Gravity for cross-border electricity trade

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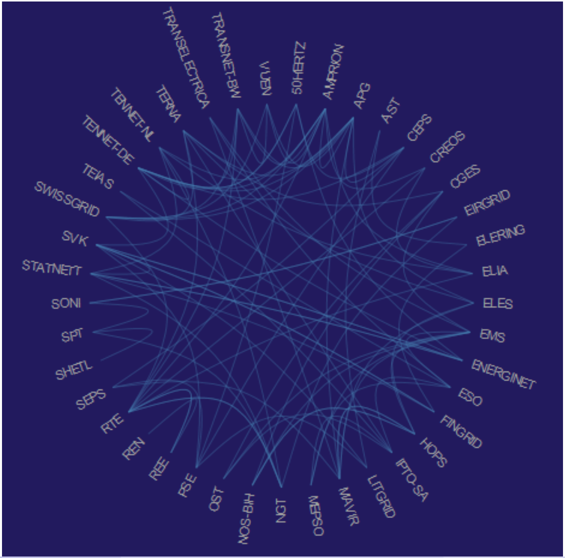
What we Talk About When we Talk About Economic Integration

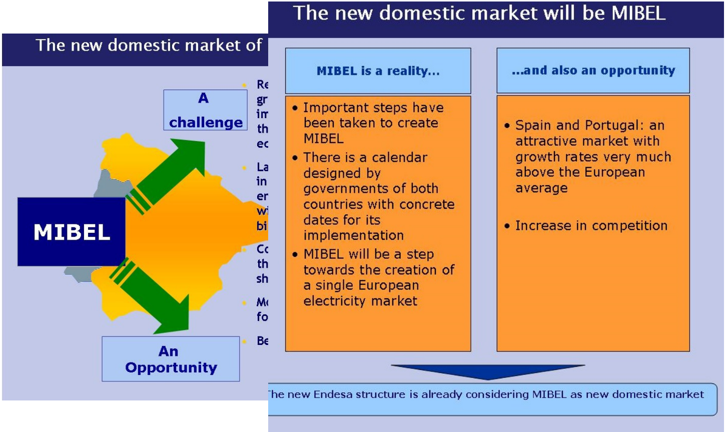
What we Talk About When we Talk About Energy Integration



If I were a country......I would be a bright one

1. United States 16,244,600
2. China 8,358,400
3. Japan 5,960,180
4. Germany 3,425,956
5. France 2,611,221
6. United Kingdom 2,471,600
7. Brazil 2,254,109
8. Russia 2,029,812
9. Italy 2,013,392
10. India 1,875,213
11. Canada 1,821,445
12. Australia 1,564,419
13. Spain 1,322,126
14. 14 Mexico 1,183,655
15. 15 South Korea 1,129,598

In 2006 (one year before 2007)

