Integrating European Electricity Markets – what impact for consumers and producers?

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Overview

Electricity market design is evolving with the increase in electricity generated from renewable sources. The market system was originally designed for dispatchable fossil fuel electricity generation with high marginal costs rather than renewable electricity generation with nearly zero marginal costs and high upfront capital costs. When short term prices no longer cover long term investment costs, new market design is needed. An alternative is to increase interconnection to facilitate increased trade between markets (Pollitt and Chyong, 2018). Economic theory suggests that eliminating barriers to trade across a regional market decreases consumer costs and producer profits in areas that increase imports, while increasing producer profits and consumer costs in areas that increase exports (Dahlke, 2018). Trade through interconnectors can exploit differences in wind and sun conditions across regions and so reduce supply variability; higher shares of renewable electricity raises the value of market integration even further (Newbery *et al.,* 2018; Newbery *et al.,* 2016).

In this context, the EU has been progressively harmonizing national and regional electricity markets, to form a single market that includes more than 500 million people. The Multi-Regional Coupling organized through European power exchanges coordinates the clearing of day-ahead markets and determines day-ahead prices across the countries involved (Politico, 2018). In the 1996, 2003 and 2009 EU electricity directives, the development of integrated wholesale power markets across the continent was encouraged in order to incentivise market-driven investment in generation across Europe. The Internal Energy Market (IEM) in Europe provides for free trade across border and non-discrimination between internal and cross-border transactions. On October 1st 2018, Ireland was one of the final countries to integrate with this market due to the small isolated nature of this synchronous system which required additional precautions to put in place new market arrangements (Figure 1).

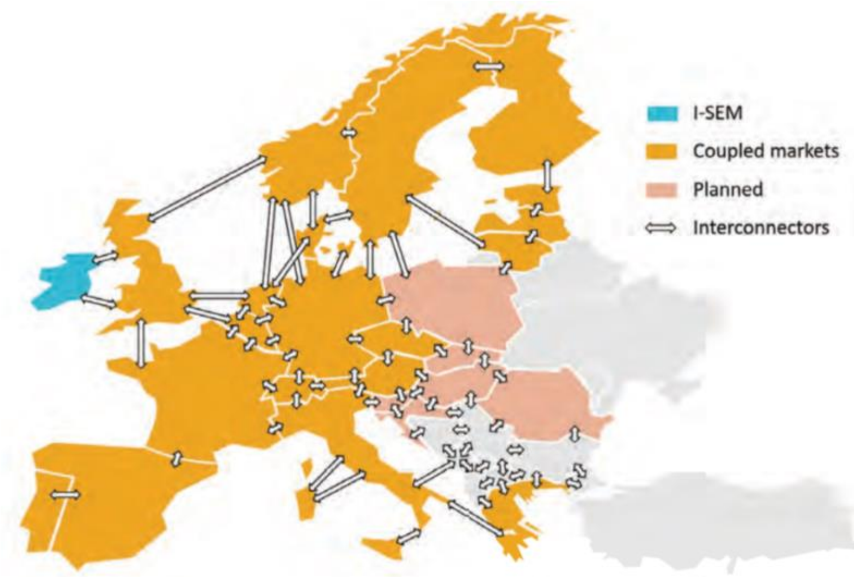

Figure 1: Interconnection across the EU (EirGrid, 2016)

The Irish electricity market has been a wholesale all-island market (including Northern Ireland, called the SEM) since 2007. The integration of the all-island electricity market with European electricity markets was expected to increase the use of the interconnector with Great Britain which should "deliver increased levels of competition which should help put a downward pressure on prices as well as encouraging greater levels of security of supply and transparency" (EirGrid, 2016). In addition to integration with Europe, other features were included in the new I-SEM market, such as changes to how energy is bought and sold; how generators are remunerated for availability; forward trading arrangements and market liquidity; market power controls; and the systems, policies and procedures that are required to operate the market (EirGrid, 2016). This has led to new balancing, capacity, and intraday markets that did not previously exist in the Irish market. With the integration of the Irish market, the IEM now comprises 20 countries, with 38 interconnectors and a total generating capacity of over 3,000 TW (EirGrid, 2016).

The European Target model sets out the common rules and arrangements for market coupling in Europe. It includes a common price coupling algorithm for scheduling day-ahead markets and determining flows between geographic regions. The energy transactions involving sellers and buyers from different bidding zones are centrally collected to maximise the most efficient and effective trades. In theory, unless the network is congested, markets should converge to a single price. When the network is congested, prices diverge.

