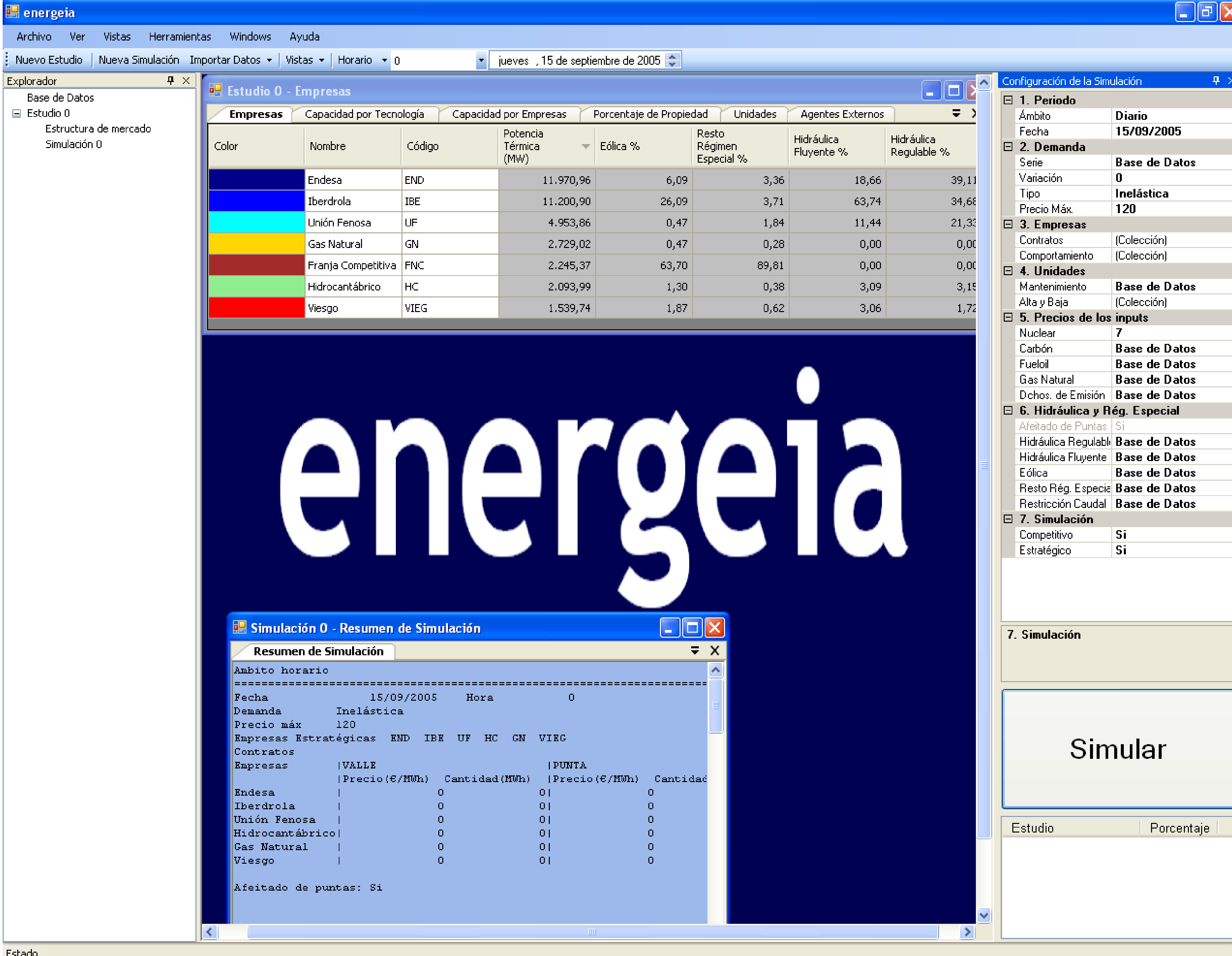
Simulating electricity market outcomes

energeia

Natalia Fabra

Universidad Carlos III de Madrid and CEPR


energeia
Archivo Ver Vistas Herramientas Windows Ayuda
Nuevo Estudio Nueva Simulación Importar Datos Vistas Horario 0 jueves , 15 de septiembre de 2005
Explorador
Base de Datos
Estudio 0
Estructura de mercado
Simulación 0
Estudio 0 - Empresas
Empresas Capacidad por Tecnología Capacidad por Empresas Porcentaje de Propiedad Unidades Agentes Externos
Color Nombre Código Potencia Térmica (MW) Eólica % Resto Régimen Especial % Hidráulica Fluyente % Hidráulica Regulable %
Endesa END 11.970,96 6,09 3,36 18,66 39,11
Iberdrola IBE 11.200,90 26,09 3,71 63,74 34,68
Unión Fenosa UF 4.953,86 0,47 1,84 11,44 21,33
Gas Natural GN 2.729,02 0,47 0,28 0,00 0,00
Franja Competitiva FNC 2.245,37 63,70 89,81 0,00 0,00
Hidrocantábrico HC 2.093,99 1,30 0,38 3,09 3,15
Viesgo VIEG 1.539,74 1,87 0,62 3,06 1,72
energeia
Simulación 0 - Resumen de Simulación
Resumen de Simulación
Ambito horario
Fecha 15/09/2005 Hora 0
Demanda Inelástica
Precio máx 120
Empresas Estratégicas END IBE UF HC GN VIEG
Contratos
Empresas |VALLE |PUNTA
|Precio(€/MWh) Cantidad(MWh) |Precio(€/MWh) Cantidad
Endesa | 0 0| 0
Iberdrola | 0 0| 0
Unión Fenosa | 0 0| 0
Hidrocantábrico| 0 0| 0
Gas Natural | 0 0| 0
Viesgo | 0 0| 0
Afeitado de puntas: Si
Configuración de la Simulación
1. Periodo
Ámbito Diario
Fecha 15/09/2005
2. Demanda
Serie Base de Datos
Variación 0
Tipo Inelástica
Precio Máx. 120
3. Empresas
Contratos (Colección)
Comportamiento (Colección)
4. Unidades
Mantenimiento Base de Datos
Alta y Baja (Colección)
5. Precios de los inputs
Nuclear 7
Carbón Base de Datos
Fueloil Base de Datos
Gas Natural Base de Datos
Dchos. de Emisión Base de Datos
6. Hidráulica y Rég. Especial
Afeitado de Puntas Si
Hidráulica Regulabl Base de Datos
Hidráulica Fluyente Base de Datos
Eólica Base de Datos
Resto Rég. Especia Base de Datos
Restricción Caudal Base de Datos
7. Simulación
Competitivo Si
Estratégico Si
7. Simulación
Simular
Estudio Porcentaje
Estado

energeia
Simulation of Electricity Markets

- **energeia** is a windows-based simulation tool that computes equilibrium outcomes in electricity markets

- The simulations are based on an oligopoly model that reflects most important features of electricity markets
  - De Frutos and Fabra (2008) "On the Impact of Forward Contract Obligations in Multi-Unit Auctions"

- **energeia** is capable of predicting (static) equilibrium bidding behavior among generators under various scenarios

- It allows to assessing the effects of (among others):
  - Changes in market structure: mergers, divestitures, etc.
  - Changes in market rules: contract obligations, emission rights, etc.