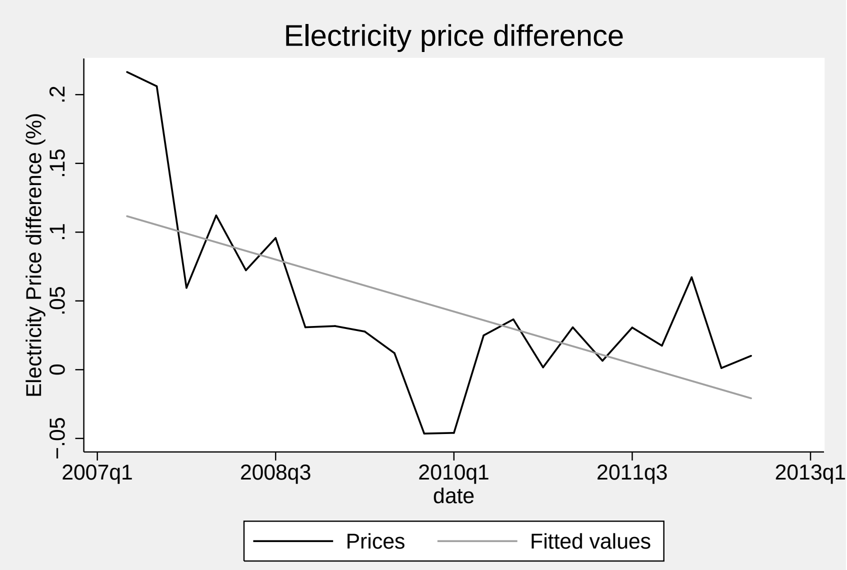


Outline

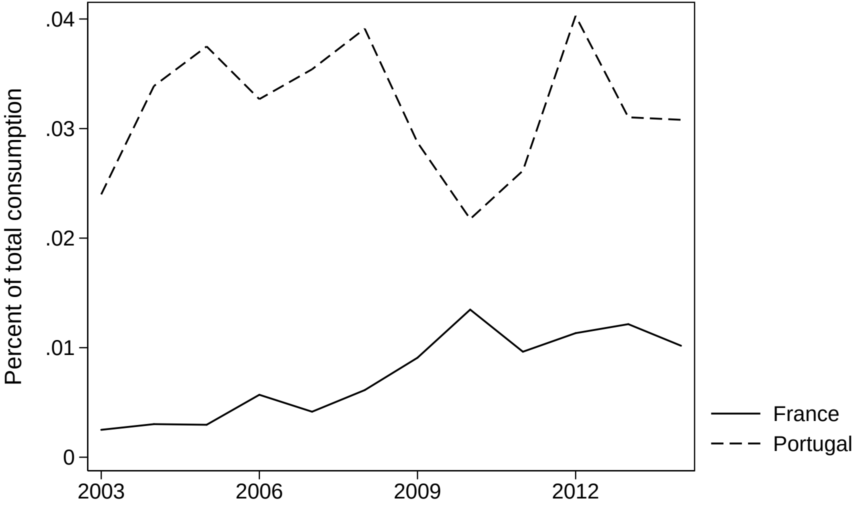
In this paper

1. we develop a stylized theoretical model to explain cross-border electricity exchange
    - Gravity for electricity trade
2. We estimate the effect of energy market integration on electricity trade
    - Provide empirical evidence to help evaluate Europe's Single market strategy

MIBEL's Price evolution



Electrical single market on the spot



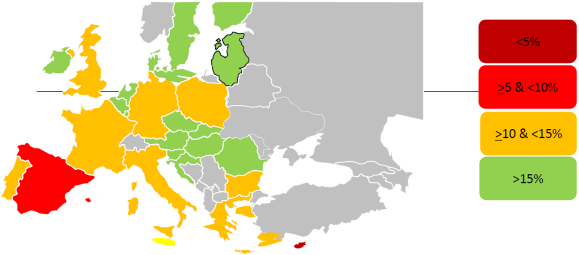
European Internal Energy Market

- Where do we come from?
  - heavily regulated sectors with an important intervention of the Governments with companies configured in a regime of monopolies or oligopolies electrical and with little competition
- Where are we headed?
  - In the last fifteen years Europe has been evolving through of an important process of economic liberalization whose ultimate objective is the configuration of an integrated market.
- The Treaty of Lisbon itself gives energy a supranational and structural character reflected in an integrated European policy on energy and the environment
- To create the European Electricity Market, the European Commission (EC) proposed a bottom-up regional approach to integration:
  1. starting from regional integration between countries with similar features and
  2. moving on to the integrated electricity market as a solution to boost the integration

Capacity constrained trade

- Any approach to the analysis of the evolution of cross-border electricity trade in Europe should take into account:
  1. Regulation of an essentially supranational nature through cooperation between different regulatory bodies throughout of recent years
  2. The evolution of physical capacity for interconnection through cross-border networks.

