The role of power exchanges for the creation of a single European electricity market: market design and market regulation

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Proefschrift

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The role of power exchanges for the creation of a single European electricity market: market design and market regulation

Le rôle des bourses d'électricité pour la création d'un marché commun Européen de l'électricité: design de marché et régulation

THESE POUR LE DOCTORAT EN SCIENCES ECONOMIQUES
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2004

Preface

The results of four years of research under the joint-supervision of the Delft University of Technology and the University of Paris IX Dauphine on the role of electricity power exchanges within the introduction of competition in European wholesale markets are presented in this thesis. The research was carried out at the faculty of Technology, Policy and Management at the Delft University of Technology in the context of the interfaculty research group Design and Management of Infrastructures (DIOC) in collaboration with the Center of Geopolitics and Raw Materials (CGEMP) of the University of Paris IX Dauphine. I owe thanks to many people for sharing their knowledge, for their cooperation and for their advice. I would like to thank some of them explicitly as without them this thesis would not have been completed as it is.

I am greatly indebted to my supervisors Margot Weijnen and Jean-Marie Chevalier. Margot was there at the origin of this project and provided me with the opportunity to come to the Netherlands to write this thesis. I would like to thank her for being confident in my ability to complete this project. Moreover I would like to thank her for her encouragement and constructive criticism throughout these four years. I would like to thank Jean-Marie for sharing his knowledge and being such a stimulating supervisor, with his inexhaustible enthusiasm for energy markets, he provided me invaluable guidance both from a theoretical and from a practical point of view.

I am fortunate in having worked with Rudi Hakvoort as my day-to-day supervisor. In following my day-to-day progress and providing comments on every single paragraph of this thesis, his intellectual contribution has been so significant, from the beginnings until the end, that I can hardly see how this thesis would have been completed without him. Thank you Rudi very much.

I am also very grateful to Jean-Pierre Chamoux who was part of this project from the beginning and reviewed several drafts of this thesis.

During my research I had the opportunity to work with a lot of people. To start with I would like to thank Denis Depoux and all the consultants from the Paris office of Hagler Bailly who offered me the unique opportunity to be confronted with the problems faced during the establishment of a power exchange in practice.

Furthermore, I owe many thanks to all the employees of the Dutch Office for Energy Regulation (DTe). In particular, I would like to mention my former colleagues of the Market Surveillance Committee staff, Cees van Gent, Martin Godfried, Gijsbert Zwart, Ingrid Seinen, Wong Tsai, Fieke Rijkers and of the Market Surveillance Committee, David Newbery, Eric van Damme, Nils-Henrik von der Fehr, and Wim Naeije. I really enjoyed working with all these people and this experience provided me with privileged insights into the functioning of electricity markets and the difficult task of monitoring these markets. Moreover, I would like to gratefully acknowledge Sylvia de Hoop from the Dutch Energy Regulatory office (DTe), Nathalie De Barstch from the French Energy Regulatory Commission (CRE) and Laurent Virassamy from the Amsterdam Power exchange (APX) for their research assistance in collecting data.

I would also like to mention all my “Ph.D. colleagues” at the interfaculty research group Design and Management of Infrastructures, Laurens De Vries, Ewoud Verhoef, Viren Ajodhia and Hamilcar Knops for the serious discussions and serious fun we had together during these four years of research at the TPM faculty.

I also want to thank Miranda Aldham-Breary who had the hard task of reading entirely two early drafts and who commented extensively the text to improve my English.

Finally, I would like to thank my family for their support and encouragement throughout all my years at school and university in particular during the four years in the Netherlands so far from home.

Merci à vous tous

François BOISSELEAU

Delft, January 2004

Contents

Chapter 1
Introduction

The electricity sector worldwide is undergoing a fundamental transformation of its institutional structure as a consequence of the complex interactions of political, economic and technological forces. The way the industry is organized is changing from vertically integrated monopolies to unbundled structures that favor market mechanisms. This process in Europe, known as the liberalization process, has had a wide impact on the European electricity industry. The focus of this dissertation is an analysis of the role of electricity power exchanges in the recently liberalized electricity markets of Europe. In the context of creating “a” competitive electricity market at a European level, the key questions considered are the functioning of these power exchanges with respect to electricity characteristics, market design and regulatory framework. The background to this research, the research objective and questions, and the research approach used are presented in this chapter. First the general features of the electricity industry are presented briefly as background for the analysis. The main aspects of the liberalization process of this industry and the role it has played in the creation of power exchanges is described. The research objectives and research questions are defined and the research approach used is outlined.

1-1 Background

1-1-1 The electricity industry

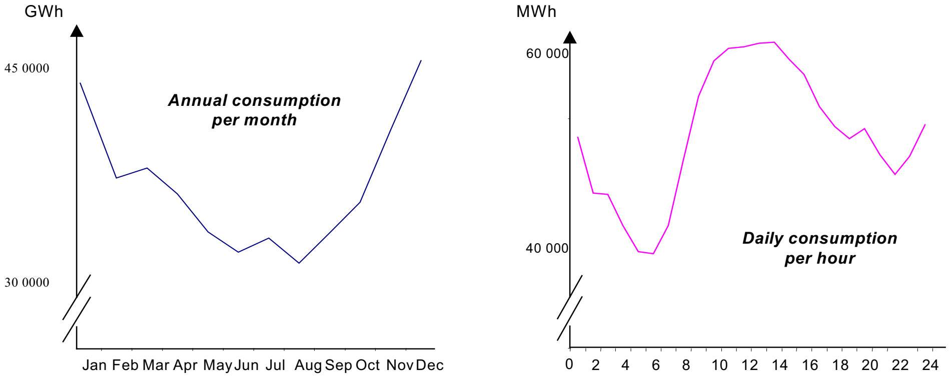
From a technical point of view, the electricity industry can be divided into three main parts: generation, transport and load. Electricity is generated by power plants. The transport consists of three different activities: transmission, distribution and system management. Finally, load corresponds to final consumption by end users. The electricity system is represented schematically in figure 1-1.

Figure 1-1: The electricity system

An important characteristic of the electricity industry is that **generation** (supply) and **final load** (demand) must always be kept in balance. Moreover since electricity is used continuously, this balancing of the system must be done at any time. This physical aspect of electricity plays a prominent role. Any shift in demand must instantaneously be followed by a similar shift in supply. In a general way, the demand for electricity varies on a temporal scale with respect to season, day of the week and hour of the day. Hence electricity consumption is higher during the day than during night and lower during weekend than during weekdays. Moreover electricity consumption may vary widely between summer and winter due to the use of heating and air conditioning systems. The seasonal variations in electricity consumption are illustrated in figure 1-2.

Generators exist in many sizes and forms, from small back-up generators to power stations large enough to provide a large city with electricity. The most common energy sources are fossil fuels, uranium and hydropower, but in principle virtually any energy source can be used to produce electricity. There is a growing contribution from renewable energy sources, such as wind and solar energy and biomass, but generally they only provide a small fraction of the total amount of electricity generated. Besides their size, the most important characteristics of generators are their reactive power generation capacities, their availability and the speed with which they can change their output. These four factors together determine the characteristics of a generator.

Figure 1-2: The seasonable variations of electricity consumption *(France 2001*)



Source: RTE (2001)

In addition, since electricity cannot be stored, the generation capacity needed to cope with peak demand is unused in periods of lower demand. This implies that some generators only run for a couple of hours per year. Secondly, reserve capacity is required to ensure security of supply when demand fluctuates at short notice and when supply faces shortages, outages, revision or maintenance. Finally, to guarantee security of electricity supply at least cost, generation needs to be ensured by different technologies. The different technologies explain the different cost structures. Hence, electricity generation is characterized by a merit order of generating plants.

The **transport** of electricity is realized through the grid. Transport on the high voltage grid is usually called transmission while transport on the medium and low voltage grid is defined as distribution. Transmission refers to transport over an interconnected network which is used by all parties. The transmission part ensures security of supply for the entire system, and distribution relates to smallest sub-systems. Transport is generally considered to be a natural monopoly, i.e. duplication of a network is wasteful.

The important feature of electricity transport is that flows follow Kirchoff's laws. Particular electricity flows from point X to point Y can not be identified. When generators make changes in their production, it impacts the entire interconnected system. Hence the failure of one generator can affect the stability of the entire system. For this reason accurate management of the system is fundamental.

Management of the system consists of balancing generation and load at any time and dealing with technical constraints such as transmission constraints. Managing the system consist of the coordination of electrical flow over the network to ensure that the system is continuously in equilibrium. This is achieved by controlling the power supplied and making sure it is equal to the power demanded at each part of the network. The management of the system is also known as ancillary services. These services are needed to maintain the reliability and security of the network.

For many decades the technical aspects of electricity supply were the determining factors of the industrial organization of the structure of the electricity industry. The electricity industry was organized as vertically integrated monopolies that combined the different activities within the same companies. The argument for such an organization was first that it was “physically” impossible to split up the different parts. Second, the economies of scale of production were prominent features that justified the existence of a unique entity. Third, the need for central control of production and transmission justified vertical integration. Finally, transaction costs after unbundling were too high.

Box 1-1: Basic technical definitions

Generator: an apparatus that converts primary energy into electricity. Primary energy sources can be hydrocarbons, nuclear energy, or sustainable energy sources such as wind, the sun, geothermal energy and biomass.

Load: any apparatus that uses electricity from the electricity network, varying from consumer appliances to industrial processes.

Transmission and distribution: both terms indicate a form of transport of electricity. Transmission typically indicates longer distances, for which higher voltages are used, while distribution indicates local transport to end-users. The transmission and distribution systems are networks, which are designed as much as possible to have multiple routes connecting any two points to enhance system reliability. As a result, it is not line capacity but network capacity that is the determining factor.

Dispatch: operating instructions for generators to increase/decrease their production.

Ancillary services: compensation for power losses, management of reactive power and voltage and frequency support.

1-1-2 The reasons for liberalization of the electricity industry

The motivation for electricity liberalization differs slightly between countries, however most of the countries share common ideological and political reasons regarding disaffection with the vertically integrated monopoly model of the past and a strong belief that the success of liberalization in other industries can be repeated for the electricity industry. The introduction of competition in the electricity industry has been justified by the perceived benefits of introducing market forces in an industry previously viewed as a natural monopoly with substantial vertical economies. Therefore the motivation behind electricity liberalization is to promote in the long run efficiency gains, to stimulate technical innovation and to lead to efficient investment (Chao and Huntington, 1999).

Liberalization requires that the market is not dominated by natural monopoly characteristics. Changes in generation technologies (Hunt and Shuttleworth, 1996; Hunt, 2002) and improvements in transmission (Joskow, 1998; Stoft, 2002) have removed the natural monopoly character of the wholesale power market.

The case of the electricity industry is especially interesting because since the beginning of the nineteen nineties economies of scale have ceased to be the rule in the generation portion of the industry. For many years, the generation part of the electricity industry was considered to be a natural monopoly because of the economies of scale that could be obtained by using large power plants, and until the early nineteen eighties, the optimal size of generating units increased continuously. Indeed, for some fifty years the trend was for larger power plants. Then came new technologies like the combined cycle gas turbine (CCGT) and the optimal plant size for electricity generation fell dramatically. These smaller and cheaper generating units have removed the natural monopoly characteristics of generation and allowed the introduction of competition at the wholesale level. This revolutionary change has had a central and important impact on the barriers to entry in this industry, which has led to changes on its industrial organization.

Even if the changes in generation technology have reduced significantly the minimum efficient scale of generators, the improvements in information technologies with respect to transmission operation have played the most important role in creating a separate competitive wholesale market. Indeed, technological progress in aggregating physical flow and in the operation of large networks dispersed over wide geographic areas with a very high level of accuracy has played the most important role separating generation to transport.

1-1-3 The liberalization process in Europe

The objective of the European liberalization process is to open gradually electricity markets to competition to improve the general efficiency of the electricity industry which in turn will improve the efficiency of the European economy as a whole. With a total annual production of 2500 TWh and 150 billions Euro of annual sales ($210 Billions in the US), the electricity industry is one of the most important of Europe's industries (EC, 2000a). This sector is critical since it has an impact on all other sectors because electricity is vital for all economic activity. Electricity can represent up to 60% of the total costs for certain large consumers such as chemical and aluminum factories. Hence, in a competitive world context, the competitiveness of European industry is strongly linked to the competitiveness of its electricity industry.

Liberalization of the electricity industry was part of the tools chosen by the European Community to ensure its energy policy objectives, i.e. security of supply, competitiveness and environmental protection. The origins of this approach go back to the Treaty of Rome (1957) which instituted the common market, and to the Unique Act (1986). The opening to competition of the electricity industry happened later than in other industries, where the aim was to create a single European market by 1992. The 1990 Directives 90/377/EC and 90/574/EC concerning the transparency of electricity prices for industrial consumers and the transit of electricity represent the first steps toward the liberalization of the electricity industry.

The liberalization process really started in Europe in 1997 with the Directive 96/92/EC (hereafter the Directive). This Directive defines common rules for the gradual liberalization of the electricity industry within the scope of the concept of a unique European market as defined in 1985. The Directive was the result of several years of negotiation between the European union Member States. It defines common rules for generation, transmission and distribution of electricity. With regard to the opening of national markets, the Directive sets minimum thresholds for a gradual opening (EU, 1996). The Directive prescribes the separation of monopoly elements from potentially competitive segments. The idea is that controllers of the monopoly part (mainly the network) should not be able to use their market power to abuse their position in the other stages of the industry. The stated intention of the liberalization process was not to achieve the creation of fifteen liberalized national electricity markets but one common

European electricity market as part of the EU's single market general objective (EC, 1999).

The Directive 96/92/EC is silent on the arrangements and institutions that need to be put in place concretely to facilitate the creation of an integrated European electricity market. It has been argued (Bergman *et al*, 1999) that the highest priority of the European Commission was to encourage cross-border trade and eliminate discriminatory practices without going into precise details of market design. While this order of priority appears understandable, in practice the organization of trading arrangements and markets institutions constitutes a fundamental issue for the creation of a common market.

This lack of guidelines has lead to a wide range of trading arrangements in each Member State. Some governments have been directly implicated in the creation of market institutions, while others have left this task to private initiatives in the market. This freedom has resulted in the creation of different kinds of markets. The emergence of organized markets in contrast to bilateral markets represents a major step within the liberalization process and their effect on competition within the electricity industry has not yet been studied. Such a study constitutes the purpose of this dissertation.

1-1-4 Context of the research: the emergence of electricity power exchanges

Liberalization of the electricity industry has created a need for organized markets at the wholesale level (Bower and Bunn, 2000). Two main kinds of organized markets have emerged: power pools and power exchanges. The differences between the two models can be explained by using two criteria[1]: initiative and participation (table 1-1).

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[1] See chapter 2 for more details on the differences between power pools and power exchanges

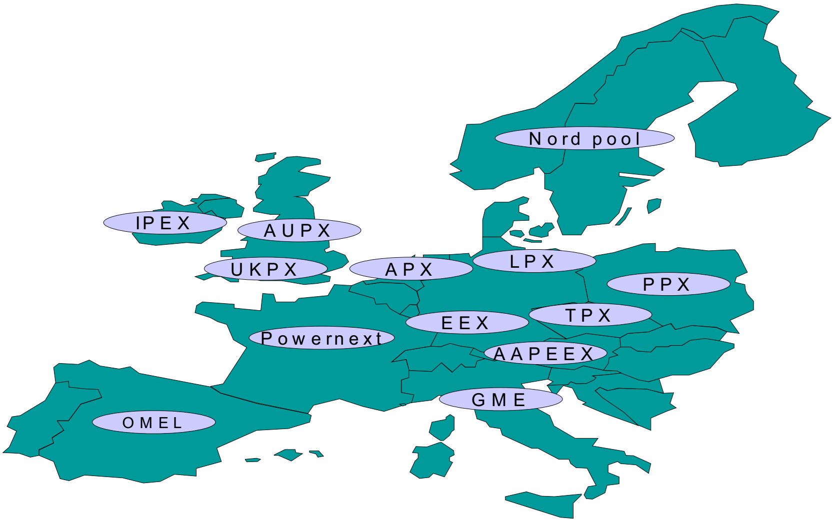
Table 1-1: Basic differences between exchanges and pool

	Power Exchange	**Power Pool**
Participation	Voluntary	Mandatory
Initiative	Private	Public

A power pool is the result of a public initiative, i.e. a government wants to implement competition at the wholesale level, and participation is mandatory, i.e. no trade is allowed outside the pool. The England and Wales's pool, as it existed before the New Electricity Trading Arrangements (NETA), was a typical example of this model. A power exchange is commonly launched on a private initiative, for instance by a combination of generators, distributors and traders, and participation in the exchange is voluntary. Nowadays the second model appears to be preferred by market players. Indeed, with the exception of the current Italian project, all recently developed organized markets (Netherlands, Germany, France, and Austria) are based on the power exchange model. Because this is now the most prevalent system, the analysis is based upon this model. To illustrate the fast spread of the development of power exchanges figure 1-3 shows the location of the major existing power exchanges in Europe and table 1-2 contains an historical chronology of the creation of organized day-ahead markets.

A power exchange (PX) is a competitive wholesale trading facility for electricity. Spot trade at an exchange is completed the day before delivery. This allows both the market participants and the transmission system operator (TSO) a reasonable timeframe for arranging the physical aspects of delivery. The genuine role of a power exchange is to match the supply and demand of electricity to determine a public market-clearing price. A developed power exchange can also provide a market for electricity derivatives like futures and options. Participants include generators, distribution companies, traders and large consumers.

Figure 1-3: Power exchanges in Europe (2001)



More than 60% of the power supply within Europe was opened to competition by the end of 2002, but this figure hides important differences between countries. The estimated traded volume in Europe was higher than 4000 TWh in 2000. Depending on the country between 2 to 90 % of this volume was captured by the power exchange.

Table 1-2: Creation of organized day-ahead markets in Europe

Country	Date	Name
England and Wales	1990-1999	Electricity pool
	2001	UK Power Exchange (UKPX)
	2001	Automated Power Exchange (AUPX)
	2001	International Petroleum Exchange (IPE)
Norway	1993	Nord pool
Scandinavia	1996	Nord pool
Spain	1998	Omel
Netherlands	1999	Amsterdam Power Exchange (APX)
Germany	1999-2000	Amsterdam Power Exchange (APXDE)
	2000	Leipzig Power Exchange (LPX)
	2000	European Power Exchange (EEX)
Poland	2000	Polish Power Exchange (PPX)
France	2001	Powernext
Austria	2002	Austria's Alpen Adria Power Exchange (AAPEX)
Italy	2003?	Gestore Mercato Elettrico (GME)

While one of the main objectives of the liberalization process is to ensure long-run efficiency, short-run markets are critical for sending the proper signals for long term investment decisions, e.g. in transmission and generation (Joskow, 1998). Hence, there is a need to design adequate short-run markets to achieve long-run efficiency gains. For this purpose power exchanges, which facilitate short term trading, represent an important tool for ensuring the creation of competitive electricity markets at the wholesale level.

1-2 Research objective and questions

1-2-1 Research objective

In Europe, very little attention has been paid to the role of these new marketplaces and to the issue of market design in general. Hence the main purpose of this work is to analyze how these marketplaces facilitate the trading of electricity and the role they can play in the construction of a pan-European competitive electricity market. Since the development of these marketplaces is a very recent phenomenon almost no academic work has been done on this topic in Europe. However, countries like the United States, the United Kingdom and the Nordic Countries, which started the liberalization of their electricity industry at the beginning of the nineteen nineties, have greater experience with market organization. For this reason, the liberalization process has been studied more and an important set of literature is available that has been developed by university researchers from Harvard (Hogan *et al*), Berkeley (Borenstein *et al*), Stanford (Wolak *et al*), MIT (Joskow *et al*), Cambridge (Newbery *et al*), Oslo (Van de Fehr *et al*) and many others. One important objective of this work was to use and adapt the theoretical concepts developed by these economists to analyze the role of power exchanges that have recently been created in Europe.

An analysis of power exchange requires taking into account the "double-duality" of such institutions. First, power exchanges are both a market and an institution. As a market they facilitate the trading of electricity and determine an equilibrium price. As an institution power exchanges have their own objectives and constraints, and play a role in the market design of the overall electricity market. Second, the relationship between electricity power exchanges and liberalization is not linear or one way: liberalization encourages the birth of such marketplaces but marketplaces are not only the results of, they are also a driving force of the liberalization process.

To begin, the willingness of many countries, and of the EU community, to liberalize the electricity market was a determining factor for the emergence of power exchanges. This is the classic idea that a market organization is preferable due to the inefficiency of regulation (Scherer and Ross, 1990). The impassioned debate between economists to prove which kind of organization, market or hierarchy[2], is the best one has not yet given, and will certainly never give a definitive answer. To date, comparisons between the two systems have been largely speculative. However, there is a large agreement that in specific segments of the value chain, market forces can function as the best coordinating system. Then when the choice to develop a market for a portion of the value chain has been made, the issue is to establish the best market design.

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[2] In institutional economics hierarchy is defined as a central organizational structure, i.e. an integrated firm, in contrast to decentralized markets. *"Markets and firms are alternative instruments for completing a related set of transactions; whether a set of transactions ought to be executed across markets or within a firm depends on the relative efficiency of each mode"* (Williamson, 1975)

With the exception of Nord pool, all the present power exchanges in Europe have been created since 1999. For this reason little academic work has been done concerning these particular entities which combine institutional and market characteristics. Therefore the objective of this project was to:

> *Use the tools of industrial organization to explain the emergence of electricity power exchanges in Europe, their functioning, and their role and impact with regard to the creation of a single competitive European electricity market.*

1-2-2 Research questions

In spite of the clear objective and reasons for liberalizing electricity markets, many fundamental problems remain. The first results of liberalization have shown the difficulty of implementing competition in an industry previously organized as a monopoly. In the United States, the meltdown of the electricity market in California has showed the risk of restructuring markets. Two of the most important institutions in this market went bankrupt while a third has been deeply restructured. About ten court cases have been filed, dozens of blackouts have taken place, and the increase in energy bills is estimated to be about $50 billion (Joskow, 2001). At the same time, New York saw prices spike at over $5,000/MWh in 2000. The UK pool which was long cited as an example of restructuring was declared a failure and all of its market rules have recently been replaced. These initial problems do not prove that liberalization is doomed but show that accurate design of the market is a fundamental issue.

The study of electricity power exchanges is at the heart of economics theory and especially of industrial economics since its main purpose is to answer the question: What is the most efficient industrial organization? The research questions can be divided in three categories. The first deals with theoretical aspects of market functioning and market design with respect to the liberalization of the electricity industry and the emergence of power exchanges. Given the double nature of power exchanges, i.e. market and institution, the research questions must address both aspects. The second category of questions looks at power exchanges as organized markets where supply and demand meet. Finally the focus of the third category of questions is on power exchanges as institutions within the design of the overall electricity market.

Part 1: Theoretical approach and the emergence of power exchanges

(1) What are the reasons for the emergence of power exchanges?
(2) What is market design?
(3) How to analyze competition?

Part 2: Power exchanges as marketplaces: the functioning of a power exchange within the context of the liberalization of the European electricity industry

(4) What are the relationships between the functioning and price formation mechanism of a power exchange?
(5) What are the relationships between the design and participant's behaviors on a power exchange?
(6) What is the impact of power exchange on competition?

Part 3: Power exchanges as institutions: What is the role of power exchanges with respect to the design of a competitive European electricity market?

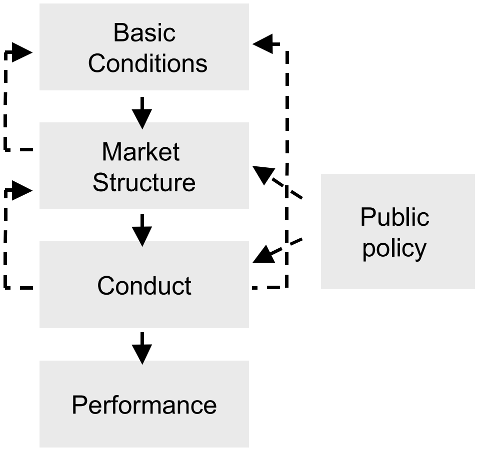
(7) What is the impact of power exchanges on market integration at the European level?
(8) How can power exchanges provide solutions for technical problems?
(9) To what extent can power exchanges facilitate the creation of a European electricity market?

1-3 Research approach

1-3-1 The SCP paradigm

The structure-conduct-performance (SCP) paradigm appears to be a relevant approach to analyze the role of power exchange in electricity markets and more generally to address their role within the context of market liberalization and market integration. The SCP paradigm is one of the most famous and robust approaches in the field of industrial organization. This paradigm has been used in the United States for many years for the determination of best public policy, which has as its objective to maximize the performance of markets as closely as possible to ideal policy standards.

