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

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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

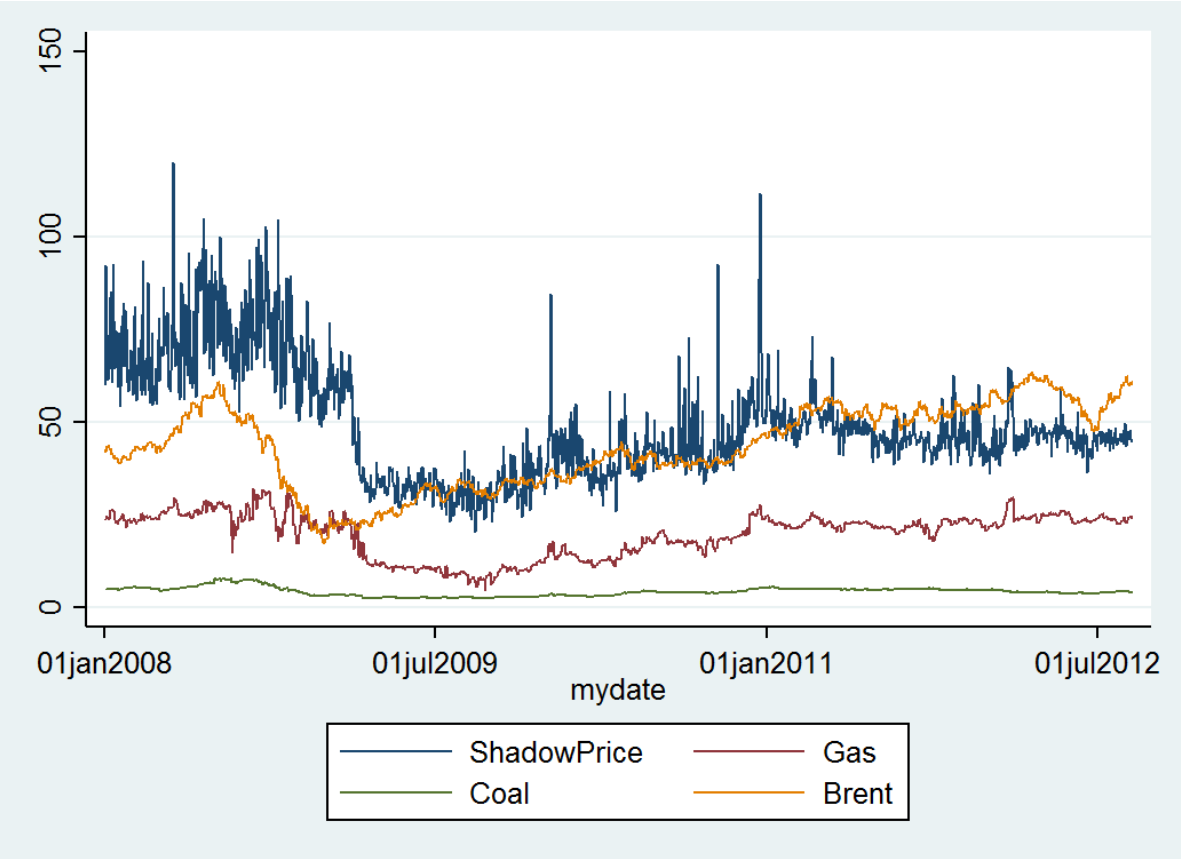
- Day ahead: generators bid, System Operator defines merit order and dispatch
- Same day: adjustment for transmission congestion/system reliability/wind/demand
- All generators receive System Marginal Price (SMP = Shadow Price + Uplift)
  - Shadow Price: bid of marginal plant (MC)
  - Uplift: cost of 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,...n,...24 (number of hours)

Shadow Price: model

System of equations with i = 1,...n,...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					

