UNIVERSITY OF CAMBRIDGE | Energy Policy Research Group

The European Single Market in Electricity: An Economic Assessment

EPRG Working Paper 1815

Cambridge Working Paper in Economics 1832

Michael G. Pollitt

Abstract The European single market in electricity has been promoted vigorously by the European Commission since 1996. We discuss how national electricity markets and cross border electricity markets have been reshaped by the process. We examine the Commission's own work on evaluating the benefits of the single market. We look at the wider evidence of impact on prices, security of supply, the environment and on innovation. We conclude that the institutional changes are extensive and there has been significant market harmonisation and integration. However, the measured benefits are difficult to identify, but likely to be small. This is partly because over the same period there has been a large rise in subsidised renewable generation driven by the decarbonisation agenda.

Keywords electricity single market, decarbonisation

JEL Classification L94

Contact m.pollitt@jbs.cam.ac.uk
Publication May 2018
Financial Support EPRG and CJBS

www.eprg.group.cam.ac.uk

EPRG WORKING PAPER

The European Single Market in Electricity: An Economic Assessment

Michael G. Pollitt[1]
Energy Policy Research Group
University of Cambridge

May 2018

Abstract

The European single market in electricity has been promoted vigorously by the European Commission since 1996. We discuss how national electricity markets and cross border electricity markets have been reshaped by the process. We examine the Commission's own work on evaluating the benefits of the single market. We look at the wider evidence of impact on prices, security of supply, the environment and on innovation. We conclude that the institutional changes are extensive and there has been significant market harmonisation and integration. However, the measured benefits are difficult to identify, but likely to be small. This is partly because over the same period there has been a large rise in subsidised renewable generation driven by the decarbonisation agenda.

Keywords: electricity single market, decarbonisation

JEL classification: L94

1. Background to the Single Market in Electricity

As early as 1988 the European Commission[2] began thinking about how the Single European Act of 1986, which paved the way for the European Single Market, might be applied in the energy sector, specifically to electricity and gas supply. This began a long process of opening national wholesale and retail electricity and gas markets to trade and competition across the single market area.

What has happened in the Europe to national electricity markets in Europe since then is a fascinating economic story and is a textbook case study in how the process of European market integration has worked and the difficulties to be overcome in achieving such integration. Globally electricity is not a heavily traded good. Of all gross electricity production only around 3% was exported across national borders in 2015 and most of this trade occurred in Europe (with a significant share of the rest being between the US and Canada)[3]. This makes electricity much less heavily traded than oil, gas and coal.

---

[1] The author wishes to thank the participants at the joint *Review of Industrial Organization* and *CEPR* conference 'Celebrating 25 Years of the EU Single Market' conference held at the Cambridge Judge Business School in April 2018 for their feedback on an earlier presentation of this paper. He also wishes to thank an anonymous referee for helpful comments. All errors are his own.

[2] See European Commission (1988).

[3] In 2015, 58% of global exports of electricity occurred from OECD Europe and 9% of global exports were from Canada to the US (see IEA (2017, p.II.5)).

While electricity trading across European borders is a key part of the single market in electricity story it is by no means all of it. National electricity systems and policies have been significantly altered by the requirements of the single market and indeed these effects have been at least as important as what has happened to cross-border trading of wholesale electricity. Here the requirement for national policies to adhere to the requirements of European directives have affected the organization of the sector and its regulation. Combined with other EU energy policies towards carbon trading (which covers the electricity sector); 2020 renewable electricity and energy targets; energy security and energy efficiency; national electricity sectors have gone through profound changes.

The primary legislative means by which the EU has brought about this change is through three single electricity market directives in 1996 (96/92/EC), 2003 (03/54/EC) and 2009 (09/72/EC). These directives have required member states (and Norway as a non-EU member of the single electricity market[4]) to meet certain requirements in their national legislation, as well as setting out pan-European policy. The electricity sector comprises of a number of elements each of which has been affected by the directives: generation (power plants), transmission (high voltage wires), distribution (lower voltage wires); retail suppliers (who bill final customers); customers (who might choose suppliers); the degree of unbundling (both horizontal and vertical between generation, transmission, distribution, retail); and cross-border trading over interconnectors.[5]

Prior to the 1996 directive a few single market countries, such as Norway, Sweden and the UK had liberalized their electricity sectors to create wholesale power markets and introduce competition in the early 1990s. However, across most of the EU, generation, transmission, distribution and retail supply were mostly in the hands of incumbent domestic monopolists (such as EdF in France, or ENEL in Italy). *Horizontal* bundling was the norm with no competition in each segment of the industry. Often incumbent monopolists ranged across generation, transmission, distribution and retail, exhibiting large degrees of *vertical* bundling of assets. Customers of these monopolists had no choice of supplier, no matter how large the customers were. Cross border trade was controlled by bilateral monopolists on either side of the border, who were able to set cross-border tariffs and allocate cross-border transfer capacity. The only example of cross-border trading on a market basis was between Norway, Sweden and later Finland, within a market arrangement called NordPool.

The directives changed this radically by establishing a process of opening-up of the market to competition across the EU. Essentially this process forced all member countries *both* to follow the example of the early market reforming states nationally *and* to promote a genuine cross-border market.

The 1996 directive envisaged that by end of 1999 all generation would be either subject to free entry into a wholesale market arrangement or competitively procured by a single buyer under a tendering procedure; all access to the transmission and distribution system would be subject to negotiated or regulated third party (RTP) access on common terms, in the absence of a single buyer; retail suppliers could freely compete with one another to acquire customers; the largest customers representing about 1/3 of demand could choose their retail supplier; all remaining vertically bundled transmission and distribution businesses would have to produce separate

[4] Switzerland is physically interconnected with the single market but it is not a full member of the single market in electricity.
[5] See Jamasb and Pollitt (2005) for a longer discussion.

accounts (so called 'accounting unbundling'); and all cross border trade would be subject to at least negotiated third party access. The 1996 directive offered a number of options which countries could take (like the choice of negotiated or regulated third party access) as a way of persuading initially reluctant reformers (such as France) to begin their reform process. Individual EU member states (MSs) were free to adopt the more competitive arrangements more quickly and indeed to go further than the minimum required by the directive (such as giving all customers free choice of retail supplier which happened in the UK in 1999).

The 2003 directive (03/54/EC) envisaged that by the end of 2007[6]: all generation would be subject to free entry into a wholesale market arrangement; all access to the transmission and distribution system would be subject to regulated third party access on common terms; retail suppliers could freely compete with one another to acquire customers; all customers, including households of any size, could choose their retail supplier; all remaining vertically bundled transmission and distribution businesses would have to held in legally separate business units (legal unbundling); and all cross border trade would be subject to regulated third party access. The 2003 directive extended the scope of wholesale and retail competition and was a way of forcing slowly reforming MSs to go further in an environment where leading countries were already completing their own internal market in electricity (see Jamasb and Pollitt, 2005). The 2003 directive also required MSs to have a national electricity regulator with a degree of independence from government responsible for regulating the charges of the incumbent transmission and distribution companies and ensuring non-discriminatory network access.

