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The benefits of integrating European electricity markets

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Keywords electricity market coupling, interconnectors, balancing, benefits

JEL Classification D61, F15, L51, L94

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The benefits of integrating European electricity markets[1]

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Abstract

The European Commission's Target Electricity Model aims to integrate EU electricity markets. This paper estimates the potential benefit to the EU of coupling interconnectors to increase the efficiency of trading day-ahead, intra-day and sharing balancing services efficiently across borders. Further gains are possible by eliminating unscheduled flows and avoiding the curtailment of renewables with better market design. In the short run the gains could be as high as €3.3 billion/yr, more than 100% of the current gains from trade. About one-third of this total comes from day-ahead coupling and another third from shared balancing.

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[1] This paper builds on and extends work under contract ENER/B1/491-1/2012, published as Newbery et al (2013). We would like to thank Martin Godfried for providing some of the data supporting ACER (2014a), commenting on an earlier draft and correcting some of the units in which the original published ACER tables were presented, but he should not be held responsible for any remaining errors in this paper.

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1. Introduction

The European Commission's Target Electricity Model (TEM) aims to integrate EU electricity markets by coupling interconnectors so that all electricity is (moderately) efficiently allocated across the EU by a single auction platform, Euphemia. By mid-2014 the day-ahead coupling objective had been achieved from Finland to Portugal, including Great Britain. Coupling means that wholesale electricity prices should be equalized across boundaries unless the interconnector is constrained, in which case prices can diverge but the interconnector should be fully utilised. Before market coupling, capacity on interconnectors was sold before the day-ahead markets opened, and traders had to predict the price differences across interconnectors and bid for that capacity. Traders faced the risk that on the day the trade would no longer be profitable, in which case the option to flow power would be abandoned and the interconnector would be under-used, or, worse, the power would flow from the high price to the low price zone.

Member States and the European Commission are understandably interested to know the size of the benefits of market coupling, as market design changes are costly, and for each country could amounts to tens of millions of euros. As a perhaps extreme example, when Britain replaced the Electricity Pool by the New Electricity Trading Arrangements (NETA) in 2001, the UK's National Audit Office cited Ofgem's estimate "that market participants could incur total costs of up to £580 million in implementing NETA over the first 5 years, and then operating costs of £30 million a year." (NAO, 2003).

In December 2012 the authors started work on a project commissioned by the European Commission's Directorate General for Energy to estimate the benefits of an integrated European energy market (gas and electricity). They delivered a near final draft in March 2013 (Newbery et al, 2013, hereafter our report), after which ACER started publishing estimates of the costs of not completing the integrated market in its subsequent reports (ACER, 2013, 2014). ACER had the advantage of direct access to some of the detailed Vulcanus data needed to make more accurate estimates (although they are still hampered by that lack of powers to request relevant data), while the pressure of time and the scarcity of data meant that our original report had of necessity to take short cuts. By mid-2015 the *Transparency Regulation* No 543/2013 (EC, 2013) should make more data public and available for more detailed academic and regulatory study.

This paper makes use of the additional data supplied by ACER (2014) to update estimates of the benefits of integration, using the original methodology of Newbery et al. (2013). That allows a comparison between the approximate methods of that report with calculations based on more accurate and extensive data. It also recalculates the way in which the gains from coupling should be extrapolated to EU-wide net benefits, and discusses what can be learned from the fuller information that ACER has been able to analyze. It adds to the ACER estimates by attempting to extrapolate ACER's partial coverage to the EU-28, and although these are necessarily somewhat speculative, they identify more clearly the sources of some of the major integration gains, although they do not include possible additional gains from increased competition.

1.1 Previous literature

Newbery et al (2013) surveyed the existing and rather sparse literature on the quantitative benefits of market integration up to early 2013, and only the briefest summary is given here, as a fuller account is available in that report. Neuhoff et al (2011) explored the benefits of the most efficient form of market integration via nodal pricing (as in PJM[5]) but including a large volume (125GW) of predicted future wind connection. They found savings of 1.1-3.6% of variable operating costs. If variable (mainly fuel) costs are roughly half total wholesale market value then the gains from full integration would be 0.6-1.8% of that value. Leuthold et al (2005) simulated the benefits of adding 8GW of offshore wind to Germany and moving to nodal pricing, estimating that gains of 0.6-1.3% came just from a move to nodal pricing and an additional 1% would come from nodally pricing the additional wind. Mansur and White (2009) compared before and after PJM expanded its nodally priced market area and found incremental gains of $3.6 million/GW capacity, which if applied to the EU with 820 GW capacity would deliver $3 billion per year (roughly €(2013) 2.3 billion) or 1.6% of wholesale value. Ott (2010) found that the *total* benefits of efficiently pricing PJM were $2.2 billion per year. However, these estimates are the benefits of moving to nodal pricing, whereas the TEM stops short at zonal pricing and so would not realize the full potential gains.

When it comes to the benefits of market coupling the literature was even sparser. De Jong, Hakvoort and Sharma (2007) simulated a simplified model of France, Germany, The Netherlands and Belgium to estimate the welfare effects that flow-based market coupling (FBMC) would have on those countries, which they found to be about €200m per year. Meeus (2011) studied the history of the 600 MW Kontek HVDC cable from East Denmark to Germany, first from the period of no coupling, through two implementations of approximate coupling, ending with one-way market coupling, still imperfect as it resulted in flows against the price differential (FAPD) of about 5%. The estimated welfare gain was about €10m per year on that one cable or about €17,000/MWyr.