Figure 1-4: The SCP paradigm



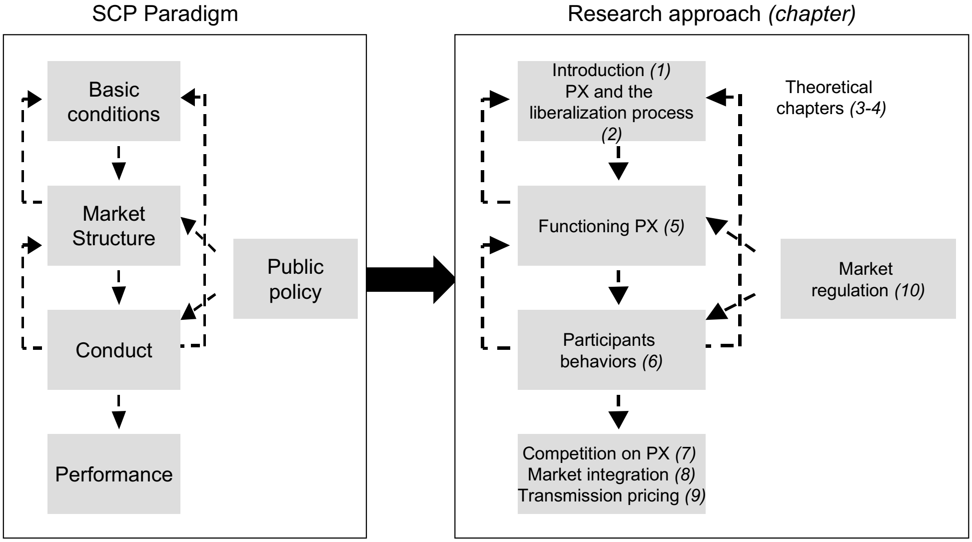
In the nineteenth century, Cournot (1838) and Marshall (1890) founded the basis of this approach with their first microeconomic models of perfect competition and monopoly. Economists like Mason (1939; 1949) and Bain (1951; 1956) developed these works to a large extent. The result of this research, also known as the *Harvard school*, states that the performance of industries is significantly correlated with the market concentration level and the level of barrier to entry. During the seventies and the eighties, among others, Stigler (1957; 1971), Demsetz (1967; 1968) and Brozen (1971), known as the *Chicago School,* critiqued the SCP paradigm. One important result of these criticisms has been the introduction of basic conditions in the paradigm, which affect the structure of the industry. Based on these studies they developed the SCP paradigm (figure 1-4), which sheds light on the relations between structure, conduct and performance, and takes into account the basic conditions within the industry in question.

The central concern of the SCP approach is market performance since it represents the outcome that affects consumers directly. Performance is a general term for naming all market outcomes, e.g. level of production, prices, employment etc. The key concept of this paradigm is that market performance is determined by the conduct of market participants, which is in turn determined by market structure. Conduct can be defined as the behavior of market participants. The indicators of conduct are pricing policies, marketing strategies, research and development, investment legal tactics and so on. According to the SCP paradigm the conduct of market participants is constrained by the structure of the market. The most important variable of the market structure is the number and size of sellers and buyers. The least competitive structure is defined by the monopoly model, i.e. one supplier, and the most competitive one by the perfect competition model, i.e. atomistic structure. Others variables like barrier to entry, product differentiation, cost structure and vertical integration represent important aspects of the market structure. Economists from the *Chicago School* introduced the role of basic conditions on market structure to take into account variables like technology, legal framework, price elasticity, substitutes etc. Finally, based on this paradigm, policy maker, may intervene regarding market structure and players conduct to ensure high performance using for instance tools like taxes and subsidies, trades rules, regulation, and antitrust legislation.

1-3-2 An adaptation of the SCP paradigm

Our research approach is based on an adaptation of the SCP paradigm. This adaptation was necessary to take into account the nature of electricity power exchanges. The SCP paradigm was developed to analyze industry, however in this dissertation the objective is not to look at the electricity industry as a whole but to focus on the wholesale market and in particular on the role electricity power exchanges play in the market. Thus the SCP paradigm was adapted as shown in figure 1-5. Such an approach allows us to be consistent and to take advantage of the SCP paradigm with respect to the objective of the research.

Figure 1-5: Research approach



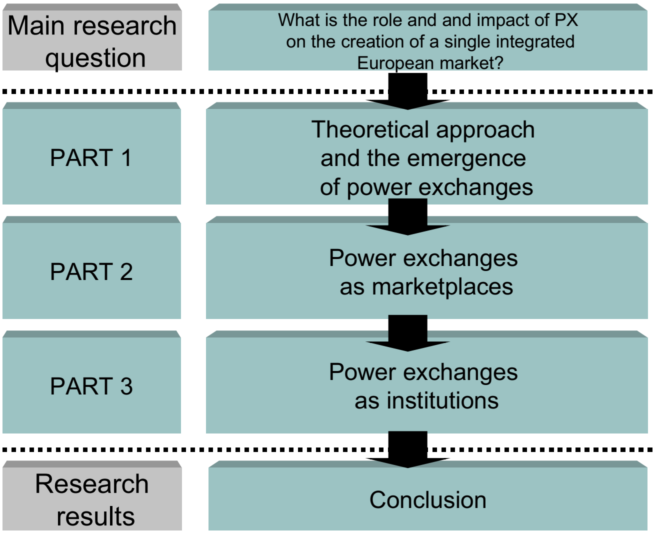
1-4 Thesis structure

1-4-1 Summary

This thesis is divided into three parts (figure 1-6). The current situation in Europe and different existing theoretical approaches in the literature are presented as a starting point for the analysis in **part 1** of the thesis. The EU legal framework of the liberalization process, the role of electricity trading and the emergence of power exchanges is presented first (chapter 2). In this chapter we define a model including power exchanges which will be used as an analytical framework for the analysis. The theoretical concepts that will be used for the analysis are presented in the following two chapters. First, the different theoretical approaches of market design are presented (chapter 3). Then the economic theory models of market functioning and their application to electricity markets are discussed (chapter 4). This description led us to divide the analysis into two parts: power exchanges are organized market places (part 2 of the thesis) and power exchanges are institutions which are part of the global wholesale market design (part 3 of the thesis). In part 1 of the thesis it is shown that the emergence of power exchanges in Europe is a fundamental aspect of the actual design of European wholesale electricity markets and that existing theoretical literature provides guidance for the analysis, but that literature applied to the European situation is rather limited.

In **part 2** of the thesis power exchanges are considered as marketplaces with a specific type of functioning (chapter 5) which in turn involves interaction from participants (chapter 6). Finally the concrete output of these interactions is analyzed using empirical observations to estimate the level of competition on power exchanges (chapter 7). The main contribution of part 2 of the thesis is to provide a primer on the functioning of power exchanges in Europe which differ from other organized electricity markets and which have so far received little attention. Looking at the electricity markets at the European level, it can be seen that most power exchanges have been designed separately and that they have been designed to function at a national level. Keeping in mind that the objective of the liberalization process in Europe is to create a single electricity market, the results derived in part 2 of the thesis become the starting point for part 3 of the thesis in which we analyze if such a piecemeal process resulted in the creation of a single integrated electricity market.

Figure 1-6: Thesis structure:



Part 3 of the thesis begins with an empirical estimation of the level of integration of European electricity markets. The level of integration is estimated using an econometric test based on power exchanges prices (chapter 8). Such an analysis shows a low level of market integration at the European level. In the next step of the analysis an attempt is made to explain the reasons of such low market integration. The hypothesis developed is that the actual wholesale market design at the European level lacks efficient transmission pricing (chapter 9). We then present some different theoretical approaches of transmission pricing (Nodal/Zonal) and an analysis of actual successful examples of integrated markets (PJM, Nord pool). We conclude by providing some empirical evidence of inefficient transmission pricing in Europe. Finally we argue that the creation of an integrated market requires design at the European level rather than national market design (chapter 10). We present the positive points and drawbacks of the recent works realized by the European Commission and other European bodies such as the European Association of Transmission System Operators and Council of European Energy Regulators. Finally, we emphasize the importance of "market" regulation through monitoring market design developments with a

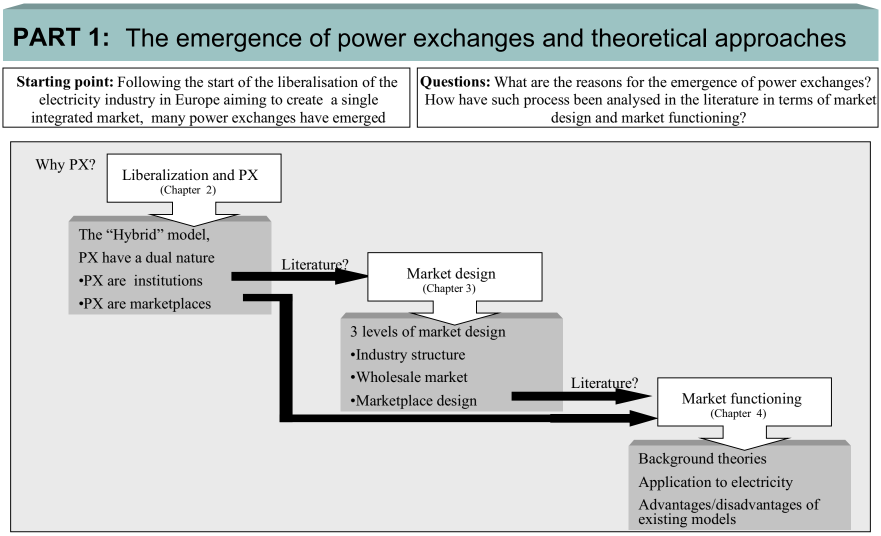
particular attention to market power concerns. The objective of this part is to show that design is a major missing piece of the European liberalization process and especially that the issues of transmission pricing and market power, while fundamental in the creation of competitive electricity markets, have been widely overlooked. The concrete output of this part is a definition of the main principles of a “European framework for market regulation” emphasizing the role of power exchanges through several recommendations for a step by step approach to the creation of an integrated market.

1-4-2 Content of part 1: The emergence of power exchanges and theoretical approaches

Part 1 starts with a description of the EU legal framework of the liberalization process and the role of electricity trading in the emergence of power exchanges. First, the main aspects of the EC treaty and of the electricity Directive 96/92/EC are discussed. Developments in the implementation of the Directive are analyzed in terms of third party access, market opening and unbundling. Second the roles of electricity trading in general, and of power exchanges specifically, are outlined. Third, the reasons for the emergence of power exchanges and their differences with power pools are presented. This chapter concludes with a definition of an analytical framework of wholesale electricity markets, ”the hybrid model”, which will be used as a reference in the rest of the thesis. This model sheds light on the double nature of power exchanges, i.e. power exchanges are organized market places and power exchanges are institutions which are part of the global wholesale market design (chapter 2).

In chapter 3 the concept of market design is introduced and a distinction is made between the three levels of market design: industry structures, wholesale market design and marketplace design. We present the different possible industry structures. The different design controversies concerning wholesale market design are analyzed. Finally the last section concludes with the different possibilities relative to the design of electricity marketplaces. The last level of market design, market place design, sheds light on the importance of rules that govern the concrete functioning of an organized market place (chapter 3).

Figure 1-7: Structure of part 1



Subsequently, we focus on economic theory models of market functioning and applications to electricity markets. For this purpose, in this chapter we provide an overview of the alternative market models in economic theory (chapter 4). Reference models of perfect competition and monopoly are briefly presented. Second, oligopoly models are examined. Third, fundamentals of electricity markets, i.e. supply and demand, are defined. Fourth, applications to electricity markets and recent works are discussed. Finally the strengths and weaknesses of models for the analysis of power exchanges are analyzed. The objective of this chapter is to describe background theories, how they have been applied to electricity markets and their interests and limits for the analysis of power exchanges.

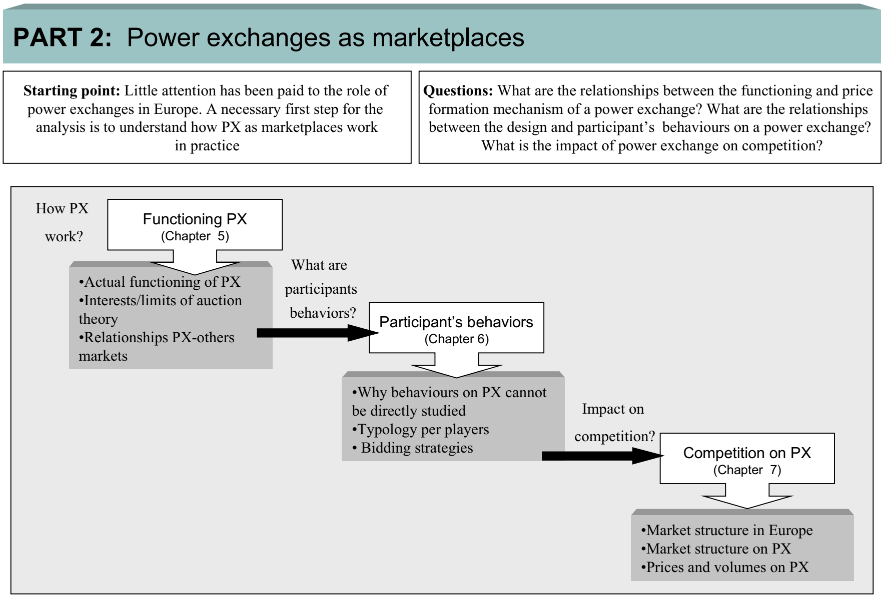
In part 1 we show that the emergence of power exchanges in Europe is a fundamental aspect of the actual design of European wholesale electricity markets and that existing theoretical literature provides guidance for the analysis but that literature applied to the European situation is rather limited.

1-4-3 Content of Part 2: Power exchanges as marketplaces

In part 2, the objective of the first chapter (chapter 5) is to provide a detailed description of the functioning of power exchanges or, more precisely, of power exchanges' spot market. While in practice differences exist between power exchanges in Europe, some general common principles can be identified. Hence the general description given in this chapter can easily be applied to the Nordic exchange (Nord pool), the Dutch exchange (APX), the British exchange (UKPX), the German exchange (LPX-EEX) and the French exchange (Powernext). This chapter starts with a general description of trading on a power exchange. Second, the different types of bids and the price determination processes are presented. Third, the relevance of auction theory for the understanding of power exchanges is analyzed. Fourth, the issue of physical delivery of trading on a power exchange is addressed. Finally the interactions between power exchanges and other markets, such as the bilateral market or the balancing market, are presented.

Once the functioning of power exchanges is well known, the natural following step according to the SCP paradigm is to analyze the behavior of participants on the market place (chapter 6). This chapter starts with an overview of firms' behavior in economic theory and in electricity markets in general. The limits of these approaches for the analysis of power exchanges as marketplaces are then discussed. Second, a typology of trading behaviors depending on the nature of participants is provided. Third, bidding behaviors, which represent concretely how players interact on the power exchange, are described. Finally two examples of specific bidding related to marketplace design are presented. This chapter shows the complexity of analyzing individuals behaviors and a basic framework for such an analysis is provided.

Figure 1-8: Structure of part 2



While individual behavior is not directly observable it is possible to look at the effect of this behavior on competition. In this chapter (chapter 7) we start with the traditional approach for analyzing competition, i.e. analysis of market structure. Two types of market structure are analyzed: market structure in generation and interconnection, market structure in power exchanges. Such an analysis shows the existence of different types of market structures at national levels, a low level of interconnection between countries, and important differences between the "physical" market structure, i.e. generators and the "commercial" market structure, i.e. participants on the exchanges. Finally competition on power exchanges is estimated using the analysis of price and volume development on the different exchanges.

The main contribution of part 2 of the thesis is first to provide a primer on the functioning of power exchanges in Europe which differ from other organized electricity markets worldwide, and which have received little attention to date.

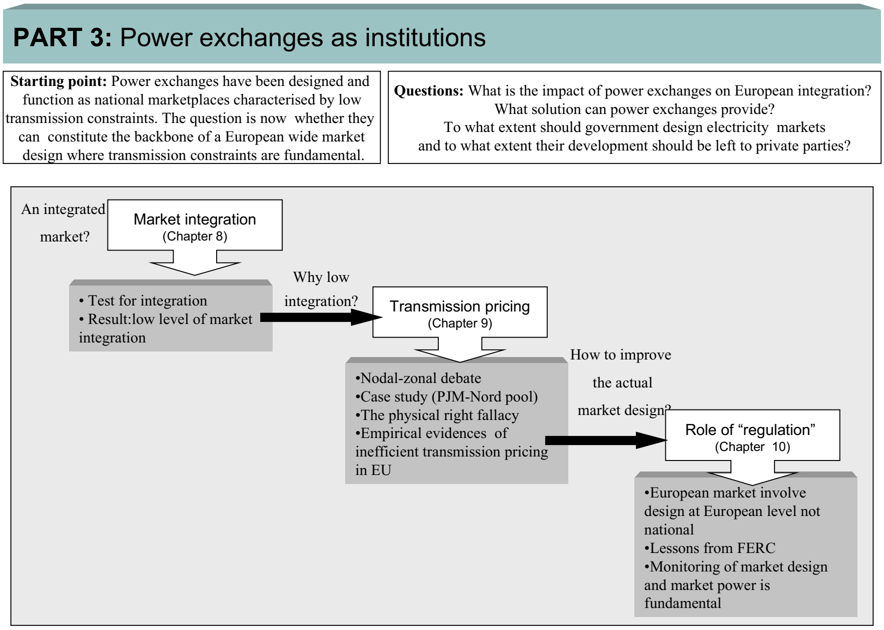
Second, when looking at the European level, part 2 shows that most power exchanges have been designed separately and have been designed to function at a national level. Keeping in mind that the objective of the liberalization process is to create a single electricity market, the results presented in part 2 are used as a starting point for part 3 which analyzes if such a piecemeal process resulted in the creation of a single integrated electricity market.

1-4-4 Content of Part 3: Power exchanges as institutions

In part 3 of the thesis, the role of power exchanges within the global design of a competitive wholesale electricity market at the European level is analyzed. Amongst the different economic motives for the integration of national electricity markets, special attention is given to the issue of market power which is a major concern in electricity markets. Indeed, chapter 7 has shown that market concentration is large in many national markets, hence we focus on the expected role of market integration in market power mitigation. Then, to determine whether the actual electricity market at the wholesale level constitutes a single economic market, price correlation is used. Two econometric analysis are done using power exchanges prices taken from five main European markets (United Kingdom, France, Germany, Netherlands, and Nordic countries). The first analysis is a simple price correlation analysis. Due to the drawbacks of such approach a second analysis using regression methods was carried out. The two analyses show a low level of market integration at the European level (chapter 8).

The next step of the analysis provides an explanation of the reasons for such low market integration. The hypothesis developed is that the actual wholesale market design at the European level lacks efficient transmission pricing. We first emphasize the importance of transmission constraints in electricity networks. While at national levels dense grids have allowed most European power exchanges to be designed ignoring transmission constraints, at the international level the existence of important bottlenecks make this issue critical. Different theoretical approaches of transmission pricing (Nodal/Zonal) as well as the study of actual successful examples of integrated markets (PJM, Nord pool) are presented. Using these two examples we identify possible lessons for the European market, amongst them it appears that an efficient transmission pricing mechanism is a fundamental cornerstone. The last part of this chapter consists of a discussion of the inadequacy of the actual transmission pricing mechanisms between European countries and provides some empirical evidence of inefficient pricing. For this purpose we compare the cost of transmission between locations, based on the result of auctions for interconnector capacity, with the differences in prices between the locations, based on power exchanges prices. This analysis shows that both from a theoretical and from an empirical point of view the actual transmission pricing mechanism is inefficient and is a fundamental yet missing piece of the actual market design (chapter 9).

Figure 1-9: Structure of part 3



PART 3: Power exchanges as institutions

Starting point: Power exchanges have been designed and function as national marketplaces characterised by low transmission constraints. The question is now whether they can constitute the backbone of a European wide market design where transmission constraints are fundamental.

Questions: What is the impact of power exchanges on European integration? What solution can power exchanges provide? To what extent should government design electricity markets and to what extent their development should be left to private parties?

- Test for integration
- Result:low level of market integration

- Nodal-zonal debate
- Case study (PJM-Nord pool)
- The physical right fallacy
- Empirical evidences of inefficient transmission pricing in EU

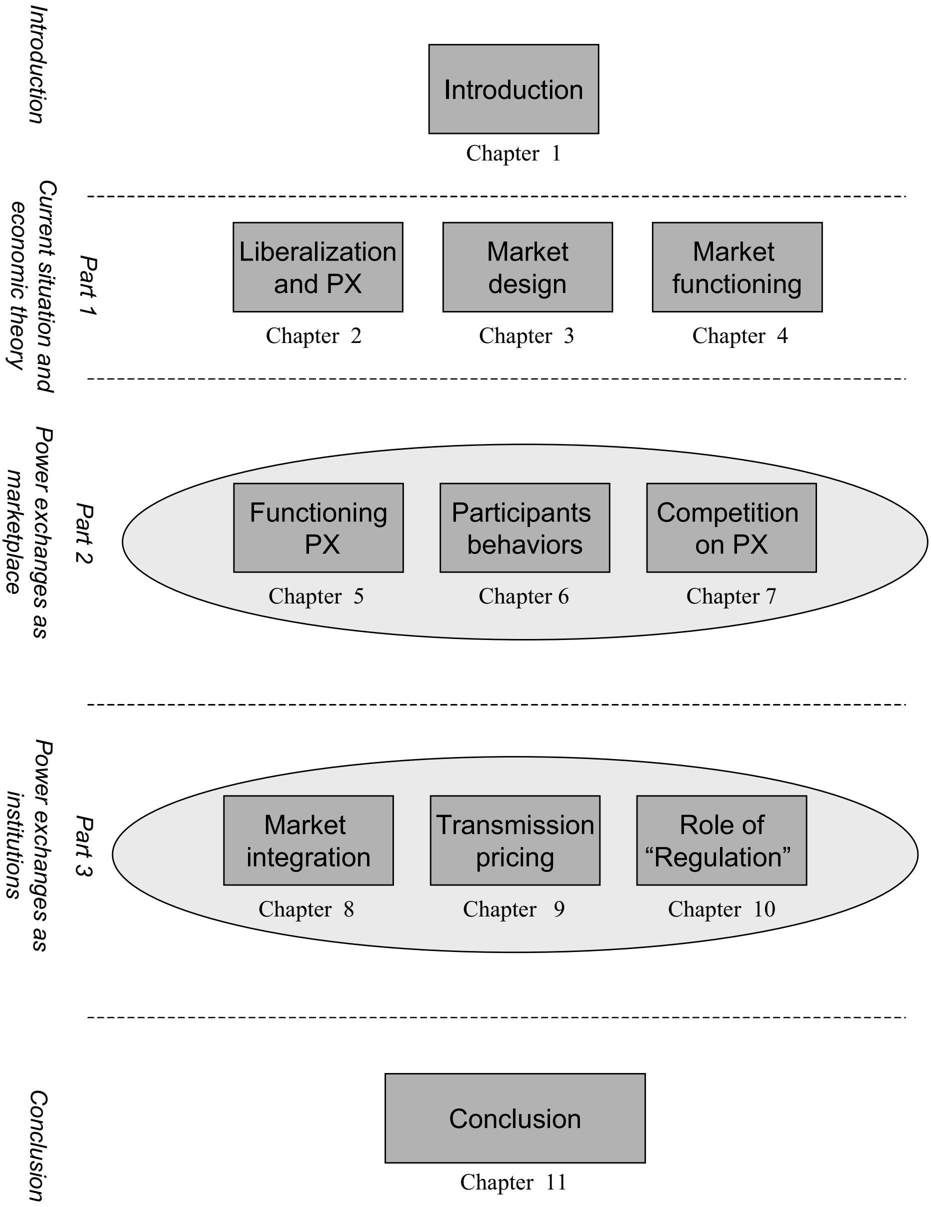
- European market involve design at European level not national
- Lessons from FERC
- Monitoring of market design and market power is fundamental

Based on the results presented in chapter 9 we argue that the creation of an integrated market requires design at the European level rather than national market design. We emphasize the importance of monitoring market design developments with a particular attention to market power concerns. Subsequently, we present the positive points and drawbacks of recent work realized by the European Commission and other European bodies such as the European Association of Transmission System Operators and the Council of European Energy Regulators with respect to transmission pricing. Finally we present some guidelines for the creation of a “European market design framework” with particular attention given to the role of power exchanges (chapter 10).

The contribution of part 3 of the thesis is to prove, based on empirical analysis, that the actual European electricity market is not integrated and that actual transmission pricing mechanisms are ill suited for an integrated market. Based on economic theory and practical experiences we demonstrate that the actual market design is unlikely to support the creation of a single integrated market. We argue that such a situation is due to the fact that the “European” market is a patchwork of nationally designed markets. An important result of the work presented in this thesis is the demonstration of the importance of market design at the European level rather than at national levels. The important output of part 3 is the definition of the main principles of a “European Market Design framework”. Such a framework emphasizes the role of power exchanges for the creation of an integrated European electricity market at the wholesale level.