A very visible effect of the directives (and of the Single Market more generally) was that it unleashed a wave of mergers across the EU of electricity and gas companies. EdF, RWe, E.ON, Iberdrola, ENEL and Vattenfall expanded substantially outside their home markets in both generation and retail. In the UK, for instance, EdF, RWe and E.ON became the three largest generators and three of the largest retailers. By the mid-2000s many of the smaller European generators and retailers had been taken over by major pan-European companies.

What followed the coming into force of the 2003 directive was a growing realization that while a lot of progress had been made in reforming national electricity markets and the internationalization of ownership, very little progress had been made in creating a genuine single market in electricity with wholesale markets extending across borders. In 2004, the European Commission began to support what became known as the 'target model'[7] which envisaged the gradual integration of national electricity markets, around a system of market coupling, whereby national markets would be merged or coordinated. Prior to market coupling a trader wishing to sell electricity between two markets would need to buy the power in one market, sell the power in another and separately procure the transfer capacity on the interconnector between them. This was a costly and inaccurate process, especially if trading periods were not coordinated across the three transactions. Under market coupling, available transfer capacity is declared to the markets and power can be bought and sold between the two markets subject to one market clearing algorithm. If there is enough transfer capacity the prices in the two markets will be the same, if there is a transmission capacity constraint power should be seen to flow from the low price market to high price one. The period since 2004 has seen a large increase in the degree of coordination between day-ahead wholesale markets as a result of the extension of individual markets and the coupling between markets.

[6] Except for certain MSs granted limited time extensions to comply with the directive.
[7] See Moffatt Associates (2007) and European Commission (2011).

Progress on market design has been assisted by pan-European competition policy in electricity. MSs have traditionally been somewhat reluctant to increase imports of electricity to protect their domestic generators (from increased competition) and partly for reasons of energy security (by making it easier for national system operators to manage their system by simply adjusting national supply and demand). This has led to allegations that transfer capacity was not being allocated efficiently at the border and that available capacity was not being offered to the market.

In response to this and other concerns about the slow progress in the creation of single market, the European Commission began a major energy sector competition inquiry in 2005. The inquiry reported in 2007 (European Commission, 2007) and spurred competition enforcement action and the third electricity single market directive in 2009. This directive significantly strengthened the unbundling requirements on transmission businesses and created a preferred model for transmission of ownership unbundling. It also established a pan-European regulatory agency for electricity and gas (Agency for the Cooperation of Energy Regulators - ACER)[8]. This agency was charged with dispute regulation between national regulators and the monitoring of cross-border competition. Since then there has been a significant move towards unbundling of German transmission assets, which has helped to promote cross-border trading and efficient allocation of transmission capacity in central Europe (discussed in the next section).

Two other sets of policies also impact the single electricity market.

Several incidents have highlighted the vulnerability of interconnected national electricity markets. In 2003, a series of blackouts across the globe drew attention to the need for increased coordination between system operators across different interconnected systems. As a result, the European Commission now lists as one of its policies for energy security an increase in national electricity interconnection from its current average level of 8% of peak capacity to 15% by 2030 (having had a target of 10% by 2020).[9] To promote this policy the Commission has been actively promoting projects of common interest (PCIs) which increase transmission capacity between nations, in particular with respect to Baltic (Lithuania, Latvia and Estonia) and Iberic (Spain – and by implication Portugal – and France) isolation.[10] In some areas, such as across the North Sea, there has been a significant increase in transmission capacity. Increased interconnection for security reasons promotes wholesale market integration and expansion.

The renewables and decarbonisation agenda are having a significant impact on the electricity industry. The 2001 renewable electricity directive (2001/77/EC) and the 2009 renewable energy directive (2009/28/EC) have together massively increased the requirement for electricity generation to come from renewable electricity sources such as bio-energy, wind and solar. These have been heavily subsidized by national governments and have significantly reduced the amount of generation being competitively added on the basis of predicted future wholesale market prices. Meanwhile the introduction of the EU Emissions Trading Scheme (EU ETS) in 2005, which included electricity within a traded carbon allowance system, has

[8] See www.acer.europa.eu

[9] See European Commission (2014b, p.10).

[10] See European Commission (2014b, p.24).

seen significant incentives at different times to favour gas fired power generation over coal fired power generation (and sometimes vice versa)[11].

The overall context for current energy and climate policy to 2020 is the 20-20-20 targets for 2020 agreed in 2007, enacted in 2009. These are a 20% reduction in CO2e (on 1990 levels); 20% of gross final energy consumption to come from renewable energy[12]; and a 20% increase in energy efficiency (energy demand relative to levels projected around 2005). The European Union have recently agreed to set a 40-27-30 set of targets for 2030 (more precisely: -40% GHG emissions, >27% renewable energy and >30% increase in energy efficiency), with primacy given to the 40% reduction in greenhouse gas emissions.[13] The EU wide targets for CO2e reduction and renewables share are disaggregated into national level targets (some greater or less than the aggregate target), whereas all member states are expected to meet the energy efficiency target.

As noted in Pollitt (2009), much of the initial implementation of these policies to meet energy and climate targets across the EU was 'patchy' with big differences between the enthusiastic reformers and lagging states.

A 4th Energy Package was tabled by the European Commission on 30th November 2016 entitled 'Clean Energy for All Europeans'. These measures are intended to lead to a new Electricity Directive and include three main goals: 'Putting energy efficiency first; Achieving global leadership in Renewable energies; and Providing a fair deal for consumers.'[14]

2. The evolution of the Single Market in Electricity

The individual member states of the EU single market have very different national electricity resources. Germany, France, UK, Italy and Spain have large national markets, significantly larger than other countries. France is dominated by nuclear, Germany has a significant share of coal, while the UK, Spain and Italy have relatively more gas in their electricity mix. Norway has significant hydro capacity. Many other national markets are small but located close to much larger countries.[15] This immediately suggests that there must be significant room for trading to exploit relative price differentials on the different marginal generation technology, non-coincident peaks in demand and the sharing of reserve capacity.

In addition to the underlying differences in technology and demand characteristics, the move to a single market can increase the number of firms effectively competing in wholesale and retail markets, either by simply increasing the size of the market (via coupling national electricity markets) or by encouraging cross-entry between former monopoly incumbents in neighbouring member states. The electricity directives encouraged this by removing barriers to entry into national electricity markets. This increased the number of effective competitors and reduced the effective market share of incumbent firms. A significant part of this process was the harmonisation of the rules for new connection, third party access to transmission and

[11] See Koenig (2011).
[12] European Commission (2006) https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52006DC0545&from=EN and Directive 2012/27/EU http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:315:0001:0056:en:PDF
[13] For a review of progress see European Commission (2017a).
[14] See https://ec.europa.eu/energy/en/news/commission-proposes-new-rules-consumer-centred-clean-energy-transition Accessed 24 March 2018.
[15] See IEA (2017).

distribution system and retailing electricity to final consumers. The rise of independent energy regulators tasked with promoting domestic electricity market competition and with incentive regulation of electricity networks facilitated increasing competition in line with the intention of the directives. A deep process of national network code harmonisation is currently underway with oversight from ACER (and largely due for completion by 2019).[16]

The process of opening up national electricity markets has been a gradual one. Globally many lessons have been learned along the way (see Joskow, 2008, for a review of international experience). In the EU, as elsewhere, continuing vertical integration between transmission, distribution and generation resulted in difficulties in new generators getting access to networks and hence the ability to supply their customers (this was a particular issue for new entrant Enron in France and Germany in the early days of reform).[17] Within electricity wholesale markets there were examples of tacit collusion between generators (e.g. within the UK, where the regulator had impose a price cap on the two leading generators in 1996).[18] There were problems with access to congested transmission links, with incumbent generators hoarding their historic access rights in order to limit cross-border trading (something which explained initially low or non-economic cross-border power flows). This inefficient utilisation of cross-border transmission links was a major driver behind the competition enquiry into the operation of the wholesale electricity and gas markets launched by the European Commission in 2005.