Importance of understanding strategic behavior

- Electricity markets possess several features that make them particularly vulnerable to the exercise of market power:
  - Electricity is non-storable
  - Demand has strong seasonal components and it is highly inelastic
  - Coexistence of several production technologies that produce a completely homogenous good, and they are all subject to severe capacity constraints
  - All electricity must be delivered through the transmission network
  - Frequent interaction among firms

"[It is] unclear if any bid-based short-term market, such as those operated in US, have benefited consumers. [They create] many opportunities for suppliers to exercise unilateral market power [and] limited upside for consumers in terms of potential for lower prices"

Frank Wolak (Stanford University)

Importance of understanding strategic behavior

Market power is a potential major source of inefficiency in electricity markets:

- Some firms raise bids above marginal costs: productive inefficiency
- Prices exceed the competitive level: allocative inefficiency and excessive rents
- Market power also distorts investment incentives, typically leading to underinvestment (unprofitable to expand capacity as this tends to depress prices)

A necessary condition to improve the performance of electricity markets is to understand how market power *could* be exercised

Simulating electricity markets

Approaches to simulating electricity market outcomes:

- Efficient dispatch:
  - Omits strategic behavior
- Standard competition models:
  - Cournot: assumes firms choose quantities
  - Supply function approach: ass. Firms choose smooth supply functions and face smooth cost functions
- Structural approach (concentration indexes):
  - Omits important variables such as demand and supply elasticities, vertical integration, frequent interaction, etc.

It is necessary to use models that reflect most important features (both technical as well as institutional) of these markets

Roadmap

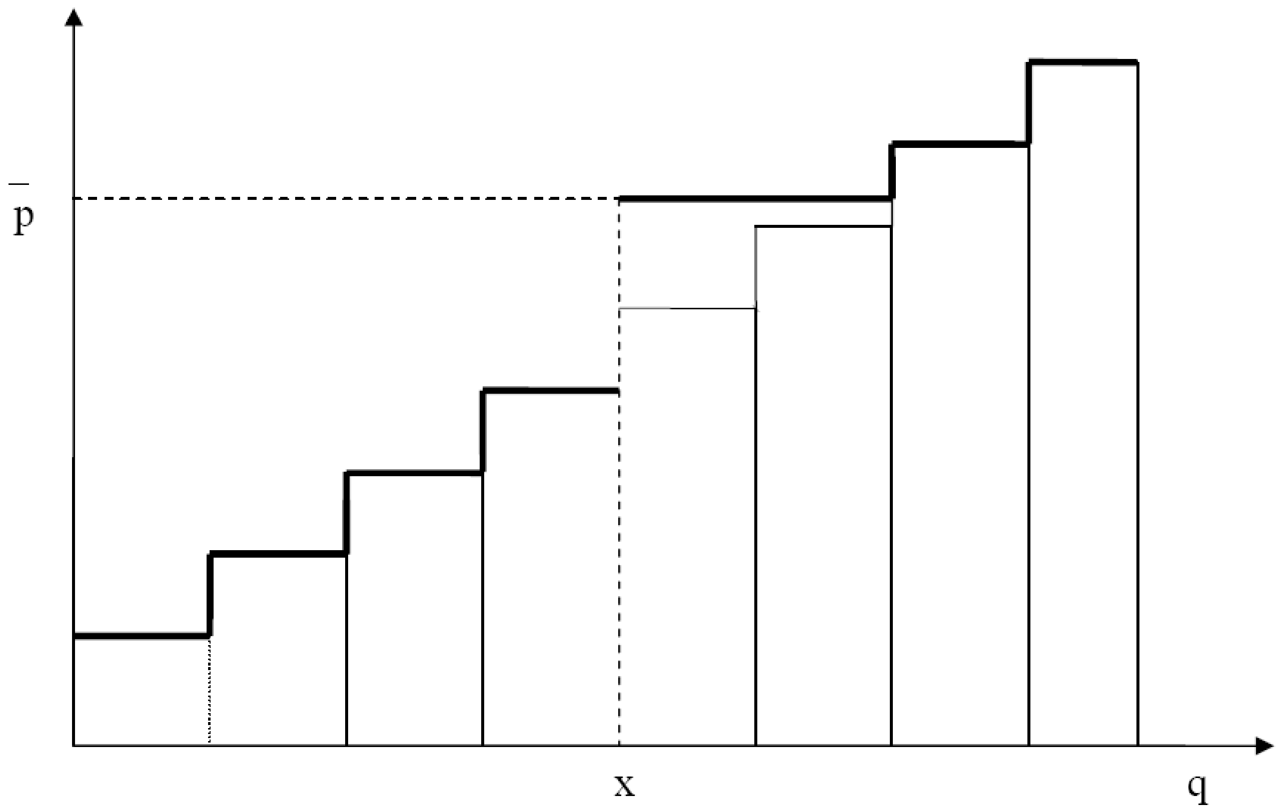
Description of energeia:
  - The model
  - The interface [DEMO]
- Some examples:
  - The effect of market power
  - The effect of CO_2 prices
  - The effect of VPPs

Model Description

Main model ingredients:

- **Firms:** oligopoly (arbitrary number of firms)
  - Each firm own a finite number of production units
  - Units may be asymmetric within a firm and/or across firms
- **Strategies**: firms compete by choosing discrete bid functions
  - Minimum prices at which they are willing to supply each unit
  - Step-wise increasing bid functions
- **Marginal costs:**
  - Constant marginal cost per production unit
  - Step-wise increasing marginal cost functions
- **Demand**: either price-inelastic or elastic

Model Description



An example of a bid function

Model Description

Main model ingredients (cont):

- Bidding and market clearing on an hourly basis:
  - We assume no demand uncertainty (short-lived bids)
- Dispatch: the low bidding units are dispatched first until total demand is satisfied
- Uniform-price auction: the market price is set equal to the last accepted bid; all dispatched units receive this prices regardless of their individual price offers
- We allow firms to hold *contracts for differences* and/or to be vertically integrated

- We characterize the (static) Nash-equilibria of the game:
  - Bid function profiles from which no firm can profitably deviate, given the behavior of their rivals.

Model Predictions
Perfect Competition

Perfect competition:

- Firms bid at marginal costs.
- The market price is the MC of the least efficient unit needed to cover demand.
- The marginal unit gets zero profits; the inframarginal units get inframarginal rents.

- The above <u>need not be an equilibrium</u> if firms behave strategically:
  - Raising the bids of some units above marginal costs may be profitable despite the output loss, as this results in an increased price for all dispatched units.

Model Predictions
Imperfect Competition

Imperfect competition:

- In equilibrium, all firms but one behave as price takers (e.g. by bidding at marginal costs)…[*Non-price setters*]
- …while the remaining firm sets the price that maximizes its profits over the residual demand [*Price setter*]
  – Firms' profit maximizing prices differ if they are asymmetric, e.g. relatively larger or efficient firms face a larger residual demand and hence have higher profit maximizing prices.
  – It is not inconsequential which firm acts as the price-setter.

- For a given price, firms prefer to be NPS as they produce more than the PS.
- However, a firm might prefer to become the PS if the current price is too low.

Model Predictions
Features of equilibria

Important remarks:

