Energy Market Integration and Electricity Trade

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ABSTRACT

This paper explores energy trade in the electricity market by undertaking a comprehensive empirical analysis of the effect of Europe's progressive Energy Market Integration (EMI). Its aim is to quantify the effect of EMI on electricity trade in Europe in order to derive corresponding evidenced- based policy implications. The empirical strategy employs standard goods trade gravity models, adapted to energy trade in the electricity market and estimated using standard gravity techniques. We use energy trade flows between European countries to quantify the effect of the successive EMI enlargements on energy flows. The paper highlights relevant fact-based policy implications for integrating electricity markets. Our results suggest that EMI creates electricity trade among members, but also diverts trade between non-members. Two main mechanisms appear to account for the EMI effect: namely, market enlargement and the integration of electricity markets.

Keywords: Energy Market Integration; Electricity trade; gravity equation; electricity markets; European single market

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1. INTRODUCTION

Energy markets have not been exempt from the process of growing international trade flows. Further, the regional integration of these markets has aroused great interest among energy policy makers as these processes are capable of generating economies of scale, increasing both short- and long-term security of supply, and promoting the integration of energy processes within the framework of policies for the protection of the environment and the fight against climate change.

According to trade theory, the competition and scale effects facilitated by market integration result in more efficient firms, lower prices and increased welfare (Helpman and Krugman, 1985). Larger markets allocate available resources more efficiently to satisfy the joint demand of integrated markets. Indeed, this theory was the inspiration behind the analysis of the European Single-market programme when first discussed in the 1980s (Winters, 1992). Since then, market integration has driven processes of regional integration in different economic sectors, including that of energy.

Specifically, cross-border trade in electricity enables countries to gain access to a more diversified portfolio of plants, increasing, as a result, production over a wider geographic area,

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security of supply and economic efficiency. In this regard, the promotion of electricity trading across European borders—the geographical scope of the present paper—has been a consistent priority of European energy policy and an integral part of its single-market project. Since 1996, Europe's single electricity market has been promoted by the European Commission by means of various legislative packages—the directives of 1996 (96/92/EC), 2003 (03/54/EC), and 2009 (09/72/EC)—that have opened up the market to competition while fostering cross-border trade.

Market integration has spurred extent academic research of its impact on international trade. However, these analyses of market integration in electricity lag behind those conducted in other markets in two main regards. First, analyses of the effects of the single market on electricity in Europe are scant (obvious exceptions being Neuhoff et al., 2013; Pollitt, 2018). This paper therefore seeks to fill this gap by contributing towards a better understanding of the effects of regional integration and the single market on electricity cross-border trade in Europe, in an effort to identify evidence-based policy implications for the sector.

Second, attempts to apply of one of the most successful tools developed by trade scholars in recent decades, the gravity equation—an equation that rests on solid theoretical grounds and which is the empirical workhorse of international economists as they seek to estimate trade flows—have proved elusive in energy economics. Conversely, cointegration analysis has proved popular for assessing market integration while electricity price convergence has established itself as the most frequently employed econometric approach (see, among others, Robinson, 2007; Nitsche et al., 2010; Bóckers and Heimeshoff, 2014).

In its canonical form, the gravity model predicts that trade between country pairs is proportional to their economic masses (i.e. their Gross Domestic Product, GDP) and inversely proportional to the distance between the countries (i.e. a proxy for trade costs). However, in recognizing the relevance of the institutional and policy context, the baseline gravity equation has been augmented with policy variables that capture the institutional context of the trading partners (e.g. market integration agreements and free trade agreements). Some attempts have been made to model cross-border energy flows with the gravity equation; however, these studies are either theoretical (Costa-Campi et al., 2018) or limit the policy context to a narrow set of countries (Antweiler, 2016). To the best of our knowledge, this paper is the first to apply the gravity equation for electricity trade flows in a multi-country setup.

The visual representation of trade in electricity data helps highlight the relevance of market demand, distance and institutional agreements in this context. The top panel in Figure 1 shows the magnitude of electricity origin-destination flows by pairs of countries in Europe. As expected in a gravity framework, the countries with the highest demand—most notably France, Germany, and the Nordic countries—account for the largest portion of this trade (Figure 1a).

