

Renewable Sources, Technology mix, and Competition in Liberalized Electricity Markets: The case of Spain


4th Atlantic Workshop, REDE

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Outline of the presentation

- Motivation
- Literature
- The Model
- Contingent scenarios and possible market results
- Spanish case
 - ① Descriptive statistics
 - ② Analysis
- Conclusions and further research

- The use and exploitation of energy sources is growing and will continue to do so in the near future.

Motivation

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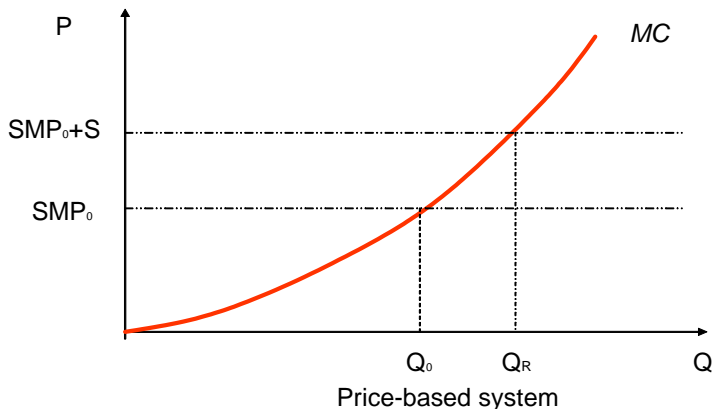
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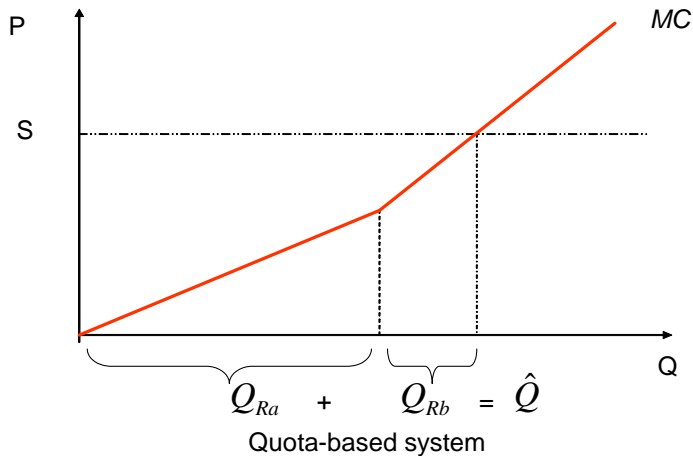
Motivation, II

- Policy mechanisms to support renewable sources within EU members are focused mainly on financial instruments:
- Price-based systems (Germany, France, Spain and Denmark which apply feed-in tariffs).



Motivation, III

- Quota-based systems,



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- Menanteau, P., Finon D., Lamy M.L., (2003). "Prices versus quantities: choosing policies for promoting the development of renewable energy". Energy Policy, 31, 799-812.
- <http://www.euractive.com>.

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- Firms minimize costs in each plant:

$$\text{Fossil plant} \begin{cases} \text{MIN}_F c_F F + \Omega \\ \text{s.t.} : F^\alpha = q_i^F, \end{cases} \quad \text{Renewable plant} \begin{cases} \text{MIN}_R c_R R + \Omega \\ \text{s.t.} : [R/\phi(e)]^\alpha = q_i^R, \end{cases}$$

$\phi(e) \in \mathbb{R}$ specifies technical maturity, with $\phi(0) = 1$, and $\phi'(e) < 0$.

- Cost function: $C_i(q_i) = c_F \cdot (q_i^F)^2 + c_R \cdot \phi(e) (q_i^R)^2, \quad i = 1, 2.$

The model, II

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- Market clearing condition $\sum_{i=1,2} S_i(\beta_i) = D(\omega)$,

$$\omega(\beta) = \frac{1}{\mathbf{1} \cdot \mathbf{p}' + \sum_{i=1,2} \beta_i \cdot \mathbf{p}'},$$

where $\beta = (\beta_1, \beta_2)$ and $\mathbf{p} = [1, (1 + \tau)]$.

Definition

$(\beta_i^{SN}, \beta_j^{SN})$ is a SN equilibrium such that each firm is maximizing profits
 $\beta_i^{SN} \in \arg \max_{s_h} S_i(\beta_i) \omega(\beta) - C_h(\beta_i, \omega(\beta))$, for $i, j = 1, 2, i \neq j$.

