



Institutional arrangements for the promotion of regional integration of electricity markets: International Experience

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Abstract This paper focuses on the institutional arrangements for facilitating electricity regional cooperation. We begin by discussing the theory of international trade cooperation in electricity, with a view to discussing what preconditions might be important in facilitating wide area trading across national borders.

We then discuss two sets of case studies. The first set of case studies focuses on three regional developing country power pools – the Southern African Power pool (SAPP), West African Power pool (WAPP) and the Central American Power Market (SIEPAC). The second set focuses on three regional power pools in more developed countries – PJM in the United States, the Single Electricity Market (SEM) in Ireland and the South East Europe market (ECSEE). These cases highlight both the potential and difficulty of having cross-jurisdictional power pools.

In the light of the theory and evidence we present, we draw key lessons in the areas of: preconditions for trading; necessary institutional arrangements; practicalities of timetabling; reasons to be hopeful about future prospects; and suggestions for future research.

Keywords electricity trade; power pools; regional electricity markets

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Institutional arrangements for the promotion of regional integration of electricity markets: International Experience

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1. Introduction

The problem of how to promote wide-area trade in electricity is a well-known one *within* individual countries. National electricity markets in advanced countries developed over time as initially local, vertically integrated distribution companies found that there were substantial cost and quality of service advantages to horizontal integration and interconnection between service territories. While some countries developed near monopoly generation utilities which made use of a national transmission system (e.g. England and Wales and France), other countries did develop (limited, but in some cases substantial) trading between continuing regionally vertically integrated utilities (e.g. Japan and the United States). The creation of a national or wide area electricity transmission system which is centrally dispatched has been key to the promotion of trade in electricity². Such a system physically allows energy from different power stations to be directed towards supplying given electrical loads from a common ‘power pool’.

Within countries such electricity trade can be facilitated within a single jurisdiction by the creation of a separate transmission system operator or TSO (National Grid in England and Wales) which owns and operates the transmission system assets (as transmission owner or TO) and operates the system in real time (as system operator or SO). Many jurisdictions follow this model (see Chawla and Pollitt, 2013). The debate about the Third Energy Package in the European Union focussed significantly on the role of the transmission system operator in promoting non-discriminatory access to the transmission grid – hence allowing different generating companies and new entrants to the generation market to effectively compete with each other to supply final customer demands. This package (2009/72/EC) favoured the creation of an ownership unbundled transmission system

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² See for example Foreman-Peck and Waterson, 1985, who document the emergence of a national integrated transmission system in the England and Wales.

operators which only owned and operated national transmission networks. This arrangement was thought to minimise conflicts of interest between the system operator and individual generation companies within a competitive wholesale electricity market. Within a single country it is possible to reorganise the distribution of network asset ownership to better facilitate trade (e.g. the creation of RTE in France as a separate transmission company owned by EdF or the reorganisation of the TSO TenneT in the Netherlands which acquired the higher voltage lines of distribution companies).

However between jurisdictions with different regulators this is very difficult and unlikely to happen easily³. Instead what is needed is the creation of wide area coordination of cross border trade where the system operation is separated from the transmission asset ownership. This has been a significant issue in the US between states leading to the creation of Independent System Operators (ISOs) or Regional Transmission Organisations (RTOs). Under such a model transmission systems can continue to be owned by a number of separate and even integrated companies, while it is the role of the ISO/RTO to operate the system in real time and to ensure non-discriminatory access to the grid for individual generators. The ISO model is gaining considerable attention precisely because the ownership of transmission assets *does not* need to be re-organised. The ISO is therefore a useful cross-jurisdictional model for facilitating trading of electricity.

Chawla and Pollitt (2013) note the rapid rise in the number of countries exhibiting either of these models – TSOs or ISOs - as wholesale power markets have been introduced and vertically integrated generation monopolies have been horizontally and vertically unbundled.

The above introduction suggests that there both physical and governance barriers that need to be overcome in order to promote trade in electricity across a wider area than was previously the case. Clearly physical interconnection is necessary, because without it no electricity can flow across pre-existing electrical boundaries. Traditionally countries have been very reluctant to trade electricity across borders and hence have limited the construction of transmission lines across borders. This is actually unusual in energy. Globally exports of electricity are around 3% of total production, in contrast to c.64% for oil and c.31% for gas and c.16% for coal (with the average for all goods and services being c.31%)⁴, suggesting that there may be substantial scope for increased trade in electricity across the world.

Where trade does occur, it does so in the context of a governance arrangement that facilitates the building and use of transmission capacity between areas. Both the TSO and ISO models are capable of providing the necessary governance to facilitate trading and indeed often run the associated markets which price wholesale power and ancillary services. Such governance arrangements have developed over time and often carefully represent the interests of generators (and their customers) across the interconnected area in a non-discriminatory way. TSOs and ISOs are two examples of institutions which embody non-discriminatory governance arrangements. In each case they received support from either national or state governments, to bring them into existence.

This paper will focus on the institutional arrangements for facilitating electricity cooperation. We have in mind the application of the lessons in the paper to other regions, such as the South Asia

³ Though TenneT did buy an adjacent transmission grid in Northern Germany. We also discuss asset ownership changes in Ireland later in this paper.

⁴ See IEA and UNCTAD statistics.

Region (SAR), namely Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. These countries are part of a free trade area – SAFTA (South Asian Free Trade Area, formed in 2006). The South Asia Region currently exhibits very little trade in electricity but exhibits significant potential for beneficial trade. We will begin by discussing the theory of international trade cooperation in electricity, with a view to discussing what preconditions might be important in facilitating wide area trading across national borders. Next we will discuss two sets of case studies. The first set of case studies focuses on three regional developing country power pools – the Southern African Power pool (SAPP), West African Power pool (WAPP) and the Central American Power Market (SIEPAC). The second set focuses on three regional power pools in more developed countries – PJM in the United States, the Single Electricity Market (SEM) in Ireland and the South East Europe market (ECSEE). These cases highlight both the potential and difficulty of having cross-jurisdictional power pools. We will then go on to draw key lessons for the South Asian Region (SAR) by looking at what aspects of the theory and experience in the earlier sections might be relevant to the promotion of electricity trade across borders in this context. We conclude with some suggestions for future research.

2. The theory of cooperation and international trade applied to electricity

In thinking about the institutional arrangements that might facilitate increased cross border in trade in electricity, it is useful to think about ideal electricity market design and institutions. Hogan (1995) suggests that a wholesale pool spot market and an independent system operator should go together. This is because short term generator dispatch and short term transmission system operation are ‘two sides of the same coin’ (Hogan, 1995, p.26). This suggests that power trading should be associated with an institution which is also responsible for the operation of the transmission system in real time. Hogan (1998) suggests that nodal pricing of the transmission system access is also desirable unless the networks are relatively simple. Thus the US Standard Market Design - which incorporates these ideas - may be the most sophisticated market design for wide area trading, but it may not be necessary for international trade in electricity.

Other designs may work, but the institutional design of markets is undoubtedly important. Stoft (1996) correctly predicted (prior to the California electricity crisis of 2001) that the institutional conflict between the California ISO and the California Power Exchange might decrease system reliability and lead to inefficient dispatch! Efficient market design is also about the participation of the demand side in the wholesale electricity market. This is increasing in importance in many of the most sophisticated markets, such as PJM and New York (see Walawalkar et al., 2010). For many countries demand side response inside their own country might be much cheaper at the margin than expanding international imports of power.

A key point about market design is the need for sufficient transmission capacity. Fuasch et al. (2013), in their examination of the EU, suggest that cost optimal trading within the EU would require to 76% more transmission capacity. It is important to note that transmission capacity is not just required at the border to facilitate cross border trading. Loop flows in the electricity system mean that the ability to export/import electricity across one transmission link is dependent on the absence of

congestion on other transmission lines, which may be internal to one or other country. Without sufficient transmission capacity cross border trade is going to be limited.

The degree of sophistication in markets may be limited when moving to cross border markets. Brunekreeft et al. (2005) note that locational marginal prices (LMPs) as recommended by Hogan and practiced in PJM may be desirable in the EU, but they are unlikely to be politically viable. This may explain why the EU has promoted market coupling between national markets and allowing some merchant interconnection, rather than LMPs. Perez-Arriaga and Olmos (2005) suggests that the problem that LMPs try to solve in the US with 200+ control areas is much less in the EU with 17 to 27 control areas. Clearly having congestion constraints imposed internationally is difficult to sell to national politicians.

International trade is always mutually beneficial under the assumption of costless adjustment of factors of production (and the other assumptions of the Heckscher-Ohlin model of international trade). However these assumptions are not clearly satisfied for the electricity sector. While one might assume that factors of production in the electricity sector can be moved to other sectors, it is not so obvious for electricity intensive industries. They may be dependent on cheap domestic power, which if it is exported may necessitate factor allocation adjustment in the wider economy.

International trade may however alter the risk profile around electricity prices. This is a version of the 'energy security' problem. In theory if two countries begin trading electricity this will normally provide some insurance against large shocks to electricity prices. This will be the case where their domestic supply/demand risks are either independent or negatively correlated. However clearly there will be some imported price volatility and the possibility of a large supply/demand shock in one country inducing a large price effect in the other country, which it could have avoided under no-trade.

Over time, there is the possibility that dependence on imports of electricity might develop and domestic production facilities might close. This could expose an importing country to a hold up problem if the other country refuses to export. However, in reality these would seem to be second order (and manageable) risks associated with increased trade dependence. It is worth pointing out that such energy security risk is two – sided , as the exporting country might become equally dependent on the export revenue from electricity sales.⁵

Trade theory has become increasingly concerned with considering departures from the assumptions of the basic Heckscher-Ohlin model. Markusen (1981) showed that if markets were initially monopolised a large country opening up to trade might suffer a loss of welfare due to the competition from another monopolist in the other country in a two country trade model. However Lahiri and Ono (1996) show that this result does not hold if new firms enter. Trade liberalisation becomes beneficial again. The general result of Dixit and Norman (1986) emphasises that trade can always be made beneficial as long as consumption and income taxes can be used to compensate losers within an economy.

⁵ We discuss the dependence of Bhutan government revenue on electricity export income in the final section. This surely makes them a more reliable supplier of electricity than would otherwise be the case.

