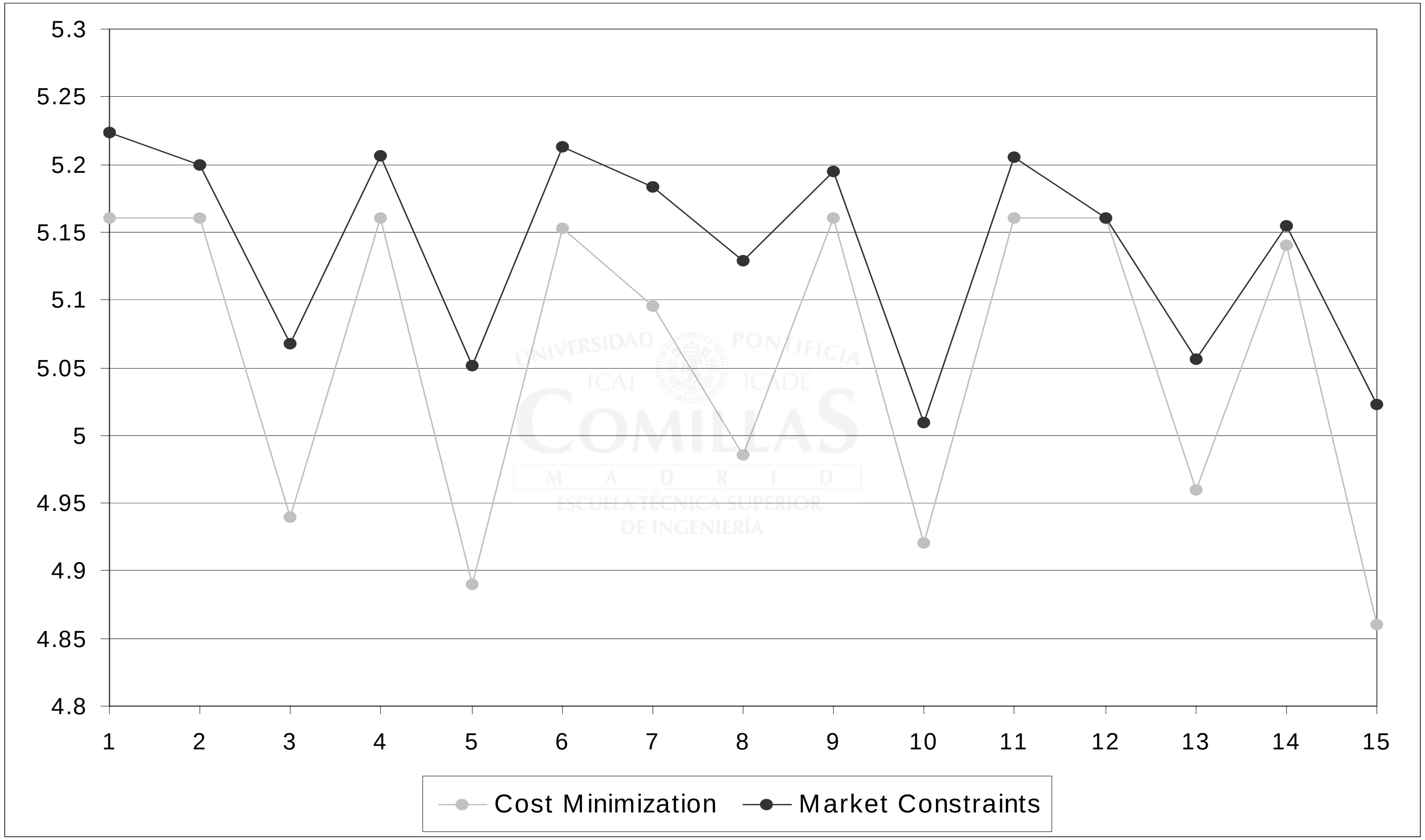
Outline

1. Introduction
2. Model Description
3. Comparison with an MCP Approach
4. Case Study
5. Conclusions

Case study

- Time scope divided into 3 periods with 3 load levels for weekdays subperiod and 2 load levels for weekend subperiod
- 18 thermal units and 6 hydro units from 3 different firms
- SMP rises from 4.86 pta/kWh in cost minimization to 5.16 pta/kWh in market equilibrium
- Total profit increases in a 5 % while the energy produced decreases in a 10 %

System marginal price



Outline

Conclusions

- Market equilibrium under an oligopoly based on the Cournot conjecture, represented by a production cost model plus market equilibrium constraints
- Iterative algorithm to calculate the system marginal cost
- Iterative algorithm to refine hydro scheduling for strategic firms
- Resulting MIP problem solved by robust, efficient and reliable solvers