The energy sector inquiry published its final report in January 2007[19]. It found that there was: 'too much market concentration in most national markets; a lack of liquidity, preventing successful new entry; too little integration between Member States' markets; an absence of transparently available market information, leading to distrust in the pricing mechanisms; an inadequate current level of unbundling between network and supply interests which has negative repercussions on market functioning and investment incentives; customers being tied to suppliers through long-term downstream contracts; current balancing markets and small balancing zones which favour incumbents'.[20] The inquiry led to a number of recommendations including competition enforcement action where necessary, unbundling of transmission network ownership from generation, increased powers for regulators and increased cross-border regulatory coordination, improved market transparency, removal of regulated retail tariffs, and competitive allocation of cross-border interconnector capacity.[21] The Commission pursued a case against the integrated German incumbent E.ON which eventually resulted in a voluntary settlement which involved E.ON divesting some generation plant in Germany and putting its transmission business up for sale in 2008.[22] The Energy Inquiry was a significant driver behind the 'Third Energy Package', which gave rise to the 3rd Single Electricity Market directive in 2009 and the creation of the pan-European regulatory agency (ACER). Transparency has been increased by the 2011 REMIT Regulation (No.1227/2011), which covers oversight of interconnectors and abuse of markets, and is overseen by ACER.[23]

---

[16] See Dale (2017).
[17] See Bergman et al. (1999).
[18] See Newbery (2005).
[19] See European Commission (2007),
[20] See European Commission website:
http://ec.europa.eu/competition/sectors/energy/2005_inquiry/index_en.html
Accessed 16 March 2018.
[21] See European Commission (2007, pp.9-15).
[22] See Chauve et al. (2009).
[23] See ACER (2016) for example.

However national markets have been increasingly integrated. In 1976 only around 6% of electricity produced in the ENTSO-E area was traded across national borders. In 2015 nearly 14% of electricity produced in the ENTSO-E area was traded across national borders. This figure was itself significantly higher than in 1996.[24]

In 2016 ACER[25] reported that across the European Union that 86% of available commercial interconnector capacity was being allocated in the 'right' (from low to high price areas) direction via the coupled day ahead markets. However, it also estimated that there were still unrealised gains of €203m per year if market coupling extended to remaining borders. However, for a selection of borders that ACER looked at in more detail only 50% of intraday capacity was being allocated in the 'right' direction and 19% of balancing action flows were in the 'right' direction.

3. The European Commission's Assessment of the Single Market in Electricity

1999 and 2003 and 2009 are the key dates of implementation of the variation stages of the single electricity market so far. The Commission has undertaken various Benchmarking and State of the Market Reports.[26] These reports mostly focus on the implementation of various parts of the directives (such as on unbundling rules). However, there is remarkably little serious analysis by the Commission (or indeed cited by the Commission) on the effects of the single market in electricity project relative to what might have happened in the absence of its interventions.

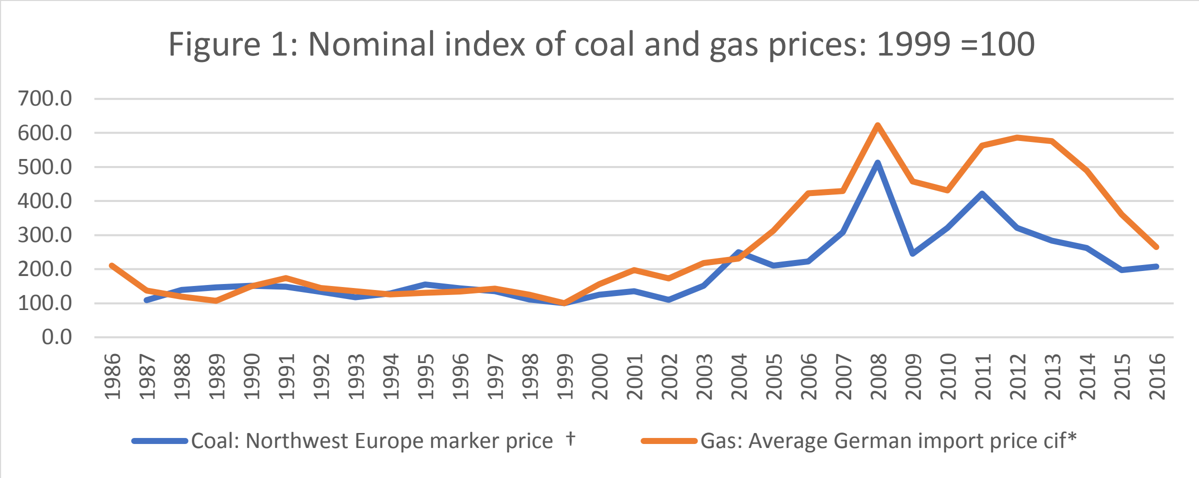
European Commission (2014a) finds that wholesale electricity prices fell 35% between 2008 and 2012. However, households and industrial customers did not see lower bills because over this period network charges went up 18.5% and 30% for households and industry respectively, while taxes and levies rose by 36% and 127% for households and industry respectively. This highlights the important issue that over the period there has been a significant imposed cost of renewables and climate policy, which obscures any impact of the single market on underlying costs and margins. It also shows the importance of network charges for final bills, especially for households. These remain regulated by national regulators and the determination of how generous these are remains outside the remit of the European Commission. A further observation is that wholesale prices remain subject to commodity price fluctuations for both gas and coal. 2008-2012 is a period of falling commodity prices (by contrast 2004-2008 is a period of significantly increased commodity prices). Figure 1 shows the underlying rise in nominal commodity prices for coal and gas in Europe over the period we are considering, and the large fluctuations it has been subject to.

---

[24] Sources: ENTSO-E (2011) and ENTSO-E (2017b).

[25] ACER/CEER (2017).

[26] See Jamasb and Pollitt (2005) and Pollitt (2009) for discussions of early versions of these reports. See European Commission (2017b) for an example of current reporting.



Source: BP Statistical Review of World Energy 2017.