SEM Committee (2011) estimated the social costs of not using the two interconnectors between GB and the Single Electricity Market (SEM) of the island of Ireland (which had a combined capacity of 950/910MW imports, 580MW exports) for 2010. The estimates included price responses and a dead band (with no trade) of €5/MWh

[5] Originally the Pennsylvania-New Jersey-Maryland interconnection, since expanded considerably.

to allow for various losses and transmission access charges. The social welfare gains from coupling were estimated at €30 million per year for an average import capacity of 930 MW,[6] or €32,000/MWyr, more than twice that of the Kontek cable.

In summary, simulation studies of FBMC find modest efficiency benefits that may underestimate the potential for two reasons. The models lack sufficient richness to identify all of the transmission difficulties that FBMC may relieve, and they are calibrated to earlier generation portfolios with less renewable generation, and which therefore probably congest transmission systems less than now. They indicate substantial value to increasing transmission capacity, and that FBMC will then be of even greater value in efficiently managing that capacity. A before-and-after study of the Kontek cable finds modest welfare benefit of (imperfectly implemented) FBMC on that cable but coupling the SEM-GB interconnectors would seem to deliver larger gains.

Since our report several new studies have been published, as well as the ACER annual reports discussed below. Böckers et al (2013) measure the extent to which market integration can share peak demand more efficiently, and find that about half of neighbouring countries peak demands are non-coincident and so the capacity needed to supply them jointly could be reduced. They report studies of price convergence that shows in some pair-wise comparisons that considerable convergence preceded coupling. They also report earlier studies that simulate the gains from improved competition and hence lower deadweight losses that our report did not explore. They roughly estimated gains from harmonizing PV support schemes and found large benefits (more than €700 million per year just be reallocating support from Germany to Spain). Our report looked forward to 2030 and found very large gains from harmonizing all renewables support, but these potential gains are not discussed in this paper.

Pellini's (2014) doctoral dissertation used a power simulation model of Italy with an econometric estimates of price formation in neighbouring markets (FR, CH, AT, SL and GR) to examine the benefits of coupling the Italian market for 2012. She found that in the reference scenario for 2012 and allowing for continued market power, market coupling increased net welfare (the arithmetic sum of changes in producer, consumer and transmission surpluses) by €33 million/year (M€/yr), but if coupling credibly increased competition on the northern border, the net welfare gain rose to 396 M€/yr, although this is still 278 M€/yr below that theoretically achievable under perfect competition. In the high scenario in which the economy recovered relative to 2010 and oil prices were higher, the welfare gain from coupling increased to 132 M€/yr without more competition, and to 742 M€/yr with more competition, although still 326 M€/yr short of perfect competition. These simulation results show that the gains from integration can be highly sensitive to relative fuel prices (which clearly can affect the gains from trade), the level of

[6] The export capacity is lower but exports are much less common.

demand in the importing country (Italy) particularly in the presence of market power and hence rapidly rising prices as demand tightens, and of course the impact that coupling has on market power.

1.2 Gains from integrating balancing markets

The aim of the TEM is to integrate markets at all timescales, from contracting ahead, to day-ahead, intraday and balancing. DG ENER commissioned a report (Mott MacDonald, 2013) in support of ACER's Impact Assessment for the development of Electricity Balancing Framework Guidelines, which estimated the potential gains from integrating the European Balancing markets. The report found annual benefits from balancing energy trade between GB and France are potentially of the order of € 51 million. The estimated annual savings of integrating the Nordic countries are approximately € 221 million compared to individual "stand alone" balancing. Looking ahead to 2030 under "hypothetical" scenarios of the future European Power System the estimated benefits increase with wind penetration factor of wind generation and which justify the cost of investment for enhanced interconnectivity, integrating Balancing Markets and exchanging and sharing of reserves could achieve operational cost savings of about € 3bn/year and reduced (up to 40% less) requirements for reserve capacity.

2. The estimated gains from integration

Estimating the benefits of integration is not straightforward, as it inevitably involves either comparing the *status quo ex ante* with a counterfactual, or comparing the situations before and after, in which many other factors may have changed, including the whole pattern of generation and cross-border flows and with that the pattern of price differences across interconnectors. In addition, as well as directly observable impacts, primarily increased flows and price changes as interconnectors are more efficiently used, there are harder to identify indirect benefits that may flow from increased cross-border competition, such as pressures to reduce cost, innovate, improve market functioning through increased liquidity, and improved sustainability if the volume of low-carbon electricity that can be delivered to final consumers increases and displaces more polluting sources. Security of supply should improve, although the full benefits of reducing EU-wide reserve capacity needed requires those responsible for assuring security to make changes in the way they assess system security and adjust domestic capacity.[7]

[7] Thus in the preparations for the UK 2014 capacity auction designed to deliver the specified security standard of a Loss of Load Expectation of 3 hours per year, the minister responsible, on the advice of the Transmission System Operator, set a standard that ignored any net contribution that the interconnectors might supply – see DECC (2014), National Grid (2014) and Newbery and Grubb (2014).

In the longer run, the economics of building interconnectors should improve, encouraging further investment and allowing a more efficient location of generation across the EU to exploit the gains from improved trade. Finally, and of direct concern to Member States, as prices are expected to change, there will be winners and losers, although the US experience supports the view that a suitable allocation of Financial Trading Rights can in principle and to a large extent in practice, adequately compensate potential losers (Newbery and Strbac, 2011).

The methodology for estimating the gains from coupling interconnectors at the day-ahead stage (which were largely complete by the end of 2014) is explained in Figure 1.

