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Integration of electricity markets in Europe: relevant issues for Italy

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Abstract

In this paper we analyse the current trend towards a higher degree of market integration in Europe and identify those aspects that are particularly relevant for Italy. The Italian involvement in this process appears comparatively modest: contributions from policy makers, practitioners and academics are, instead, necessary to estimate the potential advantages and disadvantages of integration and to indicate the preferable coupling solution. These proposals should be supported by robust analyses and sound evaluations: we identify open questions and indicate the direction for further work.

JEL Classification: L4, L5, L94

1 Introduction

The benefits of enlarging the geographical scope of power markets are, at least in theory, very clear: increased economic efficiency, lower market concentration, higher security of supply. Nevertheless, most existing electricity markets in Europe are national in scope and present significant differences in market design; moreover, cross-border trades are often seriously limited by the available interconnection capacity.

The integration of European electricity markets poses several difficult questions. Providing correct incentives to transmission operators to invest in network expansion is an important aspect of the issue. However, the integration of national electricity markets goes beyond the availability of physical transmission capacity. In particular, it encompasses the definition of compatible (not necessarily uniform) trading rules on organized markets - over several trading periods, from day-ahead to real time - in order to efficiently manage network

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constraints (i.e. to make better use of the existing transmission capacity), as well as power plants technical requirements. Moreover, it requires a higher coordination between Power Exchanges (PX) and Transmission System Operators (TSO) of different countries or, in other words, a change in governance for the institutions that are currently responsible for the functioning of electricity markets.

In fact, a novel effort to create the conditions for a higher degree of market integration has already emerged in Europe and it has produced visible results. In addition to the Nordic Power Market, which has been functioning since the '90s, as a common trading platform for Norway, Sweden, Denmark and partly also Germany, an agreement between France, Belgium and the Netherlands conducted in 2006 to the creation of a coordinated trading system for the three countries (Trilateral Market Coupling - TLC); similarly, an agreement between Spain and Portugal has lead to the creation, in July 2007, of an Iberian electricity market (MIBEL). Other initiatives are well advanced and there is much debate at the international level over a number of issues that are crucial to the well-functioning of integrated markets (for instance, EuroPEX and ETSO, 2008). For several reasons, the adoption of common, harmonized rules at a regional level has emerged as the necessary, intermediate step to the building of the Internal Electricity Market (IEM), as foreseen by the Directive 96/92/EC. To facilitate the development of these regional markets, the European Regulators' Group for Electricity and Gas (ERGEG), in cooperation with the European Commission, launched in 2006 the so called Electricity Regional Initiatives - ERI (ERGEG, March 2007).

This work focuses on the day-ahead time-frame. We underline three features of the current evolution of power markets that are particularly relevant for Italy, identify open questions and indicate the direction for further work.

First, as different integration models are being studied, tested and implemented in Europe, it is crucial to participate in the ongoing projects and discussion, with the objective to promote the implementation of desirable features in the design of the integrated market. The alternative is to join, later on, an already established multinational market - a choice that is likely to require a greater harmonization effort. As of today, we observe a significant involvement in the ERI on the part of the Italian regulatory authority for electricity and gas (Autorità per l'energia elettrica e il gas - AEEG) and, similarly, on the part of the Italian Market and Transmission Operators (Gestore del Mercato Elettrico - GME and Terna, respectively). On the contrary, other interested parties (traders, producers) do not appear particularly active on this front; moreover, the issue seems absent from the government agenda.

Second, even though the literature has extensively explored the question of how integration affects the welfare properties of electricity markets, rigorous results of a welfare-enhancing effect can be derived only for simple networks and under strong assumptions that are rarely verified in practice (full information, perfect competition, no uncertainty). Evaluation of market performance under more realistic assumptions and for meshed networks is complex and a general result cannot be derived. As for the Italian market, a preliminary evaluation is available of the inefficiencies associated with the current method for allocating cross-border transmission capacity (GME, 2008); other than this, the economic debate underlying this potential evolution of the national market is almost null. Further analysis is necessary to identify areas where efficiency gains may be found and to estimate the expected distribution of these gains across integrating countries and/or different categories of market participants.

Third, market integration requires modifications and harmonization of market architectures. In this regard, the harmonization of gate closure times, settlement times, guarantees and similar aspects, although fundamental for the functioning of real markets, do not seem to require innovative solutions. On the contrary, existing differences in products traded on national markets (i.e. in the representation of power plant constraints), in the representation of the transmission grid, as well as in the pricing rules require significant work in order to identify, for the integrated market, an efficient market clearing algorithm and an adequate model of the transmission network.

In summary, the current trend towards a higher degree of market integration in Europe calls for a stronger involvement and further study. Contributions and suggestions from policy makers, practitioners and academics should be supported by robust analyses and sound evaluations, capable to estimate the potential advantages and disadvantages of the necessary changes in market design and to quantify the expected costs and benefits of the integration for the Italian electricity industry.

The rest of the paper is organized as follows. Section 2 briefly describes the most significant experiences in market integration in Europe and discusses the different path of development that have emerged; on the basis of the available literature, Section 3 points out the potential contributions of an economic analysis of integration; Section 4 discusses several issues pertaining to market design, including the difficulties of coordinating several national markets that trade different products and adopt different network models and pricing rules. Section 5 concludes.

2 The European context

National electricity markets in Europe have evolved, since Directive 96/92, with relatively large freedom in terms of choices for market architecture. This has lead to the adoption of different solutions for managing transmission congestions and power plant constraints within the national borders, as well as to a lack of coordination in the allocation of cross-border transmission capacity.

For instance, focusing on the day-ahead time-frame, while several European markets consider the entire country as a single price zone, Italy has chosen a *zonal approach* to manage internal bottlenecks.[1] In turn, while GME accepts

[1]Zonal pricing implies the aggregation of transmission nodes into zones or, more precisely, the definition of internally well-meshed areas which can be considered as single price ares for congestion management purposes (Pérez-Arriaga and Olmos, 2005; Smeers, 2008). Generally, the different lines linking two zones are also aggregated into a single inter-area link; the flow

only hourly bids in the day-ahead market, other PXs accept orders that enable generators to handle start-up and shut-down costs and other technical requirements more easily: so called *block orders* (aggregate bids for several hours, with a fixed price and volume throughout these hours)[2] are accepted, for instance, in France and Germany, and *multi-part orders* are accepted in Spain (generators are allowed to submit the minimum and maximum output levels of their plants, the start-up costs, variable costs and ramping rates).

For quite a long time, cross-border trading in Europe was characterized by a variety of different allocation mechanisms that included not only market-based auctioning, but also pro-rata allocation. Since the approval of Regulation 1228/2003, pro-rata allocation is no longer allowed and network congestion problems must be addressed with non discriminatory, market based solutions. For most European countries, including Italy, cross-border capacity allocation occurs through *explicit auctions*: the rights to use the cross-border capacity for international trade are auctioned to market participants by TSOs, separately and independently from energy, through annual, monthly and daily auctions (transmission rights have, thus, different maturity). As illustrated in Section 3, explicit auctions are associated with inefficiencies, mainly related to the time lag between the interconnection capacity allocation and the wholesale energy market. Moreover, auction rules can differ on different borders of the same country. Finally, the capacity made available for international trade is normally calculated according to the definition of Available Transfer Capacity - ATC, a method that can underestimate the capacity of interconnectors to accommodate physical flows of electricity (ETSO, 2001). Clearly, improvements on these arrangements are possible and in some cases, have already been proposed and/or implemented in practice.

In this context, integration implies a rather broad and complex revision of the architecture of national electricity markets. First of all, integration encompasses a modification in cross-border trade, from explicit to implicit auctioning: an *implicit auction* is conducted by a PX (not by a TSO) and it allocates simultaneously energy and transmission capacity. Therefore, it implies (i) a shift in responsibility between TSOs and PXs and (ii) an harmonization in market design - this is necessary in order to clear the market, i.e. to find equilibrium prices and volumes for the countries involved. Second, these harmonization/coordination agreements might (should) also imply a modification in the representation of the grid, as a mean to enhance the use of the available transmission capacity.

In what follows, we provide a structured description of the recent experiences in market integration (Sections 2.1, 2.2 and 2.3) and derive some lessons for Italy (Section 2.4).

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limits over these links are then calculated according to the Available Transfer Capacity method (ETSO, 2001). See also Section 2.1.