Getting a sense of the impact of the single market on aggregate prices and welfare since 1999 is difficult. Copenhagen Economics (2005) provided an early assessment for the Commission of the possible effects of market opening in electricity using a general equilibrium model using data from 1990-2003. They do this in stages, by measuring market opening at the national level, then econometrically estimating the effects of market opening on individual countries electricity sector performance, and finally estimate the overall impact on the economy using their general equilibrium model of the European economy. They did find significant impacts from market opening on national productivity and estimated the long-run impact in electricity could be as high as 7-8% (and even higher % price reductions).

More recently, working for the Commission, the impacts of the single market have been analysed by Booz & Company (2013). They identify the period before 2004 as one of mainly national based reforms. From 2004, there was an increasing trend towards coupling national markets at the wholesale level (the 'target model'). This study has been subsequently published as Newbery et al. (2016). Market coupling would appear to have significant and dramatic benefits. Moss (2009) examines the coupling of the power flows between the Netherlands and France before and after the coupling of the APX and PowerNext power exchanges in November 2006. In 2005/6 prices were more than €10 different 39% of the time, in 2007/8 this had fallen to 14% of the time, by contrast prices were less than €1 different 10% of the time in 2005/6 but 72% of the time in 2007/8.

Booz & Company (2013)[27] suggest that the total value of electricity trading is roughly €16bn p.a. (308 TWh @ €50/MWh) and that the value of full market coupling is around one quarter of this (based on the degree of price convergence seen at borders) or €4bn p.a. They find that if market coupling covers 58-66% of the market the current benefits are €2.5bn p.a. A further €1.5bn p.a. of benefits is therefore possible if all interconnectors within the EU are coupled.

But the current market coupling only covers short term day ahead trading. Extending market coupling of interconnectors to cover shorter term intra-day trading of electricity, balancing services and reserve capacity and financial transmission rights would produce further gains beyond the day ahead market. Booz & Company (2013) suggest large additional gains from

[27] See https://ec.europa.eu/energy/sites/ener/files/documents/20130902_energy_integration_benefits.pdf Accessed 24 March 2018.

these measures under different scenarios of renewable penetration. However, these are yet to be realized.

Overall the impression one gets from the Commission's own evidence is that of limited gains so far in terms of proven price and productivity effects, coupled with an emphasis on the potential for much larger future gains. In the next section, we look at some of the wider academic evidence on the impact of the single market in electricity project.

4. Assessing the impact of the Single Market in Electricity

The measurement of the overall impact of the single electricity market, on prices, costs and wider GDP is difficult as the attempts by the Commission to study this illustrate.

We can start by thinking about how the single market is supposed to have an effect, through bringing about pro-competitive structural change and the quality of sector regulation, before looking at the measured economic impact.

Pro-competitive structural change and quality of sector regulation

The OECD Product Market Regulation (PMR) index provides a relative measure of the degree of deregulation of a nation's electricity sector[28]. The index has a range of 0 to 6, where 0 is most liberalised and 6 would be an unreformed integrated government monopoly. This index puts one quarter weight on entry regulation, the percentage of public ownership, the degree of vertical separation and the market share of the largest company in the sector. Under a combination of free entry regulation, regulated third party access (TPA), a liberalised wholesale power market and no minimum threshold on the size at which a customer can chose supplier, would give the lowest possible liberalisation score of zero. Under vertical integration, ownership separation gives the lowest possible liberalisation score of 0 (legal separation scores 3). Under market structure, a combined generation/import and supply share of less than 50% for the largest firm, gives a score of zero. If 100% of the shares in the firms across generation/import, transmission, distribution and supply were government owned this would score 6. The implementation of the single electricity market directives should result in a zero score for entry regulation and market share of largest firm in the sector and a maximum of 3 for vertical integration and less than 6 (due to some entry) for public ownership. Thus should imply that the maximum EU member state score under the PMR is 2.3. Indeed between 2008 and 2013 the PMR score for EU electricity did improve from 2.4 to 2.1, relative to 2.6 to 2.4 for the OECD[29].

Since 1999, there has been a significant increase in generation competition within MSs. The Czech Republic, France, Greece, Luxembourg have all increased their number of main generators (with 5% of national production) in 2015 from 1 in 2003. Effective competition has also significantly increased in Germany.[30] Estonia, France, Croatia, Latvia, Portugal have increased their number of main (with 5% of national consumption) retailers in 2015 from 1 in 2003.[31]

[28] Koske et al. (2015, p.63).

[29] Koske et al. (2015, p.63).

[30] See Eurostat data on number of main generating companies at http://ec.europa.eu/eurostat/statistics-explained/images/7/7a/Number_of_main_electricity_generating_companies-T2.png

[31] http://ec.europa.eu/eurostat/statistics-explained/images/5/57/Number_of_main_electricity_retailers-T6.png

A developing theme of the single market in electricity project has been the need to improve the quality of both national and EU level regulation of the sector. This is discussed in Green et al. (2009). They point out the importance of improving the form, process and outcomes of energy sector regulation.

The *form* of regulation can be measured on the basis of the strength of the regulator in terms their separation from government and their ability to regulate the industry. Jamasb and Pollitt (2005) scored ex ante regulation, no ministerial involvement in decision making, network access conditions set by the regulator (rather than elsewhere), dispute settlement by the regulator and strong information acquisition powers at 5 out 5, for regulatory strength. Larsen et al. (2005) focused on the scope of the regulatory functions, finding that 15 European regulators had from 1 to 7 different competencies.

The *process* of regulation focusses on the degree of transparency exhibited by the regulator, the amount of stakeholder engagement, the procedural efficiency in coming to regulatory decisions and quality of the underlying techniques utilised in carrying out their functions. Regulators which are more transparent in their decision making, deliver their decisions in a timely way, undertake good levels of stakeholder engagement and use best practice techniques of regulation are thought to have better processes.[32]

The *outcomes* of regulation are more difficult to measure. This is because regulators do operate under different rules and objectives. Process in a democracy matters for its own sake – stakeholders do like and need to be consulted. Regulatory decisions can only be evaluated ex post and it is not clear how to do this, given that there is very unlikely to be an unbiased, statistically identifiable measure of impact. Nillesen and Pollitt (2007) discuss a case study of the miscalculation of price controls in the Netherlands and how much this cost Dutch customers. It is possible to try and benchmark regulator costs across countries, but this would need to be corrected for number of regulatory functions and economies of scale in regulation (see Domah and Pollitt, 2002).

The single electricity market project has undoubtedly spread good practice in both the form, process and outcomes of regulation (especially initially, as noted by Jamasb and Pollitt, 2005). The directives have promoted independent sector regulation of electricity (notable forcing Germany to have an electricity regulator, when it initially did not). CEER (the industry association of regulators) and ACER have been fora for the spread of good regulatory practice and many European countries have much better regulators then they would otherwise have had.

The measured economic impact of the single electricity market

Here we update our earlier work (Jamasb and Pollitt, 2005; Pollitt, 2009) in order to examine economic impact under a number of different headings: prices, costs, return on capital and fuel poverty; quality of service; impact on the environment (via renewables and decarbonisation); and the impact on innovation. The first three can be summarized as: affordability, security of supply and the environment (the so called ‘energy trilemma’). The fourth is about dynamic efficiency. We conclude this section by revisiting overall assessments.