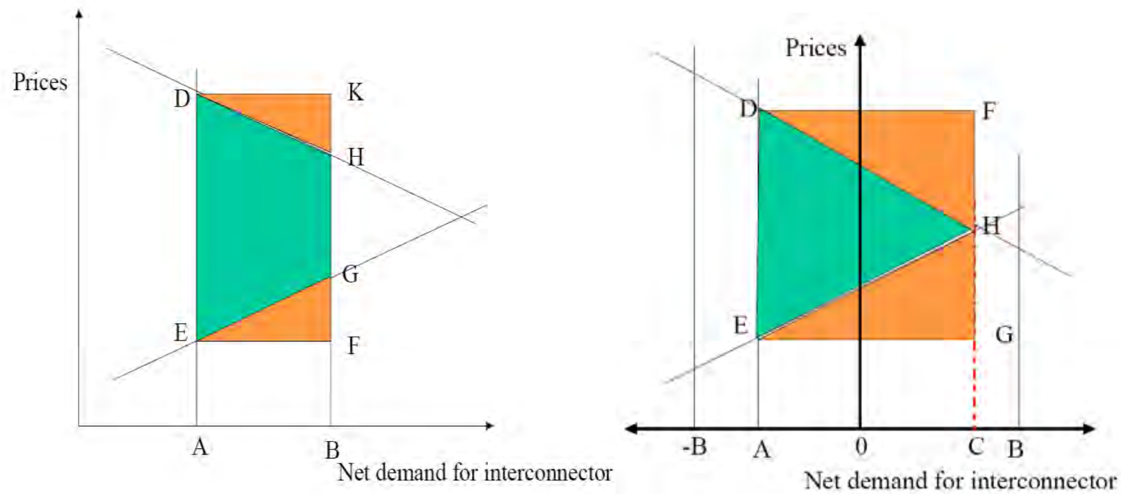

Figure 1 Benefits of market coupling: a) assuming no adverse flows and b) with flow originally against price differential

Figure 1a shows one possible configuration of the interconnector before and after coupling. Volume A is the amount used before coupling with the net supply in the direction of trade, EG, and the net demand, DH, shown. Market coupling then leads to the full utilization of the interconnector to volume B, narrowing the price difference as shown. The benefit of coupling is then the darker green coloured trapezium, on the (competitive market) assumption that the net supply represents the marginal cost (including any scarcity rents) and the net demand represents the willingness to pay for power. In algebraic terms the benefit is the average of the price differences before and after coupling times the increase in the volume of trade or the area of the trapezium DEGH. If coupling eliminated the price difference, as it does in Figure 1b, the benefit of coupling is only one half the rectangle assuming no price change.

Figure 1b shows the case in which the interconnector is flowing power in the wrong direction. In this case point A corresponds to, say, importing a volume 0A when the efficient coupled solution would be exporting an amount 0C (the capacity of the interconnector is 0B in each direction, although there is no reason why export and import capacity should be the same). In this case the benefit is half the initial price difference ED times the volume AC, or the area DEH, which is half the area DEGF that assumes prices do not change.

ACER makes the simplifying assumption that the prices do not change, which is probably valid for most Continental interconnectors embedded within the meshed AC network, but not for DC links such as IFA, where ignoring price changes would tend to over-estimate the gains by measuring the area DEFK if the estimate is made before coupling, but underestimate the gains if the post-coupled price difference is used. Newbery et al (2013) estimated that in the case of the England-France interconnector, IFA, a change of trade of 1 GW into GB would change prices by €1/MWh. In figure 1 it is necessary to correct the measured loss DEFK by subtracting the areas DKH and EFG, where the sum of KH and GF is given by the slope €1/MWh/GW and the change AB. This is half times the change in volume times the change in price, or equivalently ½ x 1 x AB^2.

In 2011 exports from FR→UK used 58% of total capacity and from UK→FR a further 12%, making the overall utilization of IFA 71%. In 2012 exports from FR→UK used 74% of total capacity and from UK→FR a further 10%, making the overall utilization of IFA 83%. The average NTC in both 2011 and 2012 was roughly 1.25 GW in each direction (i.e. only 63% of its rated capacity), so an underutilisation of 29% in 2011 would be on average is 0.36 GW and the price change might be €0.36/MWh on average over the underutilization, half of which is €0.18/MWh. The extent of underutilization was 14 TWh so the overstatement is €2.5 million, reducing the total 2011 loss from €22.4 million to €20 million or by 10% (so not insignificant). In 2012 the underutilization was 12.7 TWh so the overstatement was €2.3 million, reducing the total 2012 loss from €20.8 million to €18.5 million or by 12% (Newbery et al, 2013, tables 8.2, 8.4). The error in ignoring price impacts increases as the square of the shortfall and so becomes smaller as interconnectors are more fully used. At the other extreme, if coupling eliminates the price difference, then the actual gain would be only half the measured gain assuming no price change.

3. Comparing the various measures of welfare losses

The results of comparing the original rough estimates in Newbery et al (2013) with the presumably more accurate ACER (2014) estimates are illuminating. The estimates in Newbery et al (2013) concentrated on a few interconnectors for which there was good data and which were not then coupled. The social welfare losses adjusted for price changes on England-France interconnector IFA were 22% of potential trade in 2011 (30% of actual trade) and 12% of a higher value of potential trade in 2012 (14% of actual trade), averaging 16% of potential trade (20% of actual trade).[8] The Germany-France interconnection became coupled in Q4 2010 so the loss on the German-France interconnection was estimated for Q1-Q3 2010. The estimated loss was 26% of potential trade, ignoring resistive losses as these interconnectors were short (in theory infinitely short) AC links. The losses for France-Spain 2011 and 2013 (not given in our report but given in the Appendix to this paper) were 11 and 12%, again ignoring resistive losses.