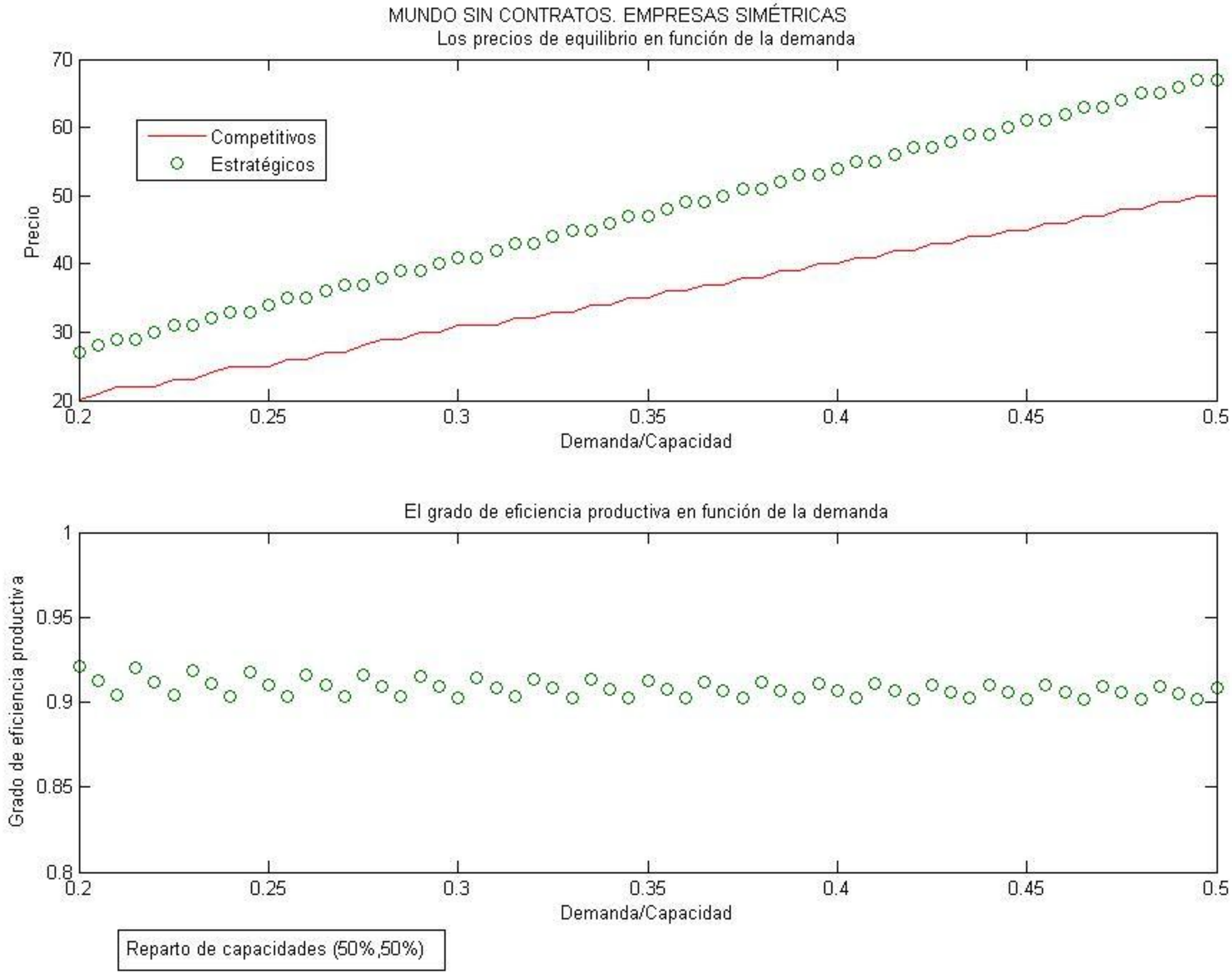
- In any non-competitive equilibrium, there is a single price-setter:
  - Otherwise, one firm could profitably deviate by slightly reducing its bid, thus increase its production with only (if any) an infinitesimal price reduction.
- There can be multiple equilibrium outcomes:
  - At most as many equilibria as firms in the market.
  - Not all the candidate equilibria are in equilibrium:
    - e.g.: a small firm cannot be the price-setter: it would set such a low price that some other firm would prefer raising the price.
- An equilibrium always exists:
  - The highest price equilibrium always exists as the NPS are making the maximum profits possible.

Model Predictions

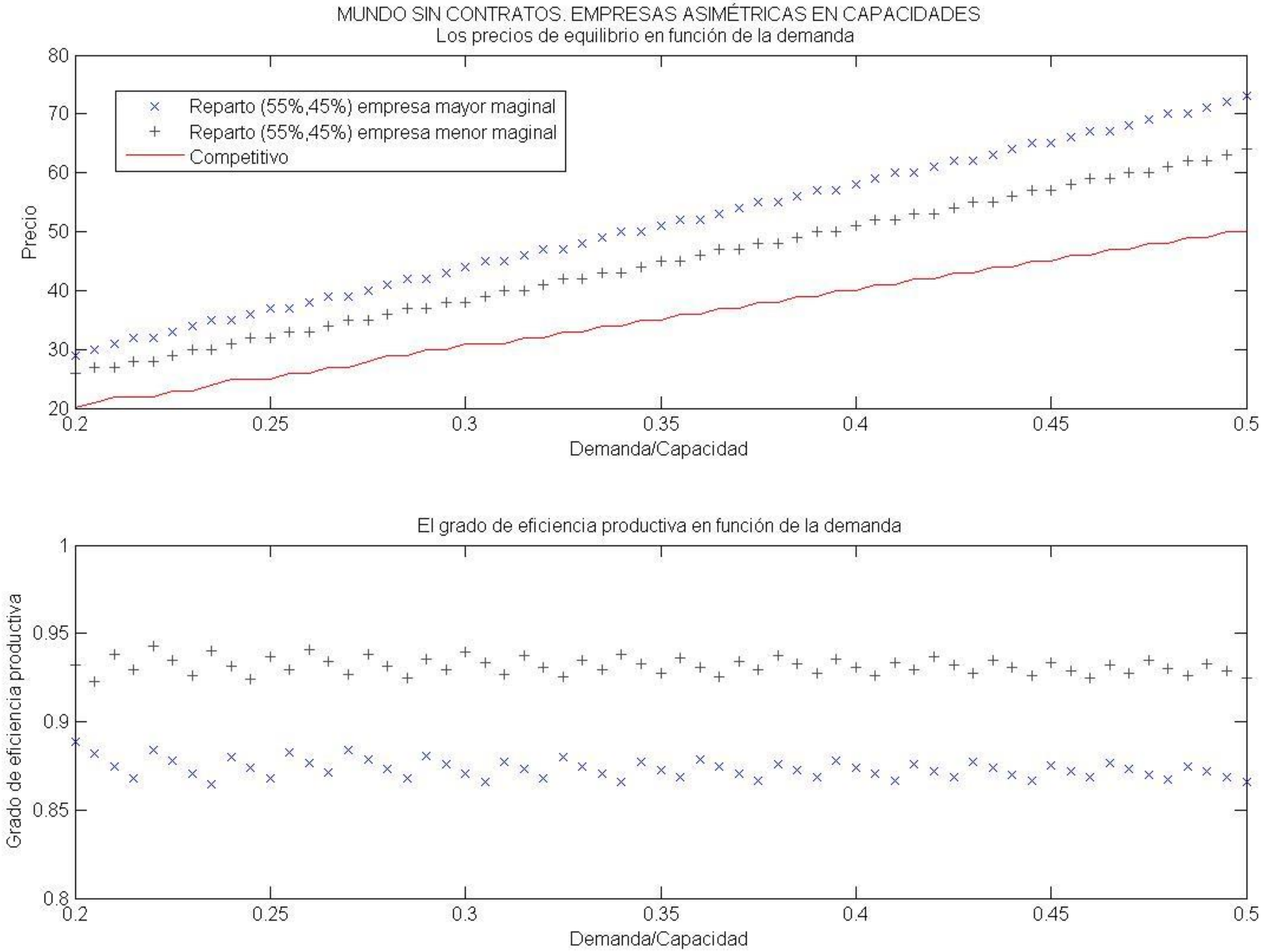
Usefulness for simulation purposes

- These theoretical predictions greatly simplify the simulations carried out by **energeia**:
  - Without such predictions, one would have to check deviations out of all the possible bid profile combinations (i.e., an infinite number of calculations!)
  - With these predictions, energeia only needs to check deviations out of as many candidate equilibria as firms in the market
    - e.g. with 4 firms, 4 computations per hour; in a year, 8760*4=35,040 computations
  - Hence, **energeia** is very fast!
  - [and it is not subject to problems arising from using a discrete price grid, such as delivering too many equilibria that would not exist with a continuous grid]