The integration of the Irish electricity market with the IEM provides a natural experiment with which to test economic theory relating to the benefits of interconnection, regional electricity trade, and market rule changes for consumers,producers and markets. While there is an extensive literature on electricity market design and theory, it is rare to find empirical data such as this with which to test the theory. This integration is relatively recent, yet it provides an ideal opportunity to examine in detail several features over the period directly before and after the change. Ireland, as an isolated market. Ireland has been identified as a country at the forefront of market change due to the high share of renewable electricity and its isolated market (Polllitt and Chyong, 2018). It also serves as a good case study, as there are less confounding factors in an analysis of market design, compared with more geographically integrated countries. We model these questions using time series econometric analysis to estimate the impact of the switch over to the new market on parameters such as prices, interconnector flow and fuel mix.

The structure of the paper is as follows. The next section provides an overview of the methodology and data. This is followed by a presentation of the preliminary results The final section concludes and outlines the next steps for the research.

Methods

The Irish electricity system has shown substantial growth in shares of renewable generation since 2005. This has mainly been due to a rising share of wind energy, thanks to an abundant resource, the availability of a subsidy in the form of a feed-in-tariff, and falling costs of the technology. There is considerable concern that more interconnection is required to sustain the significant levels of wind electricity already on the system and planned into the future both from balancing and security of supply perspectives.

We are therefore interested to examine whether increased integration of the Irish market with the European electricity market delivers benefits in accordance with economic theory – lower wholesale prices, increased shares of renewable electricity and increased trade through the interconnectors.

We initially carry out three OLS estimations with day ahead prices, imports, and efficient trade flows, as the dependent variables. We estimate separately day ahead price and import models with all variables estimated as logs.

Price model:

$$P_t = \beta_0 + \beta_1 W_t + \beta_2 D_t + \beta_3 Pk + \beta_4 M + \beta_5 (Pk * M)$$

Imports model:

$$I_t = \beta_0 + \beta_1 W_t + \beta_2 D_t + \beta_3 \frac{P_{1t}}{P_{2t}} + \beta_4 M + \beta_5 Pk + \beta_6 (Pk * M)$$

Efficiency of trade:

$$N+ = \sum(P(IE) - P(GB) > 0 \& Imports > 0) + \sum(P(IE) - P(GB) < 0 \& Imports < 0)$$

Where:

- P_t= day ahead electricity price
- W_t = Wind generation
- D_t = system demand (net wind)
- Pk = peak (6pm-10pm) or off-peak dummy
- M = ISEM dummy

- t = hour
- I= Imports
- i = 1=GB; 2 = Ireland
- N+ = incidence of efficient trade flows

We have created a novel dataset combining data from the old electricity market (SEM), new electricity market (I-SEM), and ENTSOE Transparency platform websites. Considerable time has been spent understanding the specifics of the variables collected on old and new market sites and to identify continuous variables across the sites. We have focussed on three areas: wholesale day ahead prices, where the majority of trades happen in European and Irish markets; interconnector flows; and fuel mix. The data sources and timeframes available are as follows:

Prices:

Old Market: "System Marginal Prices" (SMP) (Ex-Ante) from 2007- September 2018 ;

New Market: "Day Ahead Prices" from October 2018

Inter connector Flow:

Old Market: Variable name: "IMG"(Inter connector Metered Generation) - 2007- 2018 Database (For M+4, Indicative and Initial RunType); New Market: Variable name: "Initital Interconnector Flow and Residual Capacity"; New Market: Cross border Physical flows- ENTSOE Transparency Website - Data available from 25th September 2017 (Hourly Data)

Results

Preliminary inspection of the data shows that the average prices have not changed significantly since the integration with the European market, however the volatility and interconnector flows have both increased. The evolution of day-ahead prices in the Irish wholesale electricity market over the period March 2015 to Dec 2019 is shown in Figure 2. At first glance there do not appear to be major differences between prices in the old and new markets, however in the last 6 months of the ISEM prices seem to be settling to a lower level.