In conclusion the report estimated the social losses of not coupling for these examples at 10-20% of the gains from trade, depending on the year, the interconnector, and market prices. After coupling, these losses should fall to zero. To put this into context, EU exports (and imports) in 2011 were about 315 TWh out of 3,080 TWh supplied (or about 10%). The original report then argued that if losses were 10-20% of interconnector trade, and trade were 10% of total EU demand, then the losses would be about 1-2% of total demand.

However, the welfare losses on the interconnectors were estimated as a percentage of the *gains* from trade, which is the arbitrage gain from the price *difference*, not the standard measure of the value of trade, which is the price of the product times the volume traded. Thus to scale up the evidence from a few interconnectors one needs this measure of the gains from total EU-29 trade, which is difficult to estimate as it depends on the price difference across the borders. One way to derive a very rough estimate is to note that the average absolute price difference across IFA for 2011-12 was €11/MWh.[9] Additional estimates come from the incremental value of expanding interconnectors, which ACER (2014, fig 48) provides for a sample of such links. The values are given in € million per 100 MW extra capacity assuming no change in prices at each end, from which one can estimate the average initial price difference across each, assuming 100% utilization of the extra 100 MW. The average is €6/MWh with a range from €0-25/MWh and a standard deviation of €6/MWh.

As prices have been converging over time (ACER, 2014) it might be more reasonable to take a value closer to €10/MWh as a rough estimate of the pre-integration price difference (and arguably an underestimate), in which case this average value of the gains from trade would have been €3.15 billion/yr, compared to the value of total wholesale demand of €150 billion at an average wholesale price of €50/MWh.[10] If the estimated 10-20% welfare loss as a percentage of the gains from trade were to hold across the whole EU, the gains from efficient market coupling compared to the 2004 case of no coupling would be €315-630 million per year, or 0.2-0.4% of wholesale market

[8] Newbery et al (2013) tables 8.2 and 8.4 but correcting for the price change.
[9] Newbery et al (2013, tables 8.2, 8.4) assuming an average of 1,250MW for 8,760 hours.
[10] That was the estimate for 2011 and equal to the measured price in 2012, which fell slightly to €46/MWh in 2013, see ACER (2014b, fig 35).

value, one fifth of the 1-2% of rough estimates (as the arbitrage price difference is only one fifth of the average price).

ACER (2014) adopted the simpler form of our methodology, ignoring price changes and measuring the initial price difference times the change in volume, valid for most AC interconnections. This estimate of the 'loss in social welfare' due to the absence of market coupling is presented in Table 1. The total loss for these remaining uncoupled interconnectors averaged €365 m/yr, which is towards the lower of the estimate given above, but as many interconnectors had been coupled by this time, this figure is an under-estimate of the pre-coupling period.

Table 1 Estimated 'loss in social welfare' 2012–2013

Border	2012 € million	2013 € million	average share	NTC MW	Loss €'000/MWY	loss/trade
CH-FR	€ 66.36	€ 68.81	21%	2,300	€ 29.92	37%
NI-GB	€ 21.82	€ 21.07	7%	500	€ 42.14	54%
CH-DE	€ 39.25	€ 41.81	12%	4,000	€ 10.45	13%
CH-IT	€ 33.45	€ 17.64	8%	4,000	€ 4.41	8%
CZ-DE	€ 32.98	€ 35.13	10%	1,600	€ 21.96	27%
AT-CZ	€ 23.28	€ 16.21	6%	800	€ 20.26	31%
FR-IT	€ 18.85	€ 18.13	6%	2,700	€ 6.71	9%
AT-SI	€ 18.37	€ 18.73	6%	900	€ 20.81	26%
AT-HU	€ 17.69	€ 14.56	5%	800	€ 18.20	25%
FR-GB	€ 14.03	€ 15.85	5%	2,000	€ 7.93	9%
AT-CH	€ 13.24	€ 14.54	4%	900	€ 16.16	19%
NL-GB	€ 12.53	€ 10.06	3%	1,000	€ 10.06	14%
ES-FR	€ 8.34	€ 7.25	2%	1,000	€ 7.25	10%
IE-GB (EWIC)	€ 0.32	€ 33.58	5%	500	€ 67.16	42%
Total	€ 321	€ 333	100%	23,000	€ 14.49	18%

Source: ACER (2014b, fig 47) and ENTSO-E for estimated NTCs

The first two columns in Table 1 give the ACER data. Column 3 gives the contribution of each interconnector to the total measured loss as a percentage. Column 4 gives the Net Transfer Capacity (NTC) based on the 2012 data used by Newbery et al (2013), updated for some interconnectors from web searches. These figures should be treated as rough estimates as the variation on some interconnectors is from zero to several times the value shown in the table, and the weighted average standard deviation (SD) of the hourly 2012 NTCs on these borders was 42%.

Some of the individual values in the originally published ACER Report were implausibly high, particularly those between the Single Electricity Market (SEM, the combined markets of NI and IE) and GB). After discussions with ACER, these figures have been revised in the latest version placed on the website in December 2014. They are still high in relation to capacity, even though they have been minimized by putting the links in at their full nominal value when NI-GB has been at only 50% capacity for some time. A quick calculation for 2012 for NI-GB in Appendix Table A2 suggests a loss of €7.5 million in 2012, which is very different from the original value of €43.6 m and even the revised value of €21.82 m shown in Table 1. SEM Committee (2011) estimated the 2010 welfare loss of both SEM-GB cables together at €30 million. If the two SEM-GB interconnectors are ignored, the social welfare loss falls to €290 million, 16% of trade value.

