

Relation between wind and electricity prices in a deregulated market: the case of Ireland

Valeria Di Cosmo and Laura Malaguzzi Valeri

*Economic and Social Research Institute
and Trinity College Dublin*

TransAtlantic Infraday Conference, Washington DC

7 November 2014

Interaction between greater renewable generation and electricity prices

- ▶ Growing importance of renewables
- ▶ How does this affect consumers in the short run? (effect on prices)
- ▶ Look at actual (historic) results

Why Ireland?

- ▶ Main characteristics of Irish Single Electricity Market:
- ▶ Compulsory market with capacity payments
 - ▶ System-wide data, publicly available on (half)hourly basis
- ▶ Limited interconnection with other systems (i.e. GB)
 - ▶ Easier to identify effect of wind
- ▶ Wind has grown from 900MW to almost 2100MW between 2008 and August 2012 (instantaneous penetration up to 50%)

The Irish electricity market: SEM

- ▶ Centrally dispatched pool market with capacity payments and uniform price
- ▶ Explicit bidding code of practice and Market Monitoring Unit
 - ▶ Generators bid SRMC
 - ▶ No strategic behavior in the spot market
 - ▶ Code of practice needed to avoid market power
 - ▶ Largest firm (incumbent) had 44% generation share in 2011

The Irish electricity market: SEM

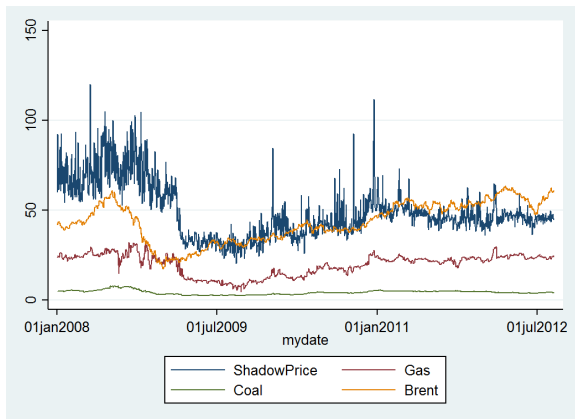
- ▶ Day ahead: generators bid, System Operator defines merit order and dispatch
- ▶ Same day: adjustment for transmission congestion/system reliability/wind/demand
- ▶ All generators receive System Marginal Price (SMP = Shadow Price + Uplift)
 - ▶ Shadow Price: bid of marginal plant (MC)
 - ▶ Uplift: cost of turning on if marginal plant would otherwise make losses (start up + no load cost)
- ▶ Constraint payments for generators that are forced to deviate from dispatch (not addressed today)

Data

1. Most of the data come from SEM-o, the Single Electricity Market operator
2. Half-hourly data (aggregate to hourly) from 2008 to August 2012 on
 - ▶ Prices
 - ▶ Shadow Price
 - ▶ Uplift
 - ▶ Plant availability
3. System Operators:
 - ▶ Demand
 - ▶ Wind generation (actual, i.e. post curtailment)
4. Daily fuel prices (Reuters)

Shadow Price and fuels

Figure: *Relation between shadow price and generation fuels, €/MWh*



Fuels prices lagged 24 hours

Summary Statistics 2008-Aug2012

Variable	Obs	Mean	Std. Dev.	Min	Max
ShadowPrice (€/MWh)	40824	49.28	22.12113	0	494.56
Uplift (€/MWh)	40824	10.89	20.987	0	645.495
Gen. margin (MWh)	40824	3398.47	963.7736	286.9665	6339.784
Wind (MWh)	40824	447.34	370.21	1.68	1833.22
Load (MWh)	40824	4060.59	885.20	2163.78	6774.00
Gas price _{t-24} (€/MWh)	40824	19.87	5.88	4.62	32.14
Coal price _{t-24} (€/MWh)	40824	4.36	1.18	2.48	8.11
CO ₂ price _{t-24} (€/MWh)	40824	12.59	6.39	0.01	24.95

Correlation Shadow Price vs Wind = - 0.06

Shadow Price: Model choice

- ▶ Time Series analysis?
- ▶ No
 - ▶ Generators bid once in the day-ahead (complex bidding)
 - ▶ Bids valid for all periods in day
 - ▶ Huisman, Huurman, and Mahieu (Energy Economics 2007), Weron (Energy Economics, 2008) suggest considering daily electricity prices as a series of 24 separate contracts
- ▶ However, there **is** correlation between hours

Shadow Price: Model choice

Aggregate data to hourly level

Structural break on 12 February 2009: estimation based on Feb 2009- Aug 2012 data.