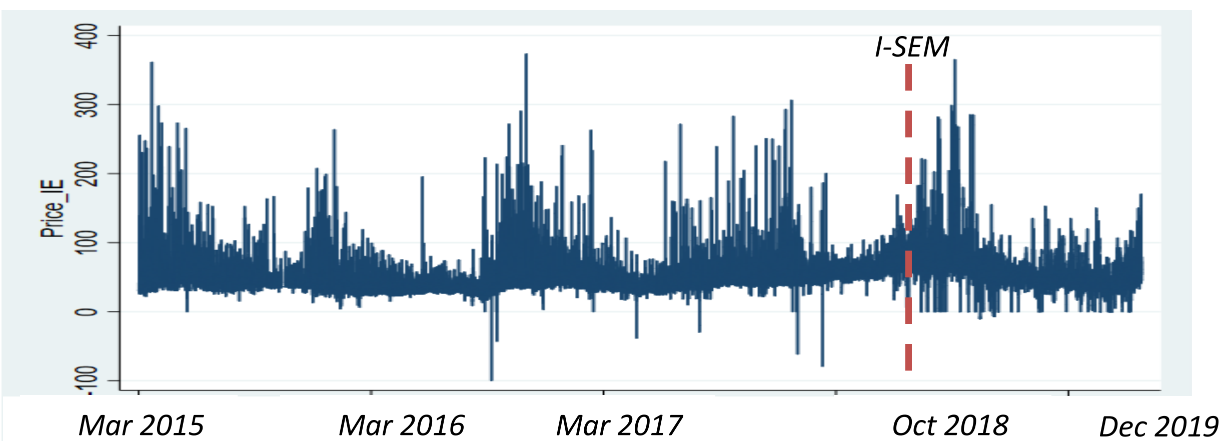

Figure 2: SMP /Day Ahead Prices (01.03.2015 – 31.12.2019)

Figure 3 shows the demand for the interconnector over the period September 2017 until February 2019. Interconnector flows seem have increased. In particular, where the value of imports or exports on the East West interconnector to Britain (EWIC) previously never rose above 300 MW, they are now regularly close to the rated capacity of 500MW in both directions. Further analysis is needed of the portfolio of plant employed since the market change and the current fuel mix, however it is notable that the record for shares of wind on the Irish system was broken three times between November 2018 and summer 2019.

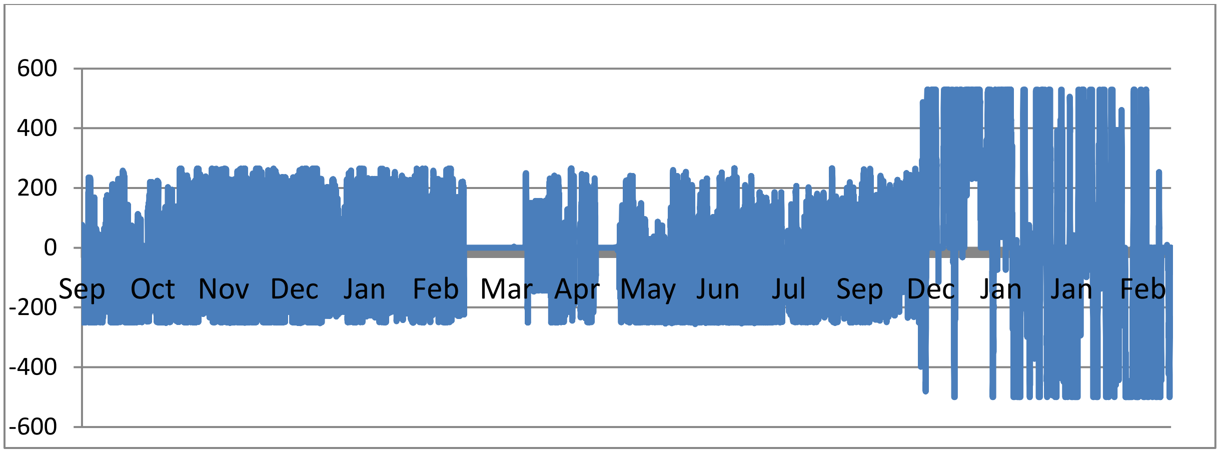

Figure 3: Flow on the East-West Interconnector September 2017 – February 2019

Using the price and imports models presented in the previous section, we estimate the impact of the new market on price and imports. The results of the impact of ISEM and peak periods combined with net market demand and wind generation on price and importss are presented in Tables 1 and 2, respectively.