The data allow one estimate of the loss by comparing it to interconnector capacity, which in Table 1 is €16,870/MWyear, or excluding the rather high value for SEM-GB, is €12,670/MWyr. Scaling this up by the lower of import and export capacity of 83 GW gives €1,052 million/yr. The final column takes the estimated loss and divides it by the value of potential arbitrage trade for 8,000 hours per year at 100% utilization and assuming an arbitrage gain of €10/MWh, and this welfare loss as a proportion of the potential arbitrage gains from trade falls from 20% to 16%, right in the middle of the range estimated above. One caveat is that if all interconnectors are efficiently coupled, then the gains over each interconnector may fall, so scaling up to the whole of the EU may overestimate the total gains.

4. Other measures of the gains from improved market integration

The Target Electricity Model aims to integrate markets not just at the day-ahead stage, but intra-day and real-time, or via sharing balancing services, as well as sharing reserve capacity and allowing more efficient cross-border trading up to three years before delivery. Newbery et al (2013, §5.3) estimated the additional gains that could come from efficiently moving away a Baseline case of national self-security, in which the only gains are short-term arbitrage of the kind discussed above. In the less optimistic case in which only half the socially beneficial transmission investment is completed and under Continuing Policy (not the most ambitious renewables targets also considered) the EU-28 gains above Baseline could be €10-€16 billion by 2020 or 7-11% current wholesale market value, and possibly to €8-€36 billion by 2030. Sharing balancing, reserves and demand side response under a fully smart EU-wide grid could almost double the lower values and increase the top of the range by 20%. Such gains would take substantial investment and considerable institutional change, as well as trust, to deliver, which will take time - the TEM has already taken nearly two decades since the initial steps with the first Electricity Directive 96/92/EC. In the shorter run it is worth estimating the more realizable gains from better intraday and balancing, both addressed in ACER (2014).

4.1 Intra-day trading benefits

Since 2010, day-ahead utilization of interconnectors has risen from 32.1% to 39.0% in 2013 or by 20%, and intra-day commercial (i.e. not TSO led) trading from 1.8% to 2.9%

of NTC, or by 61% (ACER, 2014, fig 50). On borders with continuous trading, almost half of this is requested less than three hours before delivery and is thus delivering a valuable service in responding to improved forecasts of intermittent power and demand near to dispatch.

It is difficult to estimate the benefits from better integration across the EU-28. Data provided in ACER (2014) give some indication, and are reproduced as Appendix Table A3. They suggest that the benefits from more efficient intra-day trading over the borders sampled might be €2.56/MWh (SD = €0.6) averaged over every hour of the year per interconnector. If interconnectors are only 40% fully utilized (ACER, 2014, fig 50) and if the total interconnector capacity is 83 GW,[11] and if the volume of intraday trading might double from its 2012 low level of 3%, an extra 2,400 MW might be available on average perhaps 6,000 hours per year[12] with a total value of €37 million/yr. This is consistent with scaling up the data in table A3 to the total interconnector capacity level, and assuming 200 MW are traded on the days when significant price differences are observed,[13] which would give a value of €37 million/yr.

4.2 Balancing benefits

Most countries are currently reluctant to share balancing services, but the aim is to create the institutions and trust to enhance the efficiency of balancing interconnected systems. Switzerland, for example currently procures over half its reserves from abroad (ACER, 2014, fig 54). However, as with the gains from trade, one needs to be careful in estimating the gains from shared balancing services.

ACER (2014) provides estimates of the potential gains transcribed in Table 2. The simplest benefit to be gained is the netting of imbalances, in which one side of the border is short and the other side long, so that together they can reduce imbalances on each side. The other obvious benefit is to be derived from procuring balancing energy from abroad when it is cheaper. Table 2 gives estimates of each for a selection of borders in 2013. The total value for FR-GB is €39 m/yr, which can be compared with the estimates given in Mott MacDonald (2013) of full unconstrained Common Merit Order shared balancing between France and GB of €51 m/yr, which is of comparable size, given the difficulties of properly modelling the potential benefits. If one takes the balancing benefit as €33,000/MWyr (from the bottom right average) and if that is scaled up to the 2 GW, FR-

[11] Data in convenient matrix form is available at https://www.entsoe.eu/fileadmin/user_upload/_library/ntc/archive/NTC-Values-Winter-2010-2011.pdf but post 2011 data does not seem to be available in convenient matrix form. The totals are the lower of import or export values limited by maxima.

[12] NTCs vary by season and for other reasons so this is a guesstimate of availability of 68%.

[13] The hours recorded in Table A3 assume at least 100 MW were free, so the assumption here is that as that was a *de minimis* cut-off, the actual is twice as high.

GB interconnector the result would be €66 m, rather higher than this estimate, but again comparable.