[32] See, for example, Brophy Haney and Pollitt (2013) who compare regulators on the quality of the benchmarking techniques they use to measure the efficiency of their regulated transmission companies.

Prices, costs, rate of return on capital and fuel poverty

Has the single market reduced average prices (relative to business as usual) and price dispersion as we would expect from theory, especially in the wholesale power market?

Measuring the average price effect is hard because of the confounding impact of fossil fuel price fluctuations, renewables support policy and network expenditure. There is some limited evidence of liberalization reducing household electricity prices looking at data for 23 EU countries from 2000-14 (da Silva et al., 2017). This is in line with earlier studies that suggest limited price effects due to the introduction of a wholesale power market and unbundling of transmission and generation.

There is rather more recent support for price convergence. The EU does measure the relative standard deviation of retail electricity prices in the EU member states. Industrial prices do show a degree of convergence over the period 2014-2017 (see European Commission, 2017, p.29). Market coupling does appear to be associated with strong price correlations. Ouraichi and Spataru (2015) find high price correlations between national markets within 4 regional markets (CWE, CEE, MIBEL and NordPool)[33] AND high price correlation between countries in each of two different regional markets. They conclude that the flow-based market coupling policy of the EU has had promising if incomplete results, for instance CWE (Belgium, France, Germany, Luxembourg and the Netherlands) countries only exhibit 74% correlation within the region. Using a different measure (fractional cointegration analysis) of price convergence, de Menezes and Houllier (2016) also find evidence of price convergence between European electricity markets.

We would expect that prices and costs would move in parallel: falls in prices likely imply falls in costs. We can observe prices, but costs are rather more difficult to observe. They can only be observed indirectly, if we look at returns on equity as well as prices. If returns stay constant costs and prices move together, if returns fall but prices stay the same then costs must be rising – though the price (i.e. cost) of capital may be falling - and vice versa. We would expect liberalization to reduce overall returns to capital in the electricity sector, but it is possible the profit maximizing firms are good at price discriminating across their customer base, or at bargaining with their suppliers.

Jamasb and Pollitt (2005) produced some early evidence of falling returns in the electricity sector following liberalization, as well as falling costs. More recent studies looking at returns find mixed evidence of any change to underlying profitability.

Mergers in the electricity sector have created more value for European acquirers over the period 1998-2013 (Kishimoto et al., 2017). This would seem to indicate that the benefits of the single market are being brought about by the takeover of inefficient domestic firms by more efficient ones, and is consistent with the ability of mergers to create larger firms with greater economies of scale and scope. OECD (2016, chapter 5) shows a declining trend in clean energy returns on equity (relative to the cost of equity) in Europe over the period 2004-2015, this might be indicative of tougher conditions for renewables procurement (though this is not necessarily directly related to liberalization). Tulloch et al. (2018) find declining returns on European electricity and gas utilities over the period 1996-2013, with a larger effect of the 2003

[33] CWE = Central West Europe; CEE = Central and Eastern Europe; MIBEL = Iberia; and NordPool = Nordic countries.

directives. They suggest that their results are consistent with evidence that the markets are becoming more competitive, albeit with some offsetting increase in risk. CEER (2017) find continuing wide variation in the target rates of return (WACC) used in electricity distribution and transmission, indicating a lack of standardization of network investment risks across Europe.

Since the beginning of the reform period fuel poverty has emerged as a big issue in some EU countries, notably the UK. Conventionally defined as those spending 10% or more of their household expenditure on electricity and gas it has become a focus of government policy on energy pricing. There is little evidence that this has systematically increased since 1996, but there is no doubt that energy remains a significant expenditure item for many households across the EU (see Wand, 2013)[34].

Quality of service

The willingness to pay for continuity of service in electricity is very high: typically, of the order of 50-100 times more than the value of the retailed price of electricity.[35] This suggests that small improvements in quality of service can be very valuable. For instance, an improvement of just half an hour in customer minutes could be worth of the order of 0.5% of the total value of electricity sold in the year[36]. Most interruptions to customer supply are local due to problems with local substations. Regulators are also concerned about transmission system availability as this may be an indication of more serious failings in the transmission grid and the risk of wide-area blackouts.

CEER has been monitoring quality of service at the EU level (see CEER, 2016). There does seem to be a general improvement in customer minutes lost over the period 2002-2014, based on data reported to them. Measuring this is not straightforward as it depends on how interruptions are monitored and reported (with different national definitions of what constitutes an interruption and different qualities of national reporting systems) and on exogenous drivers of interruption such as extreme weather events.

Transmission system reliability also seems to have improved for several countries. One measure here is average transmission interruption (ATI) time. However, this is from very low levels to start with: Spain improved from 2.006 minutes in 2002 to 0.441 minutes in 2014 (CEER, 2016, p.46).

One quality issue is whether increased power flows between countries and system operator areas increases the risk of wider area blackout. This is because one system operator only has full visibility on the scheduling of generators and loads within its control area, while interconnectors in an alternating current (AC) power system are subject to unscheduled loop flows as power transacted between areas A and B, may actually travel via a third area (from A to C to B, without area C having sight of the transaction between A and B)[37]. This situation is especially difficult to manage if there is an unplanned transmission line outage which affects

[34] Available at: http://fuelpoverty.eu/home/eu-inability-to-heat-home-map-031013-citation/

[35] See Arnold et al. (2007).

[36] 0.5 * 100 / 8760 = 0.5%.

[37] Bonnard (2003) reports the unplanned flows through Belgium on a day in 1999 when unidentified flows (to the Belgium system operator) increased from 600 MW to 2000 MW within four hours and were two thirds of all flows. This is because, for instance, some of power transacted between France and Germany will flow through Belgium. See ENTSO-E (2017a, p.20) for a map of the European transmission system.

flows through C. This is examined in Bialek (2004) who reviews the 2003 blackouts which saw 6 wide area blackouts in 6 weeks affecting 112 million people, five of which were in Europe (the sixth covered a large part of the North East of the US, including New York City). These included a blackout involving large parts of Denmark/Sweden and the whole of Italy (which was the largest blackout in Europe since 1945). Bialek reviews the New York, Denmark/Sweden and Italy incidents and concludes that while increased cross-border trading did not directly cause the blackouts it did necessitate an upgrading of inter system operator communication, as in both the Italy case and the similar case in New York, outdated communications infrastructure contributed to the slow communication of evolving problems in one system which ultimately had serious consequences for interconnected systems. There have been other internationally power outage incidents, such as on the 4th November 2006 incident when a power line in Northern Germany had to be switched off to let a ship pass underneath it and caused a blackout in several European countries (see UCTE, 2007).

Europe has made significant efforts to improve inter TSO coordination to reduce these sorts of problems. The association of European TSOs (ENTSO-E) has overseen the establishment of regional security coordinators (RSCs), which are made up of groups of national TSOs (see ENTSO-E, 2017). These RSCs undertake regional operational security coordination, regional outage coordination, coordinated capacity calculation, capacity adequacy assessments and provide dynamic asset information. The largest of these RSCs is CORESO, which began in 2008 and covers a population of 279m (which is a private joint venture of REE (Spain), Elia (Belgium), RTE (France), National Grid (UK), Terna (Italy), 50Hertz (Germany), and REN (Portugal)). These RSCs are designed to reduce the risks that lead to the international incidents in 2003 and 2006.