The bottom panel (Figure 1b) plots the correlation between electricity flows and the distance between country pairs. The size of each bubble represents the joint economic mass of country pairs. The red dots represent those pairs of countries with an Energy Market Integration (EMI) initiative in force. Figure 1b exemplifies how gravity works. Trading is costly between distant partners; so, distance and trade in electricity appear to be negatively correlated. However, there are several ways to escape the pull of gravity. Several of the larger countries (represented here by large dots) have large positive residuals. These countries lie above the regression line, indicating that their trade levels are higher than the expected average, conditional on their distance. The pairs of countries with EMI agreements (shown in red) also have large residuals—in this case, positive and negative. On this point, the trade literature explains the

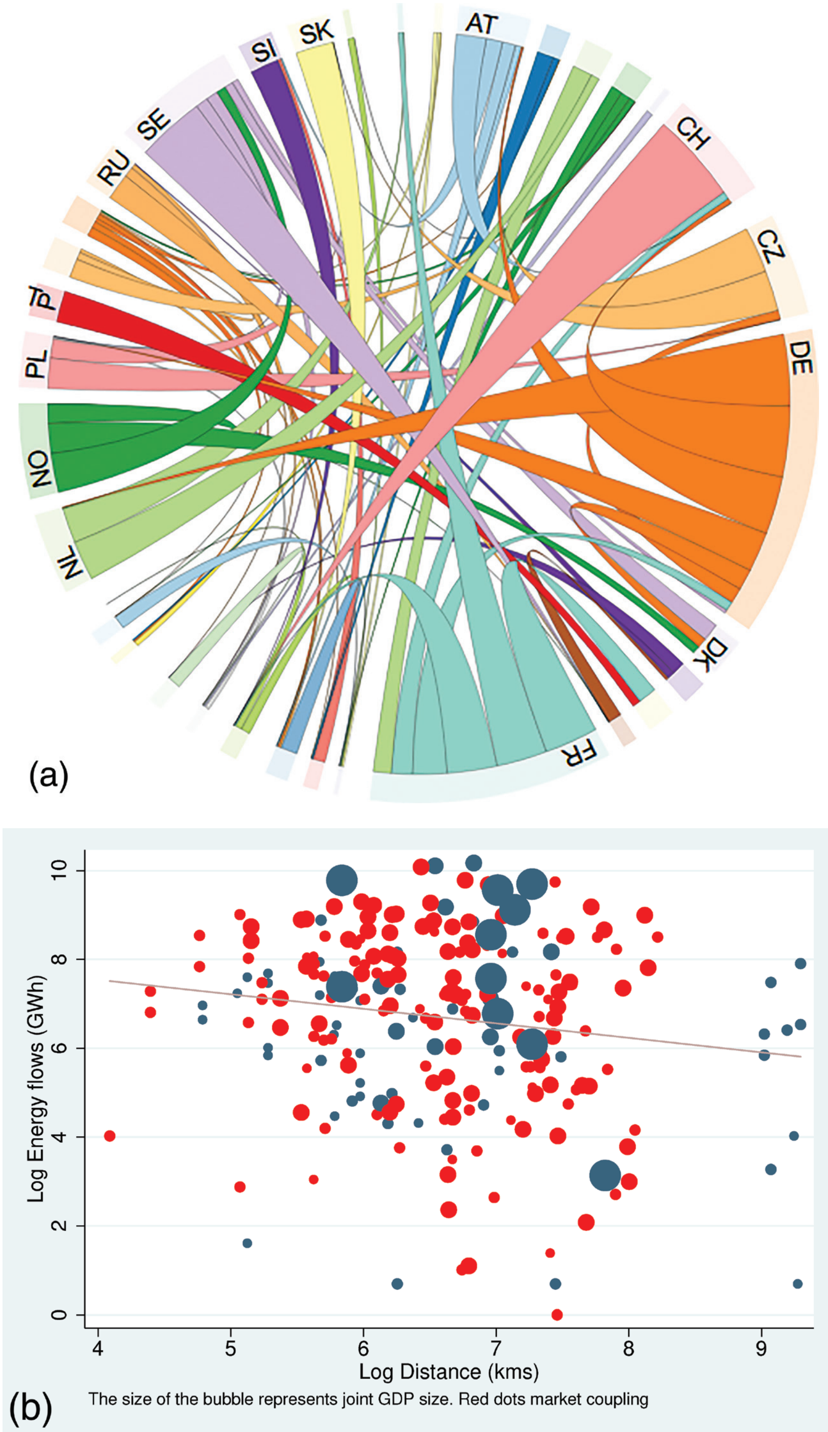

FIGURE 1

Gravity for electricity trade.

(a) Electricity exchange flows in Europe by country pairs, 2015.

Source: ENTSO-E.

(b) Energy flows vs. distance.

possible adverse effects of economic integration attributable to trade diversion (i.e. the trade lost to third parties following entry into a trade agreement).