Model Predictions
Equilibria with two symmetric firms

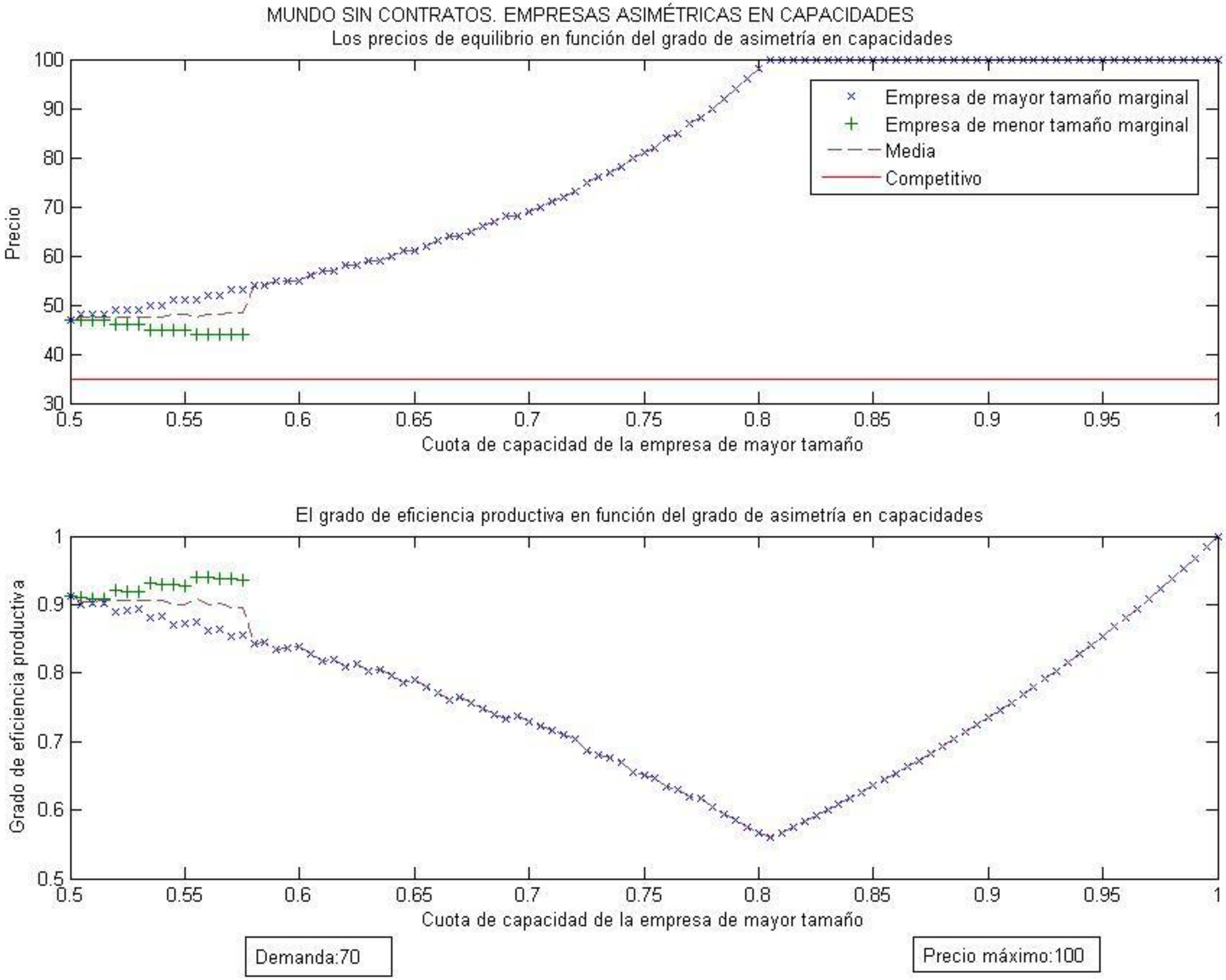


Model Predictions
Equilibria with two asymmetric firms



Model Predictions

Equilibria as a function of asymmetries



The effect of asymmetries

Greater asymmetries among firms may lead to higher prices

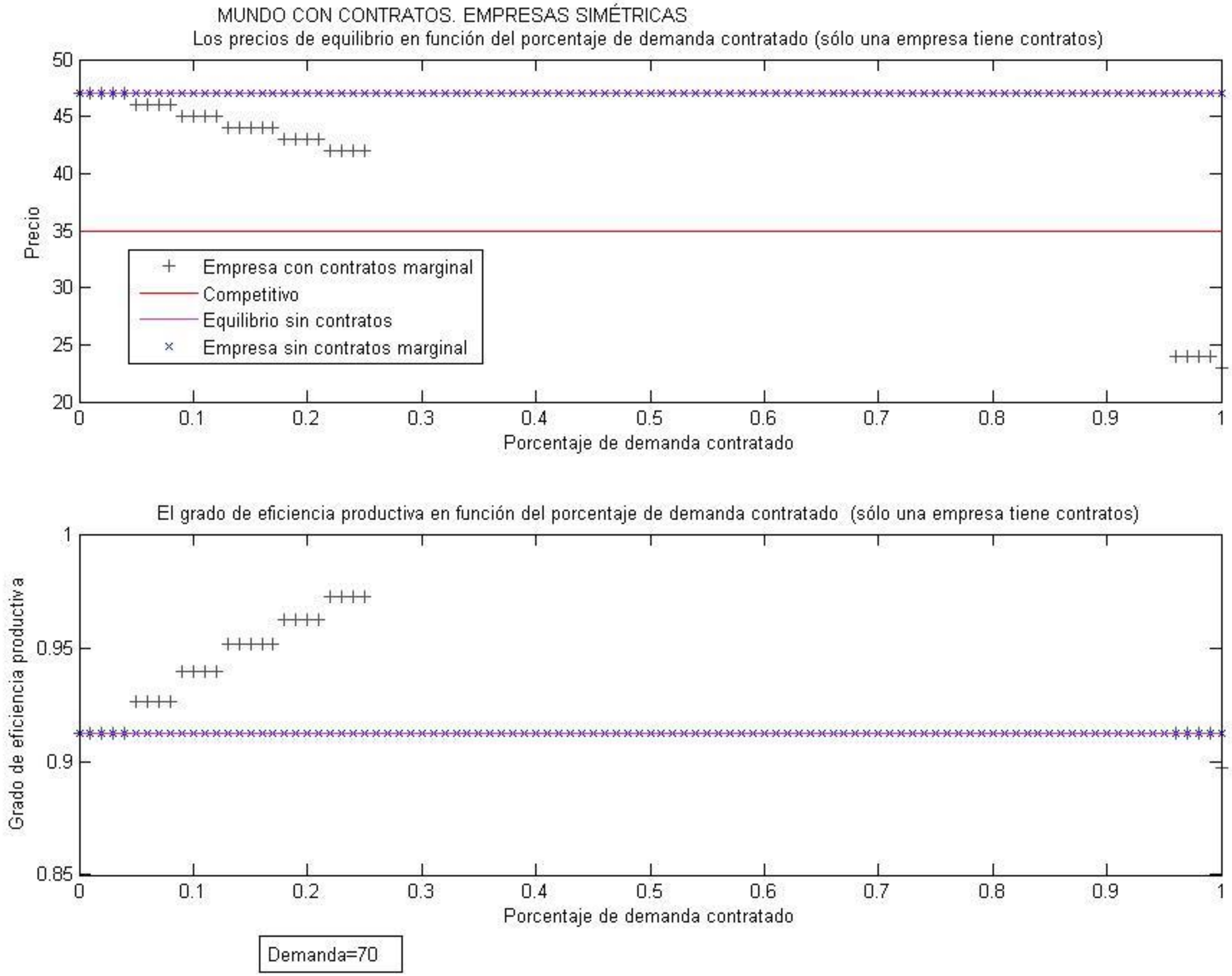
Mergers:

- A merger between the large firms strengthens their incentives to raise prices: anticompetitive.
- A merger between the small firms may give rise to new equilibria in which the merged entity sets the price. This may lead to lower prices: pro-competitive.