[2] Block orders allow participants to express their preference in terms of complementarity between delivery/consumption of energy in consecutive periods. For instance, generators might be in the position to offer lower prices for a block of consecutive hours because this allows them to spread out the start-up costs; similarly, consumers might find convenient to submit a block bid for the start-up of an energy-intensive production process (Meeus, 2006).

Table 1: Classification of electricity markets

	Countries	Day-ahead market clearing	Transmission network	Power plant constraints	Pricing rule
PJM	Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia	Single PX	Nodal pricing	Multi-part orders	Nonlinear prices
NPS	Norway, Sweden, Finland, Denmark and Kontek area (Germany)	Single PX	Zonal pricing (ATC)	Block orders	Linear prices
MIBEL	Spain and Portugal	Single PX (2 divisions)	Zonal pricing (ATC)	Multi-part orders	Linear prices
TLC	Belgium, France and the Netherlands	Separate PXs (price and volume coupling)	Zonal pricing (ATC)	Block orders	Linear prices
EMCC	Germany and Denmark (NPS)	Separate PXs (volume coupling)	Zonal pricing (ATC)	Block orders	-
CWE MC	Belgium, Luxembourg, the Netherlands, Germany and France	Separate PXs (price and volume coupling)	Zonal pricing (ATC); *Flow based*	Block orders	Linear prices

2.1 Nodal pricing and market splitting

The highest degree of harmonization among national markets is achieved when *one power exchange* manages capacity and energy auctions for all involved countries. There are some experiences of multinational markets of this sort, that differ in a number of key features (summarized in Table 1).

As of today, the PJM market in the US, is the largest electricity market in the world. It started as the the Market Operator in Pennsylvania, New Jersey and Maryland, and gradually *extended* to 13 states and the District of Columbia. PJM adopts a *nodal pricing* (or Locational Marginal Pricing - LMP) system, with nodal differentiation of energy prices (solution of an optimal economic dispatch problem (Schweppe, Caramanis, Tabors, and Bohn, 1988)); differently from most European markets, generators in PJM are allowed to submit *multi-part orders* and a *nonlinear pricing* system applies (an accepted order is settled at an hourly reference price in combination with an extra payment).

The oldest multinational market in Europe is the Nordic Power Market (Nord Pool Spot - NPS). Started as the Norwegian Power Exchange in 1995, its day-ahead trading system was *extended* to Sweden in 1996, Finland in 1998, Denmark in 2000 and partly also to Germany in 2005 (Kontek area). NPS implements a *zonal pricing* system within the region where all the ATC between bidding areas is dedicated to the day-ahead price calculation (there is no explicit allocation of any of the interconnection capacity and each country corresponds to one or more price zones). Power plants constraints can be handled by producers with the use of *block orders* and the market is cleared at *linear prices* (all orders are settled at the same price).

Another example of a single international market in Europe is the Iberian market that, since July 2007, runs a single day-ahead market for both Spain and Portugal. The two existing PXs (OMEL for Spain and OMIP for Portugal) continue to operate as, respectively, the Spanish division and Portuguese division of the Iberian Market Operator. The first is responsible for the day-ahead auction and the second for the derivatives market. MIBEL adopts a simple *zonal pricing* system that counts two zones, coinciding with national borders. MIBEL accepts *multi-part orders* and imposes *linear prices.*

A zonal pricing approach is also indicated with the term *market splitting.* Although sub-optimal with respect to nodal pricing, this is an acceptable simplification when (i) certain network areas can be identified as internally well-meshed and can thus be considered as 'single' nodes (or single price areas) for the calculation of the day-ahead prices and (ii) a balanced transaction within a single zone does not significantly affect inter-zonal flows (Pérez-Arriaga and Olmos, 2005). Inefficiencies of zonal pricing are well described in the literature;[3] we only note here that market splitting leaves significant independence to national TSOs. Although this could facilitate integration in the short-term, scholars have started asking whether there might be gains from increased coordination between TSOs.[4]

[3]First, to resolve inter-zonal congestions TSOs need to redispatch or modify the results of the day-ahead market, so that the congestion is relieved. Counter-trading, applied for instance in NPS, is a market-based method for redispatching: the TSO buys increments and/or decrements from producers and/or consumers on the basis of the bids received; however TSOs are allowed to redispatch out of merit when these changes have better effects on the congestion. This scheme may be subject to gaming by market operators who own power plants that are often called upon out of merit or who can artificially create congestions in order to be paid for relieving them. Second, typically, the cost of counter trading are socialized to all consumers and thus the economic signals derived from congestion are lost (Pérez-Arriaga and Olmos, 2005). Third, in order to limit these costs, TSOs might prefer to reduce the capacity of an interface more than what it is necessary, as a means to 'move' the intra-zonal constraint outside their control area (in turn, this leads to larger than necessary price differences) (Glachant and Pignon, 2005; Bjorndal and Jornsten, 2007).

[4]As for the Nordic market, Bjornald and Jornsten (2007) have shown that, by considering the Nordic grid in its entirety, a more efficient zonal separation can be found (for instance, increasing the number of price areas results in higher social surplus); in particular, they suggest to abandon a separation based on national borders and geographic location of the TSOs; they thus indicate that greater coordination among TSOs - to be be achieved through Nordel (the organization of Nordic TSOs) - might reduce some of the inefficiencies of zonal pricing. Glachant, Belmans and Meeus (2006) believe that one of the main obstacles to the construction of an Internal Electricity Market in Europe is the potential conflict between national and regional interests in grid management, on the part of TSOs. They suggest a change in governance and ownership of the grid, with the creation of 'virtual' regional TSOs, with a regional vision in their decision criteria, forecasts and planning, as well as cross-ownership of network assets, as a means to enhance the efficiency of investment decisions, capacity calculation, and congestion management.

2.2 Market coupling

Even less harmonized markets can implement implicit auctioning. Indeed, by coordinating the activities of their PXs, different countries in Europe have already started to couple their markets (see Table 1).

In 2006 France, Belgium and the Netherlands entered a *market coupling* arrangement, designed to coordinate their day-ahead operations (Trilateral Market Coupling - TLC). In other words, while the Norwegian PX (and the PJM market) extended their model to other countries (states) over the years, PXs in the Central Western European (CWE) region have chosen to *coordinate* their existing trading platforms and not to rely on a single auction office. In fact, when TLC started, both France and the Netherlands had already well-established PXs: Powernext in France since 2001 and APX in the Netherlands since 1999; Belgium, on the contrary, was only in the process of establishing an exchange, Belpex, which started operations in 2006 (Meeus and Belmans, 2008).

For the members of the individual PXs bidding procedures are mostly unchanged, national PXs continue to exist as legally separate entities and are not completely harmonized in their market design. The transmission model is extremely simple, with the three countries lined up (each corresponding to a single price area), and calculation of cross-border capacity is based on ATC. These transmission capacities are used to optimize the clearing of the orders presented in the day-ahead auctions (*zonal pricing*); however, in contrast with the Nordic market, a fraction of the available capacity is still auctioned in explicit auctions (about 20%).

All PXs allow trading of *block orders*, however, the characteristics of the blocks that participants are allowed to trade on each PX differ in size (maximum amount in MWh/h), type (span in terms of hours), and number of orders (maximum per day per participant). PXs have chosen not to share their order books, but only the so called Net Export Curves (NEC).[5] Consequently, the clearing algorithm involves iterations between two modules: (i) a Block Selector of each PX, in charge of the decentralized selection of block offers, decomposition of accepted blocks in hourly orders, and creation of NECs; and (ii) a Coordination Module, in charge of the centralized calculation of prices and net positions (*price and volume coupling*). These centralized operations are currently carried out by the Dutch power exchange, APX (APX, Belpex, and Powernext, 2006). In the TLC case, the amount of information that national PXs share is much lower than in the case of NPS or PJM.

Further developments in market coupling arrangements in Europe include two rather advanced projects.