Environmental impact

The European electricity system has been going through a profound transition with respect to its environmental impact. Between 2004 and 2015, the share of electricity generation from renewable sources has doubled from 14.3% to 28.8%. Hydro-electricity has barely changed in absolute quantity over this period. The increase is almost entirely due to an increase in wind, solar, biofuels and other renewables (total generation has fallen by 1%).[38]

The emissions intensity and energy efficiency of EU electricity has also improved significantly[39]. The carbon emissions intensity was 431g of CO2 / kWh in 1990, 371g / kWh in 1999 and 276g / kWh in 2014 (a decline of 36% between 1990 and 2014). The increased share of renewables and the increased use of more efficient gas fired power generation and reduced use of coal in electricity generation has contributed to average power plant efficiency increasing from 36% in 1990 to 44% in 2014[40].

Jamasb and Pollitt (2005) noted impressive improvements in emissions of sulphur and nitrous oxides from the power sector in the period from 1990 up to 2003. Between 2004 and 2014, emissions have fallen by 77% of sulphur dioxide and 49% for nitrous oxides and 81% for dust[41].

[38] See http://ec.europa.eu/eurostat/web/energy/data/shares

[39] See https://www.eea.europa.eu/data-and-maps/indicators/overview-of-the-electricity-production-2/assessment

[40] This is across all power plants where, for example, wind would be 100% efficient, nuclear around 33%.

[41] See https://www.eea.europa.eu/data-and-maps/indicators/emissions-of-air-pollutants-from/assessment-1

The econometric evidence, presented in Asane-Otoo (2016) suggests that for individual countries CO_2, NO_X and SO_2 intensity all decline with higher PMR over the period 1990-2012. Other econometric evidence from Vona and Nicolli (2014) suggests that countries with greater amounts of liberalization in their electricity sector have higher penetration of wind and solar power. Two channels for these effects might be: first, greater reliance on market forces to guide generation investment resulted in faster coal to gas substitution in the EU (and across the non-Europe OECD); and, second, that the initial efficiency gains from liberalization (discussed in Pollitt, 2008) were partly spent on supporting renewables. What is certainly true is that a combination of market liberalization (which initially favoured gas over coal), carbon pricing (which also favours gas over coal), the Large Combustion Plant Directive[42] (which forced higher emissions standards on existing and new coal fired power plants and raised their costs) and renewables support policies which have led to renewables increasingly reducing wholesale electricity prices (for both coal and gas fired power plants) have largely ended the building of new coal fired power plants in the EU (see Caldecott et al., 2017).

Impact on innovation

It is possible that over such a long period (1999-2018) the EU single market in electricity may have produced some positive short run effects which mask negative long run effects, i.e. static gains may be offset by dynamic losses. One channel for this might be the impact of liberalization on the quantity of investment in research and development, or indeed on the productivity of research and development.

This is very difficult to measure because the rate of technological progress in electricity is slow and significantly affected by environmental regulation (and other types of regulation, such as nuclear safety)[43]. However Jamasb and Pollitt (2008) discuss how we would expect liberalization to reduce R+D expenditure by electricity companies in theory (e.g. due to reductions in size and incentives to invest in R+D), they then go on to show how this effect has played out in the UK (Jamasb and Pollitt, 2011 and 2015) and evidence of similar effects across the world, notably in the US.

One significant issue is the extent to which declines in electricity company R+D actually reduce aggregate energy R+D and the productivity of energy R+D expenditure. R+D may shift to the supply chain and away from former monopoly incumbent utilities. Marino et al. (2017) find that deregulation of electricity initially increases but then reduces electricity patents across 31 OECD countries over the period 1985 to 2010. They conclude that this is evidence for an inverted-U relationship between strength of liberalization and patenting. The general equilibrium effect of the release of R+D resources to other sectors and the specific impact of higher expenditure on renewables linked to reform makes it very difficult to say what the aggregate dynamic effect of European electricity liberalization might be, even if aggregate energy R+D has declined.

Overall assessments of the impact of the single electricity market

It is striking in what we have discussed so far how little large scale evidence has been produced for the overall impacts of the single market in electricity. It is even more striking that the most

[42] 2001/80/EC.

[43] This is a phenomenon noted by Jorgenson and Wilcoxen (1990) for a range of industries in the US (including electricity) over the period 1973-1985.

convincing evidence is simulated. Simulation studies can show the benefits of market coupling and changing the pricing behavior of incumbent players. These studies find that reducing market power in pricing can have substantial benefits (e.g. Hobbs et al. (2005) who look at Netherlands-Belgium market coupling). A move from strategic interaction to perfect competition can be shown to yield big impacts, reducing the profits of incumbents significantly (Lise et al., 2006, show the profits of EdF and Tractabel falling by a third) *if* there was enough interconnection between countries. However, these theoretical gains from more perfect competition may not be realizable in a second best word.

Moving to how actual overall reform effects can be assessed: there are a number of ways to assess the overall impact of liberalization package such as that represented by the single electricity market project (as noted in Pollitt, 2012). These include: performance metric regressions on panel data (e.g. Steiner, 2001); simple statistical tests of before and after performance using t-tests (e.g. following D'Souza and Megginson, 1999); social cost benefit analyses of reform (following Jones et al., 1990) with reform as public investment project; and macro studies of reform attempt to find impacts using general equilibrium models of the economy (e.g. Chisari et al., 1999 and Copenhagen Economics, 2005). Remarkably, not all of these methods have been applied clearly to the EU single market project, as opposed to electricity reform in the OECD more generally. Fiorio et al. (2007) attempts panel data regression on reform variables to show evidence of modest productivity improvements, but ambiguous price impacts for 15 EU countries.

Reform evidence, both for samples of countries and specific case studies, seems to support the view (in Pollitt, 2012) that market liberalisation reduces costs somewhat but may not impact prices. This positive view on productivity has recently been disputed by Polemis and Stengos (2017), who suggest that for their sample of OECD countries over the period 1975-2013 electricity liberalisation does not increase their measures of productivity (which include generation per capita and labour productivity) in already liberalised countries. However a standard problem with panel data analysis is that reform is a package and identification of its effects is a problem given that multiple significant policy impacts happen simultaneously (for instance cost increasing environmental policy *and* cost reducing market reform).

What is more clear is that public dissatisfaction with liberalised energy markets in Europe remains strong. Fiorio and Florio (2011) showed that in Europe private ownership of electricity assets was correlated with increased public dissatisfaction with the industry. This dissatisfaction explains the remaining significant public ownership in European electricity, in spite of the single electricity market, and the fact that in at least half of EU countries residential price controls still exist for some household customers (something which ACER continues to condemn as limiting the impact of the single market project)[44].