Figure: Map of interconnection levels in 2020

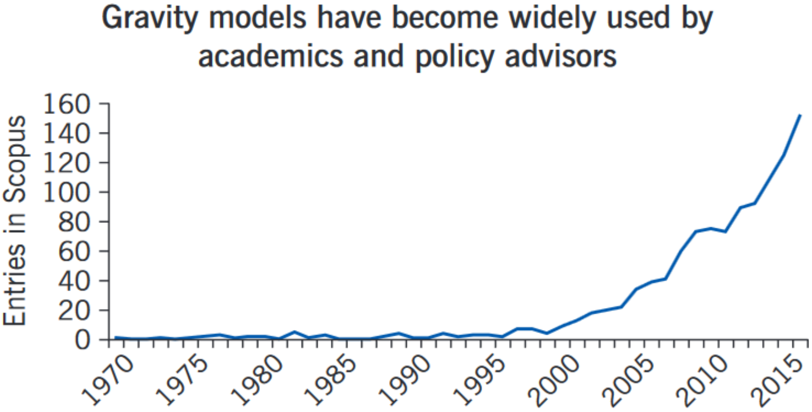


Previous work

1. The expected results of a single energy market are a harmonisation of energy prices and higher quality of service (Correlje and Van der Linde, 2006; Glachant, 2009).
2. Price convergence (Zachmann, 2008), price dispersion reduction (De Jonghe et al., 2008), price dependence (Lindstrom and Regland, 2012), insurance (Mahlberg and Url, 2003) and cross-border integration (Balaguer, 2011, Bunn and Gianfreda, 2010)
3. EMI has an influence on the economy of its members, e.g., FDI (Costa-Campi et al., 2017)
4. Internal Energy Market (Bunn and Gianfreda, 2010; Menezes and Houllier, 2015; Ringler et al, 2017)

Gravity models are very popular in economics

Ramos (2016)



Note: Shows the number of entries in Scopus when using the search term "gravity model" in the "economics" field.

Why gravity?

- Gravity will arise whenever you have:
    - CES preferences
    - Iceberg trade costs
    - And a trade separable set-up: in which the decision of how much of a good category to consume is separable from the decision about where to buy it from.
        - Spatial allocation
        - Market clearing
- Gravity fits the data well
- Include real-world features (multiple countries and trade costs)

Gravity for energy

- Costa-Campi et al., (2017) develop a Melitz-type gravity model for FDI which included energy as in input of production
  - Their main aim was to explain how energy costs (prices), intensity and EMI affect FDI
  - By doing so, they derived gravity-like equation for cross-border energy inputs
  - They showed how cross-border energy flows decreases with transaction costs τ_{ij}, capital costs r_j, and energy costs e_j.
    - Limitation: Electricity demand of foreign firms.
- Our approach in this paper is to build a more general model which incorporates into the standard elements of trade the specificity of energy

Structural gravity

- The model follows closely standard structural gravity trade models (Anderson and Van Wincoop, 2003).
  - Spatial allocation of expenditure (energy) for the importer.
  - Market-clearing for the exporter.
- Let i be the origin of the electrical production (exporter) and j be the destination (importer).
- The same parameters characterize energy consumption behavior in all world locations with common homothetic preferences and shares are invariant to income.
- In this setup, the total importer total electrical consumption E_j is a percentage of total electrical consumption.

The electricity pie

- The physical constraint of electrical production and consumption imposes that the total sales to all destination and the total purchases from all origins are equal: $E = \sum_j E_j = \sum_i E_i$.
- The pie's share allocated to country i is denoted $\pi_{ij} \geq 0$ and the follow identity holds:

$$X_{ij} = \pi_{ij} E_j \tag{1}$$

  where $\sum_i \pi_{ij} = 1$ to ensure that the exporter sells all its available electrical capacity for export.
- As in standard models of trade, we require that π_{ij} can be expressed in the following separable form:

$$\pi_{ij} = \left(\frac{p_i \tau_{ij} C_{ij}}{P_j} \right)^{1-\sigma}, \tag{2}$$

Gravity for electricity

- After some math a structural gravity model of electrical trade:

$$X_{ij} = \underbrace{\frac{E_i E_j}{E}}_{\text{frictionless trade}} \underbrace{\left(\frac{\tau_{ij} C_{ij}}{P_j \Pi_i}\right)^{1-\sigma}}_{\text{trade frictions}},$$

where Π_i and P_j are inward and outward "multilateral resistance" terms respectively:

Gravity for FDI & Energy

- In sum, our model shows that bilateral energy trade flows governed by basic economic assumptions like market clearance and spatial allocation of energy for the importer. Institutional and physical frictions shape the ideal bilateral electrical exchange relationship.
- The model delivers several predictions that can be tested with the standard gravity empirical tools:

1. Economic differentials affect bilateral electrical trade flows
    1. Larger markets have larger trade flows (frictionless trade)
2. Institutional and physical constraints affect bilateral electrical trade flow
3. Electrical trade flows increase with the installed capacity
4. Third countries have an incidence on bilateral electrical trade flows

Gravity equation

- Our structural PPML specification is the following augmented gravity equation:

$$E_{ijt} = exp \begin{pmatrix} \beta_1 \ln(Y_{it}) + \beta_1 \ln(Y_{jt}) + \beta_2 \ln(D_{ij}) + \beta_3 border_{ij} + \beta_4 colony_{ij} + \beta_5 la \\ \beta_6 smctry_{ij} + \beta_7 locked_{ij} + \beta_8 EIA_{ijt} + \lambda_t + \lambda_i + \lambda_j + \varepsilon_{ijt} \end{pmatrix} \quad (4)$$