1-5 Thesis overview

Figure 1-10: Thesis overview



Chapter 2

The liberalization process and the development of power exchanges

The EU legal framework of the liberalization process and the role of electricity trading with respect to the creation of a single European electricity market are presented in this chapter. First, the main aspects of the EC treaty and of the electricity Directive 96/92/EC are discussed. The developments in the implementation of the Directive are analyzed in terms of third party access, market opening and unbundling. Then the role of electricity trading in general and of power exchange specifically is outlined and the reasons for the emergence of power exchanges and their differences with power pools are presented. Finally, an organizational model of the European electricity markets, including power exchanges, is presented. The different types of markets, the role of the transmission system operator and allocation methods for interconnector capacity, are delineated in the model based on practical historical developments.

2-1 The European legal framework

2-1-1 EC Treaty

The trading of electricity in Europe is subject to the general rules of the EC Treaty. This Treaty has been amended several times but electricity, and energy in general, has not been one of its main concerns. The origins of the EC Treaty trace back to the Treaty of Paris[1] which was signed in 1951 and which laid the foundations for a supranational coal regime with the establishment of the European Coal and Steel Community (ECSC). Following this Treaty, the European Atomic Energy Community (EAEC) was created with the Euratom Treaty[2]. The ECSC and the EAEC were responsible for the common coal and nuclear policy. The European Economic Community (EC) was established in 1957 with the Treaty of Rome[3]. The objective of the EC was to create a common market. The EC Treaty included additional provision for agriculture and transport but nothing about energy and *a fortiori* for electricity. The process toward a common market was accelerated in 1987 with the entry into force of the Single European Act[4], which amended the first three Treaties and established the objective of an internal market by the end of 1992. Finally, further amendments were made in the Treaties of Maastricht[5] (1992) and Amsterdam[6] (1997). In general electricity is subject to two main principles of the EC Treaty. One, electricity is subject to the rules governing the free movement of goods, persons, services and capital. Two, the electricity industry is also subject to the EC competition law, in particular those provisions related to cartel and market abuse.

In 1985, the creation of an internal electricity market was regarded as too difficult to pursue by the European Commission (McGovan *et al*, 1989). This view changed in 1988 when the Commission presented a communication on the

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[1] Treaty establishing the European Coal and Steel Community (1951), 261 UNTS 167

[2] Treaty establishing the European Atomic Energy Community (1957), 298 UNTS 167

[3] Treaty establishing the European Community (1957), 248 UNTS 91

[4] The Single European Act (1987), OJ L 169

[5] Treaty on the European union, OJ C 224 1 (1992), 31 ILM 247

[6] Treaty of Amsterdam, OJ C 340/01 (1997)

internal energy market[7]. The general principles of a single European "internal market", rather than many separate markets for goods and services, were established in the Single Electricity Act (EU, 1987). In this document, the single market is defined as the backbone of economic integration. The aim of the single market is to increase European economic growth by opening up national markets to competition, and thus improve overall competitiveness and raise standards of living. Following this general document, the European commission published a working document on the internal energy market (EC, 1998) which was explicitly aimed at fully integrating the separate national electricity markets throughout Europe.

The conditions for price transparency towards large electricity and gas consumers are defined in 1989in the Directive 90/377/EC. This Directive was the first step toward the liberalization of the electricity industry. However this price transparency Directive was too weak to create competition in the electricity sector. The European Commission then decided to establish a new Directive containing stronger measures. This was done through the electricity Directive 96/92/EC.

2-1-2 The EU Directive 96/92/EC

The EU Directive 96/92/EC[8] (hereafter the Directive), liberalizing the electricity sectors within EU members States was agreed in 1997, after nearly ten years of debate. The EU directive defines common rules for the generation, transmission and distribution of electricity (articles 1-2-3). The Directive covers the gradual establishment of a single internal electricity market by opposition with 15 liberalized national electricity markets[9]. First, Member States are obliged to open their national electricity market at least a minimum share of it. This means that eligible customers must be able to choose their supplier. The generation activity is totally free to promote competition as is the construction of transport lines.

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[7] EC Commission: the Internal energy market, COM (88) 238

[8] Directive on common rules for the internal market in electricity 96/92/EC OJ L27 of 30.01.1997

Finally the operation of the transmission network has to be independent from generation and distribution, at least in management terms, in order to insure transparency of the market and avoid discrimination.

The Directive removes the monopoly any incumbent may have for the construction of new power plants to promote full competition in the generation sector. The Directive gives two options for member states between, an *authorization* and/or *tendering* procedure for the construction of new generating capacity (articles 4-5-6). Under the first option, member states have to define public criteria and procedures. Then companies willing to build new power plants have to go through an open and impartial procedure to decide whether they are allowed or not, to build their unit. Under the second option, a specific authority designated by the Member State defines the needs for new investments and solicits tenders. The tenders are then assessed using an impartial procedure.

In relation to transmission (articles 7-8-9), each Member State must directly specify (or require undertaking which own transmission to do so) a transmission operator and the main role of the system operator is defined, i.e. generation dispatch and determination of the use of the interconnectors. This part of the Directive implies that the system operator must dispatch power plant on a non-discriminatory basis between incumbents and new entrants. The goal of separation between generation and transport is to insure transparent and fair access to the network in order to avoid discrimination and cross-subsidization between consumers (eligible and captive).

Distribution must follow the same principles as transmission with regard to non-discrimination (articles 10-11-12). The Directive specifies that, in particular cases, the tariff to supply customers may be regulated. The important difference for distribution is that Member States may impose requirements on distribution companies in order to meet specific public service obligations. Even if this notion

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[9] European Commission (2001), *Completing the internal energy market*, March 2001

is not clearly defined it must fall into three categories: security of supply, quality/price of supply and environmental protection.

Given the call for separation of activities, the Directive also mandates unbundling and transparency of accounts (articles 13-14-15). Hence, companies with generation, transmission and distribution activities must present a separate balance sheet for each activity. The objective of this accounting unbundling is to avoid any cross-subsidization between different type of activity.

The central aspect of the Directive is the model of third party access (articles 16-17-18). The idea is that owners of the network are obliged to allow producers and consumers to have access to their network to trade in accordance with the objectives of transparency and non-discrimination. The Directive includes three models: negotiated third party access (nTPA), regulated third party access (rTPA), and the single buyer model. In the first model (nTPA), consumers and producers must be able to negotiate access to the network with the system operator. For this purpose, the system operator had to publish, in the year following the implementation of the Directive, average access prices for the previous year as a guide to potential new players. In the second model (rTPA), the prices for accessing to the network are regulated and not subject to negotiations. Prices must be publicly available. The system operator may refuse access to the network for technical reasons but such a refusal must be supported by a valid explanation of why access was refused. Finally, in the “single buyer model” a nominated entity acts as the only purchaser for all electricity[10]. This model was included after pressure from France to support competition in electricity generation. The member states were free to choose amongst the different models.

The Directive specifies the extent of market opening (article 19), this is defined as the percentage share of the electricity market that should be opened to

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[10] See chapter 3

competition and defines thresholds for market opening (40 GWh by 1999, 20 GWh by 2000 and 9 GWh by 2003). These thresholds represent minimum requirements for market opening of 26% in 1999, 28% in 2000 and 33% in 2003.

Box 2-1: The New Directive 2003/54/EC

On 26 June 2003, the European Commission published Directive 2003/54/EC concerning common rules for the internal market in electricity, and Regulation No 1228/2003 (See Box 10-1). The New Directive is required to be implemented into national law not later than 1 July 2004 and the Regulation is applicable from that date. Directive 2003/54/EC replaces Directive 96/92/EC, which paved the way for liberalization of the electricity markets of European Community Member States. This Directive establishes common rules for the generation, transmission, distribution and supply of electricity. The Directive, which amend and recast the earlier electricity Directive, includes provisions for the legal unbundling of the transmission and distribution system operators, consumer protection and the establishment of independent national regulatory authorities. Moreover, the new Directive aims to reduce the risk of market dominance and predatory behavior and to ensure non-discriminatory transmission and distribution tariffs and network access. Furthermore, it establishes provisions for the unbundling of transmission and distribution operators and establishes labeling requirements for electricity suppliers regarding CO2 emissions and radioactive waste from electricity production and the contribution of each energy source in a supplier's fuel mix. The major changes in the new Directive are the following:

Article 3:
Public service obligation is enlarge to universal service obligation, i.e. all consumers should have the right to be supplied with electricity at a reasonable, easily and clearly comparable price.
Articles 4-5:
Members States shall monitor security of supply.
Articles 6-7:
Members States no longer have choice between different approaches for new generating capacity, they must apply an authorization procedure. However if it does lead to sufficient capacity, the tender procedure can be use as a backup. Moreover, tender can be also use for renewables.
Articles 8 to 12:
Stricter unbundling is required for transmission system operators, in particular TSOs need sufficient decision rights to decide on new investments. TSOs are responsible for "balancing".
Article 20:
Third party access (TPA) must be regulated. Moreover national regulators have to approve at least the methodology of price setting.
Article 21:
Full market opening by July 2007.
Article 23:
Member states have to introduce a regulator. Amongst other things, regulatory authorities will be responsible for fixing or approving the methodologies used to calculate or establish the terms and conditions for connection and access to networks, including distribution tariffs.

2-1-3 The implementation of the Directive 96/92

The Directive was implemented into national legislation using different approaches and different paces (Hancher, 1997). However the most important options of the Directive were chosen in a similar way throughout the Members States resulting in similar arrangements (Bergman *et al* 2000, Glachant 2001). In this section we focus on three major aspects of implementation of the directive: third party access, market opening and the transmission system operator[11].

Third party access (TPA) is one of the important points of the EU Directive. Hence it offers three ways to insure non-discriminating conditions for access to the network: regulated third party access (rTPA), negotiated third party access (nTPA) and the single buyer procedure. With the exception of Germany which choose nTPA, and Portugal and Italy who opted for the single buyer procedure, all countries have chosen rTPA. Moreover, the countries that have chosen the single buyer model are now moving toward rTPA.

Members States have opened their market to different extents. Some countries like the United Kingdom, Germany, Sweden and Finland have opened their market at 100%. Spain, Italy, Belgium, The Netherlands, Denmark and Luxembourg have opted for an opening schedule, that is much more rapid than that imposed by the Directive. Finally, Greece, Ireland and France have opened their markets to meet minimum requirements. The level of market opening achieved in 2002 is illustrated in figure 2-1. The first bar gives the level of opening of markets in 2002 while the second and third one gives the situation for 2003 and 2007 according to current plans of the Member States. Such figure shows the important differences between Member States in terms of market opening.

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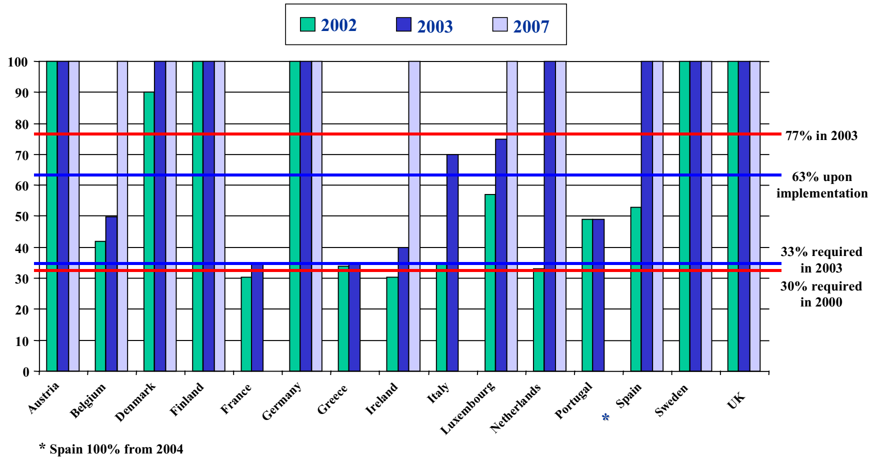
[11] The shortcomings of these indicators are discussed in chapter 10. For instance, while the German market is totally open by law and the French market open at the minimum threshold, in France it is quite easy to have access to any eligible customer while in Germany it is much more complicated for new entrants. This is due to the complexity of German's transmissions fees, stand-by charges and exit fees, most of which require negotiation.

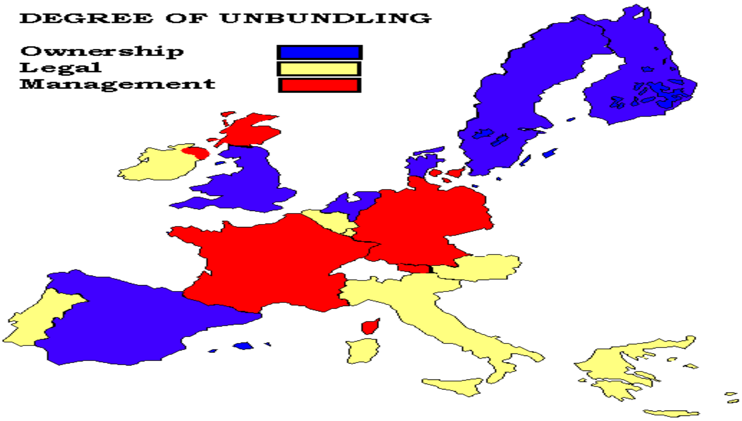
Figure 2-1: Market opening 2003



Source: European Commission, 2003

Since the autonomy of transmission system with respect to producers was an essential condition for compliance with the obligation of transparency and non-discriminatory access to the grid, most Members States have created an independent transmission system operator (TSO). However, the level of autonomy differs and can be differentiate in three categories: ownership, legal and management. Thus, the United Kingdom, Finland, Sweden, Spain, Denmark, Austria, the Netherlands, Portugal, Greece, and Italy have appointed a separate legal entity as the transmission system operator. Belgium, Germany, and France have appointed TSO, which are independent in management terms. In France, the TSO has management autonomy while in Germany the unbundling is limited to separate accounting (figure 2-2).

Figure 2-2: Unbundling



Source: European Commission, 2003

These three aspects, third party access, market opening and unbundling, represent the main criteria for implementation of the directive. It is interesting to note that while article 2 of the Directive defines a large number of concepts like for instance, generation, transmission or ancillary services, the term market is not defined. The Directive 96/92/EC grants a lot of freedom to Members States with respect to market organization. The Directive only lays down the general conditions that should be in place to assure the creation of a single electricity market but refrains from designing a concrete market organization (Schulte-Beckhausen, 2001). The Directive dictates the main principles for the development of competition through vertical separation (i.e. unbundling) of previous integrated monopolies, remove barrier to entry into production and distribution etc but leaves each country with the freedom to decide modalities and to design their electricity markets in details. Hence, the European Member States are radically changing the structure of their electricity industries following the Directive without strong guidelines on how to organize the details of their markets.

The second report from the Commission to the European Council and the European parliament on the state of the energy markets recognized that the directive only provided a general framework for the creation of a single market but that the creation of trade facilitating mechanisms is essential for the success of market liberalization. However no indications were given about the design of such "trade facilitating mechanisms" nor for the trading of electricity in general[12].

2-2 The role of electricity trading

2-2-1 Electricity as a commodity

In Europe, without any specific recommendations in the Directive the choice has been made to use an "energy only"[13] approach for electricity. Hence, as for any product, trading in electricity consists of the buying and selling of electrical energy. Trading in electricity has existed since utilities companies were formed, the main difference between trading in electricity then and now is that consumers are free to choose between suppliers. Finally, since electricity cannot be differentiated, all electrons are physically the same, it is defined as a commodity.

This "commodization" of electricity applies mainly to the wholesale level. The wholesale market for electricity can be seen as the direct result of the separation between transport and production. This new status as a commodity has led to the development of novel types of contracts for electricity trading. These contracts can either be sold on the bilateral market or on an organized market. They can also be physical contracts (for delivery) or financial contracts (hedging). However, all of the contracts share four characteristics: a defined period, a defined amount of electricity, a defined location and a price. Other characteristics can differ widely. For the purpose of this chapter we will focus on the physical

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[12] The different draft amendments of the Directive from the European Commission and related works of the association of system operators (ETSO) and the association of regulators (CEER) are discussed in chapter 10.

[13] In contrast to markets where energy, transport and ancillary services are considered (e.g. markets which take into account capacity cost and spinning reserve). In "energy only" markets, players bid only energy prices. The primary income source for recovery of capacity cost is the difference between the market price and the generators' marginal costs. When ancillary services are procured separately, generators can earn additional revenue like capacity payments.

trading of electricity, as opposed to financial trading.

2-2-2 Physical trading

The physical contracts can differ between long-term i.e. from one year up to ten, forward i.e. using current or forecast price with delivery in the future, and spot i.e. very short term, mainly day ahead. Since electricity cannot be stored, this range of contracts is necessary to keep supply and demand in balance. Consumers buy in advance using long-term and forward contracts to cover their consumption. Nevertheless, players also need additional daily, and even hourly, contracts to fulfill their consumption requirements because real consumption is not completely predicable.

Table 2-1: Trading volumes, 1999-2000

	Total trading volume, TWh			Trading as a multiple of physical consumption	
	1999	**2000**	**% Change**	**1999**	**2000**
Nordic region	1364	2072	52%	4.0	5.9
Germany	220	972	342%	0.5	2.0
UK	401	655	63%	1.2	1.9
Spain	168	181	8%	1.0	1.0
Netherlands	26	79	200%	0.3	0.8
Italy	4	10	150%	0.01	0.04

Source: Prospex Research Ltd

In most European countries, these contracts are negotiated on a bilateral basis, however due to the transaction cost related to spot trading, spot markets are usually organized by a power exchange. It does not mean that spot trading cannot occur on a bilateral basis, but that for this kind of contract power exchanges are generally preferred by market participants. In most countries power trading is growing at an impressive rate. The Nordic region so far is the most important in terms of absolute volume. In this region, the total volume traded represents more than five times the physical consumption in 2000. Nevertheless, the traded volumes within others European countries, such as Germany, the United Kingdom and the Netherlands are increasing very quickly (table 2-1). The aggregate of these volumes may soon overtake the Nordic market.

2-3 The emergence of power exchanges

The nature of electricity does not allow the possibility of true electricity spot markets, i.e. markets for immediate delivery (IEA, 2001). However, organized electricity markets such as power pool and power exchange are substitutes for a real-time spot market. In this section we identify the origins of power exchanges, which can be explained by looking at power pools. Power pools and power exchanges share many characteristics and drawing the line between these two categories of marketplace is confusing[14]. Hence, the differences between power pools and power exchanges are explained and finally an analysis of the reasons for the emergence of power exchanges is provided.

2-3-1 The forerunner of power exchanges: power pools

The term “electricity power pools” has a different meaning with regard to electricity markets and neither a standard definition nor a clear distinction are available in the literature. In this section we identify the main characteristics of a pool contrasting them with those pertinent to power exchanges described in the next section. We identify two categories of power pools: technical pools and economic pools.

“Technical” pools or “generation” pools have always existed. Vertically integrated utilities used a pool system to enable a better central optimization of generation with respect to cost minimization and optimal technical dispatch. These technical pools have been used for years by integrated utilities. In such a system the power plants were ranked on merit order based on costs of production. Hence, generation costs and network constraints were the determining factor for dispatch. Trading activities were limited to transactions between utilities from different areas. Long-term contracts for export were the principal trading activity supporting international trade, a weak level of interconnection capacity however limited this activity.

“Economic” pools (hereafter power pool) have been created to facilitate competition between generators. Hence they have mainly been created as a public initiative by governments willing to introduce competition in generation. This system has been used worldwide. For instance, in England and Wales, Spain, California, Alberta, Chile, Argentina and in the United States in Pennsylvania, New Jersey and Maryland (PJM) where the power pool system has been promoted as a good way to achieve competition and to implement liberalization.

The most important characteristic of power pools is that they take into account numerous technical characteristics, like for instance availability of power plant and unit commitment. Hence, players in a pool can only be generators. The existence of side payments is a fundamental aspect of power pools (box 2-2) and represents one of the main differences between a power exchange as defined below and a power pool. In a pool, generators bid based on the prices they are willing to run their power plants and on others variables. Because power pools attempt to take into account a lot of technical aspects, bids to power pool are very complex. This means that due to the nature of the bids submitted to power pools the price determination mechanism involves a complex optimization calculation leading to a low level of transparency.

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[14] For instance, the most famous power exchange is called “Nord pool”

Box 2-2: The first organized marketplace: The England and Wales power pool

The English/Welsh pool was created in 1990, on a basis of privatization, creating a system to permit trading for wholesale power. The pool was a compulsory day-ahead last price auction with non-firm bidding, capacity payments for plant declared available and firm access rights to transmission. Electricity was bought and sold on a half-hourly basis. The pool was a one-sided market because including sellers was considered to be impossible. Hence, the system operator estimated the demand for each half-hour. Each bidder submitted a whole schedule of prices and quantities. The unconstrained system marginal price (SMP) was defined by the intersection of the half-hourly forecast demand with the aggregate supply function provided by generators. The price paid to generators i.e. pool purchase price (PPP), was the SMP plus a capacity payment. The capacity payment came into play when there was a significant loss of load probability (LOLP) on the system, in other word when the market was tight i.e. super peak periods. The LOLP was calculated from the margin between available capacity and forecast demand. The price paid by the supplier i.e. pool selling price (PSP), was calculated by taking into account the actual production of generators per half-hour period together with additional cost for ancillary services and system constraints.

In addition to the pool, generators and suppliers usually signed bilateral financial contracts to hedge against the risk of pool price volatility. These contracts called contract for differences (CfD) specified a strike price and volume. These contracts were settled with reference to the pool price. If the pool price was higher than the agreed price on the CfD, the producer paid the difference to the consumer, if it was lower, the customer paid the difference to the producer.

The pool faced many criticisms. Price setting was extremely complex requiring at least nine different bid parameters, involving a rulebook of over six hundred pages, to describe the price calculation methodology. Capacity and availability payments rewarded generators for making plants available, not for operating them. Bids were not cost reflective due to the existence of baseload “ must run” plants, which were bid for a zero price. The lack of transparency in the price determination process put consumers at disadvantages when negotiating forward contracts cover against pool prices. The non-firm nature of the day-ahead market transferred costs and risks of plant failures from the generators to the customers, through energy uplift payments. The participation on the demand side was limited to a few very large industrial consumers. The pool was replaced by the New Electricity Trading Arrangement (NETA) in 2001 as a result of the deficiencies outlined above.

2-3-2 What is a power exchange?

An electricity power exchange provides a spot market, mainly day-ahead, for electricity, which like any other market matches demand and supply for each hour, while providing a public price index. It can be viewed as a competitive wholesale spot trading arrangement that facilitates the selling and buying of electricity (Skytte, 1999). Power exchanges are “ energy only market” since they do not take into account any technical aspects like transmission constraints or capacity payments. Hence power exchanges are defined for a region (or hub). Bids on an exchange only contain quantity and prices for a particular period. An exchange is absolutely neutral toward the market because its rules apply to both sides of the transactions. A power exchange is therefore a voluntary marketplace in competition with the classic bilateral market also called over the counter (OTC).

Competition in an electricity power exchange’s spot market occurs by generators, distributors, traders, and large consumers submitting bids for buying and selling electricity. Each sale bid specifies the quantity and the minimum price at which they are willing to supply the energy. Conversely, each buy bid specifies the desired quantity and the maximum price at which they are willing to buy the energy. The power exchange matches supply and demand along with publishing a market-clearing price[15].

In practice, there are some overlaps between the characteristics of power pool and power exchanges. For instance, the California power exchange was mandatory during the first three years in order for it to develop liquidity (Calpx, 1999). The Nord pool, is a voluntary exchange at the national level but is mandatory for cross-border trade[16]. In the Netherlands the Amsterdam power exchange is a voluntary power exchange but is mandatory for players who obtain

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[15] See chapter 5

[16] See Nord pool, www.nordpool.no/eng/htm

interconnector capacity on the daily auction[17]. Table 2-2 shows the main differences between a “ pure” power pool and a “ pure” power exchange.

Table 2-2: Characteristic of power pools and power exchanges

	Initiative	Participation	Participants	Demand Participation	Type of Bid	Bilateral market	Side payments
Power Pool	Public	Mandatory	Generators only	No	Price/Quantity /capacity/unit commitment...	No	Yes
Power Exchange	Private	Voluntary	Generators, Traders, Large consumers, Distributors	Yes	Price/ Quantity	Yes	No

2-3-3 Why power exchanges?

In countries where no “official” power pool has been set up, different kinds of privates entities, e.g. generators, distributors, traders, large consumers, stock exchanges, system operator etc or a combination of them, have promoted the creation of power exchanges. The idea is that because electricity is a homogeneous product, standardized contracts can be traded on organized marketplaces. Since such an initiative was not forbidden by any law or by the European Directives many project have emerged in response to different motivations.

Market participants, generators, distributors, traders and large consumers, have expressed the need for organized marketplaces to facilitate short term trading and reduce transactions costs for this type of trading. First they were looking for a place where they could buy or sell electricity at any time. Second, market participants wanted a transparent price index for benchmarking their bilateral transactions and hedging purpose. Third, power exchange represents another option for electricity procurement. Fourth, the existence of an anonymous

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[17] See chapter 5

marketplace is an important advantage in a competitive environment since players do not have to reveal their position to any other market participant. Finally, power exchanges reduce credit risk since all transactions are covered by the exchange's clearinghouse.