An important question in international trade theory is whether trade worsens the natural environment. This might be a concern for electricity trading where exploiting low cost resources might involve burning more coal in a low generation cost country. Antweiler et al. (2001) find that trade is generally good for the environment. This is because trade effects can be divided into three: an increased scale of activity; a composition effect on industrial structure; and an effect in improving technology. They find for a sample of sites in 43 countries over the period 1971-96, they find the scale effect worsens pollution by 0.25-0.5% for each 1% increase in GDP due to trade, the structure effect is neutral and the technology effect reduces pollution by 1.25-1.5%. This gives an overall positive effect on the environment due to trade. If wide area trading makes emissions control and the spread of low emissions technology more likely, then it is likely to be good for the global environment.

It is also important to be clear that where international trading is imposed on top of inefficient national arrangements is not always beneficial in theory. De Villemeur and Pineau (2012) model the integration of electricity markets in two jurisdictions, one selling at average cost, the other with a competitive market and prove that the overall welfare result is worse than under no interconnection. According to the theory of the second best we would expect that the price setting mechanism in each of the connecting national markets would need to be similar for trade not to worsen the initial distortions in the markets. Clearly if one jurisdiction were selling electricity at below cost and another at its true (higher cost) the result of the joining of the two markets would worsen the impact of the initial price distortion in the jurisdiction with prices below cost. This is likely to be a particular problem in some regions with a history of energy subsidies.

Thus, international power pools are simply an example of the opening up to trade of a previously non-traded commodity. The initial situation in many developing countries is that there are monopoly electricity suppliers in each country each charging below cost in order to stimulate electricity intensive economic activity. If trade were to raise prices in one country but not in another that would affect the distribution of electricity intensive industry between the two countries. Of course this effect is tempered by the fact that commercial and industrial electricity consumers value the reliability of electricity supply as well as its price (Oseni and Pollitt, 2013) and hence if trade were to improve supply reliability and increase price at the same time in a particular country then it is possible that more electricity intensive industry would be attracted to that country.

As noted above, distributional effects are important in considering whether to open up to trade. This is particularly true for electricity. First, low electricity price jurisdictions worry that electricity trading will raise prices for final consumers while increasing the profitability of electricity producers. If ownership of electricity production is concentrated while electricity consumption varies less than proportionally with income then electricity trading with higher price regions may be blocked (as is the case in some states of the US (by states with cheap coal) and between France (low price) and the UK (high price)). Similarly in jurisdictions with cheap electricity for large electricity intensive industries, there may be a reluctance to export electricity at the expense of the trade dislocation caused by a potential reduction in electricity intensive manufacturing exports (e.g. Norway). Finon and Romano (2009) suggest that this could be dealt with by a windfall tax on hydro and nuclear producers (in the context of European countries), which could then be distributed to domestic consumers if necessary. These effects explain why high price jurisdictions are naturally keener on

electricity trading with lower price jurisdictions than the other way round (see Joskow, 1997, on the United States).

Neary (2007) predicts that trade liberalisation in a particular sector will also lead to low cost firms in the country with comparative advantage in a sector taking over the similar high cost firms in the other country. This is likely to raise welfare in aggregate, but it raises profitability for producers in the low cost country at the expense of consumers generally. Neary predicts merger waves resulting from trade liberalisation (subject to capital market liberalisation). Indeed this is clearly what has been seen in the electricity sector in Europe. This may not be a problem for the distribution of welfare internationally, as long as domestic shareholders can realise the benefit of the merger at the time of asset sale, however if there is capital market inefficiency this may not be the case.

International trading of wholesale power is more valuable when the price of power fluctuates seasonally or across the day at individual locations due to weather fluctuations (Bahar and Sauvage, 2013). This means that trade will occur between countries even where their average pre-trade prices are the same. The rise of renewable energy in some countries adjacent to each other makes such trade more valuable. However it does put pressure on the physical characteristics of the system. Electricity is not a typical arbitrated product, because it has several dimensions of quality including voltage and frequency. What is needed is a market operation regime which adequately accounts for the need to maintain power quality in the face of energy price fluctuations. A good example of how important this is was the incident which occurred on 4th November 2006 when a problem in Northern Germany (a ship hitting a power line) caused blackouts in southern Europe (and other places). Market integration meant that one of the German system operators created an externality, which the Spanish grid operator failed to manage successfully.

Where there are multiple countries seeking to reach an international trading arrangement there may be additional negotiation issues. One of the parties may block the agreement in an attempt to increase its share of the benefits. If it does so excessively or in a way that may set a precedent for other international agreements between the parties this may lead to the agreement not being reached. There are obvious ways to handle this using Shapley values which look at the value to the coalition of an additional member. However there is a real problem where side payments between regions must be made. If these are politically difficult to enforce then this may prevent agreement.

Gately (1974) looks at the benefits from electricity cooperation between three Indian regions – Tamil Nadu, Andhra Pradesh, Kerala-Mysore (KM). He finds that there are substantial benefits to all three regions cooperating in terms of reduced operation costs of their three power systems. However KM always has higher costs in any bilateral or trilateral agreement. The rise in KM's costs are substantial (x3) as it exports its cheap hydro to other states, but costs in aggregate fall by 20%. Gately shows that the order of joining the agreement may influence the value which an individual party can extract from agreement. He also notes that states may not just value the reduction in costs, but also care about the loss of jobs in the electricity sector as in state costs fall. The question for market arrangements put in place is therefore whether the market allows individual nations to capture a fair – both in the national and overall sense – of the benefits to the cooperation. This may be a particular problem where a transit state which hosts a transmission line does not actually import or export much electricity from it. Compensating this state fairly for its participating in the international agreement may be subject to these sorts of issues.

Coordination of TSOs in terms of congestion management could bring significant benefits, if done under a single system operator. Kunz and Zerralin (2013) analyse congestion costs within Germany under the current regime of 4 separate TSOs versus a single German TSO. For a model calibrated to 2011, they find congestion costs of 30.36m Euros under full coordination versus 179.56m Euros under the current approach. They conclude that having four TSOs will become increasingly expensive relative to having a single TSO as the amount of intermittent generation continues to increase.

Kogut (1988) makes a general point about joint ventures which is relevant to power markets. He notes that the pooling of resources in a joint venture (in this case a power market, where the participants are countries and their firms) may not be just about transaction cost savings or strategic advantages. It may be about the benefits of tacit knowledge transfer. Agreeing to participate in a wide area power pool is a good way to learn about other markets and to benchmark against best practice for any individual firm, beyond a simple cost benefit comparison against the current national arrangements.

Arguably, the most successful international power market in the world is Nord Pool (which includes Norway, Sweden, Finland and Denmark). Amundsen and Bergman (2007) discuss how prices across the area seem to be well integrated and vary according to underlying resource constraints. A particularly successful test of the Nord Pool system occurred in 2002-03 when a significant shortage of hydro capacity in Norway led to a severe price spike. Amundsen and Bergman (2006) note how the market coped well with this supply shock, maintaining political support. They suggest that the stakeholders involved understood that allowing market clearing prices to be high encouraged long term investment and that associated financial markets (which allowed hedging) also helped. This highlights how any international power pool needs to be able to withstand the inevitable stress tests that will come. In particular there needs to be confidence in the price determination process and a willingness to understand that a supply shock in one country will need to be supported by higher wholesale prices in connected markets. Thus temporarily high prices are an important price signal and represent a payment for mutual insurance.

An interesting take on trading in electricity markets is the concept of fairness, which may be very important in extending international trade in electricity. Dickson and Kalipurakal (1994) suggest that the idea that competitive market determined prices are always 'fair' is only one of several potential concepts of fairness in market transactions. In particular the idea that if there is scarcity, scarcity prices should be charged to everyone may be one that is difficult to accept. Interestingly, Dickson and Kalipurakal (1994) find that the market traders in the US that they survey are generally happy with market determined prices (rather than the alternative of Dual Entitlement where prices go up if costs go up and do not go down if costs go down). This may not be true of electricity consumers (or their elected representatives) in general of course.

When it comes to the benefits of wide area markets there is a lot of concern about the exercise of market power, particularly if competition policy enforcement is weaker internationally than it is domestically. In the European Union, which has pan-European competition policy and enforcement, this is not a big issue. However in other regions, such as SAR, if the market design gave rise to the

exercise of market power this would be an issue. Market monitoring within wide area markets is an important activity to ensure that the market is behaving as intended.⁶

Von der Fehr and Harbord (1998) look at different types of markets which may deviate from the perfectly competitive outcome: capacity constrained markets with Bertrand competition; collusive oligopolies in repeated games; supply function equilibria; and auction approaches. Clearly there is a worry about gaming, especially between countries within regions. Changing the nature of competition, by extending the market may change the current behaviour of players within existing markets. Similarly, Neuhoff and Newbery (2005) discuss how the move to integrated markets could initially lead to higher prices until enough competition emerges to definitely lower prices.⁷

There is a question of whether existing independent power producers (IPPs) will individually participate in a power market or form a coalition (or merge) to get a higher price. Jia and Yokoyama, (2003) use Shapley values to investigate whether an IPP would be better off participating individually in a power market or via a coalition. Ferrero et al. (1997) however show theoretically that if power pools are big enough selling into them at marginal cost (and participating in a 'grand coalition') may be better than deviating and not participating in the power market. This modelling suggests that if the international power pool is big enough the gains for an individual country to participate may become bigger than refusing to participate (the EU Single Electricity Market project, may be a good example of this).

Market power is not necessarily limited to incumbent generators in an international power market. National system operators may also exercise market power. System operators manage congestion on their networks and the transmission constraints behind them represent significant barriers to electricity trading, as suggested above (Kumar et al., 2005). However they are under national incentive schemes to minimise internal congestion within their control areas. Under international trading they may have incentives to shift transmission constraints to international interconnectors to reduce constraints within their own country, reducing the benefits of international competition. The Swedish transmission system operator was recently subject to anti-trust action by the European Commission for doing this within Nord Pool.⁸

While power markets are good for short term competition and efficiency there is an issue with whether they induce optimal long term planning. Kagiannas et al. (2004), note that generation expansion planning is evaluated differently if done by several competing firms (or countries), than if done by one monopoly firm. They note that the scope for mistakes to be made in aggregate may be increased by increasing the number of firms in the market.