Table 2 Estimate of potential benefits from the integration of balancing energy markets per border, 2013

	Potential imbalance netting GWh	Potential exchange balancing energy GWh	max 2012 NTC MW	Netting benefits € million	Exchange benefits € million	Netting value per €/MWh	Exchange value per €/MWh	Total benefit €'000/MWY
GB-NL	231.95	1,816.45	1,000	€ 15.9	€ 66.5	€ 68.38	€ 36.60	€ 82.4
ES-PT	727.46	3,595.93	2,400	€ 25.3	€ 50.2	€ 34.78	€ 13.95	€ 31.4
AT-CZ	144.24	617.98	500	€ 12.6	€ 47.3	€ 87.15	€ 76.49	€ 119.7
FR-GB	927.49	1,463.55	2,000	€ 17.5	€ 21.6	€ 18.88	€ 14.78	€ 19.6
AT-HU	140.8	670.10	800	€ 9.6	€ 29.4	€ 67.83	€ 43.80	€ 48.6
HU-RO	268	1,023.94	400	€ 18.1	€ 19.3	€ 67.35	€ 18.80	€ 93.3
FR-ES	954.05	1,821.72	1,300	€ 20.2	€ 14.9	€ 21.16	€ 8.17	€ 27.0
CZ-PL	114.85	457.29	150	€ 9.7	€ 18.6	€ 84.81	€ 40.59	€ 188.7
FR-CH	110.05	1,653.60	3,200	€ 4.1	€ 24.0	€ 37.35	€ 14.53	€ 8.8
BE-NL		542.17	1,400		€ 26.8		€ 49.41	€ 19.1
PL-SK	66.82	121.93	550	€ 6.7	€ 19.8	€ 99.97	€ 162.31	€ 48.1
AT-SI		405.61	900		€ 24.0		€ 59.19	€ 26.7
CZ-SK		448.33	1,600		€ 23.5		€ 52.48	€ 14.7
CH-AT	94.82	362.33	800	€ 4.2	€ 14.6	€ 44.19	€ 40.38	€ 23.5
EE-FI	68.18	434.66	370	€ 2.3	€ 14.3	€ 34.32	€ 32.92	€ 45.0
HU-SK		300.30	180		€ 14.1		€ 46.82	€ 78.1
Total or average	3,849	15,736	17,550	€ 146	€ 429	€ 37.96	€ 27.25	€ 32.8

Source: ACER (2014, figs 56 and 58) and ENTSO-E

If this balancing benefit of €33,000/MWyr is scaled up to the 83 GW of interconnection, the result would be €2.7 billion per year, which seems very high. Newbery et al (2013, Figure 5.8) reported the gains from a model-based estimate of shared balancing at about €1.2 billion per year in 2015,[14] and perhaps €3.4 billion per year by 2030, when higher intermittency would considerably increase the value of shared balancing. These estimates, however, were additional to all the other benefits of market integration, and clearly if intra-day trading is both efficient and continued until just before dispatch, the remaining benefits from subsequent balancing will have already been

[14] This is estimated as the difference between "Int EU reserves" and "Int self-secure" in figure 5.8, which are described in Newbery et al (2013, p75) as the result of "some sharing of various balancing services between countries". As such they may be an underestimate of the potential of full sharing of all balancing services.

largely captured. In short, there are problems in allocating the gains from integration over different time-scales, particularly as forecasting improves, and so one should not attach particular weight to one part of the total gains. There is the additional point that by its nature it is difficult to properly model future imbalances in an optimizing engineering model, as these rely on imperfections that the model may be designed to ignore, as well as estimating the scarcity costs given the many short-run constraints limited their delivery.

ACER (2014, p140) admits that it is very difficult to properly value the potential benefits of sharing balancing services as that could "be obtained only through having access to (and the ability to process) all the data corresponding to the bids and offers submitted by all BSPs from all the imbalance areas". Instead the estimate is based on "the imbalance price differences across imbalance price areas in Europe." Using the data from fig 56 shown in Table 2 one can calculate the value of netting and exchanging energy in €/MWh (the penultimate last two columns) which show netting values of €32/MWh and €27/MWh respectively, substantially higher than the day-ahead arbitrage values, but not implausible for balancing markets.

Given the very high total value based on a simple extrapolation from the data in Table 2, it is worth exploring how better to extrapolate to the EU-28 from data covering only one-fifth of cross-border interconnection. From the data in table 2, the coefficients of variation (CVs) of netting and energy trading per MWh are 72% and 134% and the CV of the total benefits per MW is 146%, while the average of the two least valuable borders is one third the average value. If the remaining interconnectors are one-third as valuable per MW NTC, given that the potential benefits identified in the subset of interconnectors amounts to €575 million, (larger for this subset than all the other potential gains), the total would be €1.3 billion per year, or 41% of the *total* estimated gains from trade (and double the upper end of the estimated arbitrage gains from coupling). If so, then the benefits from integrating cross-border balancing are considerably larger than those from coupling at the day-ahead stage, and if to realize these gains more spare capacity has to be held back to facilitate balancing, that would seem worthwhile.

On the other hand, sharing balancing across borders is just one way of delivering flexibility at short notice, and as dispatch becomes smarter, and as more Demand Side Resources and storage are made available, so the marginal value of any one source of flexibility is likely to fall. Offsetting that will be the growth in need for flexibility with the growth in intermittent wind and solar PV generation.

4.3 Welfare impact of unscheduled flows

Acer (2014, figure 62) distinguishes between loop flows and unscheduled transit flows, which together are classified as unscheduled flows that arise because of imperfect coordination between TSOs, and the desire to treat each dispatch zone as a copper plate, instead of the US Standard Market Design of nodal pricing. The costs of this inefficiency has risen from €324 million in 2011 to €469 million in 2013 for the 20 borders studied totaling 35 GW out of a total of 83 GW. The gains in 2013 are thus €13 million/GW NTC, and if the remaining borders are only half as valuable, the potential gains would be €790 million/year.