	Basic model	With ISEM	ISEM interaction
Wind production	-0.064***	-0.077***	-0.077***
System demand	0.588***	0.523***	0.522***
Peak period	0.188***	0.199***	0.177***
ISEM		0.169***	0.158***
ISEM*peak			0.070***

Table 1: Day Ahead Prices estimation

The results for electricity prices are mostly as expected: we find that day ahead prices increase with higher system demand, during peak periods, and during peak periods in the I-SEM. Prices have decreased with increased wind production. Economic theory would suggest that prices should fall as a result of market integration, however this does not appear to be the case so far and prices on average have increased since the integration to the larger market. However when interacted with peak periods, we find the price increase to be significantly smaller. The OLS results of the impact of ISEM and peak periods combined with net market demand and wind generation in Table 1 show that while wind continues to have a negative impact on prices, the ISEM has not had the desired effect of reducing prices overall. However, this will need to be revisited with longer ISEM time series and more detailed modelling.

We then estimate the volume of imports based on (i) Irish prices and (ii) the ratio of Irish to GB prices. The results in Table 2 show that imports increased with higher Irish prices, or at a higher Irish to UK price ratio, at peak periods, at higher system demand, and since the advent of the ISEM. This is as anticipated; when prices in Ireland are high the volume of flow on the interconnector is higher. The effect is smaller for the ratio of Irish to GB prices, suggesting that more detailed modelling is necessary to develop te model in more detail than the averages reported here over the period. Electricity imports are found to decrease when there is higher wind production and during peak periods of ISEM, which is also to be expected.

Variable	Basic OLS	Ire/GB price 1	Ire/GB price 2
Irish price	0.41 ***		
Ire/GB price		0.073* (0.03)	0.069* (0.03)

Peak period	0.16***	0.15*** (0.02)	0.24*** (0.03)
Wind gen	-0.23***	-0.26*** (0.01)	-0.26*** (0.01)
System demand	2.21***	2.41*** (0.05)	2.43 *** (0.05)
ISEM	0.37***	0.40*** (0.02)	0.46*** (0.02)
Peak*ISEM	-0.32***		-0.30*** (0.05)
R^2	0.27	0.25	0.25

Table 2: OLS estimation of Import volume

We then examine the impact of the new market on the efficiency of trades (Montoya et al., 2019), in other words we check whether electricity is exported when there is a negative price differential between Ireland and Great Britain and imported when the situation is reversed.

Figures 4 and 5 show the price differential and imports between Ireland and Great Britain for the old SEM and I-SEM respectively. They demonstrate that there has been a change in the pattern of trades that have occurred between the old SEM and the new ISEM market, as well as the increase in volume already illustrated in Figure 3. Interconnectors operate efficiently when exports occur during a negative price differential between Ireland and Great Britain (top left quadrant) and the reverse for imports (bottom right quadrant). We see in Figure 4 that while trade often occurred in the 'wrong' direction in the SEM, under the ISEM regime we find trade flows to be better aligned with prices and clustered along the capacity of the interconnectors (Figure 5).