In the context of the EU the impact of reducing market power, through more effective competition, is potentially very significant. Lise et al. (2006) show that for a simulation of 8 EU countries in 2000 moving from a situation of strategic competition to perfect competition would reduce profits substantially. In their analysis the profits of EdF and Electrabel (the incumbent generators in France and Belgium) would fall by one third.

⁶ See Goldman et al. (2004) who discuss five case studies where market monitoring was important.

⁷ This was the initial experience within the England and Wales power pool where competition took 8-10 years to fully mature.

⁸ See http://ec.europa.eu/competition/elojade/isef/case_details.cfm?proc_code=1_39351, Accessed 31 March 2014.

Hobbs et al. (2005) estimates the benefits of Netherland- Belgium market coupling to Belgian market using a transmission-constrained Cournot model. The study projects social surplus improvements on the order of 200m €/year, assuming market coupling does not encourage the largest producer in the region to switch from price-taking in Belgium to a Cournot strategy due to a perceived diminished threat of regulatory intervention. However benefits would be higher if transmission capacity was increased to allow the competitive baseline to be achieved. This implies the importance of optimal transmission capacity and of the monitoring of the competitive behaviour of market players.

3. *Case studies of cross jurisdictional electricity trading*

In this section we examine 6 case studies of cross-jurisdictional electricity trading.

We start with two African case studies from Southern Africa and from West Africa. We then look at Central American Power System. These developing country case studies indicate both the potential for wide area trading across a number of individually small national power markets. We then go on look at the evolution of power pools in three more developed jurisdictions. First, PJM, the largest and most developed power market in the US. Second, the Single Electricity Market (SEM) in Ireland which has integrated the power market in the island of Ireland, between Northern Ireland and the Republic of Ireland. Third, the South East Europe power market which covers a number of countries from Greece to Romania, and is part of the Single European Electricity market project of the European Union involving the creation of the Energy Community of South East Europe (ECSEE).

In each case we look at the evidence on what happened to facilitate trade, the nature of the trading platform, what institutions were set up to support it, the governance of these institutions, the practical steps to implementation and the concrete evidence on the benefits of trade. The case studies are not all successful and some took many years (more than might be thought necessary) to reach fruition.

African Integrated Power Markets

Case A: Southern African Power Pool

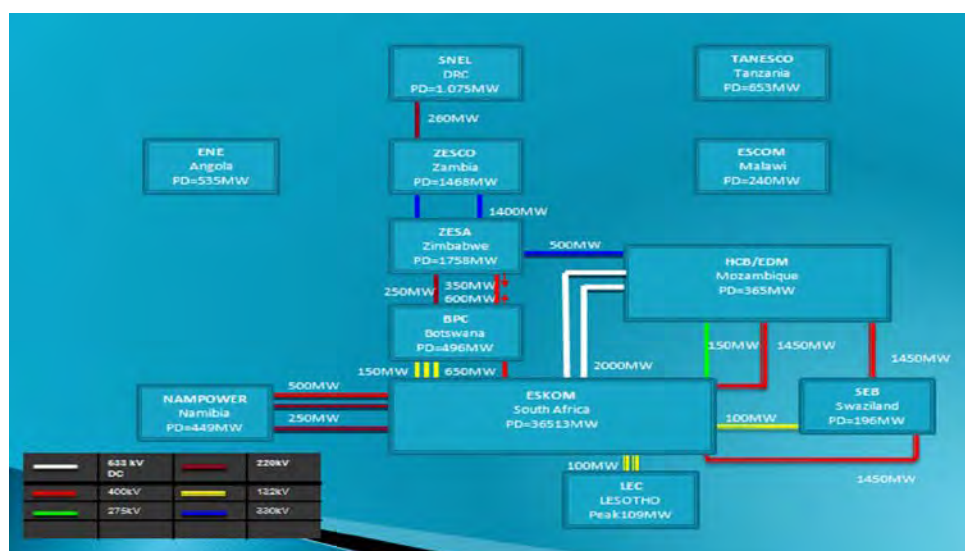
The Southern African Power Pool (SAPP), established in 1995, is currently the most advanced power pool in Africa (see Appendix 1 for details on its size relative to other international power pools). SAPP was a product of the efforts aimed at promoting energy development undertaken as part of the political goal of regional integration of the Southern African Development Community (SADC) established in 1992. One of the major political and economic forces behind the development of SAPP has been South Africa's yearning to meet future energy demand increase by importing low-cost hydropower from its northern neighbours (Economic Consulting Associates (ECA), 2009). The original agreements of SAPP were drawn from the bilateral and multilateral agreements already existing (prior SAPP) among the member countries. SAPP's guiding framework was based on intergovernmental memorandum of understanding (MOU) that authorised and guaranteed inter-utility MOU and operating agreements. *Inter-utility memorandum of understanding (IUMOU)* deals with the issue of ownership and rights among the participants. The *Agreement between operating members (ABOM)* defines the interaction between the utilities with respect to operating

responsibilities.⁹ Lastly, the *Operating guidelines (OG)* set out the arrangement for cost sharing and functional responsibilities for plant operations, maintenance and safety rules.

The highest governing body of SAPP is the executive committee which comprises the chief executives of the various power utilities participating in SAPP. The committee receives and refers matters such as the requests for membership by non-SADC members and the major policy issues to the SADC energy ministers for onward consideration. The management committee which comprises officials from the member utilities oversees the running of the SAPP. Four sub-committees, including planning, operating, market and environmental sub-committees are responsible to the management committee.

The SAPP member states and the interconnected grid are shown in Figure A1. SAPP comprises all 12 SADC member countries of which nine are operating members whose interconnected grid carries about 97% of the power produced by SAPP countries (Economic Consulting Associates (ECA), 2009). Coal dominates the fuel mix used for generating electricity and is predominantly abundant in the northern South Africa, western Botswana and eastern Zimbabwe. South Africa alone accounts for more than 80% of the total energy production in SAPP and hence coal contributes three-quarters of the total SAPP generation (Economic Consulting Associates (ECA), 2009). Hydro dominates the generation of electricity in the rest of the SADC countries, with power stations being located in the Zambezi Basin involving Zambia, Zimbabwe, Mozambique and Malawi, at Inga in the Congo, in central Angola, Northern Namibia and also in Tanzania. Overall, the generation mix in the SAPP currently stands at 74.3% coal, 20.1% hydro, 4% nuclear and 1.6% diesel and gas.

Figure A1: The SAPP Interconnected Grid



Source: (SAPP (Southern African Power Pool), 2013c)

<http://www.sapp.co.zw/docs/SD%20Bulletin,Sept,%202013.pdf>

⁹ <http://www.intechopen.com/download/get/type/pdfs/id/16031>

The introduction of SAPP has led to rising investments in capacity building, and at best spurred the trading activities between member states. For instance, net capacity of 1,700 MW was added in 2007, 1,442 MW in 2008 and 1,061 MW in 2012, and the region is expected to have sufficient capacity by 2017.¹⁰ Bilateral contracts dominate the trading arrangements in SAPP and it often accounts for between 90-95% of the energy traded. Bilateral agreements usually cover a period of 1-5 years or more. These agreements guarantee the security of supply but are not flexible enough to accommodate varying demand profiles and prices (Musaba, 2009). In order to ensure a more competitive electricity trading platform, a Day ahead Market (DAM) was introduced in 2009. Between 2012 and 2013, however only about 6% of energy demand in Day ahead Market was traded.

Transmission constraints remain a major issue within SAPP, with the African Development Bank funding new feasibility assessments.¹¹ The potential lost wheeling revenue that could have been generated in November 2013 alone was estimated at US\$316,312 (SAPP (Southern African Power Pool), 2013b). In addition only around 20% of desired trades actually took place in 2012. The South African utility, Eskom, is the dominant supplier into SAPP, because of its extremely low (potentially 'predatory') prices. In 2008 it was charging just 1.7 US cents/kWh (Economic Consulting Associates (ECA), 2009) for its exports. This is well below the cost of new fossil and hydro power and is the reason that the potential regional projects originally planned to supply South Africa have so far not been accomplished.

Case B: West African Power Pool (WAPP)

Despite its great energy potential, West African region remains among the world's lowest electric power producers. The region accounted for only 9% of the total Africa's installed capacity and about 7% of the total electricity generation in the continent in year 2000. Energy access stood at between 4% (Niger) and 70% (Benin) and it's per capital electricity consumption (127 kWh) was 3 times less than Sub-Saharan Africa's average (Zakharov, 2003). Established in October 2000, WAPP aims to promote energy trades between member countries through the integration of the national power systems in order to provide stable, reliable and affordable electricity supply to the citizenry. It comprises 14 of the 15 member countries of the regional economic community – Economic Community for West African States (ECOWAS).¹² WAPP member countries include Benin, Côte d'Ivoire, Burkina Faso, Ghana, Gambia, Guinea, Guinea Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo. WAPP, which currently has 26 member utility companies, consists of public and private generation, transmission and distribution companies involved in the operation of electricity in West Africa. Article of Agreements, as filed with ECOWAS Secretariat upon the endorsement of the Meeting of Energy Ministers, set out the objectives of WAPP and its operating procedures among the member states.

The General Assembly is the highest decision making body for the WAPP and comprises the representatives of all member states. It is responsible for the co-ordination of appropriate measures towards the implementation of the principles of the Articles of Agreement, facilitate the implementation of programs and projects, review and approve new membership applications, elect

¹⁰ SAPP (Southern African Power Pool) (2013): Annual Review Reports for Various Years. www.sapp.co.zw

¹¹ For example, for the Zimbabwe-Zambia-Botswana-Namibia project (see www.sapp.co.zw).

¹² <http://www.ecowapp.org/>

the members of the Executive Board, examine and adopt the financial regulations of the structures of governance of WAPP, among others. Next to the General Assembly is the Executive Board (EB) which, based on the overall policy objectives agreed upon by the General Assembly, has a decision making authority to develop and implement initiatives to achieve the mission of the organisation. EB directs the activities of all WAPP committees; examines and recommends to the General Assembly, the entry, exit and re-entry of members to WAPP Organisation; authorises all major contracts and [finance/debts] instruments; sets out the standards and policies of the WAPP Organization and penalties for non-compliance, and acts on appeals, among others.