4.4 Costs of curtailment at borders

Acer (2014, fig 65) gives the costs of curtailment at a selected set of borders, reproduced with NTC data in Table A4. For the 26 GW of borders for which data are available for both 2012 and 2013 the total cost averaged €670/MWyr. As several borders have been curtailed in both directions one can scale up in two ways. The higher estimate would be to take the higher value direction only for those for which we have values in both directions, for which there are 6.350 GW with data for both years, for which the average cost was €1,771/MWyr, but only include export interconnector capacity. Scaling this up to 83 GW total would give an annual cost of €147 million/yr. The lower value would be to scale up the overall average of €891/MWyr by the sum of export and import capacities of 132GW, which would give €117 million/yr. Finally, as a compromise, one can take the total value for both years and the total capacities and scale up to 179 GW (total import plus export) to give €140 million/yr. The resulting range from €117-€147 million/yr is reassuringly tight.

5. Conclusion

The high value of increasing the efficiency of interconnector use is clear at a number of critical borders. The earlier estimate of the gains from increasing cross-border trade from 10% of demand (315 TWh) to 15% of demand (i.e. by 158 TWh) assumed an average price difference before and after trade of €10/MWh and gives the benefit as €1.58 billion/yr or 1% of the value of wholesale demand. This might be an under-estimate if some fraction of trade is in a perverse direction. Just improving the existing day-ahead arbitrage trade on interconnectors through coupling is worth 10-20% of the potential gains from trade, which at €10/MWh is 10-20% of €3.15 billion/yr or €315-630 million/yr, or less than half the figure of 1% of the value of wholesale demand. This lower figure seems consistent with the day-ahead arbitrage gains estimated by ACER (2014), although the figures reported in summary table 3 are based on the gains per MW of capacity and are then considerably larger at €1 billion/yr.

However, in addition to these arbitrage gains from market integration, intraday trading might be worth €40 million/yr, balancing benefits which might be €1.3 billion/yr or could be as large as €2.7 billion/yr, with proportionate scaling. These short-term realizable gains amount to €2.4 billion/yr and are itemized and subtotaled in Table 3.

If unscheduled flows could be prevented (which might require a significant design change to nodal pricing) then somewhere between €500 – €900 million might be gained. Finally, the cost of curtailment might be €50-150 million. Including these longer-term potential benefits gives €3.4 billion/yr, which is 2.3% of the value of wholesale demand, but more than 100% of the current gains from trade over the interconnectors, which is a more relevant metric.

Table 3 Potential gains from market integration

	ACER sample 2013			EU-28 estimate	Newbery et al (2013)			EU-28 estimate
	€M	NTC 2012	value €'000/MWY or *MWh*	€M	€M	NTC	value €'000/MWY or *MWh*	€M
increase trade by 50%							*€ 50*	€ 1,575
Day-ahead market coupling	€ 279	22,000	€ 12.7	€ 1,052	€ 63	4,300	€ 14.6	€ 1,208
Intraday coupling		10,050	*€ 2.6*	€ 37				
Balancing	€ 575	17,550	€ 32.8	€ 1,343				
subtotal				€ 2,432				
Unscheduled flows	€ 469	34,900	€ 13.4	€ 790				
curtailment	€ 41	52,385	€ 0.8	€ 140				
Total				€ 3,362				

Note: the values for increased trade and intraday coupling (highlighted and italicized) are based on values per MWh, curtailment is based on import and export flows together.

Specifically, if the value of interconnectors is increased by 100%, then already commercially attractive investments in interconnectors become even more so, and perhaps a large number of currently marginal investments would look attractive. Certainly the case studies considered suggested that expanding transmission links that are severely congested is also already likely to be very cost effective. The conclusion is that market coupling delivers total benefits that should substantially exceed the costs of the required market design changes, and that the delays in market integration since the market integration project started in 1997 have been large. Further gains could be reaped from a move to nodal pricing but these would have to be counterbalanced against the claimed loss of liquidity and scope for market manipulation that such a move might risk. What emerges very strongly is the growing need for more interconnection.

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Appendix

Using the same methods set out in Newbery et al (2013) it is straightforward to compute the social welfare losses on the Spanish-French interconnection for 2011 and 2012, ignoring resistive losses as this is an AC interconnection, and similarly for the Moyle interconnector between GB and NI.

Table A1 Social welfare loss on the Spain-France interconnection

FR-ES trade data 2011

Potential value exports FR=>ES	€ 53,697,430	68%
Potential value exports ES=>FR	€ 25,517,523	32%
Potential total value trade	€ 79,214,953	100%
Loss underexport FR=>ES	€ 3,486,071	4%
Loss underexport ES=>FR	€ 3,331,524	4%
FAPD FR=>ES	€ 1,265,000	2%
FAPD ES=>FR	€ 260,053	0%
Total loss	€ 8,342,650	11%

FR-ES trade data 2012

Potential value exports FR=>ES	€ 56,482,617	55%
Potential value exports ES=>FR	€ 45,810,192	45%
Potential total value trade	€ 102,292,810	100%
Loss underexport FR=>ES	€ 5,648,860	6%
Loss underexport ES=>FR	€ 3,621,960	4%
FAPD FR=>ES	€ 986,480	1%
FAPD ES=>FR	€ 1,538,622	2%
Total loss	€ 11,795,923	12%

Table A2 Social welfare loss on the Northern Ireland – GB Moyle interconnector 2012

Potential value of trade	€ 44,285,421	100%
Value of actual imports	€ 36,814,378	83%
Value of actual exports	€ 9,418	0%
total value of trade	€ 36,823,797	83%
Losses under-importing	€ 3,001,142	7%
Losses under-exporting	€ 219,209	0%
Loses FAPD	€ 4,244,833	10%
total losses	€ 7,465,185	17%

The potential benefits from more efficient intra-day trading are shown in Table A3, using data from ACER (2014). The estimated value assumes that if the price difference is greater than €10/MWh it is worth on average €15/MWh, if between €5-10/MWh then it is worth €7/MWh, and if €1-5 then it is worth €3/MWh. Using these values the average over the 8760 hours per year are as shown in the final column in Table A3.