This paper offers two main results and identifies two relevant policy implications with regard to EMI and electricity trade. First, the effect of larger and more integrated areas on electricity trade is positive and significant. Additionally, electricity trade creation is observed among members, at the same time as trade diversion is recorded among the other countries. These results drive our policy recommendations for greater market enlargement and electricity market integration.

The rest of the paper is organized as follows. Section 2 describes the background to the creation of the internal energy market in Europe, section 3 describes the data and empirical methodology, section 4 discusses the results, and, finally, section 5 concludes by highlighting the main policy implications of the analysis.

2. BACKGROUND: EUROPEAN INTERNAL ENERGY MARKET

2.1 Design and regulation

In Europe, significant progress has been made in recent years in the legislative development of integrated climate and energy policies—directives that initially were difficult to foresee—culminating in 2009 in the Third Energy Package. However, the 2007 Treaty of Lisbon had earlier bestowed on the energy sector its supranational structure, which is shared by the Member States and reflected in an integrated European policy on energy and the environment, especially with regard to global warming. This regulatory process changed the market conditions that determine the allocation and use of cross-border capacities, which now take place under European-wide coordinated processes, covering practically the whole continent.

The liberalization process was accompanied by a significant redesign of national electricity markets, with the latter being progressively harmonized across all market segments. Prior to this process, cross-border trade in electricity had been managed by vertically-integrated utility companies and long-term, bilateral contracts closed to trade. However, the introduction of market approaches to the allocation of cross-border capacity facilitated the exploitation of potential gains by optimizing interconnection capacities. At the same time, the transformation of the different power systems favored the establishment of new energy interconnection infrastructure with the construction of electricity transmission networks.

In this context, the creation of an internal energy market has three potential benefits: First, lower energy costs that result in lower, less volatile prices, which in turn increases the overall competitiveness of the economy; second, a well-interconnected and integrated market that facilitates the entry into that market of more environmentally efficient plants (while driving out their more polluting counterparts), driving companies towards an environmentally sustainable energy model; and, third, an integrated market that enhances security of supply, an aspect of great importance in this instance given the strong external dependence of the European Union.

The creation of an internal electricity market is one of the European Commission's long-term goals given its tangible benefits in terms of efficiency, end-user prices, security of supply and sustainability. To this end, in recent decades, its energy policy strategy has been to implement common rules for this internal market. However, transforming what were formerly regulated and nationalized electricity systems is proving a complex task, one in which the improvement of existing interconnection infrastructure and cross-border congestion management rules plays a pivotal role.

Consequently, many challenges remain unaddressed. The participation of cross-border capacity in real-time market segments and the introduction of more efficient zonal configurations constitute good examples of areas where future regulatory harmonization is required. Over the last decade, cross-border transmission has been fostered through wholesale market integration and market coupling initiatives in an effort to optimize the use of interconnection capacity, while facilitating a gradual process towards a common spot electricity price (Bunn and Gianfreda, 2010; de Menezes and Houllier, 2016; Ringler et al., 2017). The reduction in electricity price differences and price volatility across markets is the expected outcome of a harmonization process that should provide for common rules enabling the configuration of common energy markets and ensuring that electricity can flow freely.

Regional trade market efficiency requires the cross-delivery of goods from one system or region to another. In the case of the gas and electricity sectors, this translates into the availability of transport infrastructure that permits the instantaneous transport of significant fractions of market demand from one region to another. Thus, energy interconnections facilitate the interregional and cross-border transport of energy and electricity and are a prerequisite for the efficient functioning of the internal energy market.

However, interconnections, while necessary, are not a sufficient condition. Market integration requires that a process of energy sector liberalization be undertaken in parallel. This process includes creating market structures where they do not currently exist and introducing competition as respective energy systems are integrated in a context of the convergence of regulatory frameworks. Having started from a position characterized by heavily regulated sectors, over the last fifteen years Europe has undergone a major process of economic liberalization, the ultimate goal of which is the creation of an integrated market.

The high degree of regulatory heterogeneity has been a major concern in the market integration process. The regulatory design has mixed both bottom-up and top-down approaches, in which supranational regulation has coexisted with cooperation between different national regulatory bodies. The bottom-up approach started with the Regional Initiatives fostered by the Council of European Energy Regulators (CEER), which have fostered notable advances in the harmonization of electricity trade. The top-down approach comprises mandatory European Directives to be followed by all nations. These include the detailed rules, framework guidelines and network codes that are deemed necessary to achieve regulatory harmonization and which are essential for creating the internal market. This mixed strategy has enabled country-specific circumstances and characteristics to be taken into account, and potential opportunities for coordinated energy policy cooperation to be explored and assessed.