The Organisational Committees of WAPP advise the Executive Board on all matters regarding collective policy formulation functions for developing, maintaining and updating common “rules of practice” on technical, planning, operational and environmental aspects of WAPP. The committees comprise the technical experts selected from WAPP members. The current Organisational Committees of WAPP are Engineering and Operating Committee, Strategic Planning Committee, and the Finance and Human Resources Committees.

Despite its existence for over a decade, WAPP regional trading activities have been almost non-existent. Not until 2012 when WAPP commissioned Mercados (a consulting firm), there were no clearly specified trading platforms in WAPP. The few bilateral trading exchanges between member countries were outside the regional electric trading system, mostly based on separate and pre-existing agreements between the parties. Towards the establishment of a regional electricity market by 2015, however, Mercados Energy Market International was employed to design and develop the market models and rules for power exchanges between WAPP Member Utilities (WAPP (West African Power Pool), 2012). The final draft of the document has since been submitted (AF-MERCADOS EMI (Energy Market International), 2012). Based on the report, the pool’s main trading platform would be in the form of long-term contracts and allocation of excess production among members. As market develops, however, spot market energy trading such as A Day Ahead utilising the remaining transmission capacity in the regional transmission system after allocating all the contracts will follow.

Why did it take WAPP nearly a decade and half to come up with its trading frameworks unlike some other regional power markets? The main reason was inadequate existing installed capacity and poor infrastructures among the member nations. Unlike the Southern African Power Pool (SAPP) whose installed capacity at inception in 1995 was 48,461 MW (with about 38,000 MW in South Africa alone), WAPP had only 9,705MW capacity as at the time it was formally created.¹³ This low capacity and lack of adequate transmission networks made regional trading difficult as member nations could not even meet their domestic energy needs, and because majority of them were yet to be interconnected. The slow progress in the regional trading in WAPP relative to the development in SAPP underscores the importance of existing infrastructural capacity in the development and progress of market integration.

Recognising the need for quick intervention in infrastructure developments, WAPP declared a state of emergency for rapid power infrastructures in its master plan. Building of power plants and transmission networks, and perfecting other technicalities required for loads scheduling and power trading were prioritised in WAPP project financing, with few investments on information,

¹³ <http://www.eia.gov/>

transparency and regulation (Pineau, 2008). WAPP master plan was designed by an American consulting firm, Nexant, and presented to the funding agency of the project, USAID, and to the ECOWAS Secretariat (Nexant, 2004b). In the master plan, WAPP countries were divided into two zones, and 14 major priority interconnections were identified (Nexant, 2004a). WAPP Zone A comprises Benin, Burkina Faso, Cote d'Ivoire, Ghana, Niger, Nigeria and Togo. Countries in Zone B include Gambia, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Senegal and Sierra Leone. Figure B1 illustrates the major interconnection projects in WAPP as of 2013.



Figure B1: WAPP Major Interconnection Projects (Source: WAPP website)¹⁴

Majority of the priority interconnection projects – which have been supported with funding from the World Bank - have since been commissioned while some are nearing completion. With the completion of many of the projects and the near completion state of the others, WAPP is set to have an operative regional power exchange by 2015. The roadmap for regional energy trading sets out three different development phases, consisting of a transition from bilateral market arrangements between neighbouring countries to an open and competitive regional market system. However, how the 2015 target for the operation of the regional market will be achieved still remains unclear considering the high level of unreliability still facing most of its member countries' power sectors.

Case C: The Central American Power Market (SIEPAC)

Although Central American countries have witnessed several electricity market reforms, individual electricity markets still differ considerably, ranging from vertically integrated to fully unbundled wholesale energy markets. Also there are significant differences in the quality of service, and the production and delivery efficiency (Reinstein, Mateos, Brugman, Berman, & Johnson, 2011). In

¹⁴ http://www.ecowapp.org/?page_id=168 See also Pineau (2008).

addition, the power system in each country has faced huge challenges of meeting growing demand and high costs of production due to their relatively small size and fragmentation. Apart from poor and unreliable energy services often experienced by the countries, the region has struggled to achieve cost-competitive energy services (Martin & Posadas, 2012). Thus, establishing a regional electricity market was considered a mean for creating a larger market that would enhance efficiency and promote competition among power producers.

The Central American Power Market is a product of the cooperation between six Central American countries to form a reliable, efficient and affordable energy market. The focus has been on the interconnection of the sub-region electric grid for the purpose of reaping economies of scale in larger generation as opposed to small production constrained by national boundaries. An important interconnection project – the Central American Electrical Interconnection System or SIEPAC¹⁵ in Spanish – involving 250 KV single circuit transmission line approximately 1,800 km long was launched following an initial feasibility study in 1987.¹⁶ A treaty was signed in 1996, but the line construction was not started until 2006 and was finally completed in 2013. The line connects the member countries, linking Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama for easy energy exchanges (Figure C1). The project has received significant financial support from multi-lateral lenders, with the Inter-American Bank providing 59% of the initial funding.

Figure C1: SIEPAC Project Map and Basic Characteristics



Source: Tarbuck (2013)¹⁷

The region's electricity market – the Central American Regional Electricity Market (MER) – was created after the governments of the six countries have signed and ratified the treaty for its establishment in 1998. To support the operations of the market, the regional regulatory commission

¹⁵ SIEPAC is the acronym for the *Sistema de Interconexión Eléctrica para los Países de América Central* (Central American Electrical Interconnection System).

¹⁶ See Economic Consulting Associates (2010).

¹⁷ Emily Tarbuck (2013), 'Panama: Regional Support Provides Relief from Energy Crisis', *The Argentina Independent*, May 17 2013, Available at:

<http://www.argentinaindependent.com/currentaffairs/newsfromlatinamerica/nama-regional-support-provides-relief-from-energy-crisis/>

CRIE (*Comisión Regional de Interconexión Eléctrica*), the regional system operator EOR (*Ente Operador Regional*), and the company that owns the grid, EPR (*Empresa Propietaria de la Red*), were also created. The MER was established as the seventh market, superimposed on the other six national markets, with regional regulation which enabled the Regional Operating Agency (EOR) perform international transactions of electricity in the region.¹⁸

Apart from the Consejo de Electrificación de América Central (the Council for Central American Electrification), established in 1985, which provides advice at both national and regional level, MER has three distinct institutions set up to support its operation. CRIE (*Comisión Regional de Interconexión Eléctrica*), established in 2002, serves as the regulator for the regional wholesale electricity market. It consists of six members, comprising one commissioner drawn from the electricity regulatory agency of each member states. The selection of representatives from the regulators of various countries was designed to minimise possible inconsistency between national and regional regulatory techniques and encourage uniformity in technical and operating procedures. The presidency of CRIE is rotated among its members. The regional system operator EOR (*Ente Operador Regional*) is responsible for the coordination of the market operation, including the day ahead, real-time dispatch, financial settlements, and dissemination of information through designated national system operators. It is also responsible for the formulation of plan for the regional generation and transmission networks expansion. Lastly, EPR (*Empresa Propietaria de la Red*) owns and operates the interconnectors connecting the six countries in the region. The interconnectors are 75% publicly owned by the utilities and transmission companies in the six member states, and 25% private sources, including the Spanish company, ENDESA.

The volumes of energy traded in the Central America regional power market have varied since cross-border exchange began and have always been less than 5% of the region's electricity consumption (CASTALIA, 2009). Power exchanges are currently dominated by bilateral contracts between parties. The bilateral contracts consist of medium to long-term agreements between parties to inject and withdraw energy at specific nodes of the regional transmission network based on the guiding rules and regulation (Prada, et al., 2004, Tinoco, 2009). Between 2003 and 2007, these contractual trading arrangements accounted for more than 80 percent of cross-border power exchange in the region (CASTALIA, 2009). It accounted for 94% and 98% of the regional transactions in 2010 and 2011 respectively. The contribution of each of the countries differs considerably. In September 2011 for instance, while 69% of the cross-border injection was contributed by El Salvador followed by 29% from Guatemala, Honduras topped the ranks of importers accounting for 44% of the regional bilateral trade withdrawals in the same month. Panama, El Salvador, and Nicaragua imported 36%, 16% and 4% respectively during that month.¹⁹

As highlighted by (CASTALIA, 2009), Central America regional market currently operates three types of spot-market transactions, namely financial contracts and two different forms of physical flexible contracts. Financial contracts are based on net settlement and have no impact on the dispatch other than through bids and offers to the opportunity market. Physical flexible contracts are bids for transmission services between two nodes and a maximum price that the bidder is willing to pay. Lastly, the second physical flexible contracts allow buyers to substitute their own planned

¹⁸ http://www.eprsiepac.com/operacion_mer_siepac_transmision_costa_rica.htm

¹⁹ <http://www.enteoperador.org/InformesEstadisticosMensuales.jsp>

generation with spot market purchases. Despite operating three different spot-market transactions, however, spot trading in the region's market has been very limited, averaged 18% of the region's cross-border power exchange between 2003 and 2007 (CASTALIA, 2009). It peaked only at 26% in 2007 before maintaining a downward trend accounting for just 5.8% and 1.6% of the regional trading volumes in 2010 and 2011 respectively.

Case D: PJM Interconnection²⁰

In the United States there are now four significant interstate electricity trading areas run by Independent System Operators or Regional Transmission Organizations (MISO, SPP, ISO-NE and PJM). These entities are of interest because they do cross traditional ownership boundaries and because they have evolved organically and often in competition with each other at their boundaries.

PJM is the oldest, largest and arguably most developed. PJM's three initial utilities began cooperating in 1927 to form the world's first power pool in order to save costs. It expanded over time becoming an independent organisation in 1997.²¹ PJM has been expanding over time in terms of coverage and in terms of the scope of its activities. In 2012 PJM covered around 61m people, 62,556 miles of transmission lines, 183 GW of generation capacity across 13 US states plus the District of Columbia. The recent history of transmission arrangements in the US is well discussed in Joskow (2005), who traces FERC's attempts to liberalise the electricity sector by promoting ISOs (in FERC Order 888) and then RTOs (in FERC Order 2000) and specifically the ISO-RTO model of PJM (in Standard Market Design proposals: SMD 2002).