5. Conclusions

Reflecting on the development of the EU single market in electricity, it is difficult not to be impressed with it in terms of the structural changes since 1996. National markets that were once dominated by a single incumbent generator and a single incumbent retailer have been opened-up to competition. Independent regulation has been significantly increased, both at the national and at the level of the EU itself. There has been significant enforcement action by the

[44] See, for example, ACER/CEER (2017, p.8) which discusses the impact of supplier of lost resort mechanisms which limit switching behaviour in the residential energy market.

European Commission's competition authority (DG Competition) to promote further reform. Legislation has evolved through successor directives and a new directive is under discussion. In parallel there has been the development of power exchanges and market coupling, as well as the emergence of non-discriminatory access to the transmission system with robust legal and ownership unbundling of transmission and increased coordination between national system operators. The ownership of the industry has been reorganized, with large numbers of pan-European mergers and acquisitions and the entry of gas incumbents into electricity. Cross border trading of electricity has increased. There has been a high degree of 'regulatory convergence' in electricity between member states, at a higher level than might have been imagined in the absence of the single market. At the same time the environmental agenda has been promoted with the introduction of a carbon market in 2005 and massive financial support for renewables which is bringing about a genuine 'energy transition'. The electricity industry has been transformed, especially for countries with less favourable initial attitudes to competition in electricity.

However, while the level of structural and institutional change is impressive, the quantification of the costs and benefits of the single market is extremely hard and the evidence we do have suggests that the overall gains in terms of price, cost and quality of service impacts are modest, especially if we consider the 25-year time frame.

The difficulty of doing econometrically robust analysis of actual data on the single electricity market is high. This is not helped by the multiple reform elements (horizontal and vertical unbundling, wholesale market developments and privatization) happening at more or less the same time. Add in the cost increasing effect of renewables support and underlying fluctuations in wholesale gas, coal and carbon prices. Furthermore, the EU itself is not the same: it had 15 members in 1996, but this had expanded to 28 by 2013. Any single market study suffers from a lack of compatible data, combined with multiple confounding factors and highly partial analysis of a narrow range of impacts.[45] Putting different econometric studies together to gain an overall picture involves comparing studies conducted over different numbers of countries and different time periods. Some of the best studies on single market-type impacts don't look at just the EU, but often the wider OECD.

What one can say, is that the 'proven' overall impacts on welfare would seem to be small. The evidence seems to be of some small productivity improvement, some wholesale price convergence and limited (if any) retail price reductions. The studies on which the European Commission relies (notably Copenhagen Economics, 2005, and Booz & Company, 2013) significantly rely on simulation of future impacts and give rather limited attention to actual data. Given that the measured overall impacts would seem to be small, this suggests the need for rather more careful attention to measuring impacts than most current studies are capable of. Indeed, in line with Pollitt (2012), it suggests little substitute for detailed cost benefit analysis of individual European country case studies of reform.

In fairness to the European Commission as architects of the single electricity market, it is important to say that the Commission does continually emphasize the fact that the single electricity market remains a work in progress.[46] The Commission together with its sector

[45] One referee of this paper asked me to think about putting in some tables and figures. However even the simplest comparative figure, such as electricity prices in the US and the EU over the last 25 years is not actually available on an internally consistent basis, because the data on the EU-28 only starts from 2004.

[46] See for example European Commission (2017, p.1-2).

regulatory organisations - ACER and the CEER - stress that more needs to be done. The fourth energy package is a commitment to doing more. Indeed, one of the genuinely good reasons the Commission may not have emphasized studies of past gains from the process is precisely to keep the focus on what needs to be done in the future. However, that is not to say that the documentation of single market gains (and losses) is unimportant. Simulation studies can always show *potential* gains from extending markets towards a first best world, but we all live in the here and now, in the second best.

Bibliography

Arnold, S., Hunt, A. and Markandya, A. (2007), *Section 1 - National and EU level estimates of energy supply externalities*, Project No 518294 SES6, Deliverable D.5.1.

Asane-Otoo, E. (2016), '*Competition policies and environmental quality: Empirical analysis of the electricity sector in OECD countries',* Energy Policy, 95: 212–223.

ACER (2016), *ACER's Annual Report on its Activities under Regulation (EU) No 1227/2011 on Wholesale Energy Market Integrity and Transparency (REMIT) in 2015*, Ljubljana: ACER.

ACER/CEER (2017) *Annual Report on the Results of Monitoring the Internal Electricity and Gas Markets in 2016 Summary October 2017,* Ljubljana and Brussels: ACER/CEER.

Bergman, L., Pollitt, M. et al. (1999) *Monitoring European deregulation: vol.2: A European market for electricity?* London: Centre for Economic Policy Research.

Bialek, J. (2004), *Recent blackouts in US and continental Europe: Is liberalisation to blame?,* Working Paper CMI EP 34 Department of Applied Economics, University of Cambridge.

Bonnard, P. (2003), *Power System Collapse: European Utility Experience,* 2003 IEEE Trans. Distr. Conf. Cited in Bialek (2004).

Brophy Haney, A. and Pollitt, M.G. (2013), 'International benchmarking of electricity transmission by regulators: a contrast between theory and practice?', *Energy Policy*, 62: 267-281

Booz & Company (2013), *Benefits of an Integrated European Energy Market,* Amsterdam: Booz & Company.

BP (2017), *Statistical Review of World Energy 2017*, London: BP.

Caldecott, B., Tulloch, D.J., Bouveret, G., Pfeiffer, A., Kruitwagen, L., McDaniels, J., Dericks, G. (2017) *The fate of European coal-fired power stations planned in the mid-2000s: Insights for policymakers, companies, and investors considering new coal*, Working Paper, Oxford: Smith School of Enterprise and the Environment.

Chauve, P., Godfried, M., Kovács, K., Langus, G., Nagy, K. and Siebert, S. (2009), 'The E.ON electricity cases: an antitrust decision with structural remedies', *Competition Policy Newsletter*, Number 1, pp.51-54.

CEER (2017), *CEER Report on Investment Conditions in European Countries 2016*, Brussels: CEER.

CEER (2016), *6th CEER Benchmarking Report on the Quality of Electricity and Gas Supply 2016*, Brussels: CEER.

Chisari, O., Estache, A., and Romero, C. (1999), 'Winners and Losers from the Privatization and Regulation of Utilities: Lessons from a General Equilibrium Model of Argentina', *World Bank Economic Review*, 13(2): 357-378.

Copenhagen Economics (2005), *Market Opening in Network Industries: Part I: Final Report*, Brussels: European Commission.

Dale, L. (2016), *The IEM Integration Process*, presentation to EPRG Workshop on 'Implications of Brexit for UK and EU Energy and Climate Policy', 6 September 2016.

D'Souza, J. and W. L. Megginson (1999), 'The financial and operating performance of privatized firms during the 1990s', *Journal of Finance*, 54(4): 1397-1438.

ENTSO-E (2012), *Statistical Yearbook 2011*, Brussels: ENTSO-E.

ENTSO-E (2017a), *Yearly Statistics and Adequacy Retrospect 2015*, Brussels: ENTSO-E.

ENTSO-E (2017b), *Annual Report 2016*, Brussels: ENTSO-E.

European Commission (1988), *Energy in Europe: The Internal Energy Market*, Brussels: European Commission.