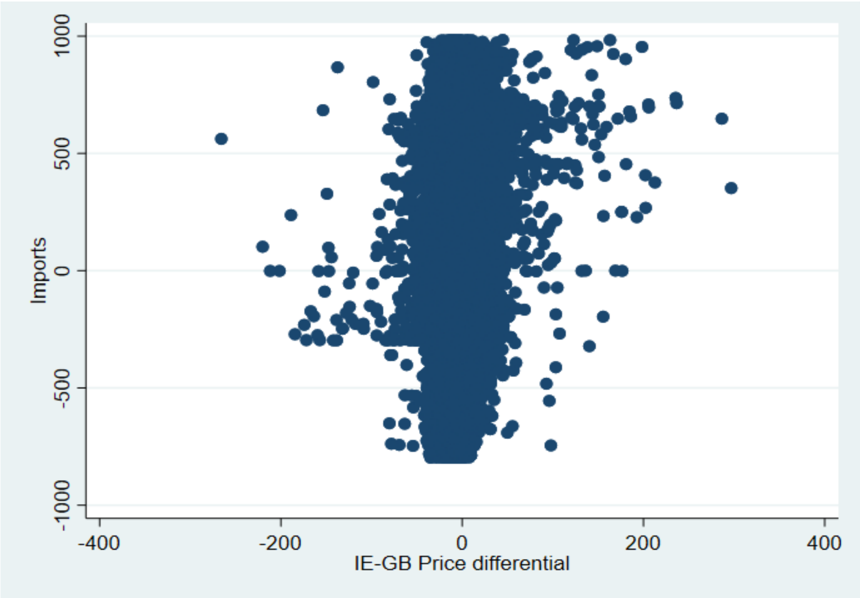

Figure 4: Pre-ISEM Imports vs IE-GB price difference

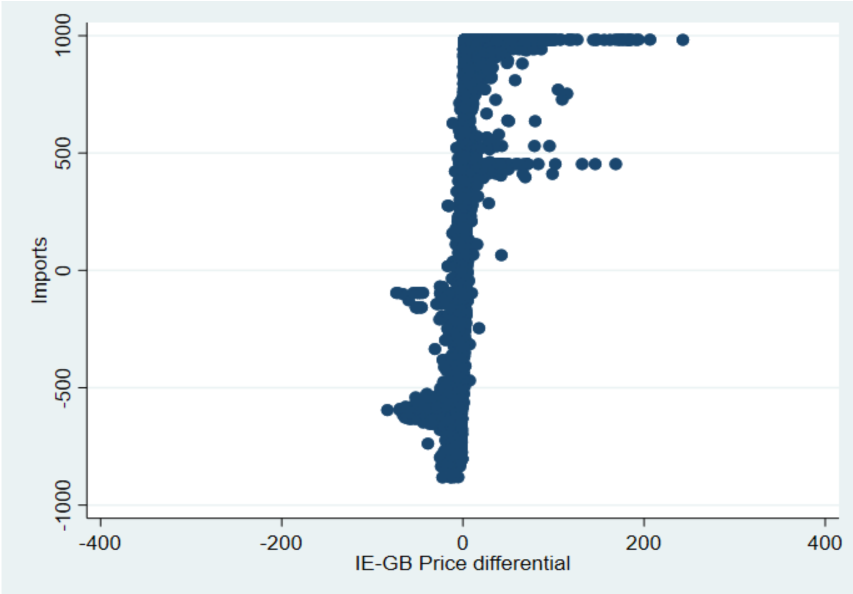

Figure 5: Post-ISEM Imports vs IE-GB price difference

To explore the efficiency of trades post-ISEM further, we construct a dummy variable N+ for each hour which reflects whether the trade of electricity is in the 'right' direction, i.e. efficient. In Table 3, the incidence of trades in the direction of price differential (N+) is modelled as a function of the underlying variables and ISEM. Increased wind generation raises the incidence of efficient trades, while higher demand in the Irish market lowers efficiency, as a rule.

N+	Basic model	ISEM effect	ISEM and peak	Interaction
Wind	0.055***	0.025***	0.026***	0.025***
Demand	-0.515***	-0.574***	-0.611***	-0.584***
Market		0.370***	0.371***	0.354***
Peak			0.075***	
PeakMarket				0.084***
R2	0.06	0.17	0.17	0.17
N	35154	35150	35150	35150

Table 3: Impact of ISEM on incidence of efficient trade flows

The ISEM has increased the incidence of efficient trades, as was already visible in Figs 4&5. Peak periods appear to have a significant impact on the efficiency of trades but are relatively small. Further estimation shows that the volume of trades has increased by approx. 37% as a result of ISEM but further analysis is needed. The results are mostly significant, however we have yet to carry out thorough robustness checks.

Conclusions

Pollitt and Chyong (2018) suggests that more interconnections should stabilise wholesale prices through convergence between key markets in Europe both in terms of price level and variations are reduced significantly. This may have consequences for financial markets and the risks associated with financing variable renewable and conventional technologies. Our results do not show a drop in average wholesale prices in the new integrated market for the data period of the study, however there appears to be a drop in prices at peak periods in the new market. Interconnector trades have increased substantially since the integration and this has facilitated higher shares of wind energy on the grid.

The findings suggest that the effect of integrating the Irish electricity market into the European market is most noticeable in the volume and direction of flow of electricity trades to the GB market. Further work will be undertaken to develop a robust analysis of the price development, including the use of a longer dataset and the development of difference-in-differences model a counterfactual price model based on unit commitment results and synthetic controls based on data from Spain and Portugal.

The insights from this research should be useful to both researchers in electricity market design and policymakers attempting to grapple with future electricity market integration in the EU and elsewhere. Future work will have a longer time series to examine the different effects. It ccan be expected that the results should become less volatile in time even with out bread-making skills.

Acknowledgements

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