In October 2008, Energinet.dk, E.ON Netz, VE Transmission, the European Energy Exchange (EEX, the German PX) and NPS have created a central Auction Office - European Market Coupling Company (EMCC) - to operate a day-ahead market coupling on the Denmark-Germany interconnection, with the

[5]NECs reflect a market's import or export volume sensitivity to price and are obtained by determining the volume differences between the supply curve and the demand curve for each hour of the day.

precise objective to improve efficiency in cross border trading.[6]

The EMCC office (i) receives available capacities from TSOs (after nominations[7] are made by operators with capacities bought via explicit auctions), relative to all interconnections between bidding areas in the region (NPS price areas plus Germany); (ii) receives from the two PXs and for each of their bidding areas, the supply and demand curves and the block orders (made anonymous); (iii) calculates the day-ahead prices and cross-border energy flows for all bidding areas; (iv) publishes only the flows between Denmark and Germany. EEX and NPS take these flows into account as price-independent bids/offers when they calculate their own prices and inter-zonal flows. A market coupling arrangement of this sort, i.e. where national PXs calculate their own prices, is called *volume coupling*.[8]

In June 2007 governments, regulators, power exchanges, TSOs and the electricity associations of Belgium, Luxembourg, the Netherlands, Germany and France entered an agreement to design and implement a market coupling arrangement between the five countries.[9] The latest development is the publication of an Implementation Study for a Central-West European Market Coupling solution (CWE MC) (CWE-MC, 2008). The first target is the launch of an ATC based market coupling for the region by the end of 2009, followed by a switch to flow-based (FB) coupling in a year's time.[10]

According to the Implementation Study, the 7 TSOs in the region are currently collaborating to develop a common methodology to calculate ATC and to design a system that aggregates the individual network data and send them to the Central Coupling Unit (CCU).[11]

[6] www.marketcoupling.com

[7] To preserve some of the benefits of capacity allocation through implicit auctions (i.e., netting, full utilisation of capacity), the allocated long-term transmission rights require a physical nomination to the TSO at maturity date (the day-ahead, before a fixed deadline, typically early in the morning).

[8] Unfortunately, unexpected small deviations in flow and price calculations between the EMCC and the PXs have led to non-optimal results regarding the utilization of the capacity between the price areas. Furthermore, in some cases the PX prices for the Danish and German market areas did not correspond to the direction of the flows on the cross-border lines determined by EMCC. Given these unexpected results EMCC was and still is temporarily suspended.

[9] This regional market will be larger than PJM, although less fine tuned and harmonized in terms of design (Meeus and Belmans, 2008)

[10] A FB network model provides a better representation of grid constraints: instead of an aggregated limit on a zone boundary, FB considers limits on individual, critical branches (all tie-lines plus a selection of internal lines) (EuroPEX and ETSO, 2004, 2008). In practice this is achieved by calculating, on a daily basis, a matrix of sensitivity coefficients (Power Transmission Distribution Factors - PTDF) that describe the incremental flow on each critical line induced by an additional injection in one zone. For this calculation an assumption has to be made about the distribution of injection/withdrawals at different nodes within the zone: this will be more accurate if the procedure is carried out the day-ahead (or closer to real time). The proposed FB model relies on a zonal representation of the network that, as of today, identifies zones with countries (or TSO control areas). According to Smeers (2008), these two aspects are to be considered carefully: he argues that (i) the assumption behind the calculation of PTDF is the main difficulty of the current market coupling proposal and (ii) that an inadequate zonal representation may hinder the benefits of moving from ATC to FB.

[11] TSOs are also expected to identify critical branches, via a common procedure, and to

Meanwhile, the 4 PXs in the region have already selected COSMOS, a branch and bound algorithm, for the calculation of prices and volumes in the CCU (a *linear pricing* rule is to be adopted). The algorithm supports several constraints pertaining to the different orders submitted to the PXs; these include standard hourly and block orders, but also products currently not available in the CWE region.[12] Moreover, the algorithm manages network constraints associated with both an ATC and a FB network representation, but also HVDC cables (NorNed, BritNed, Nordel): as of today, the project envisages *volume coupling* to be implemented between CWE MC and NPS.

2.3 Other initiatives

It emerges clearly that market integration in Europe has been progressing quite rapidly in the past few years. Nonetheless, the above description is still partial, as it focuses only on initiatives that were proposed by PXs and TSOs. Other organizations are driving this process; we briefly mention here the ERI and the recent contributions of the European associations of PXs (EuroPEX) and TSOs (ETSO).

The ERI consist of seven Regional Energy Markets (REMs) projects. Each REM brings together regulators, TSOs and PXs, Member States, the European Commission and other interested parties (traders, power producers) to focus on developing and implementing solutions to improve the way in which regional energy markets operate (Italy belongs to the Central-South region, together with Austria, France, Germany, Greece and Slovenia). In the past couple of years several, important integration issues have been addressed within the ERI framework, where energy regulators play a prominent role. A clear advantage of the ERI is that, while sharing common objectives, the different regions have been free to focus more effectively on their specific priorities, that mostly depended on their initial level of integration. ERGEG recognizes, however, that stronger inter-regional coordination is now needed for further progress: the main challenge is to ensure that different regional developments remain coherent, in the long run, with the vision of a single market: *"some version of a pan European market splitting system based on one common power exchange" (ERGEG, 2008, p. 14)*.

In their respective work on congestion management EuroPEX and ETSO have developed, over time, similar positions on market integration.[13] Encouraged by members of the Florence Forum, the two organizations have recently published a joint report where they argue that (i) the presence of overlapping re-

produce PTDF matrices on a daily basis for the entire first year of market coupling, so that the comparative performance of the two approaches (ATC and FB) can be tested by the project parties.

[12] Flexible hourly orders (accepted at the hour with highest price during calculation - available on NPS), linked block orders (whose acceptance is subject to the acceptance of another block order - available on NPS), profile block orders (with different volumes in each hour), and so on.

[13] A first joint report appeared in 2004 and illustrated the potential advantages of a FB market coupling for the day-ahead time frame (EuroPEX and ETSO, 2004).

gions (for instance, France and Germany are each part of four different regions) might result in an obstacle to further market integration (a particular bidding area can only be involved in one price coupling mechanism) and (ii) express concerns regarding the ability of the ERI to provide the necessary coordination between the current initiatives (EuroPEX and ETSO, 2008, 2009). Among other things, the report suggests two different path to inter-regional integration: Extended Price Coupling and Dome Coupling, both requiring an European-wide coordination. The first approach implies a process of horizontal integration of market regions (or individual markets) by means of control areas joining an existing market, or the merger of two or more existing markets.[14] The second solution is a form of volume coupling between different regions which would allow regions to maintain their intra-regional arrangements (explicit auctions, market coupling, market splitting) and/or to change them, while remaining under the Dome Coupling.[15]

2.4 Relevant remarks

Notwithstanding the current developments in market integration, the Italian involvement appears still inadequate both in terms of proposals by technical parties and policy makers. The two aspects are strongly related: although existing market coupling agreements in Europe have mostly seen PXs and TSOs as proponents and key participants in the projects, the government and the energy regulator have a critical role in the design of wholesale trading rules.

Current initiatives are not as advanced as in other countries. AEEG coordinates the activities of the Central-South region, with the support of both GME and Terna (see also Section 3); however, a road map for market coupling in the region has not emerged yet.[16] Moreover, GME formulated a proposal for a coupling agreement with the Slovenian market but, as of now, there are not practical developments on this front. Finally, "support to the creation of the Internal Electricity Market and coordination of spot markets (market coupling)" have been included, for the first time, in the objectives of the AEEG strategic plan for the period 2009-2011 (AEEG, 2009).

Meanwhile, the government, the energy regulator and several interested parties are currently working on a number of reforms that are expected, at least on

[14]The main advantage of this model is its evolutionary approach: it builds on existing solutions, promotes the expansion of best practices between adjoining regions and allows stakeholders to find solutions to technical, legal and regulatory issues in a sequential manner. The main difficulty of a horizontal integration is found in the need to: harmonize products and capacity calculation models; find an arrangement for the ownership and operation of common functions; and to harmonise legal and regulatory oversight over many jurisdictions (EuroPEX and ETSO, 2008).

[15]The main advantages of this approach are that it requires minimal changes in regional arrangements or their governance and its flexibility. The main difficulties are envisaged in the coordination of the central coupling platform with regional platforms, in the issues of governance of the central office, and in the harmonization of daily schedules for each region wishing to linked to the Dome Coupling, for instance, gate close times and/or the time between gate closure and and the publication of results (EuroPEX and ETSO, 2008).

[16]www.energy-regulators.eu

paper, to significantly modify the architecture of the Italian electricity market. The issues at stake are numerous and concern all relevant time frames, from forward trading to the ancillary services markets, including the day-ahead and intra-day auctions as well as the zone definition. Remarkably, the debate seems to ignore the changes that are occurring in the rest of Europe and focuses only on internal questions. For instance, as for the day-ahead auction, a shift was proposed from *uniform* to *pay-as-bid* pricing. Disregarding the numerous implications of a reform of this type, for which we refer to the literature (among others, Fabra, von der Fehr, and Harbord, 2006), we note here that none of the other European day-ahead auctions implement pay-as-bid pricing. Since the calculation of a hourly, reference price is necessary to allocate cross-border capacity via an implicit auction, the absence of a uniform price would have thus introduced unnecessary complications in view of a market coupling arrangement of any type.