Stock markets are another type of party who are motivated by the creation of power exchanges. Their knowledge of stock trading and especially of commodity trading can be leveraged for electricity trading. The motivation here is financial, they see trading of electricity as a new kind of service that they can offer. Moreover, the ultimate goal for these institutions is to develop financial trading based on the spot market because volumes of financial trading (as in Nord pool) can largely exceed physical consumption, which means important commissions for the marketplace.

Finally, from a system operator point of view, power exchanges also present interesting advantages. By aggregating spot transactions, power exchanges are a clear interface for economic transactions. Instead of having to deal with a lot of small spot bilateral contracts, the system operator only receives aggregate supply and demand from the power exchange. Moreover, like in Scandinavia, power exchange can help to solve technical problems[18]. For instance, power exchange can provide solution for congestion management. Finally, the system operator may also use the power exchange for its own needs (transmissions losses).

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[18] See chapter 9 for detailed description.

Box 2-3: The first power exchange: Nord pool

Nord pool is a power exchange open to all players in the Norwegian-Swedish-Finnish-Danish electricity market. It began in Norway then was extended to neighboring countries. It operates under a license that gives it the right to organize the trading of electricity. In contrast to the England and Wales pool participation is voluntary allowing players to choose between the power exchange and bilateral trading. There were 281 participants in the different markets operated by Nord pool in 2000. Nord pool operates a combination of four markets.

Elspot is the physical day-ahead spot market. Prices are determined in a double auction system (supply and demand) for each hour of the day. This price is used as the reference price for settling financial power contracts but is also used as a benchmark for bilateral transactions.

Elbas is a short-term physical delivery market. It allows players to adjust their position (taken previously on Elspot) during the day right up to two hours before delivery. It allows players to reconsider their position after the result of the spot market.

Eltermin is a financial market for electricity, which does not involve physical delivery. This market is used for risk management and allows players to trade futures and forward contracts. Futures contracts are settled daily while forward contracts are settle at the end of the contract. The contracts have different time horizons, i.e. days, weeks, seasons, and years. This allows participants to hedge price risks for up to three years.

Eloption is a financial market for options. This market complements Eltermin by offering other kind of financial products.

The success of Nord pool can be explained by four factors. First the industry structure is very fragmented. The largest player in the market owns less than 25 % of production assets. Such a structure obviously facilitates competition. Second, large amount of hydropower allows storage and flexibility in production. Third the structure of the network is relatively simple compared to continental Europe, which facilitate widely congestion management. Finally the level of collaboration between system operators, governments and regulators is very high in contrast to the many conflicts of interest between continental European countries.

2-4 The "European" model: a hybrid model

2-4-1 Historical developments in Europe

The creation of organized electricity markets such as power pool and power exchanges started in Europe in **England and Wales** in 1989. The liberalization process in England and Wales was not guided by European Directives but by the then established government of the United Kingdom led by Margaret Thatcher (Vickers and Yarrow, 1991). The main motivation for this reform was the low performance of the existing system based on a monopoly structure (Green and Newbery, 1992; Green, 1996; 1998). The UK Electricity Act (1989) defined the basis of this reform. The two main aspects consisted of removing the Central Electricity Generating Board (CEGB) previously a vertically integrated monopoly for both production and transport, and the creation of the Pool (see box 2-2). Three companies were created: National Power, Powergen and Nuclear Electric. The pool began operating in 1990 and was the first organized market for wholesale electricity in Europe. The British experience provides an essential reference, it was the first one to undergo market restructuring and it remains the most radical in scope (Nicolas, 1998). In March 2001, the Pool was abolished and replaced by the New Electricity Trading Arrangements (NETA). Just before the introduction of NETA, several power exchanges were expected. In June 2003, only two were active, the automated power exchange (APX) and the United Kingdom power exchange (UKPX).

In January 1991, **Norway** implemented an electricity market reform following the decision of the Norwegian Parliament (Hjalmarsson, 2000). The main principle of the reform was to separate the different parts of the electricity value chain to differentiate functions that had a natural monopoly character from functions, which could be open to competition (Midttun, 1997). Hence, functions that had a natural monopoly character (transmission and distribution) become subject to specific regulation, while others were open to competition (production and trading). A market for physical and financial trading was created. One of the main differences with the UK Pool was the optional character of the spot market

(Shuttleworth and McKenzie, 2002). **Sweden** and **Finland** adopted similar market reforms to Norway in 1996. The Nordic power exchange was then created regrouping the three countries. In 2001, the market share of the Nordic power exchange's spot market was approximately 25% of the total annual Nordic consumption (380TWh).

With strong national political support, **Spain** was the first continental country to create an organized market for electricity (Arocena, 1998). In 1997, the Electric Sector Act and Royal Decree 2019/97, created the market operator Compania Operadora del Mercado Espanol de Electricidad (OMEL) to manage the electricity market and run the organized market. This organized market is officially called a power exchange, however the existence of capacity payments means this market falls into the power pool category (Shuttleworth and McKenzie, 2002). The Spanish electricity market began operation in January 1998, with day-ahead trading. The Spanish power "exchange" is directly run by the system operator. It operates day-ahead trading and intra-day trading for adjustments. The Spanish power "exchange" is a voluntary market but in practice bilateral trade is discouraged due to the lack of capacity payment on the bilateral market in contrast with the power exchange. Hence in 2001, 96 % of Spanish consumption was traded on this market. This market is widely isolated from the rest of Europe due to limited transmission capacity with others markets.

In the **Netherlands**, the restructuring process of the Dutch electricity industry began in 1989 with the Electricity Act (Arensten *et al*, 1966; Brunekreeft, 1997), but the main changes happened after the white paper of 1995 and the 1998 Electricity Act. The Amsterdam Power Exchange (APX) was launched in May 1999, on the initiative of international traders, energy distribution companies, electricity generators, industrial end users and exchanges to facilitate spot trading. The APX trading system is based on the Nord pool's model. From the beginning the APX has been an international marketplace due to its geographical situation. The Netherlands are strongly connected to Belgium and Germany and the creation of the power exchange facilitates arbitrage with neighboring countries. Typically, German and Belgium players sell on the APX since the prices in the Netherlands are usually higher. These arbitrages were facilitated by the decision of the Dutch electricity regulator (DTe) to allocate part of the interconnector capacity directly to the APX (250 MW in 1999, 900 MW in 2000). Such allocation procedures ceased with the introduction of an auction for interconnector capacity in 2001. However, in order to continue to allow the APX to carry cross-border trade and insure a minimum level of liquidity, the regulator decided to force players who obtained interconnector capacity at the daily auction to use the APX. Hence, the APX, with the help of regulatory support, has seen a large part of it traded volume coming from Germany and Belgium. In 2001, 8 % of Dutch consumption was traded on the APX (Lapuerta and Moselle, 2001).

In **Germany**, the entire electricity market was opened to competition in 1998. The German market is the largest market in Europe, representing more than 20% of European consumption. The German regulatory framework was established by the Energy Sector Law of April 1998. Unlike most Members States Germany has no independent regulator, leaving the federal cartel office to act as a *de facto* regulator (Brunekreeft, 2002). Until the middle of 2000, electricity was traded only on a bilateral basis. The first power exchange (APX “Deutchland”, APXDE) was created in May 2000, on the initiative of the Dutch APX and using its model with the aim of developing a multi-hub market. In June 2000, this first initiative was followed by the launch of the Leipzig Power Exchange (LPX) backed by Nord pool, regional banks and regional governments. Like APX, LPX uses the Nord pool model. In August 2000, a third power exchange, the European Energy Exchange (EEX) was launched as an initiative of the German stock exchange. The EEX system differs from previous exchanges in that it uses an hourly auction system and a continuous trading system. The trading volumes on LPX and EEX have increased on a regular basis since their inception, however, APXDE, the third power exchange was a failure and it formally ceased operation in December

2000 after many months of no trading. In 2002, the LPX and EEX merged and created a single exchange.

After Germany, **France** with an annual consumption of 400 TWh represents the second largest market in Europe with a central geographic position. The transposition of the Directive into the French law took place in 2000 through the "law of February 2000"[19], one year after the deadline defined by the EU Directive 96-92-EC. Until the end of 2001 competition in France for eligible customers was on the basis of bilateral contracts (Finon, 2002). The French power exchange (Powernext) was launched in November 2001 as an initiative of the European stock exchange Euronext. Similar to APX and LPX, the initiative was supported by Nord pool.

In **Italy**, in 1999 the regulatory framework was established by the "Bersani decree" (legislative Decree 79/99). According to this decree, a "power exchange" (Gestore Mercato Elettrico, GME) run by the system operator was supposed to be set up by January 1, 2001. This target date was not met since the system operator presented its definitive plan to the Ministry of Industry only in December 2001 (Lorenzoni, 2003). The final design of this market is not yet known but a first project presented by the end of 2001 looked like a power pool where the spot market is only open to generators for supply, and demand must be specified at point of withdrawal. The important difference with the recently organized markets developed in others continental countries is that the aim of the GME from the beginning was to run a combination of markets, i.e. day-ahead, adjustment market, congestion management market, reserve market and balancing market, while all other power exchanges have first focused on the day-ahead market. Such a market would have been an exception at the European level. However in 2002, this scheme was aborted. At the time of writing, it remains to be seen what form the Italian market will take.

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[19] Loi n° 2000-108 du 10 février 2000," Loi relative à la modernisation et au développement du service public de l'électricité", available at www.cre.fr

Table 2-2 Overview of electricity organized marketplaces in Europe

	Country	Initiative	Participation	Participants	Demand Participation	Type of Bid	Bilateral market	Side payments
UK Pool (until 1999)	England & Wales	Public	Mandatory	Generators only	No	Price/Quantity /capacity/unit commitment...	No only financial (CfD)	Yes
Nordpool	Norway, Finland, Sweden, Denmark	Semi private	Voluntary (Except for international trade)	Generators, Traders, Large consumers, Distributors	Yes	Price/ Quantity	Yes	No
Omel	Spain	Public	Voluntary (but encouraged)	Generators only	Yes	Price/Quantity /capacity/unit commitment...	Yes	Yes
APX	Netherlands	Private (but is now publicly own)	Voluntary (except for interconnector capacity)	Generators, Traders, Large consumers, Distributors	Yes	Price/ Quantity	Yes	No
LPX	Germany	Private	Voluntary	Generators, Traders, Large consumers, Distributors	Yes	Price/ Quantity	Yes	No
EEX	Germany	Private	Voluntary	Generators, Traders, Large consumers, Distributors	Yes	Price/ Quantity	Yes	No
EXAA	Austria	Private	Voluntary	Generators, Traders, Large consumers, Distributors	Yes	Price/ Quantity	Yes	No
UKPX	UK	Private	Voluntary	Generators, Traders, Large consumers, Distributors	Yes	Price/ Quantity	Yes	No
AUPX	UK	Private	Voluntary	Generators, Traders, Large consumers, Distributors	Yes	Price/ Quantity	Yes	No
GME	Italy	Public	Mandatory	Generators only	No	Price/Quantity /capacity/unit commitment...	No but CfD	Yes

2-4-2 The “hybrid” model

The freedom granted to member states by the EU electricity Directive and its different implementations in national law explains the heterogeneous market design of the electricity markets. Albeit each market has its own specificity, a kind of dominant model is emerging. Hence, in European countries the design of their electricity wholesale market shares some principles. These characteristics can be classified into three categories: organized and bilateral markets, role of the transmission system operator and allocation mechanisms for interconnection capacity.

Conceptually it is useful to define an analytical framework that includes power exchanges. This is what we call the “ hybrid model”. The relationships between the electricity market and the technical system are depicted schematically in figure 2-3. The lower part shows a simplified representation of the technical system: generators feed into networks which deliver electricity to loads. The top right and left corners of the figure contain the primary actors in the electricity market, sellers and buyers. The top center box represents the electricity market where they interact. Often the interaction between buyers and sellers does not take place directly, but is mediated by traders, brokers or an organized market such as power exchanges. Hence, in most countries electricity markets are organized around four different markets while physical delivery is the responsibility of an independent system operator. These markets are a bilateral market also known as an over the counter market (OTC), one or more voluntary power exchanges (PX), a balancing market and a mechanism for allocating interconnector capacity (e.g. auction)

In continental Europe[20], in Scandinavia and in the United Kingdom after NETA, the electricity markets are hybrid models combining bilateral and organized markets. This market design was chosen to give more choice for market

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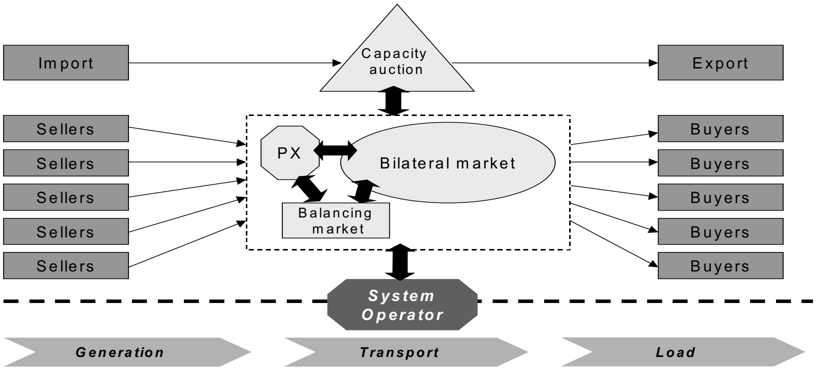
[20] With the exception of Spain and Italy

participants as to the way they trade electricity. This design allows electricity markets to operate as far as possible like other commodity markets whilst insuring system reliability. In this model, generators, distributors, traders and consumers can trade electricity either via OTC contracts or on a power exchange. In this chapter power exchange are defined as market places for spot trading.

Figure 2-3: The hybrid model



The bilateral market is the most important in terms of volume. It represents more than 90 % of total consumption in the Netherlands, Germany and France and 75% in the Nordic countries. Bilateral trades occur between two parties on a confidential basis. Most of the time the contracts sold in this market are tailor made, which explains why this market is very heterogeneous. The contracts can differ in many points: starting dates, duration, and delivery areas. In the Netherlands, the volume traded on the power exchange represents 8-10 % of total consumption, in France this amount is less than 1% this is mainly due to the youth of this exchange which started to operate in 2001.

Competition in an electricity power exchange spot market is driven by generator, distributors, traders and large consumers submitting bids for buying and selling electricity. The power exchanges match supply and demand and publish a market-clearing price (MCP). The balancing mechanism, i.e. market or regulated, is the responsibility of the system operator. Every hour, all participants inform the system operator of their physical transactions. This mechanism determines the price for any deviation measured between a participant's declaration and the real flows in the grid. The interconnector capacity market organizes the allocation of interconnector capacity between two countries. When using market based-mechanisms, this market is divided into different auctions divided into different timeframes, i.e. daily, monthly and yearly auctions. The combination of these markets shapes the actual electricity markets.

The transmission system operator is an independent organization that is responsible for physical delivery and, due to the monopoly nature of this function, is regulated at national level. The TSO acts as an interface between the technical system and economic transactions in the market. The role of the TSO in the hybrid model is comparable to the role of the TSO in most markets. However there are some differences. Since the network is a natural monopoly, network operators need to be independent of market players in order not to distort competition. The primary role of the TSO is to manage the electricity grid to insure physical delivery. The TSO maintains system stability and manage the energy balance within its dedicated area. This area is defined geographically according to national or regional boundaries. To provide added system reliability and robustness, control zones are interconnected which allow transfer of power across boundaries and different areas. When actual generation and loads deviate from the amounts that were previously notified by market parties, the TSO maintains the power balance using balancing mechanisms. If the market has projected power demands well, adjustments required to balance the dispatch pattern will be small, but they are crucial for system stability. Finally, the TSO also manages congestion, maintains reliability of service and provides ancillary services for transport. These activities are centralized due to the very short time scale involved. Hence decisions made at the time of operation are controlled by the TSO while other activities made some time before the physical delivery can be delegated to others entities, i.e. market participants, power exchanges, with the results passed on to the TSO.

The last important feature of the hybrid model is the allocation methods for interconnection capacity between countries. Cross-border trading represents a critical aspect in the development of a pan-European market[21]. Again the EU Directive provides no specific guidance. Hence, different methods for the allocation interconnection capacity coexist[22] though recent developments have shown a preference for explicit auctions. In 2001 twelve[23] different interconnector capacities were allocated via auction and one between France and Italy is in the project phase. Before liberalization, the main purpose of interconnectors between countries was system stability, the development of cross-border trading created congestion. Thus, an auction is an allocation mechanism that can be used to distribute this scarce resource. The capacity is allocated to the highest bidder. Explicit auctions separate energy flows from transmission capacity. Hence, once interconnection capacity has been secured by a market participant, the participant will need an other transaction for energy. This can be done on the bilateral market or on a power exchange. Some direct relationship may exist between the auction and the power exchange as in the Netherlands where players who have obtain interconnector capacity to import on the daily auction must obtain a related contract on the power exchange[24].

Existing markets in the United Kingdom, the Netherlands, the Scandinavian countries, Germany and France can easily be derived from this model. Given this the model will be use rather than specific countries for the analysis.

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[21] See chapter 8

[22] See chapter 9

[23] Four between Germany and the Netherlands, two between Belgium and the Netherlands, two between Denmark and Germany, two between Germany and the Czech Republic and two between France and the United Kingdom

[24] See chapter 5

2-5 Conclusion

The main aspects of the EC treaty and the electricity Directive 96/92/EC which represent the legal framework of the liberalization of electricity industry in Europe have been presented in this chapter. The Directive only provides a general framework for the creation of a single market, the creation of institutional arrangements, such as organized markets, is not mentioned. Hence, without any specific recommendation various electricity power exchanges have emerged to facilitate the trading of this “commodity”. We have identified several reasons for the emergence of power exchanges and their principal differences with others types of organized markets. Finally, we concluded the chapter with a definition of an analytical framework for wholesale electricity markets, ”the hybrid model” which will be use as a reference throughout the thesis rather than referring to specific countries. This model sheds light on the double nature of power exchanges, i.e. power exchanges are organized market places institutions that forms part of the global wholesale market design.

Chapter 3

Theory of market design for electricity

The introduction of market mechanisms in the electricity industry has shown the need for designing these markets. This issue is very recent since the creation of "markets" for electricity is a recent phenomenon. The key idea is that there is no universal ideal solution but that both academic work and practical experiences gleaned from earlier stages should be incorporated into each new market's design. However, experience has shown that some models are more suitable than others for achieving efficient electricity markets. This chapter will first introduce the concept of market design and make the distinction between the three levels of market design: industry structures, wholesale market design and marketplace design. Hence, the different possible industry structures are presented in the following section. The different design controversies concerning wholesale market design will be analyze in the third section. Finally the chapter is concluded with different possibilities relative to the design of electricity marketplaces.

3-1 The issue of market design

3-1-1 Terminology

Markets exist wherever buyers and sellers interact to buy or sell a product at a mutually agreed price. The Oxford dictionary of Economics defines a market as *"A place or institution in which buyers and sellers of a good or asset meet"*. However, the everyday sense of the word "market" also tends to include market participants, market conditions, legal framework, geographical area etc. Secondly, in practice, electricity markets comprise a sequence of overlapping markets (Stoft, 2002). Hence, a necessary step for the analysis is to define the meaning of the word "market" and other related terms with respect to their use in European electricity markets.

First, for the purpose of this work we will exclude from the definition of the word "market" generators, traders, distribution companies, and regulators. Generators, traders, distribution companies are "markets participants" while regulators, and laws and legal aspects constitute, the "market's legal framework". Second since power exchanges are markets for wholesale electricity, the retail market is excluded from our definition of a market. Hence, following the Oxford dictionary of Economics, in our analysis the word market will refer to all places or institutions in which buyers and sellers of wholesale electricity contracts meet to ratify. This includes both financial and physical contracts. Moreover these contracts can be traded on over-the-counter markets (hereafter OTC or bilateral contracts) and organized markets such as power exchanges or power pools. The rules of functioning of the market are defined by trading arrangements, e.g. NETA in the United Kingdom, which define the rules and legal agreements between players, places and institutions.

"Physical" contracts refers to contracts which involve physical delivery of power while financial contracts do not involve physical delivery, and are only used to hedge. An important characteristics of existing wholesale markets is the combination of market with physical existence (organized markets) and market without a physical existence (OTC). Markets with a physical existence or organized markets will be called marketplaces. Marketplaces have trading rules which cover the method of setting the price, the characteristic of the traded product, arrangements for delivery, settlements terms, obligations of the buyers and sellers, and a neutral organization running the marketplace (Hunt, 2002). In this section we present standards definitions of important concepts and the definitions which will be used for this work (box 3-1).

Box 3-1: Market terminology *(Oxford Dictionnary definition in Italic)*

Market:
"A place or institution in which buyers and sellers of a good or asset meet". All places or institutions in which buyers and sellers of wholesale electricity contracts meet. The market includes all organized markets, i.e. power exchanges, power pool, balancing markets and OTC markets, i.e. all type of bilateral transaction, where contracts for wholesale electricity are traded.

Marketplace or organized market:
A third party which facilitate the transaction between a seller and a buyer. Marketplaces have trading rules, which cover price setting, delivery, clearing, type of product, timing etc. For instance power exchanges and power pools.

Bilateral markets or Over The Counter (OTC):
"A market in securities not regulated by a stock exchange". Markets which are not regulated by an organized market authority. These markets involve a direct transaction between a buyer and a seller.

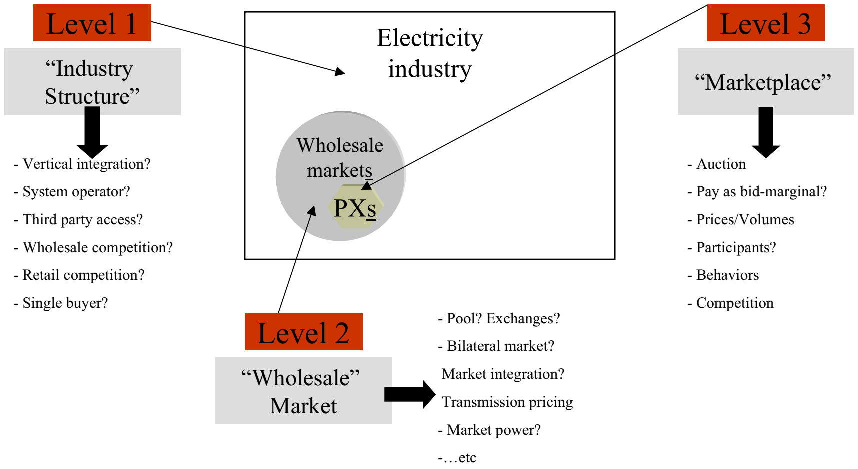
Spot market:
"A market for goods, securities, or currencies for immediate delivery or in some case a short time is allowed for delivery." In Europe, the spot market for wholesale electricity refers to the day-ahead market. In the US the spot market is the real time market. In this thesis the spot market includes all transactions day-ahead for delivery the following day. These transactions can be realized through a marketplace and/or bilaterally.

Market = Wholesale market = Marketplace + OTC
Power exchanges are one type of marketplace

3-1-2 The three levels of market design

The issue of market design is akin to the main research topic of industrial organization in which the goal is how best to organize markets. The first question for introducing competition in the electricity sector is to define which activity should be organized based on market mechanisms and competition and which activity should stay a monopoly and be regulated. In the electricity industry, market design or market architecture is a confusing notion which can refer to different types of design. For instance, for some authors market design refers to the whole value chain of the electricity industry from generation to final load, including both wholesale and retail electricity markets (Hunt and Shuttleworth, 1996). For other authors, market design refers only to the wholesale market and includes short-term spot markets, bilateral transactions, transmission congestion contracts, networks access charges etc (Hogan, 1992, 1993, 1998; Walton and Tabors, 1996; Chao and Peck, 1996). Finally in the literature, market design can refer to the detailed functioning of a marketplace such as the type of auction, the format of bids, the rules governing the marketplace (Wilson, 1997; McAfee, 1998; Green, 1998; Klemperer, 1999). We identify three different levels of design: industry structure, wholesale market and marketplace (figure 3-1).

Figure 3-1: The three level of "market" design



The first level is about the way to organize the industry as a whole, i.e. from the production of electricity to final consumption. Should players be allowed to be vertically integrated (VanDoren, 1998)? Is an independent system operator necessary (Cameron and Cramton, 1999)? Is there third party access to the network (Deng *et al*, 2000; Brunekreeft, 2001)? If yes, what are the rules? Who should be allowed to participate in the market? What is the extent of competition (wholesale/retail)? Which part of the industry should be regulated (Borenstein and Bushnell, 2000)? Which part of the industry should be open to competition (Newbery, 2001)? Obviously this level of market design should be the first to be addressed to open the electricity industry to competition and to define the basic design characteristics of the market (Gilbert and Kahn, 1996).