ISOs have been described as the 'soul of the grid'²² and as the 'air traffic controllers'²³ of the electricity system.²⁴ PJM, like the others, undertakes a number of key functions. These include: real time physical system operation; ensuring short term reliability; tariff administration and design; congestion management; and procurement of ancillary services. It also runs the associated day ahead and real time energy, capacity and transmission rights markets.

An interesting feature of the governance structure is that several of the US ISOs, including PJM, have fully independent boards where individuals should have no ongoing relationship with market participants in the sector²⁵. PJM is run as a not-for-profit organisation, owned by its member companies. The Board of Managers is separate from its Members Committee. Board of managers is the top management level of the PJM. It comprises 10 members whose responsibility is to ensure that PJM fulfils its business and legal and regulatory requirements. In order to ensure impartiality, members' actions are strictly subject to the Code of Conduct guiding the operation of the board.

²⁰ This section draws substantially on Pollitt (2012a).

²¹ Source: PJM website, <http://www.pjm.com/about-pjm/who-we-are/pjm-heritage.aspx>, Accessed 28th January 2011.

²² See O'Donnell (2003).

²³ Source: SPP website, Available at <http://www.spp.org/section.asp?pageID=1> Accessed 28 January 2011.

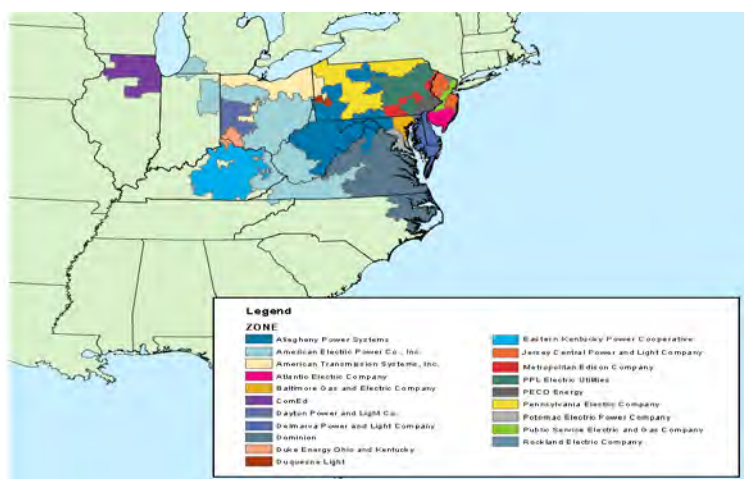
²⁴ A good general introduction to ISOs is contained in O'Neill et al., (2006).

²⁵ See: http://www.nyiso.com/public/about_nyiso/nyisoatag glance/board/index.jsp ; <https://www.midwestiso.org/Library/Repository/Meeting%20Material/Stakeholder/BOD/Corporate%20Governance%20and%20Strategic%20Planning%20Committee/2011/20110615/20110615%20BOD%20Corporate%20Governance%20and%20Strategic%20Planning%20Committee%20Item%2002%20Principles%20of%20CG.pdf> ; <http://www.pjm-miso.com/about/board-managers.html>. Accessed August 22nd 2011.

Next to the PJM Board is the Member Committee which reviews and decides upon any major changes and proposals made by committees and user groups. This committee serves as the link between the committees and user groups and the board of managers. It advises PJM and makes recommendation on all matters relating to secure and dependable operation of PJM, development and operation of a standard, competitive and non-discriminatory power market, and ensuring there is no undue influence over PJM's operations by any market participants.

Besides the PJM Board of Managers and the Member Committee, there are two other broad committee and groups that are responsible for the operation of the PJM. These include the PJM Interconnection committees and groups which are responsible for formulating, developing and refining PJM's rules and regulations, policies and procedures. The second group is the market committees. The market committees ensure the administration of an open grid and transparent energy market.

Figure D1: Map of PJM showing states and transmission ownership areas covered



Source: PJM²⁶

The estimates of the gains from the creation of ISO areas (and particularly PJM) are impressive. FERC (2004) estimates the benefits of improved market integration facilitated by ISOs in the US is of the order \$3.8-5.4bn per year. This attributes the benefits of increased generator competition to ISOs. This study also suggests that better use of transmission assets and better sharing of reserves might be worth around \$0.8bn per year (by 2010). Douglas (2006) estimates that the regional dispatch of coal fired power plants, by ISOs, has led to average variable cost savings of 1.5-3%. Mansur and White (2009) find significant gains from increased trade in their analysis of one particular expansion of PJM in 2004 when 19 Mid-west based utilities joined the PJM area. These gains were estimated at \$163m in the first year, against an initial investment cost of \$40m.

Case studies E and F: drawn from the EU Single Electricity Market

The European Union has had a significant regional push towards the creation of a single electricity market across the whole the European Union. This has involved a series of Electricity Directives aimed at setting common set of rules that national governments must pass into their national

²⁶ PJM Transmission Zones map (pjm-zones.pdf), available at: <http://www.pjm.com/documents/maps.aspx>.

legislation. The 1996, 2003 and 2009 directives gradually liberalised national electricity markets and facilitated increased cross border trading directly through specific rules encouraging non-discriminatory access to interconnector capacity and indirectly through creating consistent national market rules which reduced the entry barriers into national markets. The Single European Electricity market is part of the European Single Market project (from 1986) which aimed to encourage the creation of genuine pan European competition in all sectors by removing all non-tariff barriers to trade. The Single Market project encouraged mergers between national companies and cross-entry into markets. In traditionally heavily nationally regulated sectors, such as telecoms, electricity, gas and transport, the impact of the extension of the single market has been particularly noticeable. Progress has been considerable in terms of forcing convergence of national market rules (Jamashb and Pollitt, 2005 and Pollitt, 2009) but rather slower in causing wholesale electricity price convergence across the EU.²⁷

As early as 1988 the European Commission, which oversees competition in the EU identified the possibility of the extending the single market from traditionally heavily traded sectors into electricity and gas. A key feature of the process that emerged was the encouragement of regional sub markets between neighbouring countries where the benefits of cross border trading were clear and where interconnection capacity already existed (see Jamashb and Pollitt, 2005; Pollitt, 2009). The European Commission welcomed this process as it meant that the harmonisation of cross border trading platforms and rules could take place organically, in line with the EU's subsidiarity principle, at a pace that national governments were comfortable with. There have been notable successes with emergence of a Northwest European trading area initially involving France, Belgium and The Netherlands, being extended to include Germany and now UK and Nord Pool. These projects have involved coordinated allocation of transmission capacity and coupling of day ahead power markets.

In the next two cases we discuss two manifestations of regional markets within the EU (and its near neighbours) which are particularly relevant to the South Asian Region countries. These are the creation of the Single Electricity Market in Ireland (SEM) and the Energy Community of South East Europe (ECSEE). The Irish market is interesting because of governance structure, while the ECSEE market is interesting because of the diverse nature of countries involved.

Case E: The Single Electricity Market (SEM) in Ireland

The island of Ireland was divided into two distinct electricity markets until the creation of the SEM. In Northern Ireland there was a small market with approximately 0.7m customers and a peak demand of around 2000 MW, interconnected with both Scotland and with the Republic of Ireland. In the Republic of Ireland peak demand is around 5000 MW and there are around 1.8m customers. The system has recently been connected to Wales in Great Britain.

Prior to 1975 there was an operational North-South interconnector, rated at 300 MW. Following the escalation of the Troubles in Northern Ireland this was targeted by the IRA and remained non-operational until 1995 and the acceleration of the Peace Process within Northern Ireland. However the benefits of interconnection between the two systems were well understood, in terms of the

²⁷ Zachmann (2008) looked at the convergence of wholesale prices across the EU over the period 2002-06. He found that while there was some evidence of convergence, there was less than full convergence even allowing for transmission constraints between countries. He concluded that market integration was only 'partially successful'.

reduced need for spinning reserve capacity in the island of Ireland, the non-coincident peaks on the two systems, leading to differential prices and the different generation mixes within the two systems which led to marginal plants alternating between North and South. The emergence of wind as a major source of generation across the island of Ireland has also significantly increased the value of interconnection. Wind now accounts for 20-25% of energy generation in Northern Ireland and 40% in the Republic of Ireland, with the share being much higher than this at certain times.

In 2004 the two utility regulators laid out principles for the establishment of a single wholesale electricity market in Ireland which was approved in 2005. The market is claimed to be a world first: the first market between sovereign countries to operate with multiple currencies (Northern Ireland is in the GBP area, while the Republic of Ireland is in the Euro area). The SEMO sought to deliver a larger market, transparency, a stable investment environment, greater security of supply and greater efficiency.²⁸

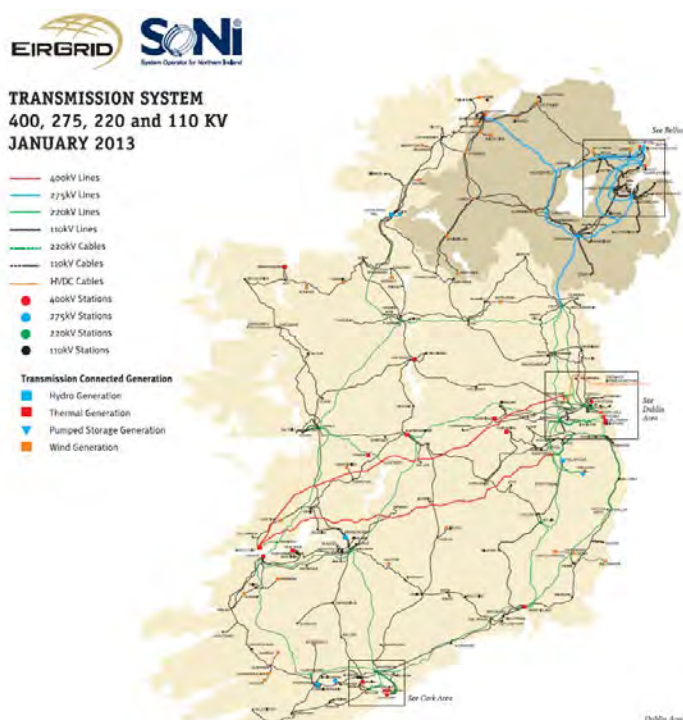
The SEM was created on 1 November 2007. The SEM is overseen by the SEM committee (SEMC) which has representatives from UREGNI, CER and an independent member. It involves marginal cost based bids from all generators in the island. These bids are then aggregated and matched to electricity demand to give a single half hourly trading price. There is also a capacity payment. This is fixed in total each year as the total required MW forecast by the transmission system owner (which is now EirGrid for the whole of Ireland) times the cost of a MW on new peak capacity. This amount is then divided up among generators over the year on the basis of their half hourly availability.²⁹

In the event of their being transmission constraints which prevent the winning bidders being dispatched in the market constraint payments are made to those forced to generate because constraints force losing bidders to generate. The use of marginal cost based bidding is significant because research prior to the opening of the market had demonstrated price based bidding would have given rise to the ability for some firms to exercise significant market power in the SEM (McCarthy, 2005). Short run marginal cost bids with a capacity payment were shown to reduce wholesale prices significantly relative to average cost bidding or medium run cost bidding (FitzGerald et al., 2005, p.73). Overall the SEM has been judged to working efficiently (O'Mahony and Denny, 2013).