Contracts for Differences:

- If the large firms sell CfDs, their net positions are reduced, thus mitigating their incentives to raise prices: pro-competitive.
- If the small firms sell CfDs, the equilibria in which such firms set prices may disappear, thus leading to higher prices: anti-competitive

Model Predictions
Contracts for Differences



Simplifying assumptions

- The model abstracts from some complexities in real markets
  - Such omissions may generate a downward bias in prices.
  - That is, lower prices than those that could potentially occur.

- Hydro production: Peak-load shaving on a monthly basis
  - Equivalent to assuming competitive behavior by hydro producers.
  - The strategic use of hydro would lead to higher prices as predicted by energeia.

- Start-up costs, ramping rates, etc.
  - It is assumed that all units are available (unless under maintenance).
  - Hence, total available capacity is greater, and competition is more intense as compared to the case in which some units are off-line.

Some illustrative examples

- We next report examples on the effects of:
  - Market power
  - CO2 prices
  - VPPs (of forward contracts)

- These examples have been computed with data of a representative country/year.

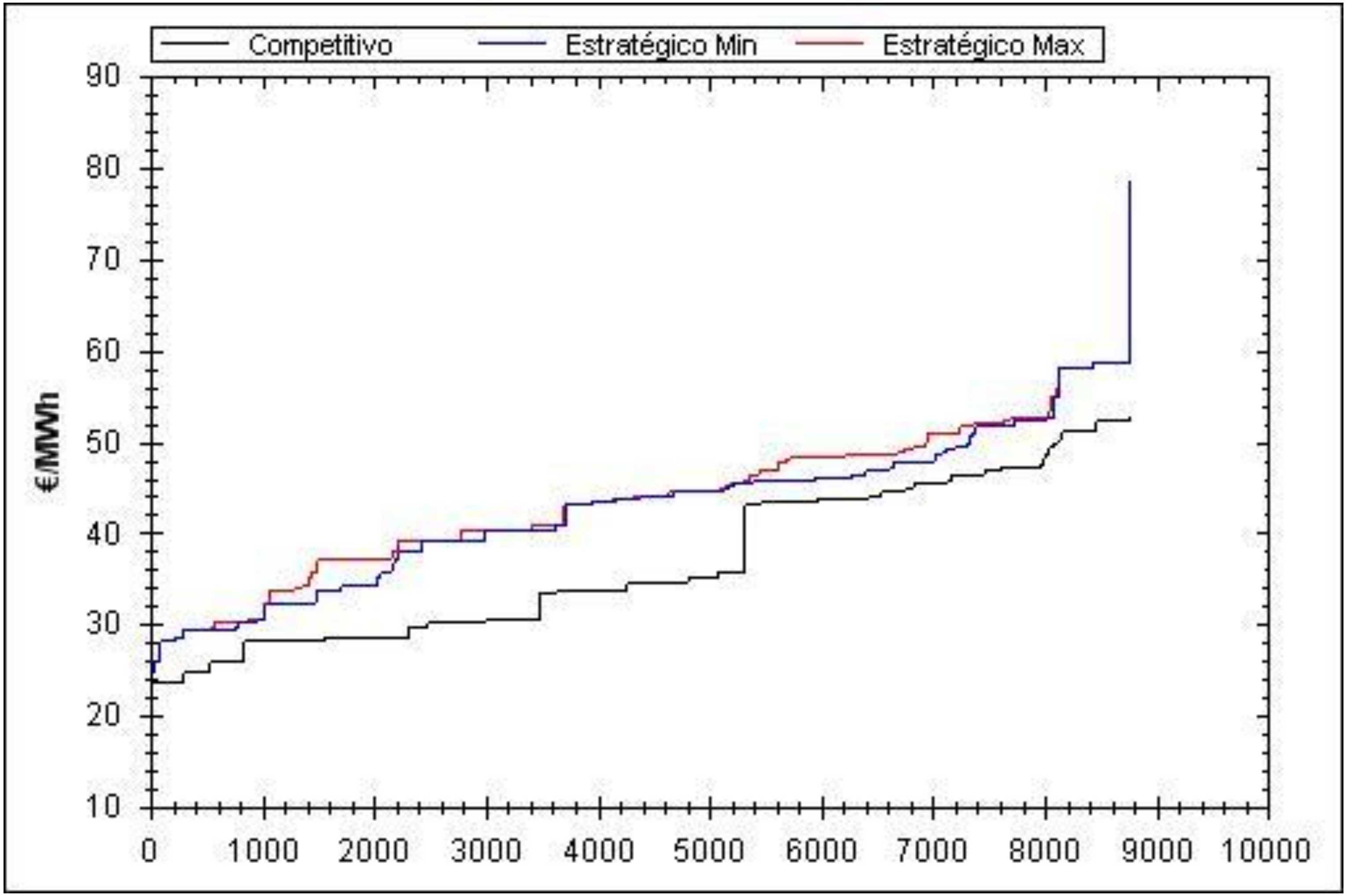
- NOTE of caution:
  - For this reason, the results need to be taken with caution, i.e., they need not extend to specific countries with different technology mixes and market structures as the ones assumed here.
  - However, they illustrate some important facts. It is not the exact figures that matter but the phenomena they exemplify.

The Effect of Market Power

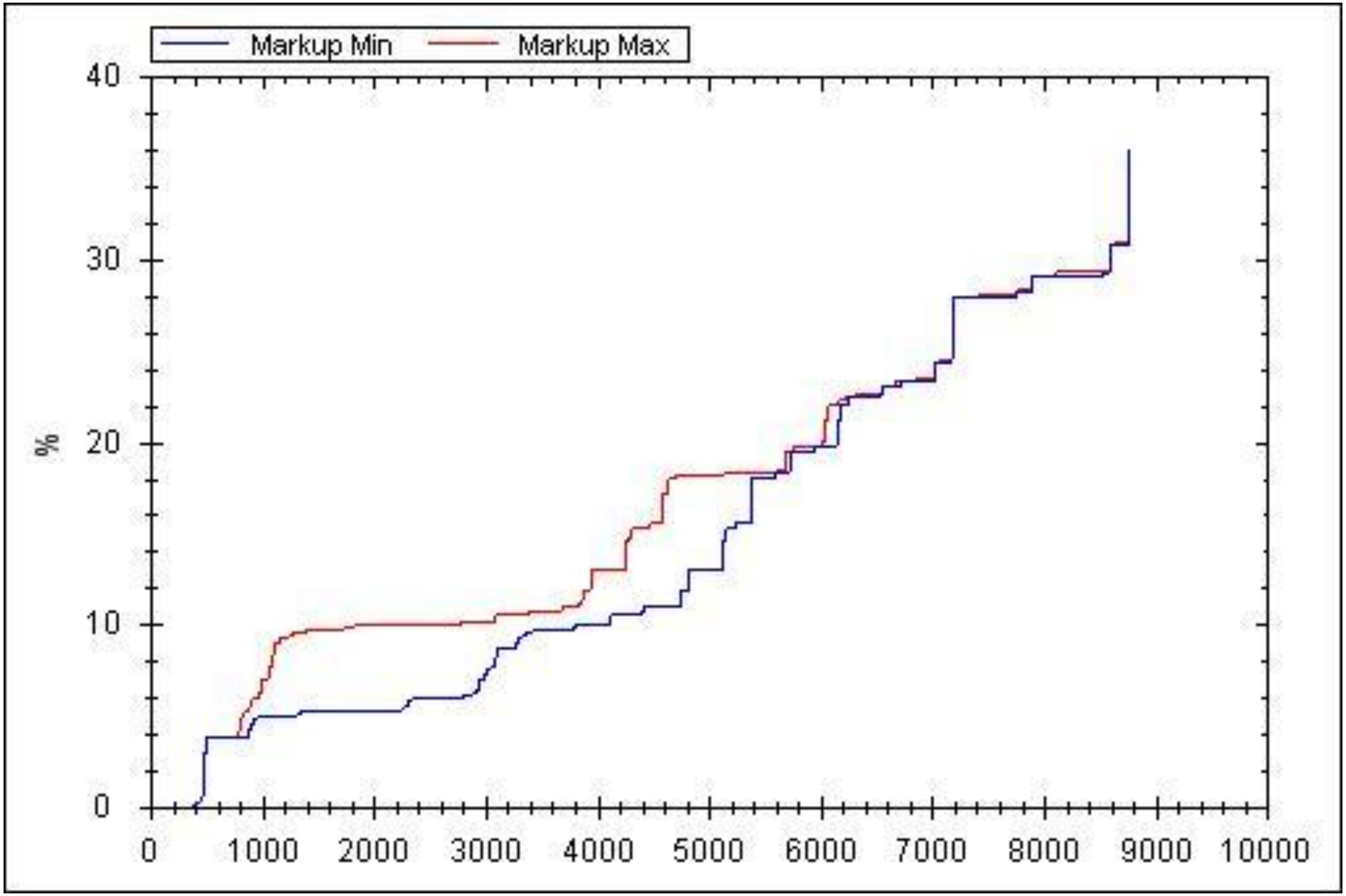
- We have compared simulated market outcomes under perfect versus imperfect competition