2.2 Evolution and current situation

Some 20 years after liberalization, conditions in the EU's electricity market are radically different from those that prevailed at the start of the century. Power sector liberalization has led to substantial changes in the way electricity is generated, used and traded. In Europe, the liberalization of electricity markets in combination with the integration of power markets has encouraged trade flows, facilitating a significant increase in cross-border electricity trade in recent decades (Figure 2).

Despite the increase in trade volumes, cross-border trade in electricity (446 TWh in 2015) represents just 13.6% of total consumption, with marked differences between European countries. Unlike other commodities, trade in electricity is restricted by the existing cross-border transmission infrastructure. This means that even if cross-country differences in production

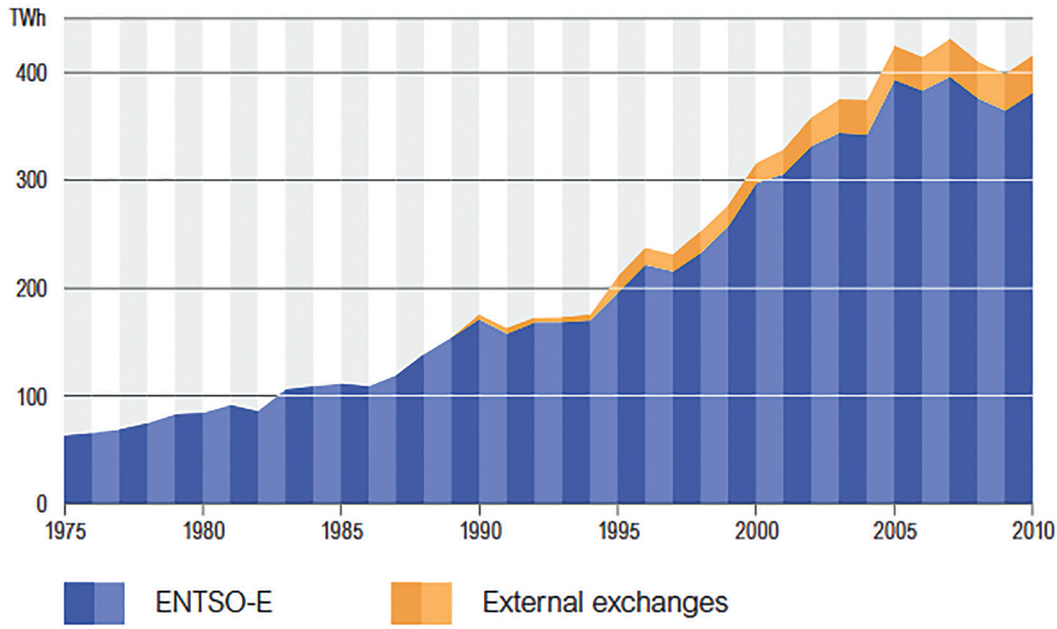

FIGURE 2
Exchange of ENTSO-E member TSOs' countries.
Source: ENTSO-E.

costs exist, trade is constrained by limited cross-border transmission capacities. If we consider the ratio between net exports and generation (Figure 3), these differences in cross-border transmission capacities become evident, there being 12 countries that exported more than 10% of their annual national generation in 2015 to their neighbors and a further 13 countries that exported less than 2%.

The data reflect the quite distinct circumstances in this market throughout Europe, with some countries having already reached (or being well on their way to reaching) the European interconnection target of at least 10% of their installed capacity by 2020, while others still require more interconnections. In the case of the latter, the European Commission considers that the target is best reached through implementation of the Projects of Common Interest (PCIs). These projects are key cross-border energy infrastructure projects designed to link up the European energy market and so help the EU achieve its energy policy and climate objectives. The PCIs offer several advantages, including an accelerated permit granting process and improved regulatory treatment.

The significant overall increase in cross-border trade in electricity has not necessarily, however, resulted in comparable increases in investment in interconnecting capacity, suggesting that interconnectors are being used more efficiently in Europe as a result of various market-integration initiatives as it will be analyzed in this paper. Regional interconnections, and more concretely the available commercial transfer capacity determined by Transmission System Operators (TSOs), constitutes a relevant aspect when considering the evolution and determinants of electricity trade flows. In this regard in future research is foreseen to consider interconnections individually, being this paper focused on the role of market integration.