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- Equilibrium magnitudes,

$$\hat{q}_i^F = \hat{q}_i^R (1 + \tau) - \frac{\phi(e) - 4\tau - c_F}{4\theta}, \quad \hat{q}_i^R = \frac{\theta + 2\tau - c_F}{4\theta(1 + \tau)}, \quad \hat{\omega} = \frac{\phi(e) + c_F}{2\theta},$$

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- yielding profits,

$$\hat{\pi}_i = \frac{(\phi(e) + c_F)(2\theta - \phi(e) - c_F)}{8\theta^2} - \frac{c_F(\phi(e) + 2\tau - \theta)^2}{32\theta^2} - \frac{\phi(e)(2\tau + \theta - c_F)^2}{32\theta^2(1 + \tau)^2}$$

$\theta(\phi(e), c_F, \tau), \theta_{\phi(e)} > 0, \theta_{\tau} > 0, \text{ and } \theta_{c_F} < 0$

Contingent scenarios and possible market results

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 - 3 wholesale price decrease as the subsidy increase, then $\partial(\hat{\omega})/\partial\tau < 0$.

Scenario 1

$$\phi(e) = \frac{1}{1+e}, c_F = 3/2 \text{ and } \tau \in \{0, 0.25\}$$

- Status quo: $\phi(e) > c_F$. ► $e = -1/2 \implies \phi(-1/2) = 2$

	π_i^{SN}	$(q_i^F)^{SN}$	$(q_i^R)^{SN}$	Q^{SN}	ω^{SN}
$\tau = 0$.085	.165	.124	.578	.422
$\tau = .0.25$.089	.140	.125	.530	.405

$$\phi(e) = \frac{1}{1+e}, \quad c_F = 3/2 \text{ and } \tau \in \{0, 0.25\}$$

- Equal marginal cost: $\phi(e) = c_F$. $\blacktriangleright e = \frac{1}{c_F} - 1 < 0 \implies \phi(\frac{1}{c_F} - 1) = 3/2$.

Table 2. Simulation for $e = (1/c_F) - 1$.

	π_i^{SN}	$(q_i^F)^{SN}$	$(q_i^R)^{SN}$	Q^{SN}	ω^{SN}
$\tau = 0$	.085	.150	.150	.600	.400
$\tau = .0.25$	.089	.123	.149	.544	.381

Scenario 3

$$\phi(e) = \frac{1}{1+e}, \quad c_F = 3/2 \text{ and } \tau \in \{0, 0.25\}$$

- RES technical maturity above fossil sources: $\phi(e) < c_F$. \blacktriangleright
 $e \in \{0, 1/2\} \implies \phi(0) = \{1, 2/3\}$.

Table 3. Simulation for $e = 0$.					
	π_i^{SN}	$(q_i^F)^{SN}$	$(q_i^R)^{SN}$	Q^{SN}	ω^{SN}
$\tau = 0$	.084	.127	.191	.636	.364
$\tau = .0.25$	.088	.097	.185	.564	.342

Table 4. Simulation for $e = 1/2$.					
	π_i^{SN}	$(q_i^F)^{SN}$	$(q_i^R)^{SN}$	Q^{SN}	ω^{SN}
$\tau = 0$	.082	.103	.235	.676	.324
$\tau = .0.25$	.085	.071	.221	.584	.301

Spanish case. Descriptive analysis

- Electricity traded by technologies,

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Table 5.- Electricity by Technologies thousand of GW/h

	Special Regime				Thermal				Total
	Distr.	Pool	Hydro	M	NU	CB	CB	OF	
02	33, 1	0, 55	21, 2	9, 41	60, 6	77, 4	4, 69	11, 4	218, 4
03	32, 5	5, 06	36, 3	8, 11	59, 6	72, 3	11, 7	6, 21	231, 9
04	35, 9	6, 50	28, 1	7, 81	61, 4	73, 2	21, 4	4, 77	239, 2
05	25, 8	23, 2	15, 9	8, 67	55, 4	74, 7	45, 2	7, 84	256, 7
06	6, 1	40, 2	16, 8	11, 7	54, 5	51, 4	42, 7	4, 39	227, 9
07	0	57, 0	26, 7	9, 91	53, 1	69, 7	53, 9	4, 06	274, 5
08	0	65, 6	20, 4	6, 79	57, 0	43, 5	82, 0	4, 39	279, 8

Source:OMEL and own construction. Distr.:distribution; NU:nuclear

CB: coal-burning; CC: combined cycle; OF: oil-fired.