Altogether, a scarce involvement in the evolution of energy markets in Europe has important implications. Until today, the integration of national markets has followed one of two different paths. On the one hand, NPS (and PJM) have grown because more and more transmission areas have joined an existing market model.[17] A well-functioning market, with clear and fixed rules, results attractive because evidence exists that the system leads to positive outcomes (Meeus and Belmans, 2008). On the other hand, countries involved in the CWE MC or EMCC projects are developing together their coupling arrangements, adapting national market architectures to a common (not uniform) market design that they have agreed upon and defined to their specifications.

As for Italy, a horizontal integration path, where well-functioning regional markets function as 'magnets' attracting new countries, will potentially result in a high harmonization effort and high conversion costs (Meeus and Belmans, 2008; Weinmann, 2007). Similarly, ignoring in the current reform the relevant design features of neighbouring European markets, might make it more difficult to reach a satisfactory agreement on compatible market rules in the definition of a coupling arrangement. Either way, market participants and policy makers should not miss the opportunity to be more involved in the ongoing integration process or, at least, in the debate on the preferable market design and path to integration.

3 Economic analysis

The current mechanism for cross-border capacity allocation between Italy and neighbouring countries is based on an explicit auction mechanism. One of the positive outcomes of the work carried out in the ERI framework for the Central South region was the adoption (in December 2007 - updated in December 2008) of harmonized Auction Rules for all borders, approved by the TSOs of Italy, France, Switzerland, Austria, Slovenia and Greece. Even if some specific rules

[17]The expansion of NPS (and PJM) has not been fostered by a commitment at a higher level existed to create a single market.

still apply, allocation rules and methods, definitions, products and nomination procedures are now common for the entire region (ERGEG, February 2008; Terna, 2008).

As illustrated in Section 3.1, explicit cross-border auctions present different types of inefficiencies. An interesting study was carried out by GME (2008) for the Italian market (Section 3.2). One must be careful, however, not to identify inefficiencies in explicit auctions solely with efficiency gains from market coupling. Section 3.3 reviews the literature on welfare properties of integration and clarifies the issue. Section 3.4 presents relevant remarks for Italy.

3.1 Inefficiencies in explicit auctions: literature review

The literature has highlighted different sources of inefficiencies associated with the allocation of cross-border capacity through explicit auctions.

Newbery and McDaniel (2002) study the interconnector auctions on the German-Dutch and on the England-French borders. They find two types of inefficiencies. The first is related to the *definition of transmission capacity*: on both interconnections the capacity to be sold is defined on the gross flows, instead of netting imports and exports. The second concerns *imperfect arbitrage*: yearly and monthly auctions on the German-Dutch border are efficient (the 2001 auctions cleared close to the price difference of year-ahead base-load OTC contracts in the two markets); on the contrary, the daily market is not well arbitraged (the daily auction cleared on average at a lower price than the spot market price difference). The authors suggest that this reflects the fact that the hourly spot prices are not known at the time of bidding for daily transmission capacity, in contrast to the yearly and monthly auctions where financial contracts can guide price discovery.[18] The authors conclude that to improve the efficiency of the auctions energy and transmission capacity markets should clear simultaneously.

Tornquist (2006) studies cross-border capacity allocation, from 2002 to 2005, on the borders between Belgium and the Netherlands, Denmark and Germany, and France and UK. He finds a first inefficiency in the fact that the level of *firmness of capacity* depends on the time duration over which the capacity is allocated (TSOs normally curtailed contracts for daily capacity first, then those for monthly capacity and finally the ones for yearly capacity). Moreover, the compensation, in the event capacity is curtailed, is not at the full market spread but equal to the price paid for the capacity. Finally, the author calculates average prices for transmission capacity; he shows that, in most cases, annual and monthly auctions appear to be valued more highly than daily auction. He concludes that there is a need to offer more capacity of longer-term duration, and then allow trading of these capacity rights in secondary markets.

[18] Similarly, imperfect arbitrage is found comparing annual and quarterly auction costs for the year 2002 on the England-French border, with the corresponding spot price difference. Average auction costs from France to England are lower that average price differences, suggesting either risk aversion, high transaction costs or illiquidity as reasons for the imperfect arbitrage (Newbery and McDaniel, 2002).

Kristiansen (2007a; 2007b) analyses auction prices for the cross-border auctions between West Denmark and Germany and between East Denmark and Germany (the Kontek cable). Against his expectations, but in line with Tornquist (2006), the author finds that annual and monthly capacity is generally valued more than daily capacity (but traded quantities are higher in daily auctions). Moreover, he finds that the daily, monthly and annual capacity auctions do not reflect the value of the underlying asset as specified by the appropriate valuation of the energy price differentials between West Denmark and Germany and East Denmark and Germany. As such the explicit auction procedure is *not cost efficient*.

The European Commission 'DG Competition Report on Energy Sector Inquiry' notes that, although on many congested interconnectors TSOs make use of explicit auctions for cross-border capacity allocation, *"this mechanism is considered not to be satisfactory by a number of respondents in the Sector Inquiry, because it suffers from the time lag between capacity allocation and wholesale market clearance" (EC, 2007, p. 183).* The Report analyses the case of the interconnection between the Netherlands and Germany. The study reveals that in many hours during 2004 (40% of all observed hours) capacity was nominated from Germany to the Netherlands while prices in Germany where higher than in the Netherlands. This result is clearly not rational. One of the explanations for these economically inefficient outcomes is that the deadline for the day-ahead interconnector auction ended before the German (EEX) and Dutch (APX) energy market cleared. The financial loss resulting from under-utilization plus incorrect utilization (wrong sign nominations) of interconnector capacity ('estimated value of unused cross-border capacity') was found to be worth almost 50 Mln € for the Dutch - German border in 2004 (equal to 46% of the total value of the interconnector capacity). Higher price volatility on APX in 2003 resulted in higher financial losses.

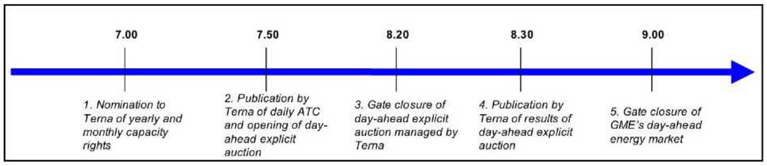
As illustrated in the following section, GME (2008) highlights two additional inefficiencies that are relevant in practical applications and quantifies the loss that results from wrong sign nominations of transmission capacity on the Italian borders.

In summary, the literature shows that *"although explicit auctioning is theoretically and with perfect foresight an efficient mechanism and it is in practice compatible with Regulation 1228/2003, it has efficiency deficits compared to implicit auctioning" (EC, 2007, p.186).* In fact, with implicit auctions

- netting of flows in opposite directions becomes feasible, which significantly increases the cross-border capacity made available to the market (and consequently it reduces cross-border congestion rents);[19]
- cross-border capacity is allocated as a function of the price differential in the two market areas: cross-schedules always go from the low price areas to the high price area (no issues arise of imperfect arbitrage and firmness of allocated capacity);

[19] This can also be achieved with a coordinated auction.

Figure 1: Time schedule of the day-ahead auction managed by Terna (GME, 2008)



- due to the absence of arbitrage errors made by market participants, correct signals prevail regarding the value of interconnector capacity; this leads to correct incentives to attract new investments in interconnector capacity (EC, 2007).

3.2 Inefficiencies in explicit auctions: Italian borders

The Italian GME (2008) has identified three areas where inefficiencies arise in the current arrangements for capacity allocation on the Italian borders: (i) operational risk; (ii) trading risk and cost; (iii) use of transmission capacity.