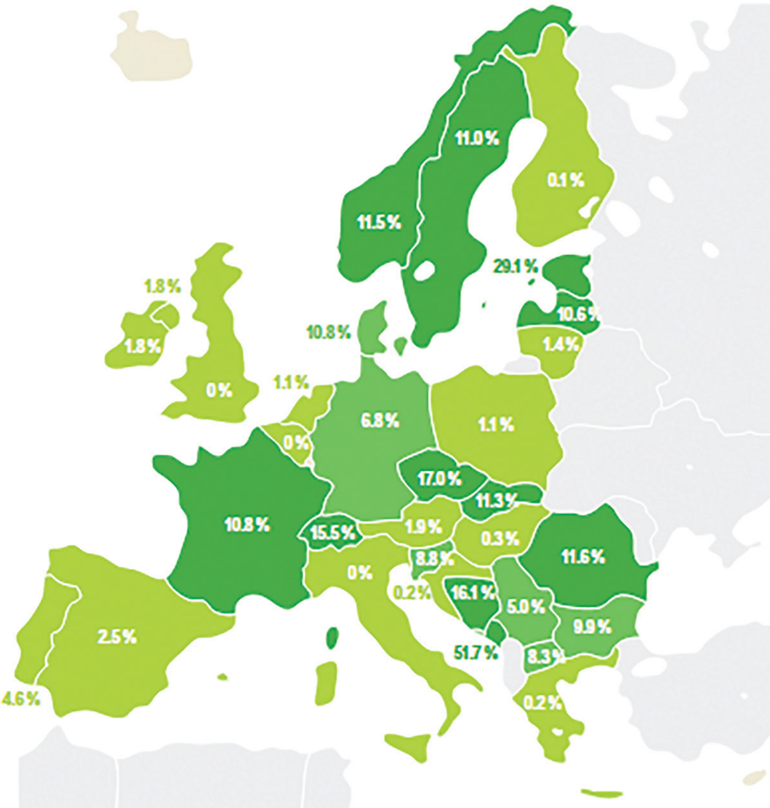

FIGURE 3
Share of yearly generation exported, 2015.
Source: ENTSO-E.

3. EMPIRICS AND DATA

The goal of this section is to describe the empirical methodology used to estimate the impact of EMI on trade in energy. As discussed, one of the most widely used methodologies for modelling trade flows is the gravity equation based on the theory originally proposed by Anderson (1979). Since that date, several econometric advances (including Anderson and Van Wincoop, 2003) have resulted in an adequate empirical technique for providing good estimates of trade flows. In fact, the gravity equation provides a good fit for other economic flows between country pairs and has been applied to a wide variety of flows such as migration, foreign direct investment, student mobility and tourism.

A number of recent studies have applied the gravity model to the energy market. Costa-Campi et al. (2018) have presented a theoretical gravity equation for firms' energy inputs and Antweiler (2016) has developed a model for cross-border trade (between the Canadian provinces and US states) in electricity. These studies provide a solid theoretical foundation on which to base the present empirical analysis.

A key concern when estimating trade data is the presence of heteroscedasticity in the error term in ordinary least squares (OLS) estimates. To overcome this, we use a non-linear variant of the gravity equation in line with that proposed by Santos-Silva and Tenreyro (2006).

Additionally, this specification does not require a log-linearization of the dependent variable and it is, therefore, compatible with zeros in the variable.[1] Our specification is the following non-linear gravity equation:

$$E_{ijt} = \exp\begin{pmatrix} \beta_1 \ln(Y_{it}) + \beta_1 \ln(Y_{jt}) + \beta_2 \ln(P_{it}) + \beta_3 \ln(P_{jt}) + \\ \beta_8 EMI2_{ijt} + \beta_8 EMI1_{ijt} + \lambda_{ij} \end{pmatrix} + \varepsilon_{ijt} \tag{1}$$

where E_{ijt} is the energy flow between home country i and host j in year t. The equation measures market demand through a number of variables; Y denotes the gross domestic product (*GDP*) and, P is the yearly average electricity price. *EMI2* is a dummy that takes a value of one if the country pair has a bilateral energy integration agreement in force. *EMI1* is a dummy variable set to one if only one country in the pair has an *EMI* in force. *EMI2* and *EMI1* capture the extent of trade creation and diversion respectively. The specification includes a full set of country-pair fixed effects (λ). These fixed effects absorb any unobservable bilateral heterogeneity and control for any variable which is invariant over time at the country-pair level (such as distance). Lastly ε_{ijt} is the a stochastic error term.