Estimate simultaneous system of equations

- ▶ residuals correlated across groups (hours of day)
- ▶ correction for autocorrelation within groups (AR1)

System of equations with $i = 1, \dots, n, \dots, 24$ (number of hours)

Shadow Price: model

System of equations with $i = 1, \dots, n, \dots, 24$ (number of hours)

$$P_{i,d} = \alpha_i + \sum_h \beta_i^h L_{i,d}^h + \gamma_i W_{i,d} + \sum_j \zeta_i^j F_{i,d-1}^j + \mu_i CO_{d-1} + \theta_i mar_{i,d} + \sum \kappa^s D_i^s + \epsilon_{i,d} \quad (1)$$

where

P = shadow price

L = demand

W = wind

F = fuel prices

CO = CO_2 permit prices

mar = generation margin

D = dummy variables (month-year)

Shadow Price: Results (select)

Hour	Load _H	Load _L	Wind	Gas _{d-1}	Gen.Marg.	PStor·Wind
1	n.a.	0.004**	-0.003**	0.830**	-0.002**	0.000
2	n.a.	0.006**	-0.003**	0.668**	-0.002**	-0.003**
3	n.a.	0.004**	-0.004**	0.814**	-0.002**	-0.005**
...						
16	0.003*	0.002**	-0.005**	1.032**	-0.005**	0.003**
17	0.012**	0.002	-0.005**	1.291**	-0.006**	0.002
18	0.034**	-0.002	-0.010**	0.967	-0.012**	0.002
19	0.016**	-0.003	-0.004	3.353**	-0.011**	-0.007*
20	0.005	0.001	-0.004	1.073*	-0.009**	-0.006*
...						
Observations	31,056					

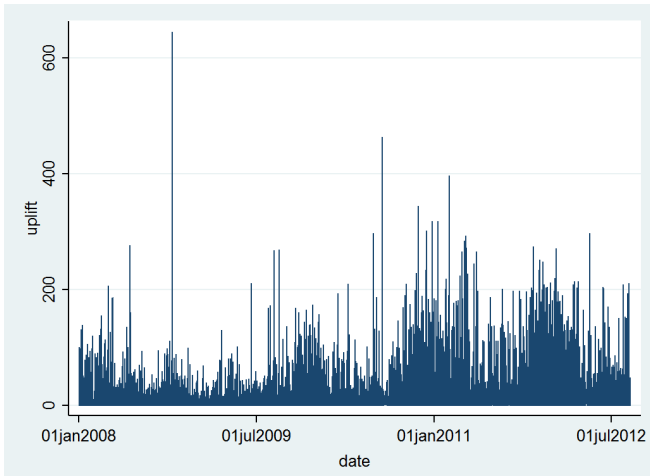
** p<0.01, * p<0.05, based on z values

Average effect of wind

Wind coefficient, averaged across 24 hours, weighted by demand:

- ▶ -0.0037
- ▶ Increasing wind generation by 100MWh → shadow price decreases by 0.9%
- ▶ Going from no wind to the average wind generation (482MWh) → shadow price decreases by 4.2%

Uplift



Uplift: Model choice

1. Zero must be taken into account
2. Distribution of the uplift rightly skewed: negative binomial

Estimation by a two-parts **hurdle model**

Uplift: Model choice

$$\begin{cases} \text{Probability}(\text{uplift} > 0 | \mathbf{X}) = F(\mathbf{X}) \\ \text{Uplift}_t = G(\beta \mathbf{X}') + \epsilon \end{cases} \quad \text{if } \text{uplift} > 0 \quad (2)$$

- ▶ Regressors in the **probit equation** are: $\Delta Wind$ and $\Delta Loads$.
- ▶ Regressors in the **poisson equation** are: *loads, wind, system margin, fuel prices, seasonal dummies, TH and Moyle dummies.*

Uplift: 1st part (prob uplift > 0)

1. Wind in difference is significant and negative (-.0014)
2. Loads in difference significant and positive (0.003)
3. Month-year dummies significant

Uplift: 2nd part (marginal results)

<i>Loads (MWh)</i>	0.0003** (0)
<i>Wind (MWh)</i>	-0.0002** (0)
<i>Gen.Marg. (MWh)</i>	-0.0001** (0)
<i>Gasprice €/MWh</i>	-0.0238** (0.004)
<i>Coalprice €/MWh</i>	0.094* (0.04)
<i>Moyle Outage dummy</i>	-0.1649** (0.056)
<i>Tur.Hill Outage dummy</i>	-0.1169** (0.031)
<i>Month-Year dummies</i>	Yes**
N.Obs.	40,824

st. errors in parentheses. ** $p < 0.01$, * $p < 0.05$

Gas coefficients per hour, 2008-2012

1	-0.007	13	0.006
2	-0.016	14	-0.006
3	0.007	15	-0.024
4	0.007	16	-0.035
5	-0.009	17	-0.029
6	-0.03	18	0.007
7	-0.286	19	0.002
8	0.015	20	-0.042
9	-0.006	21	-0.008
10	0.006	22	-0.008
11	-0.004	23	-0.005
12	-0.004	24	-0.021

values in bold are statistically significant at 5%

Conclusions

Studied Single Electricity Market of Ireland:

- ▶ Little interconnection with other systems (at least up to 2012)
- ▶ Compulsory pool system (comprehensive data)
- ▶ Generators have to bid marginal cost
- ▶ Doubling of wind installed in 4 years analysed

Findings:

- ▶ Small but negative effect of wind generation on Shadow Price
- ▶ Negative effect of change in wind on prob uplift > 0
- ▶ Negative effect of wind on uplift, conditional on uplift being positive

Future Work

Future work: analyse effect of wind on constraint payments to generators.