Figure E1: Map of all Ireland Electricity System

²⁸ See 'SEMO Success Story' available at <http://www.ventyx.com>

²⁹ See 'The SEM Capacity Payment Mechanism and the impact on trade between Ireland and GB', Presentation by John Lawlor, 19 June 2012, available at www.elforsk.se/.../Market%20Design/seminars/CapacityMarkets/9_ESB.pdf



Source: Eirgrid³⁰

One important feature of SEM is that it is designed in a way that strategically mitigates participants' abuse of market power. The pool imposes Directed Contracts on generators with significant market power, and enforces a licence condition on generators to strictly adhere to a bidding code of practice. Generators viewed as possessing substantial market share are compelled to enter into forward contracts with suppliers for a specified volume at a pre-determined price. This is done to prevent those generators from withholding capacity for the purpose of influencing the market price (Conlon, 2009). In addition, the pool has a Market Monitoring Unit (MMU) which constantly monitors participants' bidding behaviour in order to ensure participants' compliances with the market rules.

Nera Economic Consulting (2006) conducted a cost-benefit Analysis of SEM over a period of 10 years covering 2005-2016. The estimates also show that the majority (NPV €127Mn out of €155m) of the social net benefit of SEM implementation goes to consumers, with a fairly even split between NI and ROI consumers. The SEM is increasingly integrated with the market in Great Britain. The East-West interconnector between Dublin and North Wales opened in 2012, having received a grant from the European Commission and project finance from the European Investment Bank. It is estimated to bring annual benefits of 66m Euros at an NPV cost of 395m Euros, making it extremely worthwhile (see de Nooij, 2011).

Case F. The Energy Community of South East Europe (ECSEE)³¹

³⁰ All Island Transmission Map (All-Island TransmissionMap.pdf). Available at: <http://www.eirgrid.com/transmission/transmissionsysteminformation/>

³¹ The section draws on Pollitt (2009).

In 2005 nine South East Europe (SEE) countries - Albania, Bosnia-Herzegovina, Bulgaria, Croatia, UNMIK (Kosovo), FYROM (Macedonia), Montenegro, Romania and Serbia³² - signed a Memorandum of Understanding (acquis communautaire) with the EU to form the Energy Community of South East Europe, ECSEE. The MOU can be seen as an effort to get back to the roots of the EU in the European Coal and Steel Community, ECSE (see Dietz et al., 2007; 2009)). In May 2007 the ownership of the EU transferred 'ownership' of ECSEE to its member countries.

There has been some significant progress towards electricity market integration (see Vailati, 2009) in ECSEE. An inter-TSO compensation mechanism has been implemented for cross border power transfers. The TSOs conducted trials of a coordination mechanism in 2008-10 and have now moved on setting up an office to coordinate auctions of transmission capacity (the CAO). This is notable given that Kristiansen (2007) observed that the previous transmission capacity allocation mechanisms existing across the ECSEE region were different and often bilateral between countries and that these were barriers to trade across the ECSEE. However so far there has been no impact on investment in extra transmission capacity.

Figure F1: Map of ECSEE (as of 2007)



Source: Busz (2007, slide 4).³³

There is long history of regional electricity trading in general between ECSEE countries, though several were involved in the Balkan wars following the breakup of Yugoslavia. These wars redefined the country boundaries and caused substantial damage to the electricity network which existed in Yugoslavia prior to its break up. The Yugoslavian region was a significant transit route between the

³² Of these countries, Bulgaria, Croatia, Romania, Greece and Slovenia are members of the European Union and are subject to EU Electricity directives on the creation of the Single European Electricity market. The rest are actual or potential candidate countries for EU membership which would imply that compliance with the EU Electricity directives would a necessary part of any formal accession process.

³³ Busz, H. (2007). *The Energy Community of South East Europe*. 4th Poverty Reduction Strategies Forum, Athens, 26-27 June. Available at: siteresources.worldbank.org/PGLP/Resources/Busz.pdf

larger markets to the north, especially Bulgaria and Romania, connecting Greece with the rest of Europe.

However the problems in delivering electricity integration benefits to society are not to be underestimated. This may be particularly true of the smaller ECSEE countries. For small countries, where the scope for national competition may be limited and managerial expertise is scarce, the benefits of a full reform package may be small in relation to the costs. This should make interconnection more attractive but it does imply a potentially problematic loss of sovereignty in a region where this is an important issue. Thus, without adequate interconnection wholesale competition may therefore be an issue within some ECSEE countries (e.g. Albania, Bosnia-Herzegovina, UNMIK, FYROM and Montenegro).

The internal decision making in ECSEE rests with a Ministerial Council (MC) and a Permanent High Level Group (PHLG). The MC provides general policy guidelines and takes measures to ensure that the objectives of ECSEE are met. The body also delegates, when necessary, the Permanent High Level Group, the Regulatory Board or the Secretariat to carry out some functions in order to achieve the policy objectives of the Energy Community. The presidency of the MC is rotated annually between contracting parties. The PHLG which is also chaired by a president is responsible for preparing the work of the MC, ratifying technical assistance requests made by international donor organisations, international financial institutions and bilateral donors, and reporting to the Ministerial Council on progress made toward achieving the ECSEE's objectives, among others. The Regulatory Board provides advice on the details of statutory, technical and regulatory rules to the Ministerial Council or the Permanent High Level Group, and issues Recommendations on cross-border disputes involving two or more Regulators upon request by any of the parties involved in dispute. The President of the Board is elected for a term determined by the Regulatory Board while European Commission acts as Vice-President. The Secretariat serves as the administrative hub of ECSEE and is headed by a Director appointed by a Procedural Act of the Ministerial Council.

The Energy Community has developed a Coordinated Auction Office (CAO) for an effective regional congestion management system. The South East European Coordinated Auction Office (SEE CAO) is to be responsible for the harmonization of congestion management and optimization of cross-border capacity allocation. The lack of a regionally coordinated capacity allocation and congestion management system creates a barrier for cross-border electricity trade and as a consequence for the establishment of regional electricity market in South East Europe. The Office is expected to tackle this problem by acting as a central point for cross-border capacity allocation in the region. The application of one single set of auction rules and one single allocation platform for the whole region by the CAO is expected to result in the full harmonisation of the system. The CAO was expected to perform the first round of yearly auctions for 2014 annual capacities (Poyry Management Consulting and Nord Pool Consulting, 2011).

4. Key lessons from the Case Studies

This section highlights the lessons learned from the various trading arrangements discussed in this paper. We organise these under a number of key headings.

Pre-conditions for trade: Trade Agreements/Transmission Availability

Both expanded bilateral power trading and more formal power pools require a broader pre-commitment to free trade to be successful.

Electricity is just one commodity that could be freely traded across borders. It is not clear that it can be traded easily without a prior commitment to the creation of a free trade area. The existence of a regional trade can aid regional electricity trading in several ways: the existence of a regional trade reduces/removes possible trade barriers to regional power market and reduces planning time as most of the rules and regulations necessary for regional trading would have been established. The need for specific trade agreements to support electricity trade is heightened by the fact that WTO rules do not adequately address trade in electricity, partly because it combines goods (production) and services (transmission), and involves other policy objectives to do with the environment and energy security.³⁴

Free trade arrangements between countries leads to the establishment of the trust required to promote the development of a regional power pool. Five of our case studies are based within established free trade areas; the sixth – ECSEE straddles the EU and its near neighbours and is the least institutionally developed. All of them are clearly being promoted within a wider trade development context. Thus, SAPP is an offshoot of the Southern Africa Development Community (SADC) while WAPP is a subsidiary of the Economic Community of West African States (ECOWAS). The existence of regional trade might be the reason why bilateral power trades always continue to thrive even before an advanced power pool is achieved.

Our case studies are consistent with the hypothesis that greater trade openness leads to more cross-border trade in electricity, even keeping the potential gains from trade constant.

The existence of a common currency is not a pre-condition for an effective functioning electricity market. Although a common monetary unit does help facilitate trade because it signals deep trade integration, this is not necessary and fully functioning cross border electricity markets can exist in the presence of multiple currencies – the Single Electricity Market (SEM) in Ireland is a good example here. Similarly, SAPP members do not have a common currency.

Similarly, it should be pointed out that institutions of competition policy enforcement across a free trade area are not necessary for power pools to develop and function effectively (they don't exist for the SAPP or SIEPAC countries). However, such institutions are a sign of deep trade integration – and exist in the US and in the EU – and do act as regulators of mergers and market power in cross jurisdictional power pools (such as PJM, Nord Pool and SEM).

Fuel costs may be reflected more quickly in power prices in an international power market, than in a managed national market. This is economically efficient but does expose wholesale electricity price dependent customers to significant variability in prices. PJM is a good example of this. PJM note that average real time prices rose 24% in 2010 and fell 25% in 2012.³⁵ Modelling would expose whether

³⁴ For a discussion see:

http://www.wto.org/english/res_e/publications_e/wtr10_forum_e/wtr10_7may10_e.htm

³⁵ 'PJM The Cost of Electricity', PJM website.

such volatility is likely to be higher or lower with an integrated market. Such market risks may have implications for the willingness of jurisdictions to be involved in cross-border trading of electricity or their need for institutional arrangements which help mitigate risks.