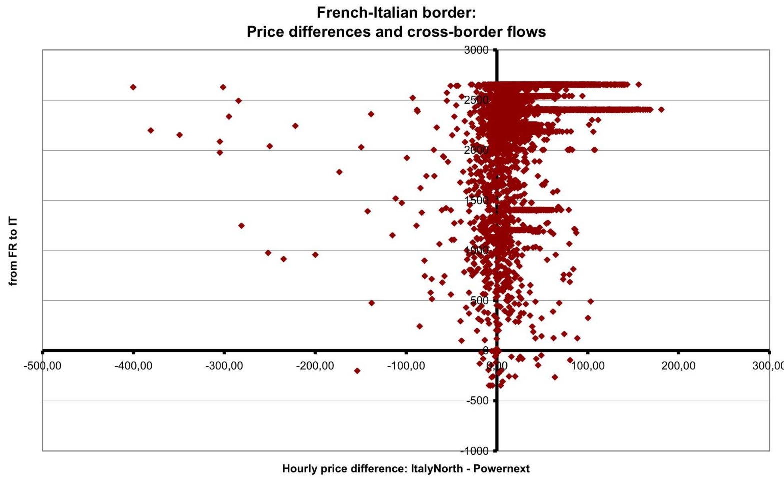
Firstly, operational risk may arise because the day-ahead stage of the explicit auction occurs in a very tight time frame (Figure 1). In this time period Terna and GME need to exchange information to coordinate the capacity market (managed by the TSO) with the energy market (managed by the PX). In the same time interval, market operators are requested to prepare and submit their energy bids, taking into account the outcome of the transmission capacity auction. Allocating all the day-ahead cross-border capacity via an implicit auction will reduce this complexity and thus the operational risk (GME, 2008).

Secondly, having separate day-ahead capacity and energy markets forces market operators to coordinate their capacity and energy positions, taking into account the risk that arises from trading these products on two different markets. Moreover, operators incur in trading costs (guarantees, IT, and so on) for two different trading platforms. These risks and costs may thus be reduced by eliminating the day-ahead capacity auction (GME, 2008).

Thirdly, explicit auctions introduce inefficiencies in the use of cross-border capacity. GME analyzed cross-border transactions on the Italian borders for the year 2007, using price and flow data for France, Austria and Switzerland - countries with a liquid index of hourly day-ahead energy prices. The reference Italian price was the price in the Northern zone.

Figure 2 shows, for each hour in 2007, the spot price differences between Italy and France on the horizontal axis and cross-border schedules on the vertical axis (imports from France in the upper semi-plane). It reveals that in many hours during 2007 capacity was scheduled from France to Italy while prices in Italy were lower than in France (IV quadrant). This result is not rational; however, it can be explained by the fact that the deadline for the day-ahead capacity auc-

Figure 2: Price difference (€) vs. cross-border schedules (MW) (GME, 2008)



tion ends before the energy market clears; therefore, market participants have to place bids based on expected market prices - and prices in Italy are generally expected to be higher than in France.[20] The consequence is that explicit auctions do not lead to an optimal use of scarce interconnection capacity.[21]

Inefficiencies in cross-border schedules were estimated as the product of (i) the difference between hourly Net Transmission Capacity (NTC)[22] and hourly day-ahead net scheduled flows times (ii) the price differential between the two market areas.[23] As for the three borders included in the study these inefficiencies amounted to around 30 Mln € for the period January-September 2007 and 132 Mln € for the period October-December 2007.

A comparison with the price differentials between the market prices shows that in the last quarter of 2007 (where more than 80% of the estimated value of the unused cross-border capacity was concentrated) price differences changed signed more frequently than in the rest of the year. In other words, large inefficiencies are found when market operators are not able to correctly predict the sign of the price difference and vice versa (GME, 2008).

3.3 Efficiency gains from market integration

The main benefits of market integration can be summarized as follows.

[20] Also the II quadrant represents an irrational outcome.

[21] A similar not rational behavior is found also on the borders with Austria and Switzerland.

[22] NTC is the maximum exchange program between two areas compatible with security standards applicable in both areas and taking into account the technical uncertainties on future network conditions (ETSO, 2001).

[23] Note that this value represents only a proxy of the inefficient use of the cross-border capacity: it relies on the rather strong assumption that prices, liquidity and bidding behavior of the operators would not change in case of an implicit auction.

Interconnection capacity was originally developed to provide security of supply rather then to facilitate trade: the fact that a lower amount of generation reserve is required to maintain a given level of supply reliability constitutes a first economic benefit of integration.

Secondly, it is easy to show, with a simple two-node network, that under the assumption of perfect competition, integrating electricity markets that were previously isolated increases total surplus - as the load can be supplied with cheaper generation. Moreover, assuming perfect foresight on the part of market participants, the outcome of the integrated market is the same under explicit and implicit auctioning (same prices and quantities, consumer and producer surplus and congestion revenues - as well as efficient locational signals).[24]

Finally, inadequate transmission capacity can isolate electricity markets and limit the number of generators competing to supply local consumers. Therefore, integration is expected to mitigate local market power, by decreasing market concentration.

The economic literature has focused on the last two aspects and it has thoroughly discussed these apparently straightforward conclusions. Increasing transmission capacity has certainly a welfare enhancing, 'substitution' effect; however, market structure has a crucial role in determining the level of competition; moreover, the way transmission capacity is allocated to market participants is relevant in defining the efficiency properties of the integrated market and it is, in no simple manner, related to the question of market power. Finally, the approach to calculate the available transmission capacity has also a significant impact on efficiency.

The literature indicates that both implicit and explicit auctions lead to a welfare-maximizing outcome in a competitive market, with full information, no uncertainty and perfect foresight (Ehrenmann and Neuhoff, 2009).[25] Although commonly applied in theoretical work to derive rigorous results, these assumptions are not realistic and any deviation from them can create inefficiencies in real markets.

For instance, in Sections 3.1 and 3.2 we saw that, ignoring strategic behavior (the behavior of market participants was assumed to remain remained unaltered), but removing the assumption of perfect foresight, explicit auctions lead to less a efficient use of the transmission capacity (a number of transactions was scheduled in the direction of the cheaper price area).

When generators' strategic behavior is taken into account, the welfare properties of market integration become extremely complex to predict. Several authors have used simple (two-node) and meshed (three-node) networks to study the behavior of generators in monopoly and oligopoly markets, with the objective to examine the effects of capacity allocation mechanisms on competition -

[24] A simple example is worked out, for instance, in Meeus (2006).

[25] Bohn, Caramanis, and Schweppe (1983) showed this for implicit auctions. Chao and Peck (1996) showed that explicit auctions with continuous trading of energy and transmission contracts and the opportunity to reconfigure transmission contracts also implement a welfare-optimizing outcome.

often assuming, instead, perfect foresight.[26] In other words, one cannot anticipate the effect of integration on welfare, without making clear assumptions on market structure and properties of the transmission capacity auction.

Neuhoff (2003) shows that, in a simple two-node network, an implicit allocation of capacity rights provides more demand responsiveness and thus reduces the exercise of market power. Also Gilbert, Neuhoff, and Newbery (2004) provide evidence of a pro-competitive effect of implicit auctions; however, using again a simple example, Willems (2002) verifies that this result does not always hold. Moreover, Ehrenmann and Neuhoff (2009) show that in more complicated networks with loop flows and strategic generators with assets at multiple nodes, finding a general ranking is not possible. In these cases, the analysis of the effect of integration requires numerical simulations with realistic parametrization.

For their numerical simulation, Ehrenmann and Neuhoff (2009) used a representation of the Belgian and Dutch markets. They found that when an implicit allocation mechanism is implemented, integration results in lower prices at all nodes. Note that also Hobbs and Rijkers (2005) studied the coupling of the Belgian and Dutch markets. Their results indicate that an improvement in social surplus is attainable, but only under the assumption that market integration does not encourage the largest producer in the region to abandon a price-taking strategy (due to a perceived reduction of the threat of regulatory intervention).[27] In addition, whether integration might benefit Dutch consumers also depended on the behavior of this company (they could also be worse off).[28]

In summary, evaluation of the performance of market integration under the realistic assumption of the presence of market power is important and the literature shows that large scale market models, solved with mathematical programming approaches, can support the choice of market design. Nonetheless, a well-know comparative work shows also that the results of numerical models can differ significantly: *"results are highly sensitive to assumptions about market design, timing of the market and assumptions about constraints on the rationality of generators" (Neuhoff et al., (2005), p. 1).*[29]

[26] Among others, Borenstein, Bushnell and Stoft (2000) use a simple two-node network to show how limited transmission capacity induces withholding strategies on the part of generators with market power; Harvey and Hogan (2000), but also Nehuoff (2003), explore the comparative effects on competition of nodal pricing with financial transmission contracts vs. bilateral trading with physical transmission contracts; Joskow and Tirole (2000) provide a comprehensive treatment of the effects of financial and physical transmission contracts in constrained two-node and three-node networks; Willems (2002) studies the welfare effects of rules to allocate demand for scarce transmission capacity in the presence of market power; Gilbert, Neuhoff, and Newbery (2004) extend the two previous studies analyzing, with respect to Joskow and Tirole (2000), a larger range of cases for different auctions and market designs and, with respect to Willems (2002), by studying welfare effects when transmission rights are obtained in an auction or inherited as legacy rights.