The second level of market design concerns the wholesale market. In practice, many states both in the US and in Europe have decided first to create a wholesale market and postpone the creation of a retail market too later stage (Bergman *and al*, 1999). Such approach allows competition between generators and offer choice for large consumers and distribution companies while sale of electricity to small consumers is still subject to regulation. In contrast to the first level of market design defined above where a large consensus can be found, the design of wholesale markets is at the center of many controversies. Do we need an organized market or should the trading be organized bilaterally (Hogan, 1994; Gilbert *et al*, 1996)? If a marketplace is suitable should it be compulsory or voluntary? Who should run the marketplace? Should the marketplace define zonal prices or locational prices (Stoft, 1998)? What kind of technical aspects must be taken into account during the design of the market (Hogan, 1998)? To what extent should governments design wholesale trading arrangement? At this level the critical activity is the one provided by the transmission system operator (Hogan, 2002; Stoft, 2002). The answers to these questions differ widely between countries, raising the question of whether an ideal solution exists.

Finally, the third level of market design is about the detailed functioning of the market and especially the rules of the marketplace. Should prices be determined by a pay-as-bid auction or by a marginal price auction (Garcia-Diaz, 2000; Federico and Rahman, 2001; Kahn and al, 2001)? Should the auction be a two-sided auction or only one sided (Green and Newbery, 1992)? Who should be allowed to participate to the auction? What should be the characteristics of the bids, e.g. only price-quantity or also start up costs, transmissions constraints and others technical aspects? What should be the timing of the market? How will the results of the market be transferred to physical delivery?

The first level of market design has mainly been defined by the electricity Directive in Europe and by the FERC in the US. At this level the possible choices are relatively limited and a large consensus can be found. This model consists of a separate transmission company, competing generation, third party access and an independent regulatory body (Littlechild, 2001). In this thesis little attention is given to the above, however to be complete we briefly present the four possible global architectures for the electricity industry (3-2). Subsequently, the second and third levels of market design, concerning respectively the wholesale market (section 3-3) and the design of the marketplace (section and 3-4), which are fundamentally relevant for the purpose of this thesis, will be analyzed.

3-2 Industry structure

3-2-1 Introduction

The central institutional part of public utility regulation is to find the best possible mix of inevitably imperfect regulation and inevitably imperfect competition (Kahn, 1995). Governments and regulators have started to liberalize their electricity markets in a large number of countries around the world. The main motivation is to increase the efficiency of their electricity industry by introducing market mechanisms. Such decisions involve important choices concerning the industry structure. Hunt and Shuttleworth (1996) have defined four basic industry models.

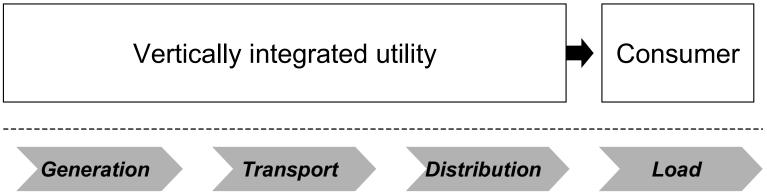
- Model 1: Monopoly
- Model 2: Purchasing agency
- Model 3: Wholesale competition
- Model 4: Retail competition

Every existing model can be seen as an extension of the four models. These models take into account two aspects, the level of competition and the nature of ownership. The four models are particularly useful for defining the general framework of the industry and for this reason we briefly present the four models[1].

3-2-2 Model 1: Monopoly

The first model is a classical, vertically integrated, monopoly without any competition. One company generates electricity, operates the transmission and distribution functions and finally is responsible for retailing to the end consumers. Hence, there is no competition. The monopolistic company is responsible for its area, which can be a city, a specific region or even a country. This model is the original one for most of the electricity industry worldwide, and thus represents the genuine starting point for any reform.

Figure 3-2 Monopoly



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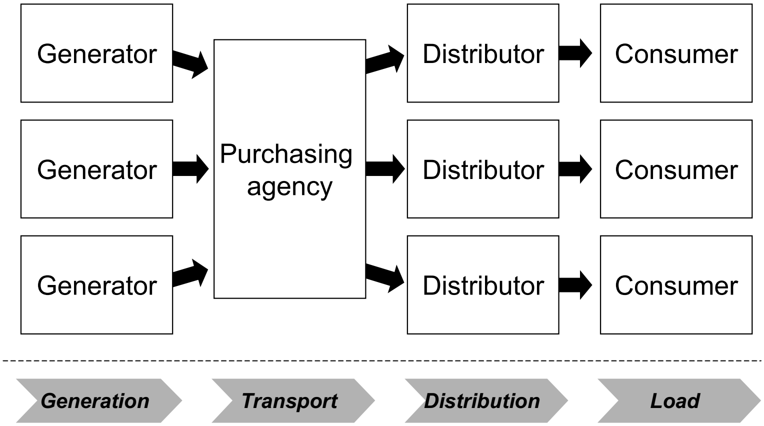
[1] For detailed descriptions see: Hunt and Shuttleworth (1996) and Hunt (2002)

3-2-3 Model 2: purchasing agency

In the purchasing agency or single buyer model, a nominated authority acts on behalf of all registered consumers. This authority negotiates with generators to buy energy and services. This model allows competition in generation. Generators compete to supply the nominated authority. In turn, the purchasing agency sells to distribution companies at a preset tariff. At the retail level small consumers do not have a choice of suppliers and retail prices are regulated, which means that distribution companies still have a monopoly over small en users. The interest of this model is that it realizes competition in generation and facilitates negotiation for consumers. One important characteristic of this model is that it is easy to introduce it. The main disadvantage of this model is that the authority represents a monopoly which is not subject to market forces (Murray, 1998).

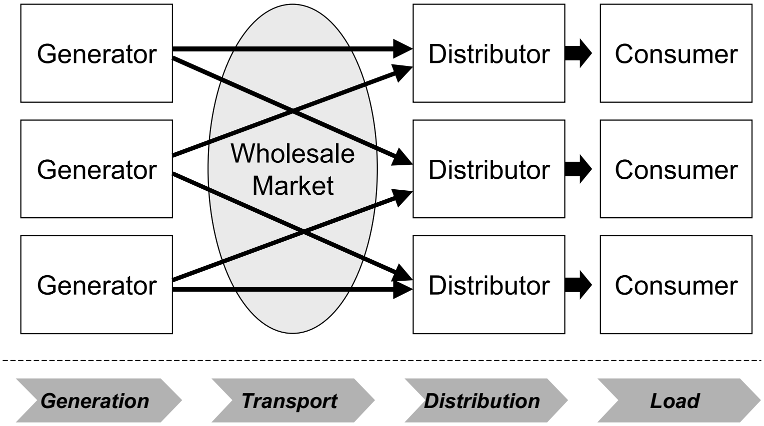
Figure 3-3 Purchasing agency



3-2-4 Model 3: Wholesale competition

The main difference between model 2 and model 3 is that in model 3 distribution companies and large consumers do not have to use any particular purchase agency but can choose their suppliers. At the same time generators are not forced to sell to the purchase agency and this gives them access to alternative buyers. This model allows real competition in production, which represents the most important part of the costs of electricity. This model expands the level of competition widely in comparison to model 2. The model makes the market more dynamic and closer to classical commodities markets by allowing more buyers to participate within the market. The advantage of this model is that it represents a serious step to full competition without disrupting the retail market. The problem with this model is the definition of what is the minimum size required to participate to the market and the combination of a free market at the wholesale level and a regulated market at the retail level[2].

Figure 3-4: Wholesale competition



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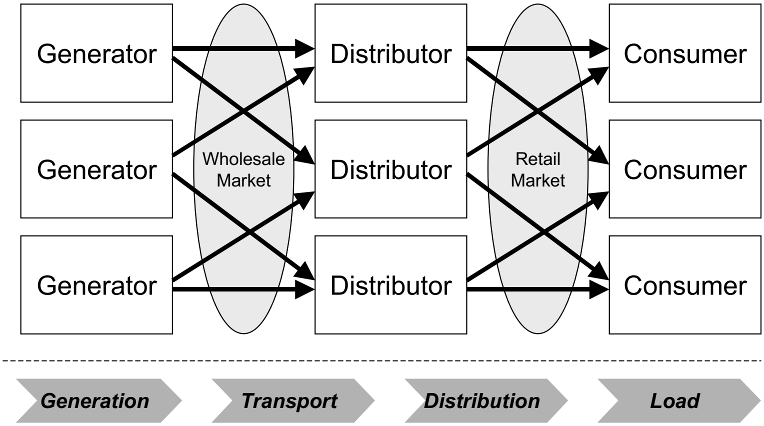
[2] On this aspect see appendix 1 about the Californian crisis

3-2-5 Model 4: Retail competition

In the retail competition model, the functioning of the wholesale market is the same as in model 3, the difference is that end-users at the retail level can choose between different kinds of suppliers. Such model requires the development of settlement process, meter reading, billing mechanisms and the education of final consumers. The main idea of this model is to allow consumers to have choice in their consumption of electricity as they have for any other goods. The problem with this model is that without any strong regulation, distribution companies may charge very high prices, or not serve, for example customers in isolated areas.

Figure 3-5: Retail competition



3-3 Wholesale market

3-3-1 Introduction

Wholesale market design is central to the introduction of competition in the electricity industry. Controversy has surrounded the subject in the US since the beginning of the liberalization process (Stoft, 2002), yet in Europe it has been widely overlooked. Though third party access to the network is definitely a necessary condition for competition, the major issues concern the role of the system operator and the existence of transmission constraints (Hogan, 1992). The design of the wholesale market also has to take into account the potential gains in longer-run efficiencies with the transaction costs associated with new rules and institutions for implementing decentralized operations and investments decisions (Joskow, 1998). At the wholesale level, two major issues exist (Stoft, 2002). The first one concerns the nature of the product traded, i.e. electricity is a sequence of products for energy and transport or electricity is a bundled service. When electricity is seen as a sequence of product, transmission constraints are ignored while these constraints are taken into account when electricity is seen as a bundled product. The second issue concerns the level of centralization of trading.

Many of the controversies surrounding the design of wholesale electricity markets relate to the technical vulnerability of electricity coordination and the existence of transmission constraints (Joskow and Schmalensee, 1983). The need for continuous synchronization between production and consumption on the entire network requires control in real time. Hence, these features must be taken into account when creating electricity markets and the main discussion point is how the different market design deal with these constraints

The existence of a system operator is a common feature of any electricity market and the extent of its role concerning market organization is at the center of the controversy surrounding wholesale market design. The larger system operator's role is the smaller is the role for privates parties.

"One side fears the inefficiency and market power abuses of privates parties playing social roles. The other side fears the inefficiency of nonprofit organizations but also covets the central market role played by the system operator" (Stoft, 2002)

An essential condition for the development of competition is free access to transmission (Einhorn, 1994). In Europe the EU Directive insists on the necessity of third party access (TPA), and thus to comply with this transport and energy have been separated. Energy is open to competition while transport is regulated. In the US, such a separation is not the rule (Kwoka, 1996).

Once a choice has been made to create an industry structure allowing wholesale competition, i.e. model 3 or model 4, the second aspect of market design is to define the architecture of the market (Wilson, 1998). At the wholesale level, economists and practitioners are still debating what kind of wholesale market design is the most efficient. Three approaches can be defined concerning wholesale market organization. The first one ignores transmission constraints and is a highly centralized system around a mandatory *poolco*, e.g. England and Wales before New Electricity Trading Arrangement. The second one also ignores transmission constraints but is a totally decentralized system based on *bilateral contracts* without organized marketplace for trading, e.g. the state of Texas USA. The last one integrates transmission constraints through *locational pricing,* e.g. PJM[3].

Table 3-1: The three models

	Bundled Product	Centralized market
Poolco	No	Yes
Bilateral market	No	No
Locational pricing	Yes	Yes

Whereas economics shows that if everything is perfect and complete the three models can provide the same results (Wilson, 1999); an analysis of the different

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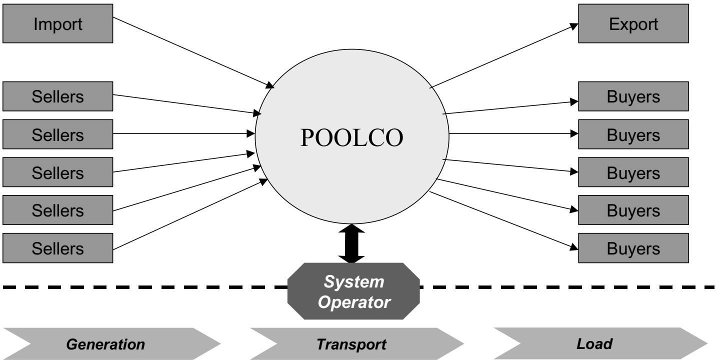
[3] See chapter 9

models allow a comparison of the strengths and weaknesses of each model and explains why some models might be preferable to others.

3-3-2 The poolco model

The reference model for wholesale market design is the poolco model which was first developed by W.Hogan in the nineties (Hogan, 1993). The poolco model is based more on engineering principles than market principles (Green, 1998). This concept has been presented as one of the best market designs for providing competitive electricity markets in many states in the US, e.g. The New England Power pool, The New York Power Pool and the Australian's Victoria pool. This model was also applied in the UK before the New Trading Arrangements (NETA). The poolco model is a general framework. Application of this model in practice can differ in details regarding, for instance, operational practices, pricing mechanisms, dispatch system etc. For the purpose of this thesis we only consider the major feature of a "mandatory" poolco model as opposed to the voluntary bilateral markets described below. Mandatory participation means that all generators have to sell their output to the poolco and that all consumers must purchase their electricity from it.

Figure 3-6: poolco model



The principles of the poolco model are relatively simples. A set of rules defining the way electricity can be trade are defined in the model (Budhraja *et al*, 1994). Each supplier submits bids to the poolco for a different time increment (mostly hours) for generation capacity that they can make available for each bid period. The price offered by the bidders reflect the level of price they are willing to accept for each hour. The poolco performs a price-based merit order dispatch which means that it dispatches to all supplier from lowest to highest bid (Garber *et al*, 1994). The last accepted bid for a given period determines the single market-clearing price. In other words, each dispatched unit receives the market clearing price which is set by the bid price of the marginal unit required to meet demand for each time interval.

In the simplest version of the poolco model transmission constraints are ignored (Hogan, 1993). A single price is set for the whole market. Hence, the same energy price applies irrespective of the physical location of generators. The TSO use a separate operational study to identify the network constraints based on the first results of the auction. When transmission constraints make it impossible to realize the first results of the pool, the system operator requires one or more generators to increase their production while others decrease their production. The additional costs are shared between all producers.

The important characteristic of the poolco is that it uses multipart bids which cover all important aspects of generator's operating costs and physical constraints. Hence, the poolco model also takes into account several technical characteristics, which are concerned initially with the physics of getting the system dispatched. This implies side payments. The poolco provides many services implicit in the economic dispatch. For instance, the poolco provides backup supplies, reactive power and spinning reserves. Every half-hour, customers pay and generators receive the short-run marginal-cost (SRMC) price for the total quantity of energy supplied in the half-hour. Generators report many details of their costs to the poolco. All this information is computed ahead of time and determines the level of price and the level of side payments with respect to technical constraints such as startup cost, ramp-rate limit etc.

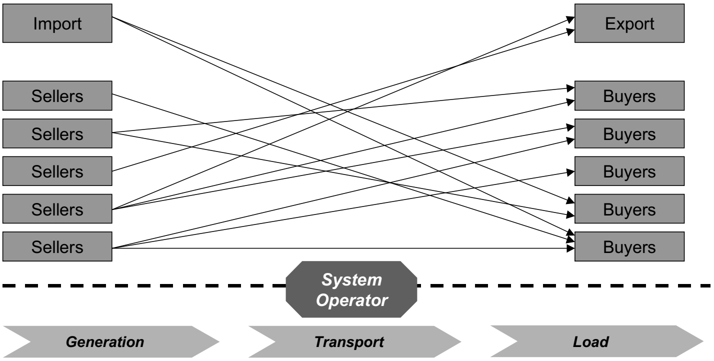
A crucial feature of the poolco model is that contracts do not play a direct part in the dispatch of power plants. Hence, financial contracts as opposed to physical contracts are used for hedging the price of the poolco. This is because in a mandatory poolco no generator can guarantee to be dispatch and that the central merit order dispatch does not involve financial penalties over and above the revenues lost due to not generating.

One of the main concerns with the poolco model is a lack of transparency. The price setting system is overly complex since it requires the submission of several parameters (Sweeting, 2000). This calculation methodology makes it difficult for players to understand how prices are determined and this then represents a true barrier to entry (Green, 1998). Moreover, side payments reward generators for making their plants available and not operating them. Hence, the existence of complex rules coupled with the repetition of the auction daily may allow generators to manipulate the market. Indeed, the complexity of poolco's bidding and price determining mechanisms make it extremely difficult to understand the relationship between price bids and available capacity submitted by generators and the actual prices. This aspect is a major concern with respect to market power.

3-3-3 The bilateral model

Bilateral trade or Over the Counter (OTC) can either be financial or physical, with the latter including actual physical delivery. Pure bilateral trade refers to direct transactions between a buyer and a seller without using any intermediaries. Hence, trading mainly takes place over the telephone without any intermediary. However, in practice, bilateral trade can also be done using a broker or bulletin board. As with stocks, brokers do not trade as a principal, but put buyers and sellers in touch with one another. For instance, a generator who has found a buyer for a part of its production may ask a broker to find it a possible buyer for the rest of the production. If the broker finds a buyer, the broker will charge a commission for this service related to the value of the transaction. Bulletin boards are mainly Internet websites where players post their offers for buying or selling electricity and define some aspects of the offer like for instance, location and duration. These offers are made available to others market parties. If a party is interested, the bulletin board will bring the two players together. Hence, a bulletin board is just a different type of brokerage. The bilateral market is then a mixture of direct transaction, brokerage and bulletin board. From a market design point of view, with the exception of bulletin boards, bilateral markets need little attention.

Figure 3-7: The bilateral model



An important characteristic of bilateral markets is that the type of contracts negotiated are totally flexible and can be tailor-made to fit the needs of each particular consumer since the consumers can specify any term they desire, examples:

- A contract signed on the 25-11-N for 50 MWh for one year baseload starting on the 01-01-N+1 at a fixed price of 20 Euro/MWh for physical delivery on the Spanish Hub

- A contract signed on 5-06-N for 10 MWh for peakload period in November N at a price based on the average price of October N for physical delivery in Germany
- A contract signed on the 2-07-N for 25 MWh for hours 10 to 15 for the 5-07-N at a price indexed based on the UK spot prices of gas.

The above are an examples of possible tailor-made contracts, nevertheless some standard contracts are also traded[4]. These contracts are listed in box 3-1.

Box 3-1: Standards bilateral contracts

Base load:
Supply for all hours for every day of the traded period.

Peak hours:
Supply between hour 9 and hour 24 (from 08:00 until 00:00) for every working day of a selected period.

Weekend:
Supply during all of the hours in Saturday and Sunday.

Nights:
Supply between hour 1 and hour 8 (from 00:00 until 08:00) of the weekdays.

Off-peak:
Combination of nights and weekends plus peak hours on bank holidays.

Of the five profiles, the first two are the most commonly traded and concentrate almost all of the market liquidity, base load being the most traded. It is often argued that in contrast to organized markets, bilateral markets give buyers and sellers broader flexibility concerning the prices and others terms of the contract because in organized markets participants can only buy and sell the product that are traded on the market. This view is incorrect. Even with the existence of a mandatory pool players can always make financial bilateral contracts. These

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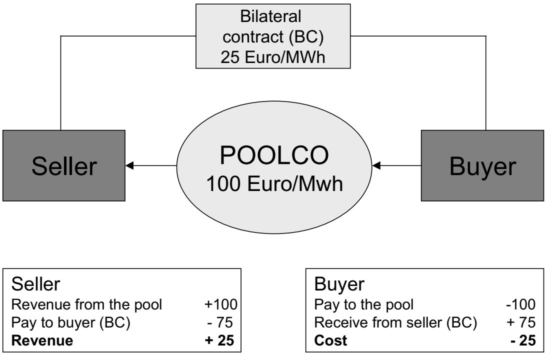
[4] See “Efet Standart contract”, available at http://www.efet.org

contracts called Contracts for Difference (CfD) in the UK can be use between a supplier and consumer to serve the same purpose as physical bilateral contracts, i.e. responding to the specific needs of a consumer while hedging against spot prices volatility. This point is illustrated in figure 3-8.

Figure 3-8: Bilateral contracts under the poolco model



In this example, a buyer and a seller have contracted bilaterally for a price of 25 Euro/MWh. The market price determined by the poolco is higher than the agreed price hence the seller pays the difference to the buyer.

An advantage of the bilateral market is that it offers fewer opportunities for sellers to take advantages of shortages by temporally withholding capacity. If a player in an organized market withholds part of its capacity it can take advantage of the increase in price for its other units. In the bilateral model, since contracts run for longer periods, withholding capacity during period of shortage will not affect the prices of most contracts and therefore will not be a profitable strategy. Second, transactions on the bilateral market are negotiated and buyers can compare the prices of different suppliers. In contrast, some players may find a way to manipulate the market-clearing price by gaming their bids in an organized market (Joskow and Kahn, 2001; Sheffrin, 2001).

Four majors concerns about the bilateral market are price discovery[5], price discrimination, liquidity and transaction costs. Since transactions in the bilateral market are done by definition between two parties, others parties can not know what the market price for power is at any hour of the day. This lack of transparency is a serious problem for consumers who can not then compare the offer made by producers to any solid benchmark. Price discovery is also very important for investment decisions and especially for entry. In theory, high prices will attract new investments. In the absence of such a signal competition might be restricted by deterring entry and a too low level of investment is likely to occur reinforcing the market power of the incumbents.

Price discrimination is directly related to price discovery. In a world of imperfect competition, price discrimination is a common business practice. For instance, price differences result from negotiations, various bargaining powers and various levels of access to information. Electricity markets are particularly vulnerable to such practices because the number of sellers is limited, the customers can easily be divided into groups and arbitrages are restricted. The bilateral model allows producers to price discriminate between customers, in others words to sell electricity to different customers at varying prices. For this reason sellers are reluctant to reveal the price of their deal, whatever the level of the price. A generator selling electricity at a high price to a specific customer does not want its competitors to know about this since a competitor will certainly propose a cheaper contract to this customer. If a generator is selling at a particularly low price to a specific customer it does not want its other customer to know this, fearing that they will ask for a decrease in price for their actual contracts. Even large customers are reluctant to reveal the price of their contracts. If they have managed to negotiate a cheap contract they might do not want their competitors

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[5] Price discovery is related to the concept of efficient market, originally developed by Fama (1970). In this approach an “efficient” market will discover a price that reflects the impact of available information on supply and demand.

to know this. Such price discrimination is not possible with an organized market since every participant receives and is aware of the market-clearing price.

Liquidity is related to the volume of trade in a power product. At this point the advantage of tailor-made contracts becomes a disadvantage. The range of contracts makes it difficult for customers to resell their contract or parts of them because the tailor-made specific terms make it difficult to find another buyer willing to take on such a contract. Hence the diversity of contract types may hamper the development of a liquid market, and this is necessary to permit buyers and sellers to adjust their portfolios. Such a variety of contracts means that there will be an equal variety of prices.

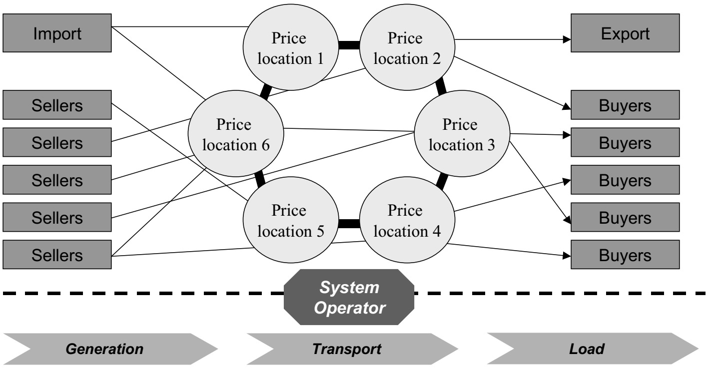
Finally, transaction costs are an important weakness of purely bilateral markets. Bilateral transactions require an actor first to find a counterpart, this involves search costs. Second, once a counterpart is found price determination and the exact terms of the contracts has to be negotiated. This is a costly process that requires time and expertise. While such costs can be justified and considered as marginal when the negotiations concern a large contract, such costs may be prohibitive for very small contracts, e.g. short term trading. Hence, a pure bilateral model does not favor short-term trading which is essential for market players to adjust their portfolio.

3-3-4 Locational pricing

Economic theory suggests applying of locational pricing in presence of transmission constraints, (Schweppe *et al*, 1988; Chao and Peck, 1996; Stoft, 1998; Johnsen *et al*, 1999). The locational pricing approach in contrast to the poolco model and the bilateral model, takes into account transmission constraints. This approach regroups nodal and zonal pricing (Harvey and Hogan, 2000). Broadly speaking, zonal pricing is a simplification of nodal pricing. In nodal pricing a different price is set for each node while in zonal pricing several nodes are aggregated to form a zone[6]. The key idea of the locational pricing approach is that the cost of delivering electricity varies around the system due to physical flows. Hence, each constrained location should have its own price that reflects transmission constraints. This approach prices generation and transmission simultaneously. All generators are scheduled and dispatched through a single market, which makes participation mandatory. The transmission system operator runs such a market directly.