We apply Pseudo-Poisson Maximum Likelihood (PPML) to estimate equation (1). PPML has additional advantages over the log-linear specification. First, it is robust to heteroscedasticity in the error term. Second, it ensures the convergence of the maximum likelihood estimation through prior inspection of the data (Santos-Silva Tenreyro, 2011). Additionally, Baltagi et al. (2014) claim that the PPML estimator is especially appropriate for short panel gravity data.

Electricity data (in GWh) are drawn from the European Network of Transmission System Operators for Electricity (ENTSO-E). We collected data from 38 European countries from 2003 to 2015. Electricity prices and GDP (in euros) were sourced from Eurostat. The EMI variables were elaborated by the authors using data from the European Commission. The details of each agreement are shown in Table 1, which highlights a geographical evolution in the main agreements.

Table 2 reports the summary statistics and the correlation matrix of the variables used in this study.

4. RESULTS

Our estimates begin with the baseline PPML results presented in Table 3. We estimated the variables in a step-wise manner so as to avoid any harmful collinearity between variables. In column 1 we introduced only GDP, in column 2 prices, and in column 3 we included all our model variables. The first salient results to emerge from this analysis is that the exporter's GDP is not significant while the importer's GDP is positive and significant. These results suggest that trade in electricity is demand-driven from the import side. Moreover, the coefficient associated with GDP is 1.3, which is greater than the expected coefficient of 1 in the GDP estimates of goods trade, suggesting a stronger relationship between economic activity and energy flows.

A second salient result is that electricity prices appear not be a significant factor in the electricity trade, all things considered. The results reported in column 4, with no fixed effects,

1. However, the zeros in our dataset stem from the fact that countries do not share an electrical interconnection. Since in our time-frame there are no new interconnections, these zeros have no impact on our estimates as they are constant at the country-pair level and captured by the country-pair fixed effects.

TABLE 1
EMI Agreements in detail.

	Nordpool	Mibel	DE-AT	CWE	SWE (Mibel+F)	CSE	CEE	NWE_	NWE_ MIBEL	EUPH
Austria			2002	2010		2015		2010	2010	2014
Belgium				2006				2006	2006	2014
Bulgaria										
Cyprus										
Czech Republic							2012			
Denmark	2000							2000	2000	2014
Estonia	2010							2010	2010	2014
Finland	1998							1998	1998	2014
France				2006	2014	2015		2006	2006	2014
Germany			2002	2010				2010	2010	2014
Greece										
Hungary							2012			
Ireland										
Italy						2015				2015
Latvia	2013							2013	2013	2014
Lithuania	2012							2012	2012	2014
Luxembourg				2010				2010	2010	2014
Malta										
Netherlands				2006				2006	2006	2014
Norway	1996							1996	1996	2014
Poland	2010						2014	2010	2010	2014
Portugal		2007			2014				2007	
Romania							2014			
Slovakia							2012			
Slovenia						2015				
Spain		2007			2014				2007	
Sweden	1996							1996	1996	2014
United Kingdom								2014	2014	2014

TABLE 2
Descriptive Statistics and correlation matrix.

	Summary Statistics				Correlation Matrix					
	mean	sd	max	min	1-	2-	3-	4-	5-	6-
1- Energy Flow (Gwh)	2813.198	4969.873	112448	1	1					
2- GDP exporter (log)	25.563	1.752229	28.652	21.843	0.123**	1				
3- GDP importer (log)	25.565	1.753094	28.652	21.843	0.148**	0.381***	1			
4- Price exporter	.059	.018	.112	.019	–0.129**	0.0879	–0.0323	1		
5- Price importer	.059	.018	.112	.019	0.118**	0.0246	0.0714	0.239***	1	
6- EMI (both)	.452	.497	1	0	0.150***	0.195***	0.206***	0.0841	0.0220	1
7- EMI (one)	.261	.439	1	0	0.0363	–0.0206	–0.0307	0.150***	0.360***	0.288***

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

TABLE 3
Baseline results (PPML).

	(1)	(2)	(3)	(4)
GDP exporter (log)	–0.0719	0.0741	–0.0992	0.0339
	(0.313)	(0.907)	(0.773)	(0.0526)
GDP importer (log)	1.365***	1.604***	1.525***	0.187***
	(0.390)	(0.584)	(0.574)	(0.0709)
Price exporter (log)		–0.289	–0.342	–0.646**
		(0.695)	(0.703)	(0.297)
Price importer (log)		–0.0560	–0.0220	0.752***
		(0.378)	(0.356)	(0.187)
EMI2 (both)			0.268**	0.244**
			(0.114)	(0.146)
EMI1 (one)			–0.310***	0.235
			(0.104)	(0.283)
Observations	1148	438	438	438
Country Pair FE	Yes	Yes	Yes	No