[27] A relevant, additional variable in determining the level of competition in a market is the regulatory threat (Ehrenmann and Neuhoff, 2009). Operators with market power anticipate regulatory interventions if they charge excessive prices and therefore moderate their behaviour (see, for instance, Neuhoff and Newbery, 2005).

[28] In general, the benefits of linking markets are not uniformly distributed: for instance, consumers in the exporting region may suffer price increases.

[29] For completeness we note that, in addition to theoretical contributions, experience with

As mentioned above, another matter that significantly influences the efficiency of an integrated market is the choice of the transmission model.

An ATC-based zonal approach introduces significant simplifications in the representation of the grid and thus to an underestimation of interconnection capacity. In brief, ATC is defined for a 'virtual line' which interconnects two countries and calculations are performed independently per border, ignoring that energy transfers in other parts of the network can induce physical flows on that border. Disregarding the meshed structure of the network thus requires TSOs to reduce the capacity that is made available on each border because of these unaccounted flows.

The limitations of the ATC representation of the network are well-know in the literature and have been discussed at length. The debate is between nodal and zonal pricing. The nodal (and in a similar, however simplified way, the flow-based) approach acknowledges that injections and withdrawals in different nodes of a zone have different impact on network flows. Market equilibrium is found by solving an optimal dispatch problem, subject to network capacity constraints, using total welfare as the objective function. This leads to a spatial differentiation of prices over different nodes. Although this solution is economically and technically optimal, market participants believe that the division of the market in many, and hence illiquid, sub-markets, increases trading complexity unnecessarily. On the contrary, a zonal approach aggregates nodes into zones and inter-zonal lines into a single virtual line; by doing so it increases the number of traders in each zone and enhances liquidity; it also reduces the number of sub-markets and thus uncertainty (Ehrenmann and Smeers, 2005).

Using the Nordic market as an example, Bjorndal and Jornsten (2007) show that, assuming perfect competition, social surplus in optimal dispatch (nodal approach) is always greater than or equal to social surplus with optimal zonal prices (solution of the optimal dispatch problem with the additional constraint that nodal prices in a given zone must be equal). In real markets, a number of simplifications are made with respect to the ideal implementation of zonal pricing used by the authors: for instance, bids are specified for a given zone and not for single nodes and zones generally coincides with the control areas of each TSO or with single countries. The consequence is that in practice the utilization of the grid become inferior to what is truly necessary to handle its capacity limitations and leads to further reductions in social surplus.[30]

the functioning of real markets has already produced sufficient data for a few empirical studies. For instance, Kube and Wadhwa (2007) observe the effect of integration on the development of wholesale prices on NPS, between 1996 and 2004. By means of a regression analysis (that includes the main supply and demand determinants of wholesale prices and a proxy for the degree of market integration) they find that market integration leads to a decrease in prices due to efficiency gains. The most probable drivers behind these gains are the diversification of the generation technology portfolio and the reduction of transaction costs. Also Lundgren, Hellstrom, and Rudholm (2008) empirically explore the electricity price dynamics in the Nordic power market, during the years 1996-2006. They conclude that a larger electricity market seems to reduce the probability of sudden price jumps. That is, the multi-national electricity market integration seems to have created a market that handles external shocks to supply and demand more efficiently than the separate national electricity markets previously did.

[30]The authors show that a finer partition of the network cannot reduce social surplus and

Although the experience with nodal and flow-based pricing in the US has been positive so far, one must also recognise that, given the current diversity in market design and regulatory regimes, proposing a centralized nodal pricing scheme for Europe is today far from acceptable (see for instance, Pérez-Arriaga and Olmos, 2005). In turn, the proposal to maintain a zonal separation, but to shift to a flow-based approach, seems to have recently gained particular support (EuroPEX and ETSO, 2004; ERGEG, 2008). The proposed flow-based solution retains the aggregation of nodes into zones but no longer aggregates lines. In particular, it uses zone-to-line Power Transmission Distribution Factors (PTDF) to describe the incremental flow induced on a certain line by an additional unit injection in a certain zone (critical lines are identified by the TSOs, but include all cross-border lines). In this sense, the FB approach improves on the current representation of the network. As thoroughly discussed in Smeers (2008), this approach is a *"fundamental step in the right direction" (p. 60)*; however, inadequate implementation choices - for instance, a poor zonal partition - might seriously undermine the efficiency gains that are potentially attainable.

3.4 Relevant remarks

As of today, the evaluation of the potential efficiency gains of integration for the Italian electricity market is still an issue for research.

Although relevant, inefficiencies of explicit auctions are only a part of the performance evaluation of a market integration; similarly, results derived from theoretical studies can provide only little guidance in practical implementations. We thus expect that, despite the limitations highlighted, significant contributions to the choice of the preferable integration approach, might come only from large scale simulation models or empirical work.

Any analysis of this type requires reliable data on generation and load as well as on the structure of the network; moreover, well-founded assumptions are necessary about the key aspects of the proposed integration approach, transmission model and regulatory regime. In other words, the task is not simple and cooperation among the involved parties seems necessary to clearly define hypotheses and objectives and to collect the necessary data.

Finally, we observe that to implicitly allocate cross-border capacity, the day-ahead auctions of the different countries need to function in a coordinated manner. This requires to various degrees a harmonization effort on the part of national markets. Efforts and costs devoted to harmonization of market designs should be included in the cost and benefit analysis of integration. Moreover, as discussed in the following Section, they might guide the choice of the preferable integration model.

propose a better partition of the grid, that does not necessarily follows the borders between control areas in the Nordic market.

4 Market design

Focusing on the day-ahead time frame, we conducted a preliminary comparative assessment of national trading arrangements for countries belonging to the Central-South (CS) region. Day-ahead auctions are run by national PXs in Austria (EXAA), France (Powernext), Germany (EEX), Italy (IPEX) and Slovenia (Borzen); EEX organizes a day-ahead auction also for the Swissgrid control area;[31] trading arrangements in Greece are, instead, in a transitional period: we refer here to the most recent proposal.

The design of day-ahead markets in the CS region differs across countries. As for institutional and organizational features of national markets, differences, although present, are not remarkable (Section 4.1); on the contrary, a diversity in the approaches characterizes the more technical aspects: traded products, network models and pricing rules (Section 4.2). In view of a closer cooperation within the region, all aspects would need to be carefully addressed (Section 4.3).

4.1 Institutional and organizational aspects

Both general and more specific, practical aspects regarding the organization and functioning of day-ahead markets can provide a first idea of the existing harmonization requirements.

Typically, PXs in the CS region organize day-ahead auctions to facilitate trading of contracts with physical delivery: orders refer to a specific point of injection or withdrawal; the only exception is France, where such indication is not required. Moreover, trading on PXs normally co-exists with bilateral, physical trading; on the contrary the Greek market will be functioning as a mandatory pool.

Market liquidity provides an indication of the amount of trades that occurs on PXs vs. bilateral trading. The range of values is quite large: Italy has a very liquid market (65% day-ahead trade/total trade, including bilaterals); in France and Austria liquidity is around 7% and 4% of consumption, respectively; the Slovenian market is extremely illiquid (0.009% of consumption in 2006). Nonetheless, experience shows that market integration increases the liquidity of the involved markets.

Necessarily, national PXs and TSOs always interact closely in organizing day-ahead trade. In general, however, also other institutions play an important role in the definition and control of wholesale market rules: mainly energy regulatory authorities and governments, often through the Ministries of economic affairs or Directorates for energy. In turn, market monitoring is a function carried out specifically by energy regulators, with the support of PXs.

From an practical perspective, some organizational aspects are relevant for a coordinated functioning of PXs. For instance, guarantees, settlements times, transparency of data, bid/offer formats, and timing of market sessions.

[31] A close cooperation exists between EEX and Powernext. In the near future, short-term power trading on both exchanges will be operated by a joint, Paris-based company EPEX Spot SE, in which EEX and Powernext hold 50% each.

Guarantees required to trade on PXs are quite similar across countries: operators must submit a bank letter of credit that covers the counter-value of the outstanding debt. As an alternative, Borzen allows participants to provide a cash deposit (100% coverage of purchase bids) and EXAA accepts bank guarantees, cash deposits or securities. In France, a guarantee deposit is required before any trading takes place; this is adjusted daily according to the average amounts of electricity purchased on the market.