In this model, the price of electricity is set for defined locations (zones or nodes) which have different energy prices. Separate locations are defined depending upon transmission constraints. Within a location the assumption is made that there are no transmission constraints, this permits any generator in the location to be used freely (Hsu, 1997). The level of interconnection capacity limits the trading possibilities between locations. The great interest of this approach is that it highlights the importance of transmission. Hence, when price differentials between two locations are important, this approach give clear incentives regarding where to invest and whether it is more efficient to invest in the transmission network or in generation capacity (Ilic *et al,* 1997).

Figure 3-9: Locational pricing



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[6] See chapter 9

Prices for electricity are set for each location of the grid in the locational approach. A number of cases, taking into account increasing number of parameters are described in box 3-3.

Box 3-3: Locational pricing

Case 1: Base case

When there is enough generation and no transmission losses or transmission constraints, there is a single price (P_1) at each location for each time period:

$$P_1 = Mc$$

Where Mc is the marginal cost of the most expensive plant in operation.

Case 2: Generation shortage

In presence of generation shortage, the price P_1 has to increase in order to decrease demand. This increase of price (S) is necessary to avoid blackout:

$$P_2 = Mc + S$$

Where S can be interpreted as the scarcity rents that pay for the fixed costs of generation.

Case 3: Transmission losses

Due to transmissions losses, supplying 1 MWh requires a generator to produce slightly more than 1 MWh:

$$P_3 = (Mc + S)\,(1+Ml)$$

Where Ml are marginal losses.

Case 4: Transmissions Constraints

Due to transmission constraints, the price at a congested location has to be increased to discourage consumption and encourage production. The magnitude of the adjustment is called the "shadow price" of the constraint. The objective of this adjustment is that the grid supply shall at no point exceed transmission capacity.

$$P_4 = (Mc + S)\,(1+Ml) + Sp$$

Where Sp is the shadow price of the constraint.

P_4 is called locational price and can be considered to be the "ideal" price of electricity since it takes into account the major characteristics of electricity.

Source: IEA, Competition in electricity markets, 2001

In the locational approach energy and transport are bundled while in the poolco model and in the bilateral model transport is separated from energy. On one hand this approach appears to be simpler because traders do not have to deal with two products. On the other hand the calculation of transport charges is left totally to the system operator, which decreases transparency. In a manner similar to the poolco model, participants in the market have to submit complex bids including technical features of power plants. Hence, such an approach shares the criticism of the poolco model for this point. Moreover the problem with the locational approach is that it introduces additional complexity in terms of feasibility. The role of the system operator is very large and this requires an extremely high level of cooperation in multi-countries markets (Hogan, 1995).

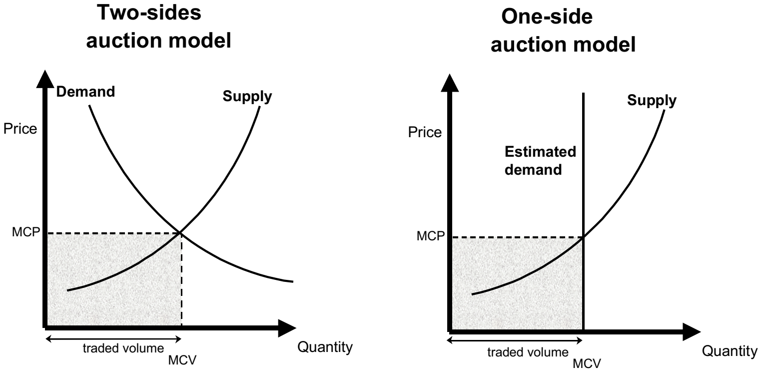
The TSO collects supply and demand bids and then computes all the bids taking into account technical aspects and transmission constraints to set the price at each location. In an unconstrained network, locational pricing will define only one price and the outcome of this system will be comparable to the poolco model (Oren, 1997). This approach is therefore suitable for weak networks subject to important constraints. Moreover such system is able to deal with loop flows, which are a fundamental characteristic of meshed networks (Stoft, 2002). While the poolco model and the bilateral model work poorly when transmission capacity is tight (McGuire, 1996), the locational model provides an efficient price mechanisms.

3-4 Marketplace design

3-4-1 One-side auctions vs two-side auctions

A first characteristic of a marketplace is the nature of supply and demand bids. One-side auctions refer to marketplaces where only supply is based on bids and demand is estimated (Bunn and Day, 2001; Green, 1998). Two-sided auctions allow both supply and demand to be based on bids from participants (Wolak, 1997). Commodities markets are usually organized according to a two-sided auction. In short, the marketplace aggregates supply and demand bids and the intersection of the two curves defines the market price[7]. However, in electricity markets demand participation may be difficult to obtain from a practical point of view. Most consumers of electricity have a low level of responsiveness to price increases. For this reason some marketplace use estimates of demand rather than bids from consumers. This was formally the case in the UK pool. The pool estimated demand for each period based on historical records and this then allowed a pool price to be determined.

Figure 3-10 Two-side auction and one-side auction model



One-sided auctions are obviously not an ideal mechanism for determining optimal market prices. Their only justification is practical, when introducing market mechanisms, in particular during the start-up phase, they can be a good way to determine a market price, however a lack of direct demand participation strongly limits the value of this.

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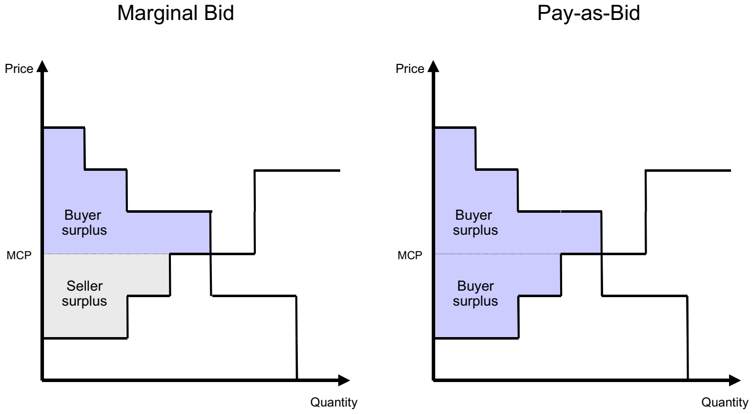
[7] See chapter 5

3-4-2 Marginal bid vs pay-as-bid

The controversy over marginal bid pricing and pay-as-bid pricing centers on the distribution of surplus and was first addressed in the United States with the treasury auction (Friedman, 1960). Both from a theoretical and from an empirical point of view, definitive ranking of the marginal bid and pay-as-bid auction is still an open question (Ausubel and Cramton, 1998; Fabra *et al*, 2002). In marginal bid pricing, all suppliers get paid the price of the marginal bid. Hence, all suppliers who bid lower prices get an extra profit called a surplus. In the same way all consumers who bid higher prices pay a lower price than the one they were willing to pay, this is called the consumer surplus (figure 3-11). From a consumer point of view it might appear unfair that a supplier who is willing to supply at a price of 15 Euro/MWh receives the market-clearing price which can be 40 Euro/MWh, and because of this it has been suggested that pay-as-bid methodology, previously experimented with in the U.S. Treasury's auction experiment (Malvey and Archibald, 1996; Reinhart and Belzer, 1996), should be implemented in electricity markets to increase the consumer surplus and eliminate these “unfair profits” (Federico and Rahman, 2001; Kahn *et al*, 2001). In a pay-as-bid auction, suppliers get paid the price they bid.

Figure 3-11: Distribution of surplus (assuming same bidding behaviors)



In a pay-as-bid auctions, if a low cost power plant (coal for instance) bids its marginal cost of 15 Euro/MWh it would be paid 15 Euro while in a marginal price auction (or single price auction) it would be paid the market clearing price which can only be equal to or higher than this amount. Hence from a generator point of view the pay-as-bid auction appears to be less attractive while in theory it allows consumers to pay the right price. However in a pay-as-bid auctions in an imperfect market generators have a strong incentive to increase the level of their bids in order to ensure a minimum level of profit. Hence, instead of bidding their marginal costs, suppliers will tend to bid what they think will be the market-clearing price (Stoft, 2002). Such behavior will lead to an increase in bids and will distort the system.

Moreover marginal costs for some technology, and especially for baseload plant, are almost zero (nuclear for instance). If players bid their true marginal costs they will not be able to recover their fixed costs. This will deter entry and involve less investment in baseload power plants thus reducing the overall efficiency of the system (Vasquez *et al*, 2000). It can also be argued that from a suppliers' point of view that pay-as-bid can also be implemented in the other way, i.e. consumers have to pay the price they were willing to pay. Moreover pay-as-bid reduce transparency by creating many prices instead of one price in the marginal price system. Finally, Gilbert *et al* (2002) have shown that in some cases marginal price auctions are superior to pay-as-bid auctions in mitigating market power as they allow competitive arbitrageurs to outbid generators where generators may otherwise secure interconnector capacity that amplifies their market power. Thus for all these reasons, marginal price appears as more suitable than pay-as-bid (Hunt, 2001).

3-4-3 Type of bids

One of important criteria for designing a marketplace is to define the nature of the bids (Shuttleworth and McKenzie, 2002). One approach considers simple bids, which only define price and quantity regardless of any technical constraint. A second approach takes into account price and quantity and technical features like start up costs, transmission constraints and unit commitment (von der Fehr and Harbord, 1998). Generally the first category is associated with power exchanges while the second is associated with power pools. The greatest advantage of the first approach is that it facilitates trading and transparency by making the system simple. Moreover, in such a system, players without assets can also participate in the marketplace. Hence, it makes it possible for traders and large consumers to participate in the market. This approach ignores the technical aspects and leaves total responsibility of physical constraints to the network operator. For this reason, this approach is more likely to be applied in areas where transmission constraints are low and the generation structure is flexible. For instance, within a country that has a dense network with low constraints.

The complex bid approach aims to take into account the technical features of electricity production (Wilson, 1998). Hence, the auction is constrained by the physics of the system to avoid overloading of lines, certain combinations of bids can be accepted while others must be rejected to ensure technical feasibility. For instance, if a generator can not suddenly stop producing electricity, which is the case with nuclear power plants, it should not be matched on one hour if it is not matched the following hour. The ramping rate constraint allows taking such aspect into account.

In conclusion, from both a theoretical and practical point of view, the choice between complex bids and simple bids is still an open question. On one hand complex bids take into account technical constraints which facilitate technical operation but hamper trading. On the other hand simple bids avoid complexity which strongly facilitates trading but overlooks physical constraints.

3-4-4 Day-ahead vs real-time

Day-ahead markets and real time markets are often confused since they are often regrouped under the term “spot market” (Stoft, 2002). For this work, as defined in box 3-1, we define the spot market as the day-ahead market, which can be organized bilaterally or/and on a marketplace. The real time market refers to real power balancing by the system operator. Due to the high transaction cost involved in bilateral day-ahead trading, the day-ahead market is usually organized on a marketplace. The real-time market or balancing market is always an organized market because it requires real time operation from the system operator to balance the system.

Since electricity consumption is difficult to predict and consumers can better estimate their consumption one day in advance than one year in advance the day-ahead market allows participants to adjust their portfolio one day before delivery. When they are organized on marketplaces, day ahead markets take the form of either power exchanges or power pool. Day-ahead markets contain four stages. One, participants submit bids. Two the marketplace determined the market price by accepting and rejecting bids. Three, transactions are settled. Four the results are transferred to the system operator in order to ensure physical delivery.

The real-time market is used to price deviations in supply and demand from contract specifications. These deviations, intentional or unintentional, must be corrected by the system operator to ensure physical delivery. The real time market is used to price these deviations and to keep the system in balance, the system operator needs to be able to call in extra production at very short notice, that is why the real time market must be centralized. Bilateral markets are too slow to handle very short term operations. Moreover beyond balancing the real time market provides two mains others ancillary services one, transmission security and two, efficient dispatch. In a vertically integrated monopoly (model 1), the division in charge of system operation used to have direct control of power plants allowing it directly to increase or reduce the output of a unit. In a market environment with unbundling the system operator must rely on real time prices.

In conclusion, day-ahead marketplaces and real-time marketplaces serve different purposes and are complementary. They represent the two main kinds of organized marketplaces in electricity. Their functioning is quite different and they should not be confused. In this thesis we will focus our attention on day-ahead marketplaces.

3-5 Conclusion

In this chapter, we have introduced the concept of market design by differentiating three levels of market design. Interestingly, it appears that only the general level of market design, i.e. industry structure, has been addressed by the Directive and that the two others levels, i.e. wholesale market design and marketplace design, have not been considered. Subsequently we have presented an overview of the different alternatives for wholesale market design. The main principles of three major models were analyzed for this purpose. Finally, we have discussed different issues related to marketplace design, which represent an important aspect of wholesale market design. This differentiation allows us to categorize electricity power exchange into marketplaces that are part of wholesale market design. In the next chapter we will present how competition in these marketplaces can be analyzed using economic theory and pertinent electricity market literature.

Chapter 4

Economic theory of market functioning

The different market designs for electricity markets were analyzed in the previous chapter. The focus of this chapter is economic theory models of market functioning and their application to electricity markets. An overview of the alternative market models in economic theory is given. Reference models of perfect competition and monopoly are briefly discussed, then oligopoly models are examined. We then define the fundamentals of electricity markets, i.e. supply and demand, followed by a discussion of how the models can be applied to electricity markets. Finally the strengths and weaknesses of using economic models to analyze electricity power exchanges are discussed. The objective of this chapter is to describe background theories, how they have been applied to electricity markets and their strengths and limitation when used as a basis for analyzing power exchanges.

4-1 References models: perfect competition/monopoly

4-1-1 Introduction

The perfect competition and monopoly models are presented in this section. The objective is to describe briefly the concepts of these two polar extreme models between which all other market models are ranged. Only the main hypothesis and results are given for each model and the simplest version of the model is used, for instance, marginal costs are assumed constant. For detailed descriptions and criticism of these models see Katz and Rozen (1998), and Begg *et al* (2000).

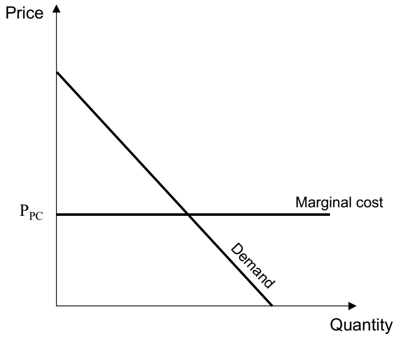
4-1-2 Perfect competition

According to the theory of perfect competition, and assuming a market for a homogeneous product with many buyers and sellers, the most efficient outcome is achieved if firms price at marginal cost. The model of perfect competition is based on four central assumptions.

1. Atomicity: there are so many buyer and sellers that no single buyer and no single seller can affect the price.
2. Product homogeneity: the product provided by the different competitors is exactly the same.
3. Free entry/exit: any firm can enter or exit the market freely.
4. Perfect information: all the players know the prices set by all the firms.

Each firm sets its price at the level of its marginal costs to maximize its profits. Hence, if a firm sets a price above the price of other firms it sells nothing. If a firm sets a price below the other firms’, it will have to supply all of the market demand for the product. If a firm charges less than marginal costs, it will fail to break even for that unit of output. Results: in the perfect competition model marginal revenue equals price and each firm is price taker.

Figure 4-1: Perfect competition equilibrium



There are generally two types of equilibrium in perfect competition: short run and long run equilibrium. In the short run there is too little time for new firms to enter the industry while in the long run new firms can enter.

4-1-3 Monopoly

The monopoly model assumes that there is one single firm, which supplies a well-defined market and that entry in the industry is blocked. The firm, called the monopolist, sets price *p* or a quantity q at a value that maximizes its profit. Since price and quantity are related to demand D(*p*) it is does not matter if the monopolist chooses the optimal price or the optimal quantity. The level of supra profit depends on the elasticity of demand. The monopolist is therefore price maker, figure 4-2 shows that the difference between the monopoly equilibrium price and the perfect competition price depends on the elasticity of demand, represented by the slope of the demand curve[1]. When demand is inelastic the marginal revenue of selling an extra unit is low because a small increase in the quantity leads to a large drop in price.

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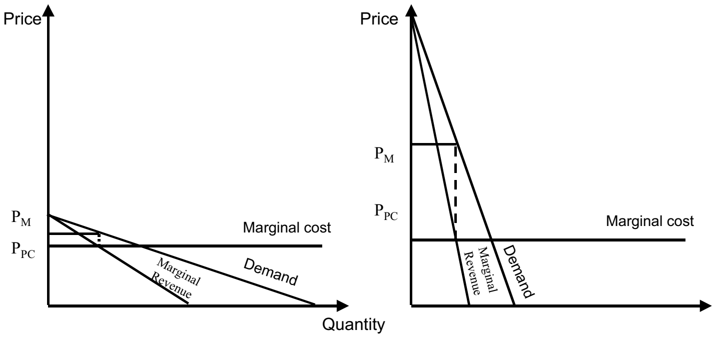
[1] On the left the elasticity of demand is high, on the right the elasticity of demand is low.

Figure 4-2: Monopoly equilibrium



A monopolist can increase the price of a good by restricting its level of output. As shown in figure 4-2 the ability to increase prices is limited by the elasticity of demand.

4-2 Oligopoly competition

4-2-1 Introduction

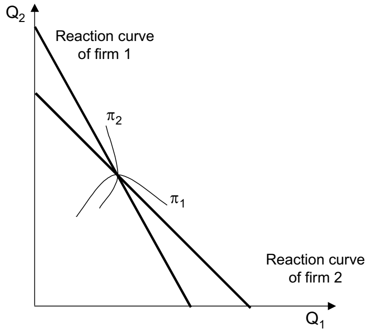
Since both perfect competition and pure monopoly are extreme cases that are rarely seen in practice, to analyze real markets, economists have developed alternatives models. The objective of these models is to cover the broad range of oligopolic competition between perfect competition and monopoly.

Oligopoly competition refers to a market structure where a few players coexist. One of the key ideas of such competition is that each firm believes its profits are affected by the actions of others firms, and that these actions also influence the profits of other firms. Taking perfect competition and monopoly models as the end points, there is an infinite number of theoretical possibilities for oligopoly models, all of which differ mainly in the assumptions used to characterize market structure and firm interdependencies (Bresnahan, 1981). First we present some models which assumed that the players are essentially equal, then some models in which one player is assumed to be dominant, finally we describe some approaches that do not fall into the two other categories.

4-2-2 The Cournot Model

Cournot developed the first model of oligopoly competition in 1838 (Cournot, 1838), this model takes into account the interdependencies between firms. Cournot's assumption of is that each firm will choose a level of output with respect to the rival's production decisions. Thus, in such a model players compete on quantity. The basic model is a duopoly model (n=2) where each firm has identical constant marginal production costs and faces linear demand[2].

Figure 4-3: Cournot equilibrium



The equilibrium formation of Cournot's model is shown in figure 4-3. The two axes define the output of the firms, so that any point represents their respective production volumes. In this model the reaction curve represents how much each firm would produce given an output decision from the other firm. The intersection of the two curves defines the equilibrium where each firm has maximized profit, given the output of the other. This equilibrium is a Nash equilibrium[3] since each

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[2] Entry is not considered and the product is homogeneous in this model.

[3] A Nash equilibrium is a situation where each player's predicted strategy must be that player's best response to the predicted strategies of the others players.

firm is following its best course of action, given its expectations about its rival's actions and that the expectation are fulfilled.

Box 4-1: Cournot Equilibrium

Under the Cournot model the price depends of the level of output:

$$P(Q)=a - bQ \qquad (1)$$

Where P is the market price and Q the total volume of output.
The total level of output is the sum of the production of each firm:

$$Q= \Sigma q_n = q_{1+} q_2 \qquad (2)$$

Where q_1 is the volume produced by firm 1 and q_2 the volume produced by firm 2
The profit of each firm n is defined by the difference between its revenues and total cost:

$$\pi_n= P(Q)\, q_n - cq_n \qquad (3)$$

$$\pi_n = (a – bQ)\, q_n- cq_n \qquad (3.1)$$

$$\pi_n = (a – bQ-c)\, q_n \qquad (3.2)$$

Where c is the unit cost. In the Cournot model each firm assumes that the other will keep its level of production. Hence, firm n maximizes its profit by differentiating π_n with respect to q_n. The maximum level of output is found by calculating the first order conditions:

$$d\pi_1/dq_1 =0 \qquad (4)$$

For firm 1 the maximum level output is then defined by:

$$d\pi_1/dq_1 = P(Q)+(dP/dQ)\, q_1 - c = 0 \qquad (5)$$
$$d\pi_1/dq_1 = a-2bq_1 – bq_2 –c \qquad (5.1)$$

Hence, the level of production of firm 1 can be express using the level of production of firm 2:

$$q_1 = (a-c)/2b – 0.5\, q_2 \qquad (6)$$

This equation defines the reaction function of firm 1 to the level of output of firm 2. Similarly the reaction function of firm 2 is:

$$q_2 = (a-c)/2b – 0.5\, q_1 \qquad (7)$$

The equilibrium solution is defined by the intersection of the two curves

$$q_1 = (a-c)/2b – 0.5[(a-c)/2b – 0.5\, q_1]$$
$$q_1 = (a-c)/3b \qquad (8)$$

4-2-3 The Bertrand Model

Bertrand (1883) extended Cournot's model of by changing the rivalry notions using prices rather than quantity. In the simplest version of the model, two firms set their prices simultaneously. Since the two products are perfect substitutes the firm which sets the lower price will attract all the demand for the product in question. Again, we can use a reaction curve, only this time for prices rather than quantities. It is critical for the model that each firm has identical cost curves, otherwise the one which has lower marginal costs will always supply the entire demand. The Bertrand equilibrium is achieved when each firm's expectations about the price behavior of its rival are realized. The fundamental result of the Bertand's model is that industry has price and output level similar as under perfect competition. The reasoning is the following: when firm 1 has selected its price to maximize its profit, the best strategy for firm 2 is to undercut firm 1 by a small margin and take all the market. Hence, the best response of firm 1 is to undercut firm 2. This process ends when neither of the two firms can go any lower, i.e. when price equals marginal costs. For any price of a rival, a firm will opt for a price that is just lower. Equilibrium is obtained when price equals marginal costs.

4-2-4 Others theoretical approach

The *Stackelberg leader-follower* model (1934), built on the Cournot model, assumes that instead of the firms making simultaneous output choices, a dominant firm announce its output first (Stackelberg, 1952). The difference is that firm 2 maximizes its profit assuming that the output of firm 1 is fixed and that firm 1 will take this follower behavior into account. Hence, firm 1 incorporates the reaction of firm 2 into its profit-maximization problem.

The *Edgeworth's* model (1925) is a variant of the Bertand's model. Like Bertrand he assumes that firms compete in price, but unlike Bertrand, Edgeworth assumes that both firms have limit capacity which mean that neither can supply the all market. The great advantage of this assumption is that it improves the realism of the model. However such model does not allow for the definition of an equilibrium solution since prices oscillate between a monopoly price and lower prices.

Klemperer and Meyer (1989) developed a model where a firm facing uncertain demand, rather than competing only on price or quantity will define a supply function (price and quantity). The idea is that when firms have to decide of their strategy, before knowing what the demand will be, they will define an entire supply curve with different prices for different quantities. This hypothesis makes such approach more realistic than traditional “one-variable” approaches. According to this model, in the absence of uncertainty, any price exceeding marginal cost along the demand curve can be a supply function equilibrium. In general all supply curve equilibria are bounded by the Cournot and Bertrand equilibria. When demand is uncertain, the set of possible equilibrium is reduced.

Box 4-2: The contribution of game theory

The foundations of game theory were laid in 1944 by Von Neumann and Morgenstern. While all oligopolistic models recognize the importance of interdependence between firms, game theory focus on the study of interactive decision making and because of this game theory can be seen as a direct development of classical oligopolistic competition models. Game theory has been applied in many fields of economic analysis and its application to the electricity industry is just one of its many applications. Game theory is especially relevant for the analysis of competitive bidding, collective bargaining, auctions, and cooperative and non-cooperative strategies.

Game theory models (or games) are traditionally divided into two categories: static and dynamic models. In static models firms do not know the strategy of the other and cannot change their strategies in response to others' strategy. Moreover the game is played only once and the firm is not interested in futures interactions. In dynamic games, a firm can observe the decisions of competitors and can react to these decisions in following games. Cournot and Bertrand models can be considered as static games since in these models no firm will change its strategies given the strategies of the others because there is no possibility to improve one's profit.