- Iberdrola and Endesa are pivotal firms in generation.

Table 6.- Marginal Plants						
Firm	2002			2008		
	% hours	From RES		% hours	From RES	
		Hy	Non-hy		Hy	Non-hy
IB	42.5	40.1	0	14.55	40.47	1.23
Peak IB	72.5	71.8	0	26.39	45.49	2.03
Off-Peak IB	10.9	6.5	0	8.20	34.95	0.36
EN	23.4	7.2	0.01	17.58	15.84	0
Peak EN	12.3	11.6	0	12.25	19.67	0
Off-Peak EN	36.4	0	0	20.58	11.96	0

Spanish case. Descriptive analysis, III

- Iberdrola has larger renewable power generation than Endesa

Table 7. Generators' Capacity, 2002 and 2008 (GW)

Technology	Firm					
	EN		IB		UF	
	2002	2008	2002	2008	2002	2008
Hydroelectric	5.2	5.3	8.5	8.6	1.8	1.8
Other renewable	0.2	2.9	0.1	5.5	0	1
Total Renewable	5.4	8.2	8.7	14.1	1.8	2.8
Nuclear	3.6	3.6	3.3	3.3	0.7	0.7
Coal	5.8	5.8	1.2	1.3	2.0	2.0
Oil-fired	1.5	1.3	2.0	2.0	0.8	0.8
Combined Cycle	1.4	2.4	3.2	6.0	2.1	4.0
Total Non-renewable	12.3	13.1	9.7	12.5	5.8	7.5
TOTAL	17.7	21.6	18.4	26.6	7.5	10.3

Sources: Firms' web pages, REE, and OMEL.

Islands not included. Provisional values for 2008.

- Market shares in generation,

Table 8.- Market shares

	IB	EN
2002	0.43	0.30
2008	0.25	0.20

Summary statistics of variables

	Mean	Std. dev.	min	max
Dep. Variable				
SMP	38.4	18.6	0	158.4
Indep. Variables				
Available Nuclear	7113	758	4587	7735
Available Coal-burning	9517	577	7431	10273
Available Oil-Fired	6092	450	4327	7011
Available Combined-cycle	4879	2904	8	11898
Available Hydroelectric	15622	345	14627	16386
Available Windmills	?	?	?	?
Available Other	?	?	?	?
Source: OMEL, CNE and own calculations				

Spanish case. Analysis, II

- Behavior of the SMP depends on past values: the variance of the current error term is a function of the variances of the previous time period's error terms. Arch models: in electricity markets volatility of the variance is also dependent on previous periods variance volatility.

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- Behavior of the SMP depends on past values: the variance of the current error term is a function of the variances of the previous time period's error terms. Arch models: in electricity markets volatility of the variance is also dependent on previous periods variance volatility.
- Two different specifications: Equation [1] does not include explicitly time effects. Equation [2] includes time dummies, T_{th} . SMP is a function of the fraction of fossil fuel plants (nuclear, D^N , coal-burning, D^{CB} , oil-fired, D^{OF} , and combined cycle, D^{CC}) available for the following day (which is announced the day before, that is in $t - 1$), expected weather conditions for each hour, W_{th}^{NH} , and water reserves, W_{th}^H .

$$SMP_{th} = \alpha + \beta_1 D_{t-1}^N + \beta_2 D_{t-1}^{CB} + \beta_3 D_{t-1}^{OF} + \beta_4 D_{t-1}^{CC} + \gamma_1 W_{th}^H + \gamma_2 W_{th}^{NH} + \varepsilon_t$$

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where $h = 1, \dots, 24$.

- Estimation results for the two specifications of the Arch model.

Estimation from two alternative models		
	[1]	[2]
Nu	-0.019***	-0.016***
Co	-0.025***	0.003
Of	0.008***	0.021***
Cc	-0.010***	0.007***
Hy	0.005	0.032***
Time dummies	NO	YES
Log likelihood	-7714	-8059

***Significant at 1%.

Conclusions and further research

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- The *special regime* must encourage trading renewable energy at the pool in order to increase efficiency.
- Increasing the share of renewable sources strongly depends on subsidies and technological innovations.
- Preliminary estimation results for the period 2002-2008 show how market prices are higher when the share of hydroelectricity is higher.

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Conclusions and further research, II

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- Further research: improve model predictions and empirical insights.

Thanks for attention

- Comments are welcome,...