- **Main Findings:**
  - Equilibrium prices are above the competitive price 94% of the year
  - The average mark-up for the year is 15%
  - Mark-ups vary with load because competitive conditions vary depending both on the value of inframarginal capacity as well as on the marginal technology:
    - (23%,16%,11%, 50%) for the (25%,50%,75%, 100%) load percentiles

Equilibrium prices under perfect and imperfect competition



Markups equilibrium price vs. competitive price

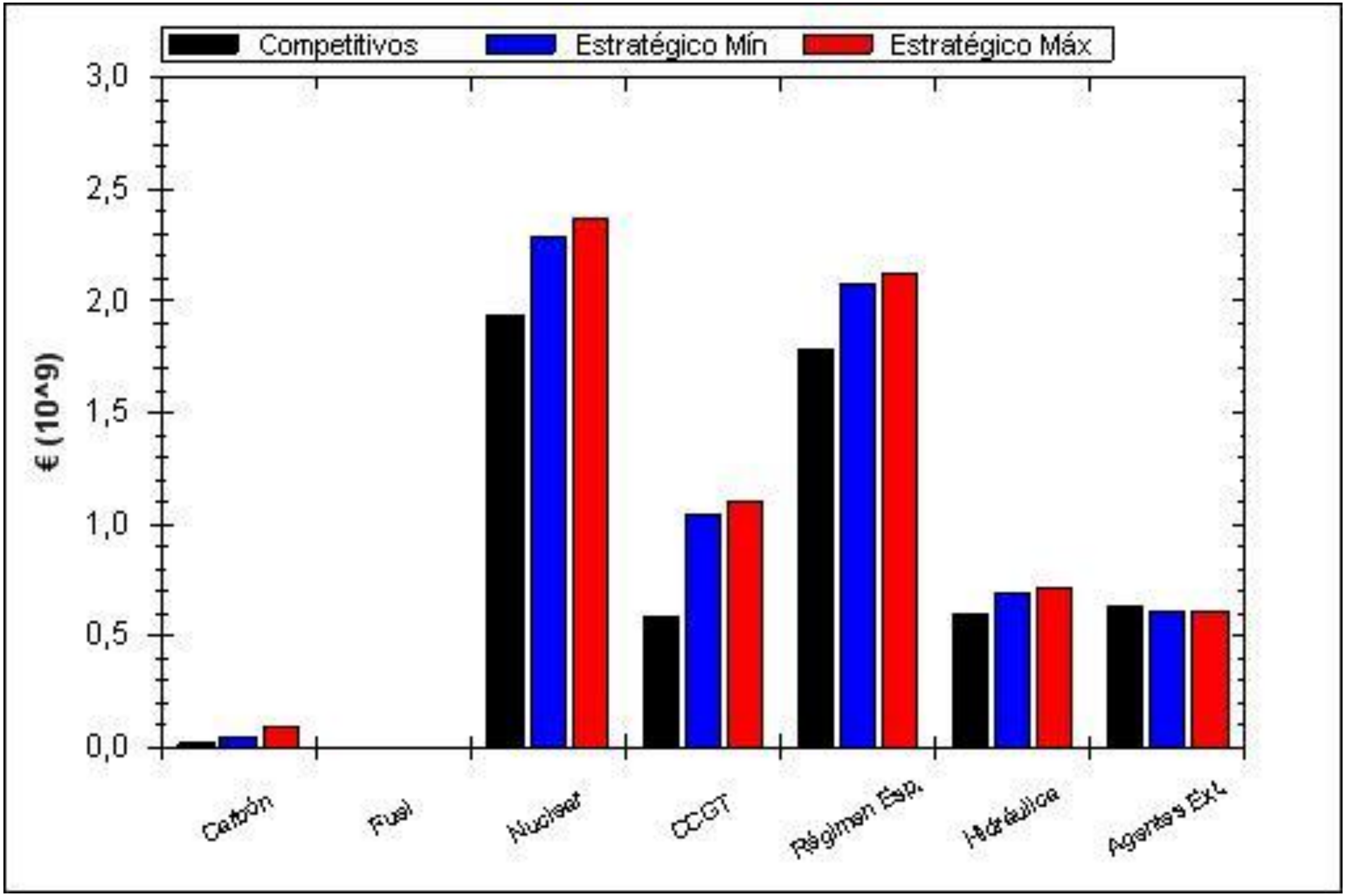


The Effect of Market Power

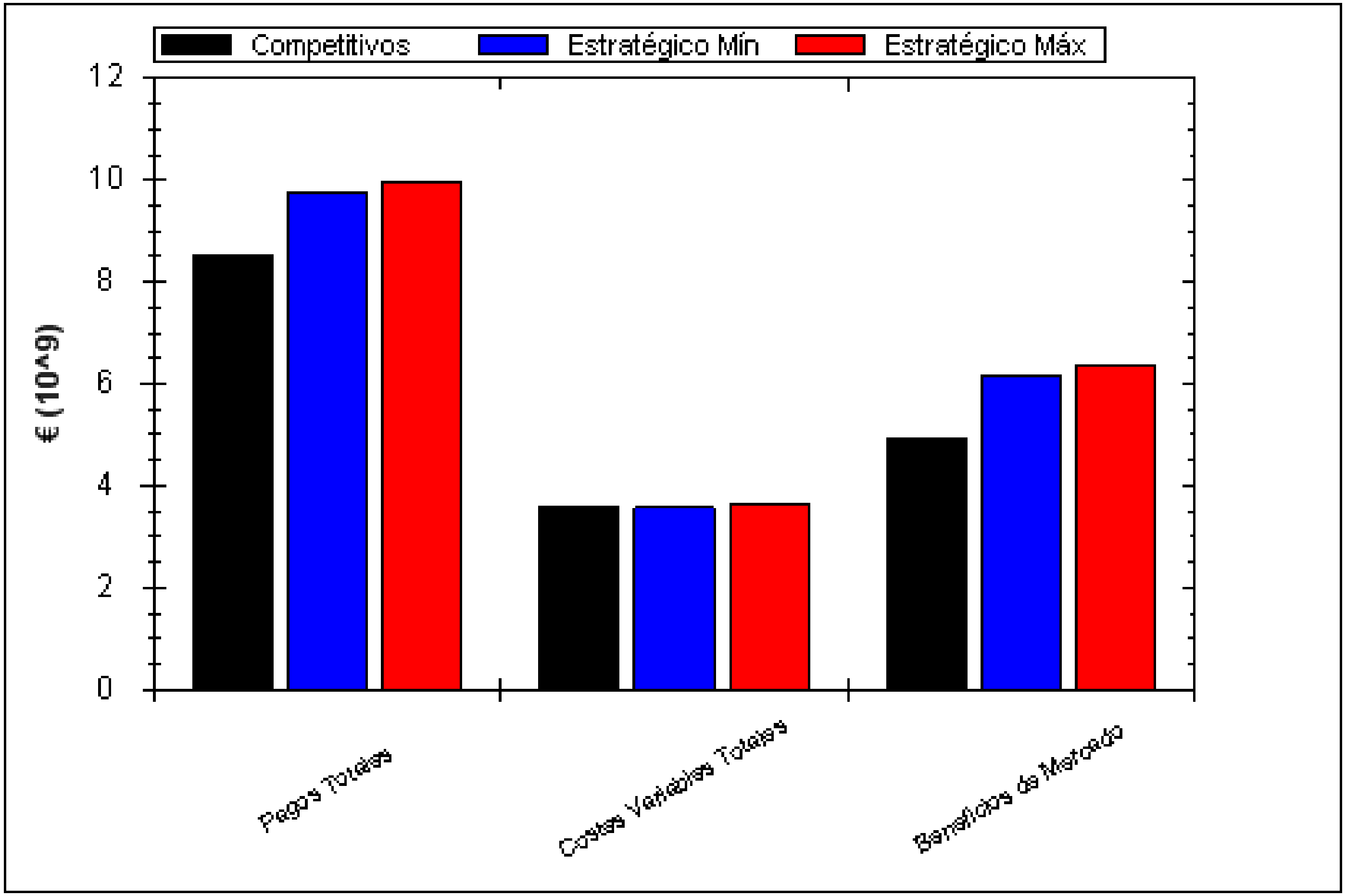
Main Findings (cont.):

- Payments to generators are 15% larger, while their profits increase 22% as compared to the perfectly competitive scenario.
- Market power has distinct effects on different technologies:
  - Out of the increase in total profits, 65% goes to Nuclear, Hydro and Renewables, while 30% goes to CCGT and 5% to Coal
- Market power also creates productive inefficiencies: costs rise 0.5%

Profits under perfect and imperfect competition by technology



Total payments, variable costs and market profits under perfect versus imperfect competition



The Effect of CO_2 prices

- Under the EU Emission Trading Scheme, generators are obliged to cover their CO_2 emissions with emission permits.