Robust standard errors in parentheses, clustered by country pair.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

suggest that the effect of prices is absorbed by unobservable heterogeneity at the country-pair level. These column 4 estimates match theoretical expectations. A 1% increase in the exporter's electricity price reduces energy trade by an average of 0.7%, whereas a similar increase in the importer's electricity price increases energy trade by an average of almost 1%. This result is in line with economic intuition concerning the standard notion of comparative advantage in international economics. Countries will tend to trade more when they have a relative comparative advantage (lower prices abroad or higher prices at home). Our results suggest that similar mechanisms could underlie energy trade, at least as far as yearly price averages are concerned. In the short run, however, electricity trade prices reflect electricity deficits and surpluses. Nonetheless, our analysis shows that with fixed effects we are implicitly controlling for price differences, which appear to be relatively parsimonious and fixed at the country-pair level.

The third result of interest is the effect of EMI on electricity trade. The estimates show that trading partners within an EMI agreement trade 39% more (on average) than country pairs with equal economic characteristics.[2] Furthermore, energy trade diversion is also observed. EMI members trade 27% less with non-members with similar characteristics to those of member states. EMI increases the energy trade of its members and reduces energy trade with non-members who otherwise would have been expected to trade at higher levels.

These results are in line with the effect of economic integration on goods trade. In a meta-analysis of the effect of common currencies on trade, Rose and Stanley (2005) document that a currency union increases bilateral trade by between 30% and 90%. The authors show that studies applying the methodology employed herein (i.e. gravity equation with fixed effects) have a pooled mean estimate of 0.29, with 95% confidence intervals that overlap our estimates. However, a meta-analysis of the effect of regional trade agreements (RTA) indicates that RTAs increase trade by 10% on average (Cipollina and Salvatici, 2010). As such, our estimate of the effect of EMI on bilateral electricity flows is closer (in terms of magnitude) to that

2. Calculated by $(\exp(\hat{\beta})-1)*100\%$.

of currency unions on bilateral trade flows. Costa-Campi et al. (2018) report that EMI fosters price convergence and stability, similar mechanisms to those present in currency unions.

The results reported in Table 4 disentangle the effect of individual EMIs.[3] We observe that the general effect of EMI is driven by Nordpool, NWE and NWE+MIBEL. These EMIs include countries with a high degree of economic integration. Nord-pool countries (Denmark, Estonia, Finland, Latvia, Lithuania, Norway, Poland, and Sweden) are countries with close cultural, social and economic ties. NWE countries are basically the same set of Northern European countries plus CWE (that is, Austria, Belgium, France, Germany, Luxembourg, and Netherlands). The effect of CWE is not significant and the effect of NWE is positive and significant with a higher order of magnitude than that of MIBEL. This means that the group of heterogeneous countries that do not foster electrical flows actually increases the effect of EMI due to an enlargement effect. The group of integrated electricity markets benefits from a larger market, even though they are integrated enough to have an effect by themselves. The same parallels can be drawn for NWE+MIBEL, which adds the countries of Portugal and Spain. In sum, we observe two effects driving our results: an integration effect and a market enlargement effect.

In light of these results and to help draw policy implications, it is worthwhile discussing certain theoretical mechanisms that underlie an EMI. Countries joining an EMI benefit from a certain predictability and signal their institutional commitment and stability (Costa-Campi et al., 2018). The gains to a country from joining an integrated market equal the savings it makes from avoiding the uncertainty and price volatility of a free exchange market. On the other hand, these countries sacrifice their discretionary policy-making powers in the electricity market. The integration of countries prior to the EMI determines the balance eventually struck by these varying effects and with it the effect of EMI on trade in electricity.

The policy implications that derive from the preceding observations are many. However, our results suggest that countries need to increase their integration prior to entering the agreement by, for example, homogenizing aspects of their electricity markets prior to market interconnection.

5. CONCLUSIONS AND POLICY IMPLICATIONS

In this paper, we have evaluated the effect of regional integration on electricity trade flows using the gravity equation. One interesting insight derived from the study is that the standard partial equilibrium gravity trade model provides a good fit for cross-border electricity trade data. Additionally, a number of interesting policy implications can be drawn. The merger of national energy systems, which hitherto had been allowed to develop individually, represents a major challenge in terms of being able to harmonize their respective regulatory frameworks. In this respect, the estimates reported herein should help in the development of evidence-based policies for this sector.