One of the most promising applications of game theory for electricity markets relates to auctions. Since most organized markets use auctions to determine prices and auctions are repeated games, game theory represents an interesting approach to analyzing the behaviors of market participants. However, Game theory is difficult to use for analyzing actual competition because it is almost impossible to isolate the behavior of a firm in reaction to a rival's behavior. For this reason game theory is use mainly as an analytical tool, to help analyst to understand possible behaviors. However, valid results that can be used by competition authorities and others, are unlikely to emerge, because reality is almost always too complex to be modeled in a game. Thus game theory is use mainly for theoretical experiments rather than for real case studies.

4-3 Characteristics of electricity markets

4-3-1 Introduction

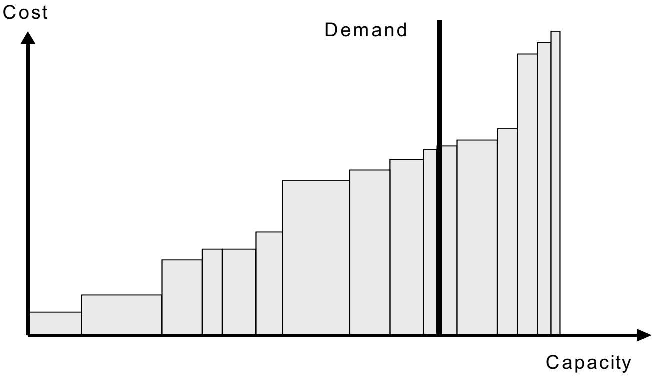
When applying economic theory to electricity markets one is confronted to two major difficulties concerning the nature of demand and supply. One, elasticity of demand is very low if not zero. Two, the characteristics of supply costs in electricity markets are not compatible with the assumptions made in competitive economics. We will now describe how supply and demand are usually presented in electricity markets and their main characteristics.

4-3-2 Supply

Supply in electricity markets is the combined output of all generators used to satisfy the consumer's demand for electricity. As in any market, the supply curve shows the total amount offered for sale at any given price for any given period. In the short term electricity supply is considered to be fixed while in the long term the production capacity may be altered. Three main aspects of electricity supply must be considered: the different cost levels, the nonconvexity of generator costs and the concentrated structure of the market.

When an electricity market is defined, the total electricity supply is usually represented by a merit order curve. Such curves range from the least expensive to the most expensive units, figure 4-4 is a representation of a supply curve in which each unit is shown as a step. The merit order curve presents the costs and capacities of all generators. The differences between costs are mainly due to the technology used and its related fuel. For instance hydropower and nuclear power plants have usually low marginal costs compared to gas powered plants.

Figure 4-4: Merit order curve



Taking a single power plant, the characteristics of supply are not compatible with assumptions of competitive economics because production costs are not convex. Convex costs have the property that twice as much output always costs at least twice as much to produce (Stoft, 2002). Electricity production costs are not convex due mainly to the existence of startup costs and no-load-costs. For instance if the startup cost of a plant is 20 Euro/MWh and if its marginal cost is 25, producing one MWh over two hours would cost 70 Euro/MWh[4] while producing two MWh in the same period would only cost 120 Euro/MWh[5]. Hence, producing twice as much is cheaper per unit. This characteristic is important when estimating the real cost of production in a competitive environment.

Finally, since the electricity industry in the past was organized as a monopoly, most power plants today are owned by a small number of companies. Given this history the number of sellers tends to be low and this is a major problem when attempting to establish competitive markets. At present, in half of the major European electricity markets, one player owns more than 50% of generation capacity[6]. Such a market structure represents the most important barrier for competition and a serious concern in term of market power.

4-3-3 Demand

Market demand is generally defined as the quantity of electricity that end-users are willing to consume at any given price. Electricity demand has three important features: seasonal variations, segmentation of consumers and low elasticity.

The seasonal variations of demand presented in figure 1-2 of chapter 1 are usually summarized in a load duration curve. This curve plots demand against duration. Such a curve can be constructed for different time scales and areas.

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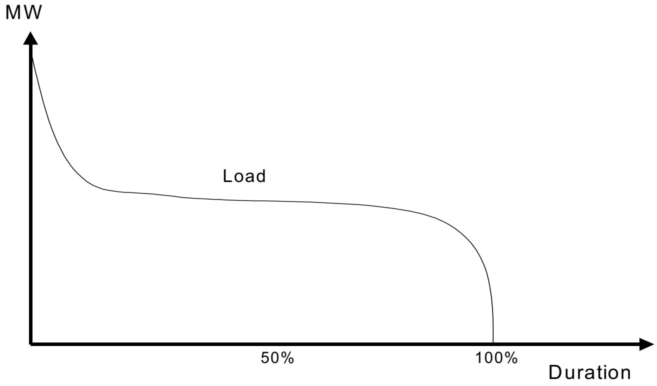
[4] 20+25+25

[5] 20+50+50

[6] See chapter 7

Figure 4-5: Load duration curve



The demand of electricity varies widely between peak time (day) and off peak time (night) and seasons (winter/summer). This variation is simply due to the fact that most companies and households do not consume electricity during the night. Very high peaks of demand occur during very hot or very cold weekdays when everyone is using air conditioning or electric heating. The lowest levels of demand for electricity occur in the middle of the night.

Demand can be divided into several segments according to the level of need and sensitivity to price change of its buyers. Different categories have been defined in Europe, as a result of the adoption of Directive 96/92EC, and in accordance with the requirements of Directive 90/377/EC, to improve the transparency of electricity prices charged to industrial end-users and domestic consumers. Domestic consumers and industrial consumers are broken down into three categories according to their level of electricity consumption: small, medium and large consumers. An overview is given in box 4-3.

Box 4-3: An example of segmentation of demand

Domestic consumers

Small: Annual consumption of 600 kWh; subscribed demand: 3 kW; standard dwelling: 50m2

Medium: Annual consumption of 3.500 kWh; subscribed demand: 4-9 kW; standard dwelling: 70m2

Large: Annual consumption of 7.500 kWh; subscribed demand: 6-9 kW; standard dwelling: 90m2

Industrial consumers

Small: Annual consumption of 50 MWh; maximum demand: 50 kW; annual utilization: 1000 hours

Medium: Annual consumption of 2.000 MWh; maximum demand: 500 kW; annual utilization: 4000 hours

Large: Annual consumption of 50.000 MWh; maximum demand: 10 000 kW; annual utilization: 5000 hours

Source: Eurostat, http://europa.eu.int/comm/eurostat/

The elasticity of demand is a sensitive issue in electricity markets. As in any market, the elasticity of demand represents the responsiveness of consumers to a change in price, in this case electricity prices. In electricity markets elasticity of demand is very low for most consumers due to the lack of substitutes and the high importance given to the product by consumers. Large consumers directly connected to the high tension grid and acting at the wholesale level can react to some extent to electricity prices. Households and small and medium industry are almost unresponsive to price fluctuations because wholesale volatility is not passed on to retail consumers, or at least not in real time. These small consumers, which do not act directly on the wholesale market do not have the incentive to respond to price volatility because they pay a retail price that is averaged over time.

Table 4-1: Price elasticities of demand for UK industries

Type of firm	Maximum	Average
Water supply firms	-0,860	-0,400
Copper/brass manufacturing firms	-0,300	-0,060
Hand tools/finished metal goods manufacturers	-0,062	-0,002
Steel tubes manufacturing firms	-0,014	-0,004
Timber and wooden furniture manufacturing firms	-0,036	-0,004
Food, drink and tobacco manufacturing firms	-0,00035	-0,00001

Source: Patrick, Robert H., and Frank A.Wolak (1999)

In most markets, consumers choose whether to consume or not depending on the market price. In electricity markets, consumers do not reduce their consumption when supply becomes tight simply because they do not see a price difference in the short term; even large consumers have low demand elasticity. Patrick *et al* (1999) have estimated price elasticities for large and medium size consumers purchasing electricity on the wholesale spot market in England and Wales for different time periods (table 4-1). Their study shows that, with the exception of water supply firms that have the ability to shift the pumping of water to different periods at very short notice, all the types of firms studied had a price elasticity inferior to 0.06 on average. This means that a one percent increase in price during a pricing period may lead to at the most a 0.06 percent decrease in electricity consumption in that period. Moreover this value is even lower than 0.01 for four of the six categories of consumers studied. This lack of demand response hampers load reduction in response to price increases. Combined with a concentrated market structure this lack of responsiveness of demand represents a major concern, that requires specific attention with respect to market power and market modeling.

4-4 Economic theory applied to wholesale electricity: recent developments

4-4-1 Introduction

Technical models have been developed and used for many years by integrated utility and system operator to ensure the smooth operation of electricity systems. Technical models are used to simulate least-cost production solutions for a given level of demand and available generation resources (Miller and Malinkowsky, 1970). The characteristics captured by these models are: heat rate, capacity level, minimum up/down times, outages rates, fuel costs, maintenance costs etc. These models provide solutions for a utility to use a specific power plant. Dealing with electricity flows, transport constraints and unit commitments, these models are also used by system operator to ensure operation of the grid (Grainger and Stevenson, 1994). For instance the “Norwegian power pool model”[7] focuses on flow into reservoirs and weekly production in a hydro-based system.

While the genuine purpose of these models in the past was cost minimization for regulated utilities, such models are still useful nowadays but are utilized from a profit maximization perspective (Davidson *et al*, 2002). The output of these models provides a relevant benchmark for analyzing the level of competition. However there are some limits. For instance, some assets may be used in totally different ways before and after liberalization. Secondly, these models were mainly developed for well-defined isolated areas, today, cross-border trading plays an important role in the price determination process. Finally the most important weakness of technical models is that they totally overlook economic interactions between competitors. Hence, these traditional technical models have little relevance when analyzing liberalized markets consisting of a number of competitors.

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[7] See www.risoe.dk for more information

Similarly, theoretical economic models, such as perfect competition and monopoly models, are too generals to be applied directly to the electricity industry since they do not take into account many fundamental aspects of actual electricity markets. Given the above, the liberalization process of the electricity industry worldwide has led to important efforts in the research community to develop models that reflect the new market context. Using existing tools taken from the two approaches, i.e. technical operation and economic theory, an important set of economic literature in which new models, adapted to take into account the features of new competitive wholesale markets, has been developed.

Recently developed models combine the technical characteristics of electricity based on operational models and the modeling of firms behaviors based on oligopoly competition theory. The models differ mainly in the set of assumptions and of variables they deal with. We present a survey of the most relevant models in this section focusing on the technical characteristics they take into account, the economic model they use and the purpose they serve. The relevance, advantages and disadvantages of these models are presented and analyzed with regard to using them for the study of power exchanges.

4-4-2 Recent developments

It is well recognized that, given the concentrated nature of the market structures, oligopoly competition models are the most suitable models for analyzing electricity markets. The choice between Bertrand and Cournot competition represents the two major alternatives (Hobbs *et al*, 1999). Depending on the purpose of the model and the type of market, one approach might be more relevant than another. In general, and especially in period of high demand, it appears that the Cournot paradigm corresponds more closely to electricity markets (Borenstein and Bushnell, 1999). The use of Cournot Competition is supported by the fact that electricity suppliers have limited capacity. In the Bertrand approach, any firm can capture the entire market by pricing below other competitors but, since electricity producers have increasing marginal costs and limited installed capacity, Bertrand's assumptions regarding behaviors appear less realistic (Hobbs, 1986). However, in some circumstances, e.g. periods of low demand, it has been argued that Bertrand models might be a relevant approach (Green and Newbery, 1992; Wolfram, 1998). Hence, the level of demand and the level of capacity constraints are fundamental variables that need to be taken into account to choose between Cournot and Bertrand competition.

Kahn (1998), Hobbs (2000) and Ventosa *et al* (2002) have examined the characteristics of the different economical models applied to the electricity industry. These models can be classified using different criteria. For instance, models can be classified by the degree of competition they assume, i.e. perfect competition, Cournot, Bertrand, supply function; the intended market, e.g. California, United Kingdom, Spain; time scope, e.g. short-term, long-term; the intended user, e.g. system operator, competition authority, generator; and so on. One classical approach consists of identifying the purpose the model serves. Since giving insight into a problem is the reason why models are developed (Sterman, 1991) this criteria is especially relevant. The purpose of the models are multiple, e.g. risk management (box 4-4), strategic bidding, economic planning, congestion management etc. For instance, Ventosa *et al* (2002) define two categories of models: equilibrium models and optimization models. In equilibrium models, the behavior of each participant is modeled taking into account competition among all participants while the behavior of only one firm is considered in optimization models. Optimization models are formulated as a single optimization program in which a firm maximizes its profit. Equilibrium models take into account the profit maximization of each firm simultaneously. Drawing up a full list of existing models applied to electricity markets with all their characteristics is beyond the scope of this work. Below, we focus on recent developments.

Kahn (1998) focuses on models, which analyzes market power. Kahn's models assume profit maximization of market participants under oligopolistic competition. Two categories of oligopolistic competition are modeled. The first one is Cournot competition (quantity) while the second model uses the supply function approach (price-quantity). Kahn's main conclusion is that the Cournot approach is more flexible and tractable and that is why it is more commonly used. However he argues that the supply function equilibrium approach is conceptually superior to the Cournot competition.

Box 4-4: Model and risk management

In a competitive environment characterized by uncertainty and price volatility, models are used for risk management. Risk management models are mainly derived from financial models. For instance, they use specific tools such as Black-Scholes analysis or Monte Carlo simulations. These models rely mainly on historical data to estimate volatility. For this reason such models can only be applied in mature markets where price data are available and the level of liquidity is sufficient (Fleten *et al,* 1997). In Europe, only Nord pool fulfills these criteria.

Monte Carlo simulations have been recently used for electricity markets. The Monte Carlo method is used to calculate the variation in prices using a sample of randomly generated price scenarios that are assumed to be equally probable. Such an approach requires making assumptions concerning market structure, about the stochastic processes that the prices follow and about the correlation between risk factors and the volatility of these factors. Monte Carlo simulations can combine historical information with market expectations. For instance, Monte Carlo simulation can be use to model forced outages (Borenstein *et al*, 2000). The first criticism of this method is that it is computationally demanding. Moreover, the mathematics underlying the calculations are complex which makes the outcome very sensitive to assumptions. Another criticism is that it requires subjective input in the choice of simulation model structure. In general the fact that a Monte Carlo simulation use a random process represent an important limit in operational circumstances.

Green and Newbery (1992) and Bolle (1992) were the first to employ the supply function equilibrium approach in electricity markets. Their objective was to estimate the level of competition in the British electricity spot market. Bolle used this method to estimate the risk of tacit collusion in a concentrated market. Rudkevich *et al* (1998) have also used the supply function approach to analyze strategic bidding and to attempt to predict joint behavior of market participants. Falk (1998) criticize their model showing that the number of simplifications led to astounding conclusions. Day *et al* (2002) have extended the supply function approach by introducing the anticipation of firms concerning the output of rivals (Conjectured Supply Function). Hobbs *et al* (2002) have applied this model to the Benelux, French and German markets in order to analysis the inefficiency of transmission pricing in Europe[8].

The most recent developments in market modeling in the literature are related to the Californian crisis. Borenstein and Bushnell (1999) used historical cost data to simulate the California electricity market assuming static Cournot competition. They argue that such approach is superior to classical Hirschman-Herfindahl Index (HHI) which appears to be unsatisfactory for electricity markets[9]. Joskow and Kahn (2001a) used a very sophisticated model to analyze pricing behavior in California during the crisis in the summer 2000. The objective of their analysis was to build a competitive wholesale benchmark and to compare it to the prices that were actually observed: the difference between the two values represents an estimate of the level of market power. In their model they take into account several factors such as hydro output, imports, natural gas costs, air emission regulation (nitrogen oxide, NOx), heat rates, forced outages rates etc. This model has been extensively criticized by Harvey and Hogan (2001) who argue that market power might be one of the reasons for the very high prices but that other factors should not be forgotten. In response Joskow and Kahn (2001b)

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[8] See chapter 9

[9] See chapter 10

replied somewhat sharply[10] to Harvey and Hogan criticism and made some improvements to their first model.

In conclusion, research into modeling electricity markets is continuing and is the subject of many debates. All types of competition (Cournot, Bertrand, supply function…) are utilized and have their advantages and disadvantages for electricity markets. It is well recognized that models cannot address all questions of interest, however they appear to be a powerful tool for understanding whether electricity markets are delivering the expected benefits of liberalization.

4-4-3 Relevance of models: the inevitability of using models

Models have been used widely in economic analysis for decades from worldwide macroeconomics to local microeconomics studies. Such models have become an important tool for analyzing and forecasting, in public institution and private companies. Models are useful because they can be used to compute and interrelate many factors simultaneously; this allows us to simplify reality and helps us to better understand a complex situation.

Electricity markets have specific features which make modeling a very interesting approach to use in this field. First, the nature of the product is very easy to identify. All electrons are comparable in contrasts to foods or cars. Second, estimations of production costs are relatively easy to do compared to others products. The production process is well defined and the cost of 1 MWh for a specific power plant, or type of plant, is quite simple to estimate based on the technical characteristics of the power plant and the cost of fuels used in the plant. Finally existing technical models containing historical data and well-defined parameters, can be used to facilitate the development of economic models.

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[10] *"[...] we find that their arguments as a whole are unpersuasive, that they are applied inconsistently [...]"; "Harvey and Hogan present a litany of largely unsupported arguments that ignore what economic theory and common sense suggest about behavioral incentives"*

In practice, models that have been developed for electricity markets have three main uses. One, they are indispensable for gaining insight into the modes of behavior of the market participants (Hobbs, 2000). Such models can be used to model the different possible behavior of market participants to allow comparison between participants behavior and the impact of this on competition. For instance, simulating market prices in a defined market and changing the market structure in terms of ownership of the power plants provides insights into the role of market concentration on competition. Two, they can be used for forecasting. Based on historical data, models can be used to provide forecasts of market outcome to help decision-makers. Three, models are useful for ex-post analysis. Models can be used to provide a benchmark to understand what happened in a market. The analysis then consists of explaining the difference between the model output and the actual output. This last type of analysis is especially useful for the analysis of market power (Borenstein *et al*, 1997, Joskow and Kahn, 2000)

4-4-4 The disadvantages of models

Models in general have a variety of limitations and problems, which are not specific to electricity models. Assuming that data are available and reliable, the main limits of models concerns how realistic are the assumptions made in the model. Making assumptions is the first step when building models and this represents the true weak point of a model. Assumptions are made during the description of the system to be modeled and of the relationships between variables. For instance, in electricity models it is assumed in a majority of models that players compete on quantity (Cournot) rather than on price (Bertrand), while in practice the two parameters are important. Secondly, in order to permit calculation, model builders have to define a value for price elasticity. This parameter is exogenous and the value chosen crucially influences the outcome of any simulation. Indeed, a price elasticity of zero, which appears to be the most realistic in the short-term, leads to infinite price under Cournot competition. Moreover, under Cournot competition, rivals do not change production if the price changes. This assumption is very restrictive. Moreover, the definition of the objective function, the problem of linearity, the lack of dynamic, the choice between endogenous and exogenous variables, the quantification of soft variables and the choice of model boundaries (Sterman, 1991) represent critical assumptions which widely impact the outcomes of models.

The objective function of market players in economic theory is usually profit maximization, because of this most models assume that players will take decisions that allow them to maximize their profit. Though this hypothesis is widely accepted by economic theory, in reality, companies can have different objectives. For instance a company may try to maximize its market share, which involves a different strategy. A company may also make investments, which reduce its short-term profit but will increase its long-term profits. Hence, behaviors that diverge from profit maximization are ignored while they can be perfectly rationale. Moreover, many economic models assume perfect information, which implies that players can perfectly anticipate the consequences of their actions and those of their competitors. Such assumption makes little sense in reality. In the real world the level of information is always incomplete leading to biased decisions.

Linearity is a common feature of large models, because large models involve hundreds or thousands of variables and constraints, the problem of finding a solution is extremely difficult. For this reason, the relationships between variables are often modeled as linear. The cost of a power plant is most of the time explained by a linear relationship with the cost of fuel used, e.g. 2 units of fuel are necessary for the production of 1MWh. Albeit such estimates can be made, but overlook the differences in efficiency of a power plant with respect to levels of use (Stoft, 2002), i.e. when a plant is used at 20% of its maximum capacity its efficiency may be lower than when it is used at 80% capacity. Concerning elasticity of demand, consumers may not react to a price change until a 20% price increase, but they will start to consider decreasing their consumption, they will actually start to decrease their consumption when prices increase by 30%. Hence if linearity is mathematically convenient, in reality it is often invalid and its use can strongly biase results.

Most models do not incorporate dynamic aspects of competition. They define an equilibrium situation for a particular moment in time regardless of any possible changes with time or “learning process” on behalf of participants. For example, take the problem of modeling and accounting for the impact of entry with regard to new generating units or the construction of new transmission capacity. Another example is the fact that in a market with repeated interactions, firms will learn how their competitors behave and will adapt their strategies. Static models do not capture such aspects. Dynamic models, however complex, this complexity often causes the results of the model to be unrealistic or indeterminate (multiple equilibrium). Furthermore, dynamic models do give a clear guide to the net effect that dynamic factors have on prices.

When all relevant parameters and variables have been identified, choices have to be made as to whether they are endogenous or exogenous. Exogenous variables are not calculated using the model. These parameters usually include: elasticity of demand, number of player, capacity of lines, production costs, production efficiency, level of demand, prices of fuel etc. Endogenous variables are mainly prices or costs. Defining exogenous variables simplifies calculation while integrating of all variables as endogenous will result in additional complexity, which can make the model insoluble. The existence of these two categories of variables makes impossible to take into account the feedback between the types of variables (exogenous and endogenous). For instance if the level of prices simulated by the model are very high, new players may enter the market which in turn will influence the market structure.

Models are powerful tools for analyzing a large amount of numerical data, however they are limited when it comes to dealing with soft variables. Soft variables are qualitative data that are difficult to quantify. They represent descriptive information, which may be crucial for the functioning of a market. For instance, political environment, organizational realities, non-economic motives, regulatory framework, market design, reputation of players, business practices etc all have an important role in the functioning of a market and yet it is difficult to handled these variables in models. For instance, in an oligopolistic market structure, actual prices can be lower than prices simulated by a model because firms fear regulatory intervention. Psychological aspects are also soft variables. One important weakness of models is their inability to take into account such aspects. Yet these qualitative data are especially important in decision making since decisions made by a company are made by people not machines. Decision-makers will have different perceptions and interpretations of market situations, and these differences are difficult to include in a model.

Defining the boundaries of a model is an important issue for modeling. The classic boundaries of electricity models are time horizons and geographical area. Electricity prices vary hour by hour, even by minute in some markets, in response to constant changes in supply and demand, which in turn are influenced by several parameters, e.g. weather, time of the day, outages, maintenance, transmission constraints etc. Hence even if some parameters can easily be identified as more relevant than others, neglecting some implies assuming zero impact and this is probably the only value known to be wrong (Forrester, 1980). Moreover, electricity market models are very often related to a geographical area, and hence, exclude other geographical areas. Excluding other areas for a country like New Zealand has no consequences since it is an island that is unconnected to others areas. However, such approach is more arguable for interconnected countries. Thus, modeling the German or the Californian market, make little sense because import and export of electricity may have a large influence on the market. A common way to deal with this is to assume that import and export are constant or that exports are only a part of demand while imports are only an “extra” generator. In a competitive international environment, however, the price of two or more areas will be interdependent and changes in one market can explain changes within another.

In conclusion, models are an inescapable analysis tool. However, their use should be restricted to a specific purpose. A single model cannot address all issues. How even sophisticated they might be, models are only simplifications of reality, and they rely strongly on assumptions. This is best illustrated by the fact that two models developed by equivalent, top-level economists can produce radically different results due to minor, and reasonable, differences in the assumptions made when beginning to model. Moreover, a fundamental problem in modeling is that, due to the central role of assumptions, the margin of error may well be larger than the magnitude of the effect that one is attempting to measure (Hogan, 2001). For these reasons models should be seen as a complementary tool for analysis that help the analyst to improve their judgement and intuition, and should not be seen as substitutes for critical analysis on behalf of the analyst (Sterman, 1991).

4-4-5 The advantage of using modelling for the analysis of power exchange

Modeling of spot markets for electricity has been widely done for power pools. These models have been developed mainly for the United Kingdom, and California (Wolfram, 1999; Green and Newbery, 1992; Borenstein and Bushnell, 1999; Wolak and Patrick, 1998;). However, with the exception of Nord pool (Hjalmarsson, 2000) there is no available model in the literature for power exchanges' day ahead spot market, hereafter power exchange. This is surprising because at a first glance building models for electricity power exchanges appears to be a promising approach.

The important feature of power exchange which favors modeling is the explicitness of the price determination process, i.e. the auction. Buyers and sellers submit bids, which are aggregated by the exchange. Hence, estimating the impact of any increases (or decreases) of supply or demand can be easily achieved since reproducing the algorithm used daily by the power exchange to determine the market-clearing price can easily be done. For instance, if one wants to know the impact might have been on prices for supplying one additional MWh, a simulation using all actual bids and a new bid with this extra quantity can easily be done.