- The fact that these permits have been allocated for free does not imply that their true cost will not affect bidding strategies.
  - CO_2 prices have a real value as an opportunity cost that should be treated as a short-run marginal costs of production
- Coal plants are more affected than CCGTs because of their higher emission rates (the merit order may change depending on heat rates, price spreads).
- The resulting increase in the electricity price affects all dispatched output (including the output covered by free permits as well as the inframarginal output with no emissions).

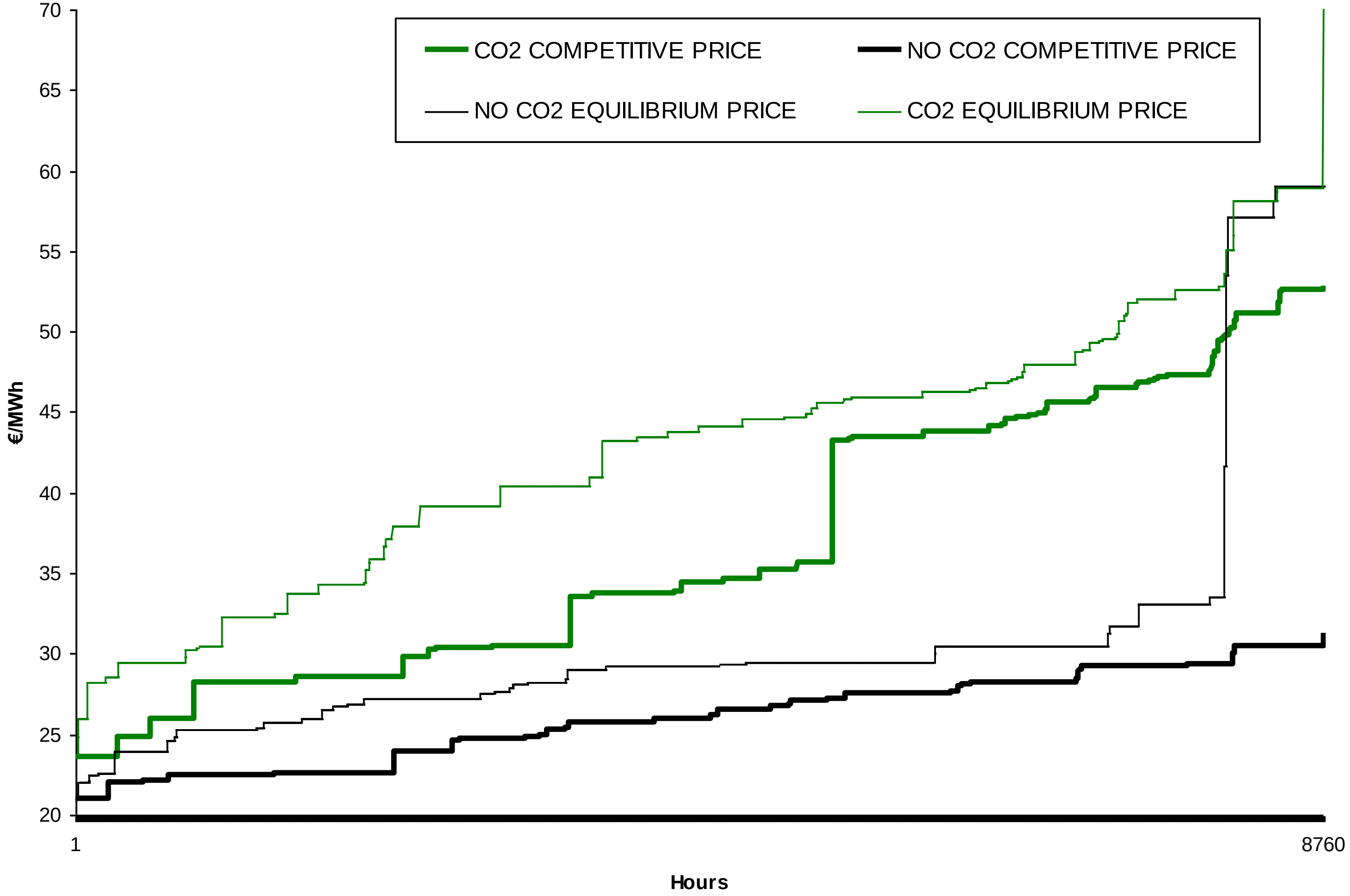
The Effect of CO_2 prices

- We have compared simulated market outcomes with and without CO_2 prices in order to assess their effect on total payments and profits under the following assumptions:
  - Perfect competition (unless otherwise mentioned).
  - Generators pay CO_2 permits at market prices.

Main findings:

- (Competitive) Prices increase by 29%.
- Total payments to firms increase 28%:
  - generation costs increase by 15%;
  - firms' profits increase 34% despite having to pay for permit prices.
- Out of the increase in total payments, 22% corresponds to the increase in costs while the remaining 78% implies greater generators' profits.
- What is the cost (in terms of payments to firms) of reducing 1 CO_2 Ton?
  - ….around 235€ [compare this with the price of EUA!]