- PPML (Silva & Tenreyro 2006)

Data

- Electricity data comes from European Network of Transmission System Operators for Electricity (ENTSO-E)
  - 38 European countries from 2003 to 2015
  - Data in Gwh
- Gravity controls come from CEPII
- Electricity prices from Eurostat

	(1)	(2)	(3)	(4)	(5)	(6)
GDP exporter	0.245***	-0.236	-0.0719	0.230**	0.325	0.0741
	(0.0289)	(0.336)	(0.313)	(0.0932)	(0.917)	(0.907)
GDP importer	0.227***	1.549***	1.365***	0.0762	2.210**	1.604***
	(0.0292)	(0.351)	(0.390)	(0.0705)	(0.936)	(0.584)
Distance	-0.244**	-0.0139		-0.289	0.0527	
	(0.104)	(0.139)		(0.218)	(0.235)	
Landlocked	0.195**	-0.651***		-0.129	-0.0514	
	(0.0849)	(0.244)		(0.203)	(0.372)	
Border	-0.0904	0.283*		-0.0414	0.139	
	(0.148)	(0.163)		(0.183)	(0.236)	
Common language	0.265***	-0.0107		-0.0281	-0.0157	
	(0.0970)	(0.162)		(0.250)	(0.453)	
Colony	0.104	0.407**		0.211	0.489	
	(0.125)	(0.182)		(0.180)	(0.309)	
Same country	0.0773	0.178		0.00366	0.377	
	(0.102)	(0.162)		(0.154)	(0.301)	
Price exporter				-0.731**	-0.0563	-0.289
				(0.311)	(0.555)	(0.695)
Price importer				0.905***	-0.643	-0.0560
				(0.263)	(0.343)	(0.378)
Observations	1259	1259	1148	489	489	438
Country FE		Yes			Yes	
Country Pair FE			Yes			Yes
R^2	0.141	0.526		0.113	0.334	

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

	(1)	(2)
GDP exporter	0.149	-0.0992
	(0.881)	(0.773)
GDP importer	1.929**	1.525***
	(0.855)	(0.574)
Distance	0.0619	
	(0.231)	
Landlocked	-0.0619	
	(0.364)	
Border	0.182	
	(0.237)	
Common language	-0.00935	
	(0.459)	
Colony	0.510	
	(0.313)	
Same country	0.372	
	(0.312)	
Price exporter	-0.119	-0.342
	(0.555)	(0.703)
Price importer	-0.550	-0.0220
	(0.335)	(0.356)
ALL_ij	0.349**	0.268**
	(0.141)	(0.114)
ALL_1	-0.459***	-0.310***
	(0.164)	(0.104)
Observations	489	438
Country FE	Yes	
Country Pair FE		Yes
R^2	0.337	

Robust standard errors in parentheses

	(1)	(2)	(3)	(4)	(5)	(6)
nordpool_ij	0.492***					
	(0.179)					
nordpool_1	-0.598***					
	(0.167)					
CWE_ij		0.197				
		(0.131)				
CWE_1		0.218				
		(0.187)				
SWE_ij			0.287			
			(0.202)			
SWE_1			-0.494			
			(0.345)			
NWE_ij				0.594***		
				(0.206)		
NWE_1				-0.385**		
				(0.172)		
NWE_mibel_ij					0.376**	
					(0.148)	
NWE_mibel_1					-0.516***	
					(0.146)	
EUPH_ij						0.0748
						(0.147)
EUPH_1						-0.0427
						(0.192)
Observations	438	438	438	438	438	438
Country Pair FE	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Take-aways

- Energy trades falls within gravity pull.
  - Distance's coefficient of is smaller than in trade
- EIA trade increases electricity trade between 39% and 42% (on average)
- Results suggest diversion: EIA members trade between 27% and 37% less with non-members with similar characteristics as member states
- The general effect of EIA is driven by three EIA: Nordpool, NWE and NWE+MIBEL.

In the pipe-line

- Network capacity
  physical capacities of interconnectors and the commercial capacities made available to the markets
- only a small part of the physical capacities is actually offered to the market and that there are important variations between regions.