European Commission (2006), *Action Plan for Energy Efficiency: Realising the Potential, 19.19.06*, Brussels: European Commission.

European Commission (2007), *Communication from the Commission: Inquiry pursuant to Article 17 of Regulation (EC) No 1/2003 into the European gas and electricity sectors (Final Report),* Brussels, 10.1.2007 COM(2006) 851 final.

European Commission (2011), *Public consultation on the governance framework for the European day- ahead market coupling*, 28 November 2011 D(2011) 1176339, European Commission: Brussels.

European Commission (2014a), *Progress towards completing the Internal Energy Market*, 13.10.2014 COM (2014) 634 Final, Brussels: European Commission.

European Commission (2014b), *European Energy Security Strategy, 28.05.14*, Brussels: European Commission.

European Commission (2017a), *Third Report on the State of the Energy Union, 23.11.2017* COM(2017) 688 final.

European Commission (2017b), *Quarterly Report on European Electricity Markets Q3 2017*, Brussels: European Commission.

Fiorio, C.V., Florio, M. and Doronzo, R. (2007), *The Electricity Industry Reform Paradigm in the European Union: Testing the Impact on Consumers*, Paper delivered at Consumers and Utility Reforms in the European Union Conference, Milan, June 8-9, 2007.

Fiorio, C.V. and Florio, M. (2011), '«Would you say that the price you pay for electricity is fair?» Consumers' satisfaction and utility reforms in the EU15', *Energy Economics*, 33 (2): 178-187.

Green, R., Lorenzoni, A., Pérez, Y. and Pollitt, M. (2009), 'Policy assessment and good practices', In: Glachant, J.-M. and L´vêque, F. (eds.) *Electricity reform in Europe - towards a single energy market.* Cheltenham: Edward Elgar, pp.172-205.

Hobbs, B.F.; Fieke A.M.R.; Boot , M.G. (2005), 'The More Cooperation, The More Competition? A Cournot Analysis of the Benefits of Electric Market Coupling', *The Energy Journal*, 26(4), 69-97.

IEA (2017), *Electricity Information 2017*, Paris: OECD.

Jamasb, T. and Pollitt, M. (2005), 'Electricity market reform in the European Union: review of progress toward liberalization and integration.', *The Energy Journal*, 26, Special Issue: 11-41.

Jamasb, T. and Pollitt, M. (2008), 'Liberalisation and R&D in network industries: the case of the electricity industry.', *Research Policy*, 37(6-7): 995-1008.

Jamasb, T. and Pollitt, M.G. (2011), 'Electricity sector liberalisation and innovation: an analysis of the UK's patenting activities.', *Research Policy*, 40(2): 309-324.

Jamasb, T. and Pollitt, M. (2015), 'Why and how to subside energy R+D: lessons from the collapse and recovery of electricity innovation in the UK', *Energy Policy*, 83: 197-205.

Jones, L. P., Tandon, P. and Vogelsang, I. (1990), *Selling Public Enterprises: A CostBenefit Methodology.* Cambridge, MA: MIT Press.

Jorgenson, D.W. and Wilcoxen P.J. (1990), 'Environmental Regulation and U.S. Economic Growth', *Rand Journal of Economics*, 21 (2): 314-340.

Joskow, P.L. (2008), 'Lessons Learned from Electricity Market Liberalization', *The Energy Journal*, 29, Special Issue 2: 9-42.

Kishimoto, J., Goto, M., Inoue, K. (2017), 'Do acquisitions by electric utility companies create value? Evidence from deregulated markets', *Energy Policy*, 105: 212–224.

Koenig, P. (2011), *Modelling Correlation in Carbon and Energy Markets*, EPRG Working Paper No.1107.

Larsen, A., Pedersen, L.H., Sorensen, E.M., and Olsen, O.J. (2005), *Independent Regulatory Authorities in Europe*, Presentation to SESSA Conference on Regulation, Bergen, March.

Lise, W., Linderhof, V., Kuik, O., Kemfert, C., Östling, R. and Heinzowe, T. (2006), 'A game theoretic model of the Northwestern European electricity market—market power and the environment', *Energy Policy*, 34(15): 2123–2136.

de Menezes, L.M. and Houllier, M.A. (2016), 'Reassessing the integration of European electricity markets: A fractional cointegration analysis', *Energy Economics*, 53: 132–150.

Marino, M., Parrotta, P., Valletta, G. (2017), *Electricity (De)Regulation and Innovation*, Strasbourg: BETA.

Moffatt Associates (2007), 'Market Coupling: Key to EU Power Market Integration', *APX Energy Viewpoints*, Autumn, pp.5-9.

Moss, I. (2009), *APX-ENDEX Market Coupling & BritNed*, Presentation at the BritNed Connect Seminar, London, 8th December 2009.

Newbery, D.M. (2005), 'Electricity liberalization in Britain: The quest for a satisfactory wholesale market design', *The Energy Journal*, Special Issue: 43-70.

Newbery, D., Strbac, G. and Viehoff, I. (2016), 'The Benefits of Integrating European Electricity Markets', *Energy Policy,* 94, 253–263.

Nillesen, P.H.L. and Pollitt, M.G. (2007), 'The 2001-2003 electricity distribution price control review in the Netherlands: regulatory process and consumer welfare', *Journal of Regulatory Economics*, 31(3): 261-287.

OECD (2016), *Business and Finance Outlook 2016*, Paris: OECD.

Ouraichi, A. and Spataru, C. (2015), Integrating regional electricity markets towards a single European market, *12th International Conference on the European Energy Market (EEM).*

Koske, I., I. Wanner, R. Bitetti and O. Barbiero, (2015), *The 2013 Update of the OECD Product Market Regulation Indicators: Policy Insights for OECD and non-OECD Countries*, OECD Economics Department Working Papers, 1200/2015.

Polemis, M.L. and Stengos, T. (2017), 'Electricity Sector Performance: A Panel Threshold Analysis', *The Energy Journal*, 38 (3): 141-158.

Pollitt, M.G. (2009), *Electricity Liberalisation in the European Union: A Progress Report*, EPRG Working Paper, No.0929.

Pollitt, M. (2012), 'The Role of Policy in Energy Transitions: Lessons from the Energy Liberalisation Era', *Energy Policy*, 50, November: 128-137.

da Silva, P.P. and Cerqueira, P.A. (2017), 'Assessing the determinants of household electricity prices in the EU: a system-GMM panel data approach', *Renewable and Sustainable Energy Reviews,* 73: 1131–1137.

Steiner, F. (2001), 'Regulation, Industry Structure and Performance in the Electricity Supply Industry', *OECD Economic Studies*, No. 32 (1): 143-182.

Tulloch, D.J., Diaz-Rainey, I. and Premachandra, I.M. (2018), The impact of regulatory change on EU energy utility returns: the three liberalization packages', *Applied Economics*, 50(9): 957-972.

UCTE (2007), *Final Report: System Disturbance on 4 November 2006*, Brussels: UCTE.

Vona, F. and Nicolli, F. (2014), *Energy Market Liberalization and Renewable Energy Policies in OECD countries*, IEB Working Paper 14/18.