Competitive and equilibrium prices with and without CO2



The Effect of CO2 prices

Main findings (cont.):

- The effects on profits are asymmetric across technologies: coal loses profits, while all the rest enjoy a profit increase.
- Out of the increase in profits due to CO2:
  - 35% goes to Nuclear,
  - 17% to Hydro,
  - 27% to Renewables, and
  - 27% to CCGT

Virtual Power Plants (VPPs)

In an attempt to mitigate market power, several regulators worldwide have imposed on to firms the obligation to auction-off the right to use part of their capacity through Virtual Power Plants (VPPs).

VPPs have been used in:

- Merger cases (e.g. EDF/EnBW; Nuon/Reliant).
- Antitrust proceedings (AGCM vs. ENEL).
- Form part of more general powers of national regulators (Electrabel; Endesa and Iberdrola).

Virtual Power Plants (VPPs)

VPPs are:

- Call options giving the buyer the right to nominate energy for delivery
- During a certain period of time
- At a pre-defined strike price
- In exchange of paying a capacity price, which is determined through an auction

VPPs are optional:

- The VPP holder has the right to exercise the option
- If he exercises it, he pays the strike price and receives the market price
- He will exercise the option if expected price> strike price

Theoretical Effects of VPPs

1. VPPs reduce firms' incentive to exercise market power

- When a firm exercises market power, it faces a trade-off:
  - Higher profits made on the firm's infra-marginal output
  - Loss of profits on the lost output
- The VPP reduces the firm's incentives to raise prices since spot prices only affect firms net positions (*as if* infra-marginal capacity was reduced)

2. VPPs reduce firms' profits

- Since the market becomes more competitive….
- …the future profits made by the VPP winner will be lower than the profits the owner would had made without the VPP
- Hence, the capacity price set in the VPP auction will be lower than the profit the owner would have made without the VPP

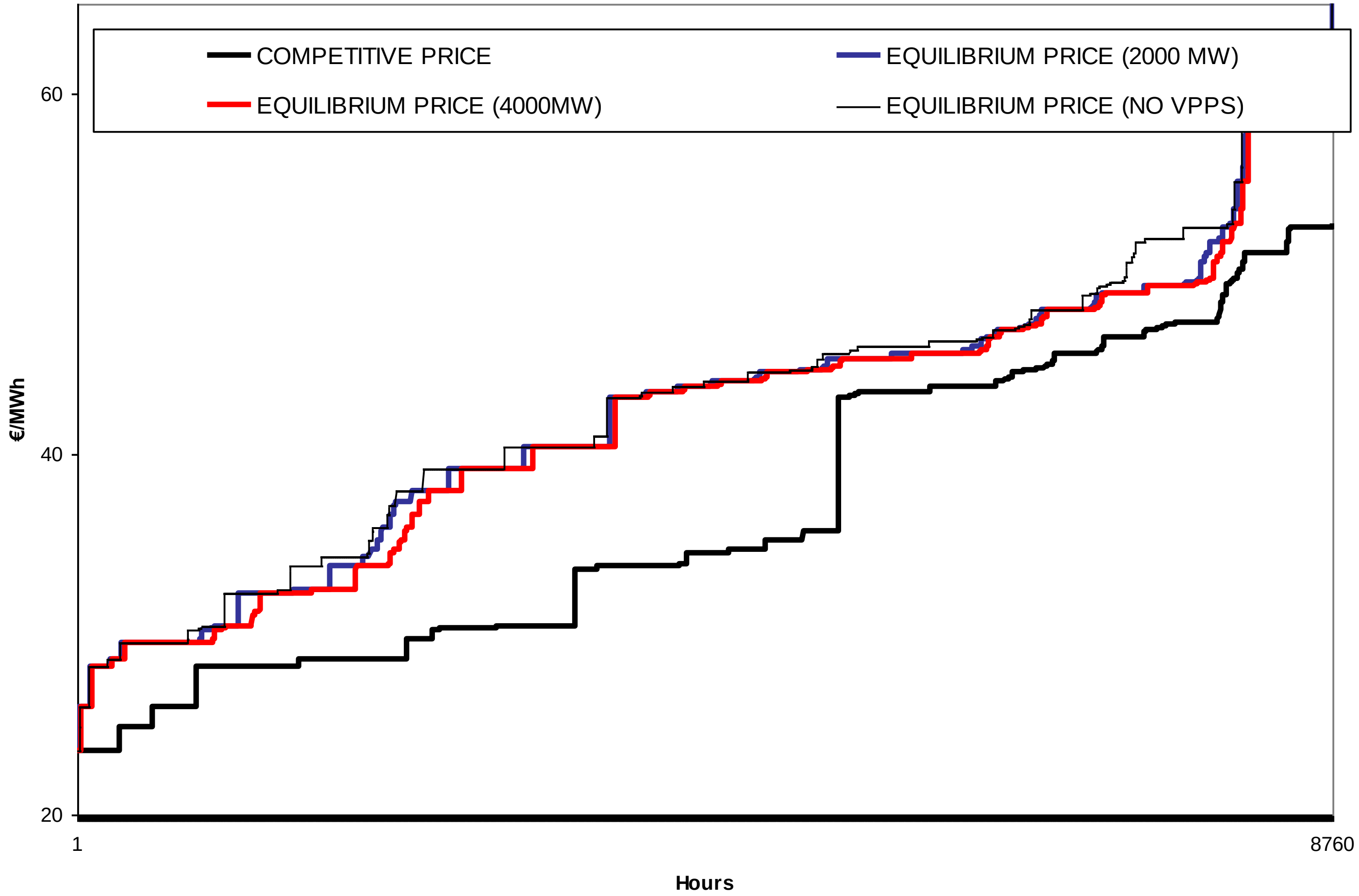
The Effect of VPPs

- We have compared simulated market outcomes with and without VPPs with a zero strike price (i.e., as in forwards) and volumes 2000 MW and 4000 MW (approx. of thermal capacity)

Main findings:

- (Equilibrium) Prices decrease by 1.2% with 2000MW-VPP and 1.8% with 4000MW-VPP as compared to the no-VPP case.
- Still markups are significant: above 13% and 12.4%, as compared to in the no-VPP case in which the markup is 14%.
- Total payments to firms decrease by 1% and 2.5 %:
  - generation costs decrease by 0.9% and 1.7 %;
  - firms' profits (w/o VPP revenues) decrease by 1.4% and 3.3%.

Competitive and equilibrium prices with and without VPPs



Thank You.

For background and
related papers see
http://www.eco.uc3m.es/nfabra

EFECTOS HORIZONTALES GN+UF EN EL SECTOR ELÉCTRICO
El mercado de generación mayorista (IV)

CNE

Impacto de la operación sobre los indicadores de "pivotalidad"

Año	2007 (Q3-Q4) – 2008 (Q1 -Q2)		
	Situación actual		
	RSI*	PSI **(horas)	PSI** (días)
Endesa	8,4%	1,8%	8,5%
Iberdrola	13,5%	4,4%	19,4%
Otros	0,0%	0,0%	0,0%
	Fusión GAS NATURAL – UNIÓN FENOSA		
Endesa	8,4%	1,8%	8,5%
Iberdrola	13,5%	4,4%	19,4%
GN + UF	**5,9%**	**0,4%**	**3,0%**

Fuente: CNE

* % de horas en las que el RSI de un agente es < 110%.

** % de horas o de días en los cuales un agente tiene condición de "pivote".

- Pivotalidad antes de la fusión de GN y UF es cero.
- El nuevo grupo tendría un grado de pivotalidad relevante en un 5,9% de las horas (RSI superior al umbral del 5% del test de Sheffrin)
- El indicador PSI muestra que la nueva entidad sería "pivote" en un número pequeño de horas (0,4% en un año) y de días (3%).