It almost goes without saying that for trade to occur, there must be a no trade price differential between the potential parties to the trade. This implies that there must be a relatively low electricity price country, where the unit value of electricity exports to the relatively high price country is greater than the willingness to pay for a unit electricity consumption within the country. In many countries of WAPP this is not the case, in the sense that the price an importing country would be willing to pay for a kWh is less than the willingness to pay of demand for a kWh within the potential exporting country. This could be case for a country with a lot of un-served load and underdeveloped hydro capacity. In theory this country should be exporting, but only after satisfying its latent domestic demand. This fact may explain the slowness of the development of international interconnection from countries with favourable export potential.

Adequate transmission capacity is essential for a power trading to occur. Thus, agreements for expanding transmission capacity are integral to the development of an international power pool.

A generalised commitment to free trade is not enough to promote the development of a fully functioning cross-jurisdictional power pool, with a single market price. This would seem to require physical investment in sufficient cross-border transmission capacity. SEM only came about after the re-energising of the North-South interconnector. The development of WAPP beyond bilateral trading has been prevented by a lack of transmission capacity. Lack of transmission capacity has not prevented the emergence of spot markets in SIEPAC or SAPP but has severely limited their significance and explains the prolonged dominance of bilateral trading. By contrast in developed regional power pools such as PJM or Nord Pool there has been a significant amount of transmission capacity which has supported the development of significant power pools. While our case studies suggest power markets can come before the development of interconnection (e.g. in the case SIEPAC), they can only be significant in the presence of sufficient interconnection.

The development of sufficient transmission capacity is a problem within all power systems. This is because there almost always practical and political problems in allocating the gains from transmission capacity expansion. This explains why in national power systems transmission expansion costs were historically socialised across the whole of society (e.g. within the CEGB in England and Wales, or within US vertically integrated utilities) rather than fully allocated to specific sets of customers and generators, via locational charging. Thus it is easy to understand the difficulty in getting agreements to allocate the costs of interconnecting transmission between jurisdictions.

However 'cross border' investments in transmission capacity did occur to a limited extent historically where there were sufficiently large bilateral gains relative to the cost of transmission expansion (i.e. large price differentials which can be arbitrated by relatively short distance wires). This explains the existence of some transmission capacity between jurisdictions within all of our case studies, prior to their most recent institutional incarnation. However the expansion of this initial transmission capacity - to the extent that it has occurred – has been supported by feasibility studies which have attracted multilateral agency finance. SIEPAC, WAPP, SAPP have all been financed by international development agencies (IADB, World Bank and AfDB); while the EU has financially supported interconnection projects in the SEM and ECSEE.

Institutional Arrangements

The role of strong, efficient and independent institutions in ensuring an effective functioning integrated power market cannot be over-emphasised.

An integrated power pool needs an efficient operator who can oversee and sanction the activities of participants in order to prevent predatory pricing, non-disclosure of capacity, and other forms of unruly behaviour. Cross-border institutional arrangements are essential, but can take a variety of forms. WAPP and SAPP are international arrangements for electricity exchanges. PJM is an actual cross-jurisdictional ISO. The ECSEE has evolved a joint institution for allocating cross border transmission capacity, separate from the national system operators. While the strength of the institutional arrangements governing cross-border trading is undoubtedly limited if it is cross border, it clearly is possible to build strong cross-border power markets (as demonstrated by SEM and SIEPAC). The SEM has involved the merger of the system operators in both participating jurisdictions (though they still continue to exist separately). This is helped where the parties to the transaction are private entities and can submit themselves to be bound by a common legal system. Indeed the problem is not the lack of a common legal system to which all the parties can be bound, but the unwillingness of sovereign countries to bind themselves to a common enforcement mechanism. Such institutions do involve some additional cost (as Mansur and White, 2009, found for PJM) but these are likely to be small in relation to the benefits.

Getting the appropriate combination of regulation and market design for power pools is important.

While a new cross border regulatory agency is not necessary some regulatory oversight is beneficial. SAPP could have benefited from some regulation of Eskom's potentially predatory pricing behaviour. The SIEPAC, PJM, SEM and ECSEE are subject to some form of external regulatory oversight. PJM is clearly the most developed as it is subject to oversight from the US national energy regulator, FERC. Cross-border electricity markets within the EU are subject to the jurisdiction of the European Commission, which regulates EU wide competition. Market design may be important for reducing the need for cross-border regulatory enforcement action. For instance, in small markets such as Ireland price based bidding would have involved large distributional transfers and potentially significant welfare losses. Hence the introduction of cost based bidding with a capacity market in the SEM. The price determination process should both be based on underlying economic cost and take account of the potential for market power and the existing pricing inefficiencies within the trade partners. Clearly disputes about price determination are potentially more difficult to resolve in a cross-border market than in a national market and hence should be avoided.

Countries may have rational reasons to wish to mitigate the price risks associated with electricity market integration. Small countries faced with increasing their exposure to foreign sources of electricity price volatility may be unwilling to have much exposure to short term international market prices and prefer most trades to occur under long term contracts at fixed prices. This may explain the lack of trading in the DAM market of SAPP and the preference for bilateral contracting in SAPP and SIEPAC. Clearly as long as the price determination process for long term contracts is reasonably efficient then this may not be a problem and the market should decide the mix of contract terms under which electricity is exchanged.

The use of day-ahead markets and/or real time markets facilitates more trade and greater market efficiency.

Day-Ahead/real time trading leads to more competition than in bilateral arrangements and therefore results in more efficient utilisation of resources. The bidding mechanism in day ahead/real time market tends to make suppliers to be more efficient in order to keep their marginal costs as low as possible since they can be bid out of trade/market if they bid too high price. A day ahead/real time market also is more flexible and does more to facilitate trade than bilateral arrangements alone. This seems to be in line with the experience of SIEPAC (where most trade is bilateral) vs the SEM in Ireland (where there is a compulsory day ahead pool).

Timeline/Process of how to get there

The creation of cross border trading capacity often has the effect of inducing further market integration.

Trade success demonstrates the concept of trade being mutually beneficial. Several of our examples show that initial trading arrangements have expanded over time to include more jurisdictions, building on the initial cooperating group. This is true of PJM (extending from 3 utilities) and SEM (which is extending its transmission capacity and increasingly integrating with the GB market).

There can and should be a timetable for reform and development.

Developing and keeping to a timetable and is essential for the rapid development of integrated power market. It is necessary that agreeing parties design a timetable with clear objectives and the procedures or processes required to get there. This would allow them to keep tracks of their progress as well as having a definite focus. In each of our jurisdictions a timeline of development can be identified. The setting of a clear timetable in the case of the SEM and ECSEE seems to have been successful in reaching the next stage of development in the market.

There can be an important role for international organisations to facilitate the creation of power pools.

The creation of a regional power pool requires substantial investments in building and updating generation capacity, transmission networks, and human development. All five of the international power markets we look at have received significant external development support and financing (from the AfDB, IADB and the EU). The support levels are significant (59% of the funding for SIEPAC came from the IADB). Thus, the evidence is that the support of international organisations or foreign capital (as bilateral aid or development finance) is required.

In SAPP the gap between bids and actual traded volumes in DAM are always due to transmission constraints. Similarly, the slow development of trading in the WAPP are caused by lack of adequate funding required to embark on massive infrastructural developments necessary for effective trading arrangements, although they do receive foreign support. Things probably would have been better if an international organisation had fully charge of the creation and development of the WAPP for a possible hand-over to the member countries at a later date.

Clearly sovereign countries *may* be reluctant to do this, but the fact is that the SIEPAC and ECSEE countries have been willing to do this. The creation of the ECSEE is a particularly good example of such initial agreement between an international organisation and the countries, which has now been given to the countries.

The viability (or otherwise) of an international power pool should be assessed in advance by a careful cost-benefit analysis.

Clearly any major policy change should be subject to an impact assessment. This is particularly true of electricity markets which lend themselves to modelling and can provide a quantification of likely benefits and identify the need for any side payments to countries who facilitate trade but do not directly benefit (this was a particular issue in the SIEPAC case). Also, fuel costs may be reflected more quickly in power prices in an international power market, than in a managed national market. This can expose wholesale electricity price dependent customers to significant variability in prices. Modelling would expose whether such volatility is likely to be higher or lower with an integrated market.

Power pools can (and should) start with a small number of countries and grow over time.

The US and EU experience also suggests that regional power markets – involving just 2 or 3 parties - might be a good place to start on the road to full market integration. SEM involves 2 countries, PJM started with 3 utilities. Nord Pool became an international power market by expanding from Norway to include Sweden in 1996 (it now covers trades between 9 countries). Indeed, one of the observations from our case studies is that the most integrated markets are those that have grown organically rather than those that started with a large number of jurisdictions. The slow growth of WAPP may be a function of the large number of participating countries – 14 - at the beginning. Starting small means that large gains from trading can be demonstrated and new parties willingly opt in to an existing working arrangement. This would seem to offer more chance of steady deep progress, rather than prolonged initial development periods.

Reasons to be hopeful about the prospects for international power trading in the other regions, such as SAR

Trust building around electricity trading is possible even between countries with a history of conflict.

Five of our six case studies are drawn from troubled regions. The nature of the trouble was not necessarily at the border but sometimes internal conflict (and hence a potential source of supply risk for international partners). However in the case of SAPP and ECSEE there have been cross-border conflicts in the past. Often electricity trading by reinforcing mutual interdependence can be a significant positive outcome for the conflict resolution process (e.g. SEM and hopefully ECSEE).

The potential gains within the South Asian Region (SAR) from cross-border electricity trade are large.

ESMAP (2008) discusses the nature of the gains from increased energy trading in the SAR. This report discusses the bilateral (and multilateral) electricity trades that might be mutually beneficial within the region. Of these, six are relevant to our initial list of eight SAR countries: Pakistan-India and Pakistan-Afghanistan; Bhutan-India; Nepal-India; Bangladesh-India; India-Sri Lanka; and Bangladesh, Bhutan, Nepal and India multilateral trade.