On the contrary, settlement times can be quite different. In Slovenia and France, settlements occur a few days after the trading day. By contrast, payments in Italy are settled within the 16th working day of the second month following the month of trading. In Greece and Austria, payments are settled once a month. Therefore, harmonizing settlement times to the shorter periods would require PXs in Italy, Austria and Greece to settle cross-border trades in advance of domestic trades. Consequently, these PXs would have to take non zero net financial positions.

As for transparency, publication of aggregated supply and demand curves, traded volumes and prices and others indexes is a common practice. Although it is not expected to be a major issue, note that Greece intends to publish all data made available to the TSO and concerning the day-ahead market, with no significant time lag. In particular, auction participants will be able to see all submitted bids and individual results of the auction (not only traded volumes and prices). Market coupling could be implemented without imposing any change on the current national rules for publication of information regarding national transactions. However, a higher harmonization on transparency rules is on the ERIs' agenda for the CS region.

Market integration might require harmonization of the bid/offer formats. Price and volume steps of sale and purchase orders are rather uniform across countries.[32] On the contrary, price caps or values of lost loads present large variations. The lowest price cap is implemented in Greece (150 €/MWh) and the highest is found in France and Italy (3000 €/MWh).[33] No specific limitations exist in Slovenia and Austria. In general, as for multi-national markets, coordination on the value of lost load might be crucial in times of generation tightness. For instance, a Greek price cap of 150 €/MWh is likely to make export to Italy attractive in tight supply conditions, as prices in the Italian zone connected to Greece (Brindisi) might result higher, inducing imports from Greece to Italy.

Finally, one of the aspects that would require the highest harmonization effort is the timing of the day-ahead auctions. As illustrated in Figure 3, there is an apparent heterogeneity both in terms of gate closure times and in terms of computation time. Gate closure varies between 9.00 (Italy) and 11.00 (France and Greece); the time to run the clearing algorithm and to compute individual dispatching orders also varies from 15 minutes (Slovenia) to 6 hours (Greece -

[32] Prices have minimum intervals of 0.01 €/MWh; the smallest volume step is found in Italy (0.001 MWh) and the highest in Slovenia and France (1 MWh).

[33] Maximum prices of the order of 3000 €/MWh represent the value of lost load, rather than an attempt to limit price spikes.

Figure 3: Timing for the day-ahead auctions

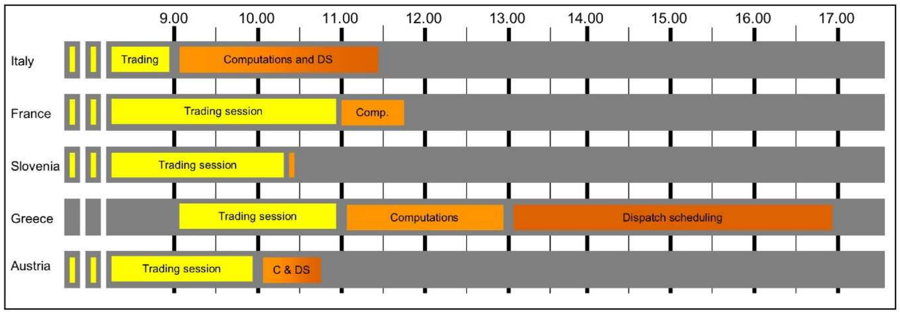
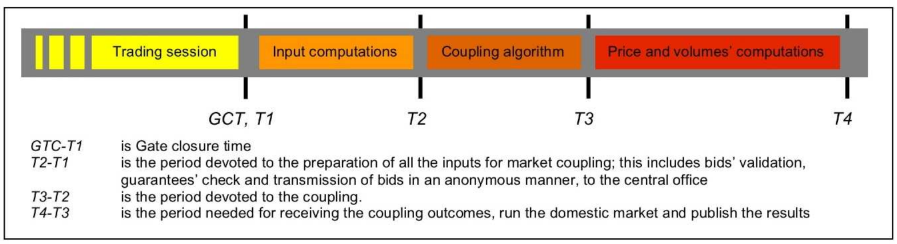


Figure 4: Generic timing of market coupling



where, actually, a unit commitment problem is solved).

A market coupling arrangement requires to synchronize at least in the following deadlines: (i) gate closure time: collection of demand and supply bids by all involved markets must end before the coupling algorithm is run; (ii) publication of domestic market outcome by each national PX: this must take place after the market coupling results are calculated. Figure 4 shows a generic timing for market coupling, divided in four steps: trading session, input computation (bids' validation, guarantees check, etc.), coupling algorithm, and computation of prices and volumes for each PX; as a reference, we recall that the computation time in TLC is 15 minutes.

In summary, on the one hand, harmonization of most of the above-mentioned market features, although critical for the functioning of real markets, does not seem to require specific or innovative solutions. Adequate agreements between different parties are, however, necessary and these might be difficult to reach. Differently, as discussed below, the harmonization of computation times is subordinated to more complex choices of market design.

4.2 Technical aspects

We discuss here three key design features of day-ahead auctions: transmission model, power plants constraints (i.e. traded products) and pricing rules; in turn, these pose relevant questions regarding the market clearing algorithm.

As for internal transmission constraints, Austria, France, Germany and Slovenia are single price markets; instead, Italy and Greece implement a zonal pricing approach. Congestions (and intra-zonal congestions), if any, are managed by the TSOs through redispatching. As for cross-border trade, all countries in the CS region (with the exception of Germany) share common rules for the explicit auctions that allocate cross-border capacity on a yearly, monthly and daily basis.[34] Arrangements for market participants to notify import-export schedules to TSO's are, however, not uniform and they will likely have to be revised, in some countries, as part of a harmonization process. Considering the neighboring regions, as of today, implicit allocation of cross-border capacity is carried out only at the France-Belgium border.

With respect to network modelling, a first important aspect is the use, in Italy and Greece, of locational prices to allocate the available domestic transmission capacity. Consider a price and volume coupling arrangement, with price areas that coincide with national borders. The main question is whether domestic market splitting would induce problems in terms of coherence of cross-border flows. To maintain an internal zonal pricing rule, national markets would need to separately run a market splitting algorithm and thus to recalculate the area prices which were calculated by the central coupling office; such a recalculation could lead to deviations between the final national prices set by the internal market splitting, and the prices calculated by the central coupling algorithm, from which cross-border flows are determined. The issue might be quite relevant also assuming a form of volume coupling (as mentioned in Section 2.3, the EMCC experienced unexpected deviations in flow and price calculations between the central coupling office and the PXs).

As indicated by the literature, additional issues would be worth exploring. For instance, a better zonal partition might exist, that does not necessarily coincide with control areas of national TSOs (finding the optimal zonal partition requires the solution of a combinatorial optimization problem). Moreover, a FB approach has the potential to better account for the real possibilities of the network (it might also introduce computational issues in clearing algorithms). Finally, both grid partition and computation of ATC values (or PTDFs) are better performed with an overall view of the entire network (in turn, this requires a higher centralization in grid management, and exchange of critical information than currently occurs in the CS region).

As for products traded on the day-ahead auctions, an important distinction can be made between markets that allow trading of hourly products only (for instance, Italy and Slovenia) and markets where both hourly and block orders can be traded (Austria, France and Germany).[35]

[34] An important consequence of market integration is a change in responsibility over cross-border capacity allocation between TSOs and PXs. Several legal aspects regarding the relationship between TSOs and PXs and, in particular, the contractual framework between the two, would need to be updated in order to consider the new regime and to cover new issues (shipping agent, data flows, payments and guarantees, etc.).

[35] Block orders are generally standardized and restrictions may apply on the number and volumes traded. For instance, on EXAA, 11 standardized products are traded and the maxi-

It is worth noticing that most markets enable trading of block and hourly products also in continuous day-ahead and intra-day markets. This practice, as well as the trading of financial products, does not appear to be incompatible with coupling day-ahead markets.

On the contrary, the presence of block orders complicates the clearing of electricity auctions. In addition to constrained continuous variables for hourly orders, a market clearing problem with blocks requires the inclusion of binary variables, in order to model all-or-nothing constraints on block orders. This leads to the formulation of mixed-integer optimization problems which are difficult to solve. In addition, with block orders (or, similarly, with multi-part orders), linear market clearing prices do not necessarily exist for an auction problem. This implies that a number of blocks can be paradoxically rejected: hourly clearing prices obtained when a block is rejected would give an average price, for the hours indicated in the block, that is higher than the price limit of the block (assuming that it was a supply-side order). Any coupling agreement would thus require the development of efficient heuristic procedures for the central clearing office, capable to provide optimal or nearly optimal solutions in viable computation times.