Table A3 Potential for intraday cross-border trade and efficiency in the use of cross-border intraday capacity on a selection of EU borders – 2013 (number of hours)

border and auction	Direction	Max NTC 2012 MW	Number of hours with ID price dif. >10 Euros/MWh and CB capacity available	Number of hours with ID price dif. 5-10 Euros/MWh and CB capacity available	Number of hours with ID price dif. 1-5 Euros/MWh and CB capacity available	Number of hours with ID nominations in the right direction	Number of hours with full ATC used in the right direction	% of hours when the interconnector is used in the 'right' direction (right axis)	estimated value for 1MW	value/MWh over year
ES-PT (implicit)	ES->PT	2,400	81	74	237	392	392	100%	€ 2,444	
	PT->ES	2,300	67	86	225	378	378	100%	€ 2,282	€ 0.54
FR-DE (implicit cts)	FR->DE	1,500	976	168	32	813	13	69%	€ 15,912	
	DE->FR	1,200	878	153	58	693	30	64%	€ 14,415	€ 3.46
ES-FR (explicit)	ES->FR	900	784	535	364	922	288	55%	€ 16,597	
	FR->ES	1,100	616	397	282	651	301	50%	€ 12,865	€ 3.36
FR-BE (pro rata)	BE->FR	2,000	463	780	*700*	509	5	41%	€ 14,505	
	FR->BE	1,200	467	399	542	693	108	49%	€ 11,424	€ 2.96
FR-IT (explicit)	FR->IT	2,500	447	372	614	567	82	40%	€ 11,151	
	IT->FR	1,000	254	426	306	370	-	38%	€ 7,710	€ 2.15
FR-GB (explicit)	GB->FR	2,000	431	321	423	435	24	37%	€ 9,981	
	FR->GB	2,000	419	452	1,680	829	44	32%	€ 14,489	€ 2.79
	Total	10,050								
	Average per interconnector		981	694	911	1209	303	56%	€ 22,296	€ 2.55

Sources: ACER (2014 fig 53), ENTSO-E

Table A4 takes the raw data from ACER (2014) and rearranges the borders into the directions with the larger of the two flows on that border in the top part, then the smaller valued direction, then the borders with only one direction recorded, first for which both years' data are available, then for those with data in only one year, and finally totals and averages for each year and for both years. The values are then related to the estimated NTC values for 2011 from the ETSO NTC matrix.

Table A4 Total curtailment costs per border €

border	2012	2013	NTC	average/MW
GR->IT	€ 659,035	€ 2,418,188	500	€ 3,077.2
BG->GR	€ 2,400	€ 24,068	550	€ 24.1
AT->IT	€ 57,179	€ 328,270	220	€ 876.0
DE->CH	€ 35,115	€ 12,643	1,500	€ 15.9
FR->UK	€ 9,239,274	€ 8,942,479	2,000	€ 4,545.4
ES->FR	€ 328,482	€ 211,612	580	€ 465.6
NL->UK	€ 88,026	€ 139,902	1,000	€ 114.0
major pair	€ 10,409,511	€ 12,077,162	6,350	€ 1,770.6
IT->AT	€ 589	€ 301	285	€ 1.6
CH->DE	€ 8,205	€ 2,681	3,500	€ 1.6
IT->GR	€ 33,825	€ 111,359	500	€ 145.2
UK->FR	€ 3,326,577	€ 807,553	2,000	€ 1,033.5
FR->ES	€ 114,263	€ 69,357	1,300	€ 70.6
UK->NL	€ 271	€ 197,946	1,000	€ 99.1
minor pair	€ 3,483,730	€ 1,189,197	8,585	€ 272.2
all pairs	€ 13,893,241	€ 13,266,359	14,935	€ 909.3
FR->IT	€ 19,816	€ 3,022,625	2,575	€ 590.8
FR->CH	€ 146,186	€ 82,229	3,200	€ 35.7
CH->AT	€ 2,081	€ 783	1,200	€ 1.2
CH->IT	€ 2,660,783	€ 1,832,740	4,165	€ 539.4
subtotal	€ 2,828,866	€ 4,938,377	11,140	€ 348.6
DKw->DE	€ 13,690		585	€ 23.4
PL->SK	€ 31,288		*500*	€ 62.6
DE->NL	€ 4,700		3850	€ 1.2
subtotal	€ 49,678		4935	€ 10.1
IT->CH		€ 2,564	1810	€ 1.4
SL->IT		€ 502,712	160	€ 3,142.0
IE->UK		€ 6,033	500	€ 12.1
UK->IE		€ 5,661,833	750	€ 7,549.1
subtotal		€ 6,173,142	3,220	€ 1,917.1
Total 2012	€ 16,771,785		23,090	€ 726.4
Total 2013		€ 24,377,878	23,090	€ 1,055.8
Total all	€ 16,771,785	€ 24,377,878	23,090	€ 891.07

Sources: ACER (2014 fig 65), ENTSO-E

Note: there are no data for PL=>SK so the NTC is from SK=>PL