The ESMAP report discusses the absence of electricity interconnection between Pakistan and India and the difficulties of interconnecting Pakistan with Afghanistan, suggesting that the gains from trade are modest. Bhutan-India is the one electricity trade success story in the region, with Bhutan deriving significant government revenue from the export of hydro based electricity to India. In 2010 Bhutan exported 5.4 TWh (or 75% of its production)³⁶ to India. Nepal-India has the biggest unexploited trade potential. Nepal has 43 GW of identified economic hydro capacity, and an installed capacity of just 721 MW in 2010. Much of any hydro capacity could be exported to India, but current total exports were 1% of its current production (or 0.03 TWh) in 2010. Bangladesh-India electricity trade is also at a very low level in spite of good prospects for the export of gas based generation from Bangladesh to India. In 2010 Bangladesh imported a total 0.5 TWh of electricity (with zero exports). In spite of considerable under-utilised hydro resources in Sri Lanka and a mere 30 km of sea to India, there remains no interconnection between the two countries.

In terms of a regional electricity market, there would seem to be a lot of potential for a joint Bangladesh, Bhutan, Nepal and India market, aimed at exploiting the considerable hydro potential of Bhutan and Nepal. Studies carried out by USAID under its SARI-E program³⁷ identified relative low cost transmission investments (\$9m to \$52m at the time) which would significantly increase cross border transmission capacity in the north east border region of India and its three neighbours.

Chattopadhyay (2013) quantitatively examines the high benefit to cost ratios across three potential cross border links within the SAR: India-Sri Lanka, India-Bhutan and India-Nepal. The major sources of benefit are avoiding unserved energy, operational cost benefits and capacity benefits, when measured using an investment planning and optimisation model. These benefits are \$1.8bn p.a., against one-off transmission line costs of \$700m. Chattopadhyay does not discuss the distributional impacts and why the links are not already built if they are really so beneficial. Clearly if such large potential gains exist it would be worth understanding what barriers stand in the way of electricity trade across the SAR and how they can be overcome. The measured benefits in the SEM and PJM cases were significantly less attractive than this (proportionally), but are in the process of being realised, in the light of the prescriptions for successful power pool development outlined above.

Taken together ESMAP (2008) and Chattopadhyay (2013) identify considerable potential for regional electricity trading, much of it unexploited, and only at the feasibility study stage.

Suggestions for further research

There is much we do not know about the promotion of international electricity trade. While the empirical literature has extensively examined the impact of electricity liberalisation on electricity market outcomes (see Pollitt, 2012b, for a review of the literature), there has been relatively little examination of either how international electricity trade can be promoted or the impact of trade. There has been some work on the impact of market extension within the US, but outside the US the work is almost entirely at the level of impact studies of the *potential* for trade. What is required is work looking at actual market evolution and impact.

³⁶ Source of recent electricity production, import and export figures: CIA The World Factbook. Available at <https://www.cia.gov/library/publications/the-world-factbook/index.html>.

³⁷ See: <http://www.sari-energy.org/>

A number of interesting areas for future econometric work suggest themselves.

First, what explains the extent of involvement in international trade? We have described the evolution of six power trading arrangements that took years to develop. Can we explain the extent of trade with reference to opportunity, national institutional variables, membership of a free trade area, institutions of the international electricity market, international financial support etc? Taking a sample of countries over time, this analysis would draw on the New Institutional Economics literature (in line with Erdogdu's (2013) analysis of national progress with electricity reform). Nord Pool evolved steadily (and reasonably quickly) from its starting point in Norway. WAPP has taken decades to get going, while SIEPAC has finally completed its major transmission line (more than 25 years after its initial feasibility study). Distinguishing the relative impact of trade potential and institutional arrangements would seem to be worthwhile.

Second, what price or quality of service impact does international trade in electricity actually have? These impacts could be on national electricity price levels or volatility, power shortages etc. Trade should have an impact in bringing about price convergence (following Mansur and White, 2009, on PJM extension). It might also mitigate domestic power shocks (such as hydro shortages, or a major power plant outage). It might relieve shortages of electricity (or allow domestic market extension to more customers). Econometric analysis of national wholesale or industrial prices, could be linked within trade involvement variables to see the extent to which international power trading has demonstrable national impacts. Clearly, small amounts of power trading might be enough to cause significant price convergence between neighbouring countries. Such analysis could focus on particular institutional developments within power pools. For example, SAPP has existed for many years and has shown significant institutional development. One could look at the impact of the move from bilateral trading only to a Day ahead Market.

Third, what is the productive efficiency impact of electricity trade? The merit order within a trading region is significantly altered when the market moves from being national to being international. Following, Douglas (2006, on US coal fired power plants), the efficiency of power plant utilisation after the introduction of a power pool can be examined (e.g. within SAPP or SIEPAC). It would also be possible to examine the extent to which international trade impacted the efficiency of individual power plants, in a way similar to the impact of privatisation or liberalisation more generally. Alternatively, the impact of involvement in a power pool on the promotion of electricity productivity could be examined, at the plant or utility level. For instance, Estache et al. (2008) and Jaunky (2013) look at utility level productivity evolution within SAPP.

Finally, it is worth noting that it would be good to see more careful cost-benefit analyses of the actual outturn performance of power pools in order to see if the potential initially identified is being realised. SIEPAC and SEM were both undertaken following positive cost benefit analyses: it would be highly informative to undertake actual cost benefit analyses (following Newbery and Pollitt, 1997) of their realisation in order to quantify the outturn impacts of these developments.

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APPENDIX 1: *Cross-Border Trading in Selected Countries by Power Pool*

The table below shows the proportion of cross-border electricity trades to interconnector capacity (transmission capacity) and total electricity consumption in some selected countries across various Power Pools. Data on annual electricity consumption and trades were converted from kWh to MW for them to be in the same unit as interconnector capacity. Conversion was done by dividing the annual data on each variable in kWh by $1000 \times 24 \times 365$. The results as reported in the table indicate that a lot of trades take place in Nord Pool and in SAPP than in the other power pools. For instance, while the interconnection capacity utilisation are respectively 39% and 50% for Nord Pool and SAPP, WAPP and SIEPAC records just approximately 9% and 4% respectively. Similarly, the proportions of cross-border trades in consumption are 28% and 21% for Nord Pool and SAPP respectively, whereas WAPP and SIEPAC trade only 5% and 2% of their consumption. It is worth noticing that while SAPP appeared to have utilised its transmission capacity (50%) more than the Nord Pool (39%), Nord Pool has traded more of its consumption (28%) than the SAPP (21%).

The performance of SAPP does stand out relative to other developing countries' power pools. The reason for SAPP to have achieved so much might be because of the (excess) existing capacity in South Africa which makes trading possible. Unlike the WAPP whose installed capacity stood at only 9,705MW as at the time it was formally created, Southern African Power Pool (SAPP) installed capacity at inception in 1995 was 48,461 MW, with about 38,000 MW in South Africa alone. Similarly, SAPP had been created many years before other pools in developing countries - e.g. WAPP was established in 2000/2001. Those years of existence might have been used to develop the pool – development and upgrading of transmission networks, etc, in order to promote trading within the pool.

Table A1: Share (%) of Trade in Electricity Consumption and Transmission Capacity in Selected Countries by Pool

Selected Country	Transmission cap. (MW)	Installed cap (MW)	Electricity consp (MW)	Exports (MW)	Imports (MW)	Crossborder trade (MW)	Trade % of transmission cap.	Trade % of consp
Nord Pool								
Norway	5395	30180	14703.2	1,974	390	2,363	43.8	16.1
Sweden	11825	36510	15353.9	1,679	1,455	3,135	26.5	20.4
Finland	3310	16680	9960.0	381	1,839	2,220	67.1	22.3
Denmark	6405	13710	3915.5	1,297	1,463	2,760	43.1	70.5
Estonia	1941	2751	877.4	264	156	420	21.6	47.9
Latvia	2084	2166	778.8	242	530	772	37.1	99.2
Lithuania	2714	3820	1097.3	754	645	1,399	51.5	127.5
Total	33674	105817	46686.1	6,591	6,479	13,070	38.8	28.0
West African Power Pool (WAPP)								
Ghana	627	1985	650.9	28.4	49.7	78.1	12.5	12.0
Nigeria	855	5900	2192.9	0.0	0.0	0.0	0.0	0.0
Senegal	100	638	158.0	0.0	0.0	0.0	0.0	0.0
Cote d'Ivoire	327	1222	368.8	88.1	0.0	88.1	27.0	23.9
Total	1909	9745	3370.7	116.6	49.7	166.2	8.7	4.9
Central American Power Market (SIEPAC)								
Guatemala	300	2745	812.2	15.1	0.9	16.0	5.3	2.0
El Salvador	300	1491	533.8	0.8	4.3	5.1	1.7	1.0
Honduras	300	1701	536.1	0.0	1.3	1.3	0.4	0.3
Nicaragua	300	1108	293.3	0.0	7.3	7.3	2.4	2.5
Costa Rica	300	2800	920.5	8.8	23.2	32.0	10.7	3.5
Panama	300	1976	590.2	14.3	1.0	15.3	5.1	2.6
Total	1800	11821	3686.1	38.9	38.1	77.0	4.3	2.1
Southern African Power Pool (SAPP)								
DRC	260	2437	684.6	218.7	0.7	219.4	84.4	32.0
Zambia	1400	1679	1008.9	30.6	25.3	55.9	4.0	5.5
Mozambique	5800	2428	1159.8	1,349.3	945.0	2,294.3	39.6	197.8
Botswana	1450	132	302.3	0.0	249.0	249.0	17.2	82.4
South Africa	2050	44260	24554.8	1,616.4	1,206.6	2,823.1	137.7	11.5
Lesotho	230	76	35.1	0.0	28.2	28.2	12.3	80.5
Namibia	750	508	415.0	10.4	287.6	298.0	39.7	71.8
Total	11940	51520	28160.4	3,225.5	2,742.4	5,967.8	50.0	21.2

Data Sources: CIA: The World Fact Book <https://www.cia.gov/library/publications/the-world-factbook/index.html>

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