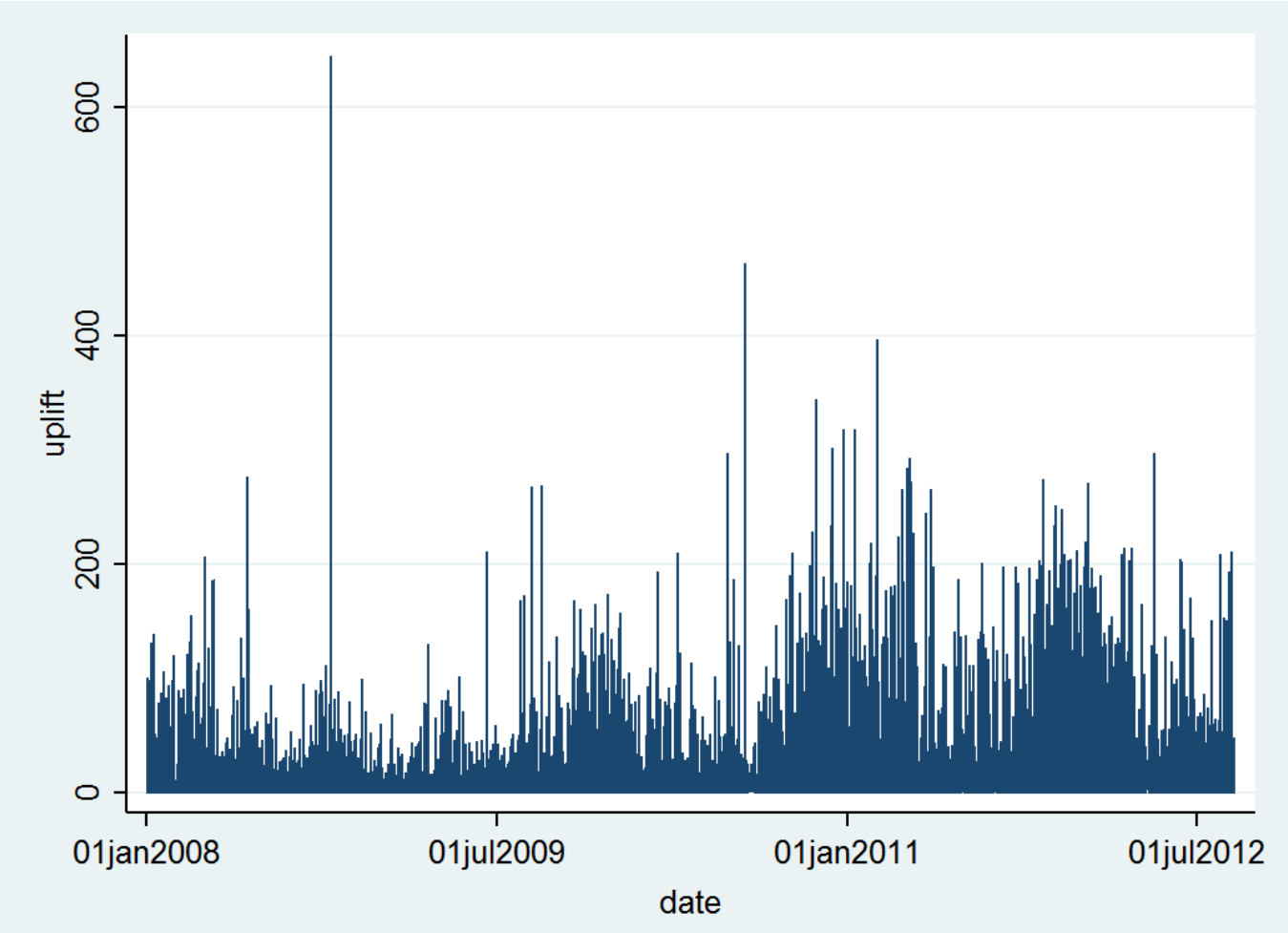
** $p<0.01$, * $p<0.05$, based on z values

Average effect of wind

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

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

Uplift


uplift
0
200
400
600
01jan2008
01jul2009
01jan2011
01jul2012
date

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

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

- 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)

Loads (MWh)	0.0003**
	(0)
Wind (MWh)	-0.0002**
	(0)
Gen.Marg. (MWh	-0.0001**
	(0)
Gasprice €/MWh	-0.0238**
	(0.004)
Coalprice €/MWh	0.094*
	(0.04)
Moyle Outage dummy	-0.1649**
	(0.056)
Tur.Hill Outage dummy	-0.1169**
	(0.031)
Month-Year dummies	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.