The value of flexible generation: the case of the Irish power system

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1 Introduction

Renewables and Electricity Prices: Intermittency & Price Dynamics

- Wind generation reduces average electricity prices but increases price volatility.
- Intermittency and uncertainty inhibit effectiveness of renewable generation

Value of Flexibility

- Heterogeneity in price volatility across Markets (French and Texan for example).
- Flexible generators are a key source of system stability.

2 Why Flexibility Matters

- Flexibility refers to the ability of the power system to respond rapidly to changes in supply and demand.
- We define **flexible generation** as plants with ramp-up capability of at least 6 MW/minute.
- Flexible generation and interconnection help mitigate price volatility, particularly under tight system conditions.

2 Key Research Questions

- What is the marginal value of flexible generation capacity?
- How does this impact “merit-order" effect of renewable generation?
- Interconnection as a source of flexibility?
- **Our goal:** Quantify the “system value of flexibility" using marginal price effects from observed outages.

3 Identification Strategy

Objective: Estimate the causal effect of flexibility and wind intermittency on SMP.

Strategy Overview:

- **Forced outages** as quasi-random shocks:
- **Wind decomposition:**
  - Wind modeled as:

$$W_t = \underbrace{W_{t-1}}_{\text{persistence}} + \underbrace{\Delta W_t}_{\text{intermittent}}$$

- **Interaction terms:**
  - Specification: $Outage_t \times \Delta W_t$
  - Tests whether price sensitivity increases under low flexibility

Core Equation with Wind Decomposition and Interactions:

$$P_t = \underbrace{\beta_1 W_{t-1}}_{\text{Persistent wind}} + \underbrace{\beta_2 \Delta W_t}_{\text{Intermittent wind}} + \underbrace{\beta_3 D_t}_{\text{Electricity demand}} + \underbrace{\beta_4 \, \text{Outage}_{it}}_{\text{Forced outages}}$$
$$+ \underbrace{\beta_5 (\text{Outage}_{it} \times \Delta W_t)}_{\text{Outage} \times \text{wind interaction}} + \underbrace{\beta_6 \, \text{Fuel}_{it}}_{\text{Fuel prices}} + \underbrace{\alpha_h + \gamma_m + \delta_y}_{\text{Fixed effects}} + \epsilon_t$$

4 Irish SEM Data

- Period: Jan 2016 – Sept 2018
- All-island market
- 30-min intervals; price, wind, load, fuel, outages

5 Marginal Effect of Wind by Flex Outage (with Interactions)

Table: Marginal Effect of ΔW_t on SMP
Evaluated at levels of Outage^{Flex}, using interaction model

	| Outage^{Flex} = 0	| Outage^{Flex} = 0.2	| Outage^{Flex} = 0.5	| Outage^{Flex} = 0.75	| Outage^{Flex} = 1.0
ΔW_t (€/MWh)	-20.92***	-18.38***	-14.56***	-11.39***	-8.21**
Standard error	(1.96)	(1.40)	(1.67)	(2.61)	(3.73)

Model: $\frac{\partial P_t}{\partial \Delta W_t} = \beta_{12} + \beta_5 \cdot \text{Outage}^{Flex}$ $\beta_{12} = -20.92, \quad \beta_5 = 12.71$

- Wind has a stronger price-reducing effect when flexible generation is fully available ($x = 0$).
- As outages increase, wind's marginal effect weakens (becomes less negative).
- Interaction term β_5 captures this loss of price-suppressing power under system stress.
- Intuition: Flexibility supports the system's ability to absorb wind shocks efficiently.

5 Marginal Effects on SMP by Residual Demand (Eqn 3)

	Full	<25%	25–75%	75–90%	90–100%
$Outage^{EWIC}$ (GW)	6.36***	0.64	3.99***	8.75***	20.13***
	(0.75)	(0.62)	(0.84)	(2.14)	(4.89)
$Outage^{Moyle}$ (GW)	0.22	0.06	-0.70	4.14**	8.91**
	(0.50)	(0.53)	(0.52)	(1.51)	(4.11)
$Outage^{Flex}$ (GW)	4.01***	1.08***	3.47***	5.1***	17.94***
	(0.48)	(0.32)	(0.56)	(0.99)	(4.15)

- The impact of *Flex outages* and *EWIC outages* on prices are most pronounced under high levels of residual demand.
- The effects of *Flex outages* and *EWIC outages* are comparable across different levels of residual demand. As such, *EWIC* behaves very much like a source of flexible generation.

5 Main Regression Findings

- ΔW_t: strong negative price effect
- Flex outages: + €4.01/MWh
- EWIC outage: + €6.36/MWh
- Effect of ΔW_t on price falls from €20.92/MWh to - €8.21/MWh when flexible outages increases to 1 GW.
- Effect of outages increases across higher levels of residual demand.

5 Value of Flexibility (/MW)

	EWIC Interconnector	Flexible Generation	Inflexible Generation
Value (/MW)	228,463	144,047	85,135

- The value of Flexible generation and EWIC Interconnector flows are high due their ability to respond to wind volatility and tight demand conditions.
- The value of available flexibility and Interconnector flows save the system about €180,000 and €230,000 on an annual basis.

6 Key Takeaways

- Renewable generation lowers prices but increases price volatility.
- To reduce price volatility and enhance renewable effectiveness requires integration with flexible sources generation.
- Residual Demand matters!
- The value of available flexibility and interconnector flows save the system about €180,000 and €230,000 on an annual basis.

Thank you

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