The solution implemented in TLC (a price and volume coupling arrangement) makes use of an iterative procedure between a Coordination Module and the different PXs; this approach would hard to extend to additional countries or more complex transmission models (currently, a radial network with the three countries lined-up). Moreover, a more efficient solution can be reached by implementing block constraints in a central solver algorithm (Dupuy, 2008; Meeus, 2006). This is also the approach proposed in the CWE MC project; however, it implies sharing more information with the central office. A third alternative is to implement a form of volume coupling which, instead, minimizes the amount of shared information.

A third design feature of the involved markets may have a significant impact on the coupling model: in Italy (and Greece) zonal prices clear the supply side of the market; differently, the price applied to power withdrawals is nationwide uniform, calculated as the weighted average of zonal prices (in Italy: PUN, Prezzo Unico Nazionale).[36] The issues introduced by this peculiar pricing rule are two:

- price deviations might arise between the central and national solutions;

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mum volume tradeable per block is 500 MW. On Powernext, participants have the possibility to submit block orders that link a minimum of four hours of the day together. Each trading day, the participants are allowed to submit a limited number of block bids and the maximum tradeable quantity is fixed at 100 MW per block.

[36]In Italy the PUN is applied only to withdrawal points in national geographic areas, thus excluding import and export orders that are traded at zonal prices. This is consistent with the idea that the PUN is a cross-subsidization method introduced for the benefit of national consumers and, for this reason, it should not concern trades that occur cross-borders (indeed, they are not included in the calculation of PUN). Similarly, in the Greek market, imports are paid the zonal price at the relevant interconnection. Therefore, these arrangements do not create discrimination as far as foreign trade is concerned.

- the time to run the local market clearing algorithms could be incompatible with market coupling: the market clearing algorithm implemented in Italy takes around 20 minutes to run, which would make it impossible for Italy to generate a full-information NEC in a time consistent with the functioning of a full-fledged coupling solution.[37]

The issues of price discrepancies and timing deserve further analysis. In fact, the PUN is a price that must fulfill, at the same time, two requirements:

- to be the weighted average of zonal prices;
- only demand bids whose price is not lower than the PUN are accepted.

To ensure that the above mentioned requirements are satisfied, the PUN cannot be calculated *ex-post*, as the weighted average of the zonal prices calculated by a 'pure' market splitting algorithm, but it needs to be embedded in the algorithm itself.[38]

A possible approach to the problem is the following. Assume that the Italian reference price for market coupling is the price of the Italian zone that is found on the border where the coupling mechanism is implemented (North zone for France, Switzerland, Austria and Slovenia, Brindisi zone for Greece). Therefore, the NECs that GME calculates are the curve describing the prices of these relevant zones with different quantities of import/export from/to the coupled market. To reduce the time of the computations these curves could be calculated by considering domestic congestion using a 'pure' market splitting algorithm.

Even in this case, at the end of the coupling process, when the GME algorithm is run and the PUN is calculated, minor price discrepancies may arise between the relevant Italian zonal price calculated by the market coupling and the zonal price calculated by GME. We can conjecture, however, that those price discrepancies might be rather small. First of all, the Italian NEC sent to the coupling office would embed the solution of domestic congestions. Secondly, demand is typically entered in the Italian market at prices far above equilibrium level (most often bids are at Value of lost load); as a consequence, most of the times the Italian PUN is equal to the weighted average zonal price that would

[37]Based on the information that the expected time to solve the unit commitment problem in Greece is around two hours, we guess that Greece would face a similar issue.

[38]Assume to run a market with two zones, A and B and assume also that by running a 'pure' market splitting algorithm the outcomes are: (i) 40 €/MWh in the zone A; (ii) 50 €/MWh in zone B. Suppose that the weighted average of the zonal prices is 48 €/MWh. Therefore, if the PUN were calculated *ex-post*, it would be equal to 48 €/MWh. In case we had a demand bid submitted in the zone A at a price that is higher than 40 €/MWh, but lower than 48 €/MWh, this bid would be accepted on the basis of the pure market splitting algorithm, but it would be forced to pay a price higher (48 €/MWh) than the one it was willing to pay. Vice-versa, if we had a demand bid submitted in the zone B at a price that is lower than 50 €/MWh, but higher than 48 €/MWh, this bid would not be accepted on the basis of the pure market splitting algorithm, even if the average price calculated *ex-post* is lower (48 €/MWh) than the one the consumer was willing to pay. Therefore, to avoid those paradoxical outcomes, the PUN cannot be calculated *ex-post* and the market splitting algorithm must be able to find a heuristic solution that detects the optimal PUN.

be calculated *ex-post* if GME used a 'pure' market splitting algorithm; for this reason, we don't expect differences in the equilibrium output determined by the central office and by GME.

4.3 Relevant remarks

This overview of national day-ahead markets in the CS region has identified several areas where harmonization is required to integrate electricity markets; even if difficulties may arise, differences in practical, organizational aspects of the current auctions do not appear critical.

Similarly, differences in market design do not appear to be an obstacle to a progressive market integration in the region; however, they pose extremely interesting questions for further research. Several solutions can be studied to represent network and machine constraints or to define prices in day-ahead auctions. In turn, these solutions have a different impact on the level of cooperation required to TSOs and PXs, the amount of information which they need to share, and the computational complexity of clearing algorithms. Conversely, the different degrees of complexity of these solutions can also guide the choice of the preferable coupling solution. For instance, if a large number of national features are to be maintained, the most viable solution for integration would be a 'loose' form of coupling (volume only). A higher harmonization of PXs, would make price and volume coupling the preferable solution.

Moreover, this comparative assessment has shown that the Italian market design stands out for rather uncommon choices in the CS region: the absence of block orders, a domestic market splitting, a peculiar pricing rule. Although these choices are not incompatible with market integration, they also lead naturally, in the short term, to prefer a form of volume coupling, if they are to be preserved as domestic-specific characteristics. Alternatively, viable coupling solutions could be proposed to neighbouring countries, which extend some of these choices to a multi-national market, whenever they can be proven more efficient and thus worth preserving. In any case, further work is necessary to identify the preferable course of action, by means of by robust analyses and evaluations.

Of course, the present discussion has neglected important issues: for instance, the obstacles derive from the fact that several countries in the CS region are already involved in other coupling agreements; likewise, the inter-temporal dimension of electricity markets. Some observations on the first issue were discussed in Section 2.3. With respect to the latter, we note that differences in market design are not limited to the day-ahead auctions but encompass all time-frames from day-ahead to intra-day and real-time trading. In a recent work, Smeers (2008) argues that the same market design should apply to all trading stages; we do not elaborate this question further and refer to his work for an exhaustive discussion.

5 Conclusions

This work has explored several aspects pertaining to the integration of electricity markets in Europe; focusing on the day-ahead time frame, it has highlighted several issues that are particularly relevant for Italy and identified directions for further work.

From the observation and characterization of existing and prospective multinational markets in Europe it emerged that, comparatively, the Italian involvement in the integration process is quite modest. Since a path of progressive coordination with foreign markets seems preferable to a scenario where more advanced projects simply extend their market design on latecomers, we suggested that market integration should receive greater attention by policy makers and market participants as well.

Moreover, a review of the properties of the current cross-border allocation scheme (an explicit auction) indicated the presence of several inefficiencies. Using simple market models it is easy to show that a welfare increase is attainable with an implicit allocation of transmission capacity. This result is more difficult to prove when realistic assumptions are made on generators' behavior and network structure. For this reason, we observed that an indication of potential efficiency gains of integration is more likely to come from numerical solutions of large scale market models rather than from theoretical work.

Finally, a comparative assessment of market design for the day-ahead auctions in the CS region identified areas were integration would 'simply' require a harmonization effort and areas where efficient solutions are to be defined. Important choices on domestic congestion management, traded products and pricing rules set Italy relatively apart from other European countries. Further work is thus necessary to identify a coupling mechanism that, while accommodating these differences, avoids unreasonable results in prices and volumes for the individual markets and makes a better use of the existing transmission capacity.

At least two relevant questions were not addressed in this work. First, a closer collaboration in market operation is expected to produce, across Europe, important modifications in the ownership and/or governance structure of PXs and TSOs. Second, the integration of day-ahead markets is expected to lead to the progressive integration of intra-day and real-time markets. We leave these aspects for further research.

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