The first relevant policy implication to be drawn from this study is that, when analyzing trade in electricity, EMI adheres to a very straightforward logic: the bigger, the better. Here, there are many potential underlying mechanisms that might explain the importance of the size of the integration. First, from a general microeconomic perspective, increasing economies of scale could contribute to the stronger positive effects of larger EMIs, in which the connected

3. MIBEL, DE-AT , CSE and CEE agreements had insufficient observations to report results.

TABLE 4
Results (PPML): Energy integration agreements.

	(1)	(2)	(3)	(4)	(5)	(6)
Nordpool (both)	0.492***					
	(0.179)					
Nordpool (one)	–0.598***					
	(0.167)					
CWE (both)		0.197				
		(0.131)				
CWE (one)		0.218				
		(0.187)				
SWE (both)			0.287			
			(0.202)			
SWE (one)			–0.494			
			(0.345)			
NWE (both)				0.594***		
				(0.206)		
NWE (one)				–0.385**		
				(0.172)		
NWE+MIBEL (both)					0.376**	
					(0.148)	
NWE+MIBEL (one)					–0.516***	
					(0.146)	
EUPH (both)						0.0748
						(0.147)
EUPH (one)						–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, clustered by country pair. Control variables included, but not reported.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

economies are representative of market size. Second, as the EMI increases in size, the potential for making a more efficient use of energy technologies and resources also increases. Exploiting the complementarity between sources—with different generation profiles and with different demand coverage—across a larger number of members could stimulate the flow of energy in the integrated market and, ultimately, this might result in better overall system performance. International trade is also likely to present opportunities to reduce excessive reserve capacity as well as to import electricity from neighboring countries that have a comparative advantage in their electricity generation costs. In order to exploit these potential benefits, regulatory harmonization is a prerequisite, as it allows electricity flows to follow economic signals.

An additional impact serving to strengthen trade flows can be attributed to a divergent EMI opt-out: that is, in addition to trade creation, we also observed trade diversion. Thus, the flows of a country left out of the EMI group decrease in relation to those of countries joining the group. Potentially, this is driven by the high degree of standardization associated with forming part of an EMI, and can be considered a “ side effect” for those countries deciding to opt out.

The second relevant policy implication to be derived concerns the degree of electricity market integration achieved. Here, our results confirm the pertinence of the approach followed by the European Commission to promote the creation of a regional market. After years of debating the respective merits of a top-down vs. a bottom-up approach to create the European Electricity Market, the Commission eventually proposed a mixed regional approach to integration: this began with the regional integration of countries presenting similar features followed by the integration of the electricity market as a means to boost integration.

By adopting a more pragmatic approach, the European Commission seeks to promote the development of the internal electricity market, while taking into account the needs and particularities of each area. A regional approach of this nature, taking into consideration country-specific circumstances and characteristics, allows the Commission to explore and assess potential opportunities for coordinated energy policy cooperation. At the same time, it can identify the specific characteristics of national situations that are at times ignored when policy objectives are translated into regulation and implementation at the EU level. In line with our results, by promoting international markets in those regions where such convergence can be initiated (such as Nordpool, in the case of the Nordic countries, and the Iberian Market, in the case of Spain and Portugal), it could be possible to advance towards an internal electricity market.

Our study opens up multiple avenues for future research. Fostering regional markets and developing mechanisms to promote trade between regions (by providing, for example, appropriate systems for the management of interconnections) are positive steps towards achieving a single market that integrates all regions. However, it remains unclear as to the characteristics of the infrastructure that might enhance international interconnections between countries (the third pillar) in the case of trade in electricity. A better understanding of the effects of EMI on other economic variables, such as capital investment and goods trade, represents another interesting extension of this present study. Indeed, this line of study was initiated by Costa-Campi et al. (2018) for the case of MIBEL, the Iberian market, and it would be of interest to analyze the effect of EMI on foreign direct investment and/or trade with a larger set of countries participating in an electricity market.

One limitation of our study is the time span employed as it does not allow us to quantify correctly the effect of the Pan-European Hybrid Electricity Market Integration Algorithm (EUPHEMIA). Future research needs, therefore, to replicate our analysis in order to assess its effects. In addition to the coordination and harmonization of market rules and standards, the implementation of EUPHEMIA has meant the application of exactly the same algorithms in all markets. For this reason, with respect to size, if the impact of EUPHEMIA adheres to the same logic, its effects on electricity flows can be expected to be much greater than those observed in early stages of integration. Moreover, given that regional interconnections are critical for the successful integration of power markets, it would be interesting to disentangle these two effects: that is, the existence of interconnection capacity vs. the regulatory framework harmonization process.

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