A model can be useful for analyzing power exchange to estimate any change in the rule of functioning of the exchange. For instance, if an exchange wants to introduce pay-as-bid instead of marginal pricing[11], simulations can be realized to study the reaction of participants and the possible changes in market equilibrium. Hence, models can be used to test new auction system. Even if the model can not predict exactly what will be the new behaviors of participants, running simulations can quickly show the potential disadvantages of a new system. Though a model does little to prove that the new rules of the auction will work in practice, it can definitely eliminate wrong options.

Finally, the reasoning use in models is interesting for an analysis of competition on power exchanges. Keeping in mind the different kind of interaction between players (Bertrand, Cournot, Supply function…) can be use to guide the analysis of actual data. If empirical observation shows that a player has decreased the level of its supply and that this has resulted in an increase in prices, market analysts will certainly opt for the use of a Cournot model. Similarly, if a player has decreased the price of its bids to maximize the volume of its sales, a Bertrand model might be more relevant.

4-4-6 The weaknesses of existing models for analyzing power exchanges

The first challenges for modeling power exchanges is the nature of the players. While in classical power pools, the sellers are generators and their characteristics are directly identifiable through their assets, in power exchanges every type of market participant can be a seller. In most existing models for the analysis of electricity markets, supply is estimated based on installed capacity and different characteristics of power plants. However, on a power exchange, any participant that has over-contracted on the bilateral market can be a seller on the power exchange's spot market. For instance a distribution company or a large consumer can sell electricity on the power exchange if they realize, one day before actual consumption, that they will actually consume less than what they had forecast weeks or months before when they signed physical bilateral contracts. Moreover, pure traders, without physical assets, can sell electricity on a power exchange, which can initially come from a bilateral contract or from arbitrage with another country. Finally producers of electricity have developed trading departments which also act as pure traders, i.e. make arbitrage between type of contract or between location. Hence, a producer which sells 10 MWh on the power exchange may have bought this amount of energy from a distribution company which in turn bought it from another producer. From a modeling point of view this separation between physical asset and sale on the power exchange make the identification of sellers characteristics difficult and represents a serious problem for the estimation of supply.

Defining the relevant approach to estimate the nature of competition on a power exchange is also a difficult task. As described above, most models of electricity markets assume Cournot competition. However, on a power exchange, players bid on price and quantity and manipulating prices can be done using price and/or quantity, e.g. not offering 1 MWh or offering it at 1 billion Euro can be considered as equivalent or at least as having an equivalent effect. For this reason the supply function approach developed by Klemperer and Meyer appears to be a more realistic approach. In practice, this is difficult because supply function models have a major drawback due to the multiplicity of solutions provided. These solutions range from perfect competition to Cournot equilibrium.

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[11] See chapter 3

The possibility for pure traders, distribution companies and large consumers to act as sellers on the power exchange also represents a serious problem with respect to the use of oligopolistic models. Indeed, the number of participants in most existing power exchanges is over thirty[12] and assuming that at least half of them are active as sellers, it is questionable whether oligopoly competition is a sufficiently adapted framework.

The problem of identifying the relevant market players is also due to the fact that power exchanges are voluntary markets. In an extreme case a large generator may not participate in a power exchange. Furthermore, a large producer can find it more economic to buy electricity on the spot market rather than using its own units. Hence, a generator can buy on the power exchange to honor its bilateral contracts. A generator can even be a very large buyer if it faces an outage of one of its plant and buys electricity on the exchange that has come, for instance, from an over-contracted distribution company.

By definition a power exchange represents only part of the market and companies are likely to use power exchanges as part of their overall trading strategy. Since spot trading can also occur on a bilateral basis, depending on the trading practice some companies may favor the use of the bilateral market even for spot trading rather than the use of the exchange. This is true for both mandatory centralized markets (pool) and voluntary exchanges, because of the existence of bilateral contracts (financial or physical) that limits the relevance of the spot price. Hence, a model focusing only on trading on the power exchange will overlook all possible behaviors on the other markets and their interaction with the power exchange.

The dynamic aspects of competition are fundamental in a power exchanges' spot markets. Interactions between firms take place daily and repeatedly. Hence, the fact that firms will adapt, with time, their bidding behaviors is crucial. Moreover, in

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[12] See chapter 7

a concentrated market structure with repeated interactions tacit collusion is likely to occur to decrease the level of competition. The importance of dynamics in power exchanges is therefore a serious limitation for the use of classical (static) models.

Finally spot trading is particularly sensitive to random external events. Amongst them, outages represent the most common reason of price spikes. When a generator loses one generation unit, in the short term buying electricity on the power exchange represents the best alternative before having to pay balancing charges. Unexpected hot or cold weather conditions also have a direct impact on spot prices. Similar to outages, an unexpected temporary reduction of interconnection capacity can dramatically influence price level on power exchanges. Other considerations like cooling water problems, a worker's strike at a very large consumer or the end date of a specific bilateral contract are also reasons for the extra volatility of power exchanges. There is also the problem of the lack of historical data, and when it is available it may be invalid due to changing conditions on the market. This characteristic of power exchanges represents an important challenge for modeling because models are not well able to take into account a high level of volatility.

In conclusion, due to the nature of the power exchanges' spot market which differs widely from power pools, existing models are unlikely to be able to handle all the factors which influence competition on power exchanges and their functioning in general. For this reason even very sophisticated models appear not to be capable of incorporating all factors which influence trading on these markets. However very simple models might be useful for testing very specific aspects of the power exchange and further research will certainly improve existing approaches.

4-5 Conclusion

This chapter consists of a review of different economic theory models of market functioning and their application to competition analysis in electricity markets. This contains descriptions of background theories, how they have been applied to electricity markets and their value and limits for the analysis of power exchanges. Reference theoretical models were briefly presented. Subsequently, we identified the major difficulties encountered when applying economic theory with respect to the nature of demand and supply in electricity markets. Different applications for models in electricity markets and recent work in the field were discussed. Finally the strengths and weaknesses of models for the analysis of power exchanges were analyzed. Based on this work, it appears that we need to understand the general functioning of power exchanges better before we can build relevant models.

Chapter 5

The functioning of power exchanges

The objective of this chapter is to provide a detailed description of the functioning of power exchanges or more precisely of the power exchanges' spot market. While in practice differences exist between power exchanges in Europe, some general common principles can be identified. Hence the general description given in this chapter can easily be applied to Nord pool, APX, UKPX, LPX, EEX and Powernext. This chapter starts with a general description of trading on a power exchange. Then the different types of bids and the price determination processes are presented, followed by an analysis of the interests of auction theory for the understanding of power exchanges. The issue of physical delivery of trading on a power exchange is addressed and the interactions between power exchanges and others market, such as the bilateral market or the balancing market, are analyzed.

5-1 Trading on a power exchange

5-1-1 Introduction

Electricity power exchanges are marketplaces, i.e. they are a third party which facilitate the transaction between a seller and a buyer. Hence, power exchanges have trading rules, which cover the setting of prices, delivery, clearing, type of product, timing…etc. The role of a power exchange is to facilitate the trade of short-term products. The aim is to help market participants balance their purchase and sale obligations in the short run. Concretely, a power exchange offers a neutral marketplace where all trading participants trade anonymously (Schulte-Beckhausen, 2001). One interest of power exchanges is that they provide a public price index which can be used for the whole power market.

5-1-2 Products

The main products exchanged on European power exchanges are hourly spot contracts. Spot contracts on a power exchange are agreements to buy or sell electricity for the following day for a certain price. These contracts specify the asset, the contract size, how the price will be quoted, where and when delivery will be made and how the price paid are be determined. The asset is clearly defined unambiguously as electricity on the high voltage grid. In practice, the contract size is mainly defined by a minimum value of 0.1 to 1 MWh. Power exchange’s prices are quoted mainly in Euro per Megawatt hours in continental Europe, in Scandinavia and in the UK the price are quoted in national currency. The place for delivery is defined with the system operator[1].

5-1-3 Exchange clearinghouse

As for any organized market, e.g. stock markets, a clearinghouse is subordinate to the power exchange and acts as an intermediary for transactions. The role of the clearinghouse is to guarantee the financial reliability of the parties of each transaction. Its main task is to keep track of all transactions. The clearinghouse can then calculate the net positions of each participant which are required to maintain a margin account with it. Depending on their transactions, participants may have to add or remove funds to their margin. The principal objective of the margining system is to reduce the risk that market participants would not be able to pay for their transaction. In turn such a system hedges market participants against credit risk

5-1-4 Regulation

The purpose of market regulation[2], from a power exchange point of view, is to provide uniform, non-discriminatory rules for fair-trading on the power exchange. Power exchanges defined rules and instructions to provide an adequate functioning of their markets. Power exchanges monitor the trade of electricity on their spot market and supervise the observance of the rules by the participants in the same way that all organized markets do, e.g. like stock markets and financial markets. While classical organized markets are regulated by specific authorities, most existing power exchanges are not subject to the supervision of any external regulatory body. Regulatory bodies are responsible for licensing exchanges and approving contracts. They also deal with complaints and ensure disciplinary action when it is appropriate.

For instance, in the United States, futures markets are regulated by different bodies like the Commodity Futures Trading Commission (CFTC), the National Futures Association (NFA), the Securities Exchange Commission (SEC) etc. In Germany exchanges are considered to be institutions under public law and therefore they are subject to public law. The legal bases are the exchange laws under the supervision of the Exchange Supervisory Authority[3]. In the Netherlands, the Electricity Act 1998[4] which implement the EC Electricity Directive does not provide any rules with regards to the regulation of the Dutch

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[1] See section 5-3

[2] See chapter 10

[3] See LPX-EEX website: http://www.lpx.de/organization/regulations/index_e.asp

power exchange (APX). Hence, neither the Dutch energy regulator (Dte) nor the Supervisor of financial institutions (Ste) are charged with the supervision of APX (Roggenkamp, 2001). The regulation of electricity trading on the French power exchange is based under financial regulation as, by a legal fiction, operators are supposed to trade only financial instruments but not physical electricity contracts[5]. Moreover, the French energy regulator has access to the data of the exchange[6]. In conclusion, it is worth noting that the regulation of most electricity power exchanges in Europe differs and does not have formal and direct legislation governing trade in spot trading.

5-2 Price formation mechanisms

5-2-1 Introduction

All power exchanges have trading rules. Amongst them, the method of setting the price, i.e. price formation mechanism is fundamental since it represents the heart of the exchange. Several examples are given below[7]. First we describe the two main categories[8] of bids, i.e. hourly bids/block bids, then we analyze the matching mechanism.

5-2-2 Hourly Bids

Bids are an offer made by markets participants addressed to the power exchange to buy or sell a certain quantity of electricity at a maximum or minimum price expressed in Euro/MWh. Hourly bids[9] are the basic type of power exchange order, representing the largest share of volume traded[10]. Each participant selects its own range of price steps and build its own bid based on consumption need, delivery obligations, cost of own production and position on the bilateral market. Hourly bids consists of five types of information: Name of the participant, type of

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[4] Available at : http://www.minez.nl/energie

[5] Available at : http://www.powernext.fr/

[6] Article 4.5 of the exchange regulation

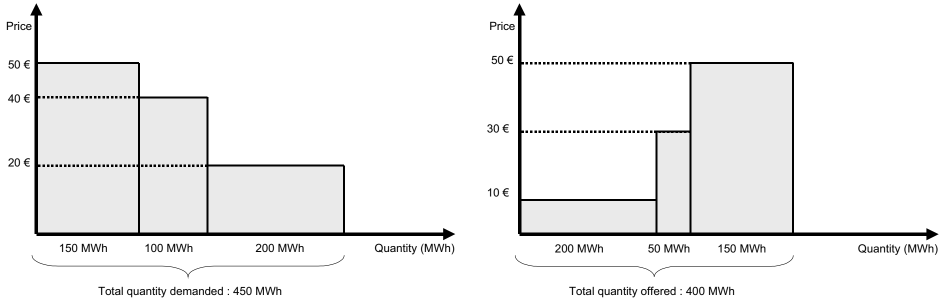
[7] The different examples are taken from LPX's, APX's EEX's UKPX, Powernext's and Nordpool's brochure, available on their respective website.

[8] Note that Nord pool also offers flexible hourly bids, see http://www.nordpool.no/marketinfo/index.html

[9] It is worth noting that unlike power pools, supply offers to power exchanges are not required to be linked to any production facility.

bid (sale or purchase), hour of the day (1 to 24[11]), quantity of energy and price. Within the same hour, participants are allowed to offer different price-quantity pairs.

Figure 5-1: Examples of bids on a power exchange



Player	Type	Hour	Quantity	Price
Company Y	Purchase	22	150	50
Company Y	Purchase	22	100	40
Company Y	Purchase	22	200	20

Player	Type	Hour	Quantity	Price
Company X	Sale	13	200	10
Company X	Sale	13	50	30
Company X	Sale	13	150	50

Figure 5-1 presents two examples of bids for a buyer and a seller for two different hour of the day. These bids can be read as follow. For hour 22, company Y is willing to buy until 150 MWh at a maximum price of 50 Euro/MWh, an additional volume of 100 MWh at a maximum price of 40 Euro/MWh and finally an additional volume of 200 MWh at a maximum price of 20 Euro/MWh. For hour 13, Company X is willing to sell up to 200 MWh at a price of 10 Euro/MWh or higher, an additional volume of 50 MWh at a price of 30 Euro/MWh or higher and finally an additional volume of 150 MWh at a price of 50 Euro/MWh or higher.

Within a single hour, each participant can also bid for sale and purchase. To illustrate the functioning of such bids, we will consider the case of a producer (hereafter producer P) that needs to cover, at hour 12 the following day, a

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[10] See Nord Pool, *Bidding on the spot market*, available at http://www.nordpool.no/information/index.html

[11] Hour 1 refers to the time period between 0h00 and 1h00, hour 2 refers to the time period between 1h00 and 2h00 etc.

demand of 20 MW and has an available capacity of 30 MW at a variable cost between 20-25 Euro/MWh[12].

Table 5-1: Simultaneous sale-purchase bid

Player	Type	Hour	Quantity	Price
Producer P	Purchase	12	20	19
Producer P	Sale	12	10	26

In this example the producer will buy from the market, rather than use its own resources, if the market clearing price (MCP) turns out to be lower than its lowest production cost (less than 20 Euro/MWh). If the MCP is higher than its highest production costs (more than 25 Euro/MWh) the participant will use its own resources to satisfy the demand of 20 and will sell its extra capacity to the market[13].

5-2-3 Block bids

Block bids are unique to electricity exchanges compared to other commodity exchanges. They are designed to capture the peculiarity of electricity. Since electricity is traded on an hourly basis and since some power plant are not flexible at short notice, or the cost of starting and stopping the power plant is high, block bids allow participants to sell or buy electricity for a period of consecutive hours during the day. This kind of bid contains a “limiting price” that indicates that if the average clearing price over the period is lower than the limiting price, the trade algorithm will withdraw the whole bid.

If the average clearing price over the period is higher than, or equal to, the limiting price, the trade algorithm will take into account the whole bid. The bid will also have a volume condition: the whole amount of energy has to be accepted by the matching process. Block bids can be specified by the exchange or by

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[12] For the purpose of this example technical aspects such as starting costs are ignored

[13] See chapter 6 for more about participants behaviors

players. For instance a "baseload" block bid consists of a bid for hour 1 to 24 while a tailor made block bid can be a bid for hour 9 to 12, 9 to 20, 16 to 24 and so on. For instance Nord pool has five different block periods:

- Block 1	Hours 1-7
- Block 2	Hours 8-18
- Block 3	Hours 19-24
- Block 4	Hours 8-24
- Block 5	Hours 1-24

Just as with hourly bids it is also possible to place several bids for the same block.

5-2-4 Matching

Most European power exchanges[14] are based on a two-sided auction. This means that both offers and demand are taken into account to fix the price. The auction is characterized by the fact that all bids are first collected and then used to determine the prices[15]. The bids are anonymous which means that bids of each participant are not revealed to any of the other trading participants.

The power exchange collects the bids for all players for every trading session and for each hour an aggregated purchase curve and an aggregated sale curve is obtained. The aggregated sale curve is obtained by adding the energy offered in increasing order of prices, regardless of participants. The aggregated purchase curve is obtained in the same way but in decreasing order of prices, see figure 5-2 for an example of the aggregation of two sale curves.

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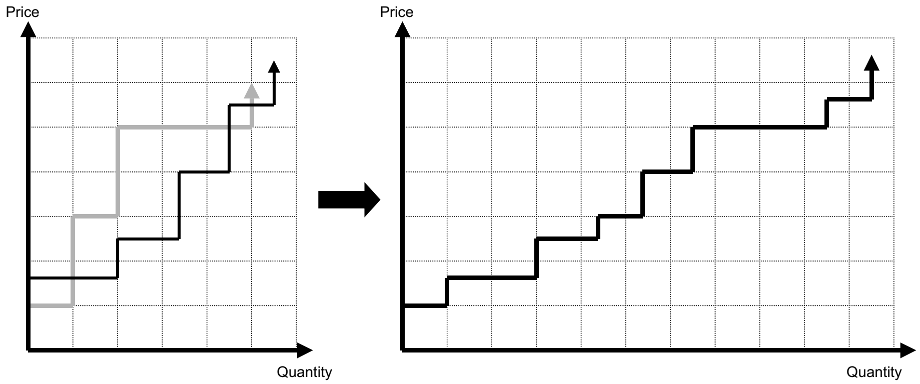
[14] APX, UKPX, LPX-EEX, Powernext, and Nord Pool

[15] Note that in addition to the auction EEX offers continuous trading mechanisms, see http://www.eex.de/spot_market/info/market_model/index_e.asp

Figure 5-2: Aggregation of sales curves



Sales and purchases bids are grouped and plotted as step functions (or curves) as shown in figure 5-2.

The intersection point of the two curves defines the market clearing price (MCP) and the market clearing volume (MCV) for each hour (figure 5-3)[16]. In other words, the sellers are prepared to offer MCV at MCP and the buyers are prepared to purchase MCV at MCP. The sale bids submitted with a price lower or equal to the MCP and the purchase bids with a price equal or higher than the MCP are accepted while the others are rejected.

Block bids are integrated into the hourly auction by changing block contracts into price independent bids for the hours concerned. In the first phase of the calculation, the limit fixed by the participant is ignored. When the first price calculation is finished, the average hourly price of the corresponding block hours is compared to the price limit of the block bid defined by the participant. If the

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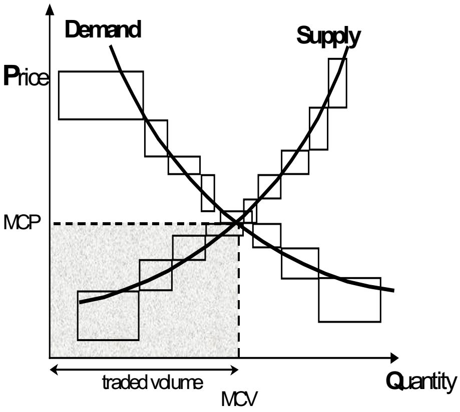
[16] Some exchanges, like Nord pool and Powernext, make a linear interpolation of volumes between each adjacent pair of submitted price steps (which ensures only one intersection point) while others use the step functions directly (which involves a set of rules for when the supply and demand curves cross at many points)

average hourly price is equal or higher than the limiting price, the block bid is fulfilled.

Figure 5-3: Determination of MCP and MCV



5-3 An auction theory approach of power exchanges' functioning

Auction theory[17], with the development of organized electricity markets, i.e. power pools and power exchanges, that use auctions to determine equilibrium prices appears to be an interesting approach for analyzing these new markets. It is worth noting that most auction theory restricts attention to the sale of a single indivisible unit (Klemperer, 1999) and this cannot be applied directly to electricity. However recent researches on multi-unit auctions can be directly applied to power exchanges. In this section we present the main strengths of auction theory for analyzing a power exchange's functioning.

In auction theory terms, power exchanges are organized as first-price (or uniform), multi-unit (Kahn *et al*, 2001), double sided auctions (Wilson, 1985). In this type of auction, market prices are determined by the bid price of the marginal

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[17] For an historical perspective on auction theory see Shubik (1983). Two very readable introduction are Maskin and Riley (1985) and Klemperer (1999)

accepted bid[18] (*first price*). In such an auction buyers bid demand curves and sellers bid supply curves for a homogeneous good (*multiunit*). Finally on power exchanges buyers and sellers are treated symmetrically[19] with buyers submitting bids and sellers submitting asks (*double auction*). While within this general framework many differences in auction design exist in practice, auction theorists have identified three features of electricity auctions that are crucial for the analysis: the number of bids that may be submitted, the duration of suppliers' bids, and the existence of binding constraints (Fabra *et al*, 2002).

Box 5-1: The four basic types of auction in theory (for a single object)

The ascending-bid auction:
In this auction, also called the open, oral or English auction, the price for an object is raised successively until one bidder remains, and that bidder wins the object. This auction can be run by having the seller announcing prices, or by having the bidders call out prices or by having bids submitted with the highest bid securing the object.

The descending-bid auction:
This auction works in exactly the opposite way to the ascending-bid auction. The auctioneer starts at a very high price and then lowers the price. The first bidder to indicate he will accept the current price secures the object at that price.

The first-price sealed-bid auction:
In this auction each bidder submits independently a single bid, without seeing others' bids. The object is then sold to the bidder who makes the highest bid at the price of this bid.

The second-price sealed-bid auction:
This auction (also called a Vickrey auction), works in exactly the same as the first-price sealed-bid auction, the object is sold to the bidder who makes the highest bid. However, the price paid is that of the second-highest bidder's bid.

Source: Klemperer P. (1999), "Auction Theory: a guide to literature"

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[18] In contrast, in discriminatory auctions (or pay-as-bids), such as the England and Wales balancing market, suppliers are paid their bids and consumers pay an average price (see chapter 3)

[19] In standard auction theory a single buyer controls the trading mechanism while many buyer submit bids.

On a power exchange, the number of bids submitted is limited by time period. For each hour (or half-hour), suppliers can only submit a limited number of bids. For instance, on the Spanish electricity "pool" and on the Amsterdam Power Exchange 25 price-quantity pairs can be submitted by suppliers, 62 can be submitted on Powernext and Nord pool etc. Hence the bids consist of several price steps. These types of auctions are called *discrete* multi-unit auctions in contrast to auctions for perfectly divisible goods (Klemperer, 2000; Elmaghraby and Oren, 1999). Such a distinction is important because the output of auctions with discrete bid function can differ significantly from auctions working with a continuous bid system (Von der Fehr and Harbord, 1993; Nyborg 2001). Auction theory shows us that the design of the functioning of a power exchange has a large influence on the behavior of the exchange's participants:

"[…] in the continuous auction, suppliers can bid in very steep supply functions which eliminate a rival's incentive to bid more aggressively. Discreteness in the bid functions rules this out, however. When suppliers are limited to a finite number of price-quantity bids, a positive increment in output can always be obtained by just slightly undercutting the price of a rival's unit. Since this "quantity effect" outweighs the "price effect", the collusive equilibrium found in the continuous auction cannot be implemented" (Fabra *et al*, 2002).

The duration of suppliers' bids represent an important characteristic of an electricity auction. In most power pool models, e.g. Australia, Argentina and the now defunct England and Wales pool, generators bids are valid for long period, e.g. bid valid for one week or one year. In contrast bids are only valid for a single period on most European power exchanges. Such differences between validity of bids greatly influences the functioning of the marketplace (Back and Zender, 1993). Finally, since in many periods, mainly peak hours, there is no excess supply when the capacity of a single firm is taken out of the market, there are binding constraints. The existence of these binding constraints has a strong impact in the formation of the equilibrium.

In conclusion, auction theory definitely provides us with a very interesting and promising approach for the analysis of price determination process on power exchanges. This approach is well suited because most of the electricity markets created to date are characterized by auctions. However it is worth noting that this approach has mainly been used for mandatory pools (Von der Fehr and Harbord, 1998; Green an Newbery, 1992) and when we use it for "European style" power exchanges we are confronted with a major difficulty (already mentioned in the previous chapter) regarding market modeling, i.e. power exchanges represent only a part of the market. Therefore relationship between generator production and bids on the power exchange is difficult to identify. In Europe the bilateral market represents an important part of the overall market and its functioning, and this influences the power exchange, yet it is not based on an auction but on bilateral negotiation. Moreover, the role of the block bid, that is interrelated across time periods, is specific to electricity power exchanges and their exact role in the price determination process remain difficult to assess from a theoretical point of view.

5-4 Physical aspects

5-4-1 Delivery

Once the market-clearing price and market clearing volumes have been determined, spot trades on a power exchange lead to physical delivery. The place of delivery is commonly defined as a hub. In most European markets the hub is a geographical area consisting of the national high voltage grid. This hub is determined in collaboration between the system operator and the power exchange. If players want to buy electricity on a power exchange for delivery on another hub or sell electricity from a different hub they have to enter the procedure for cross-border exchanges. For instance, a participant based in France that is willing to sell electricity on the UKPX in the United Kingdom must first acquire interconnector capacity on the auction[20] between France and the UK

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[20] See http://www.rte-france.com/htm/an/offre/offre_inter_2.htm

which is run jointly by the French and the British system operator. Secondly when the desired volume of interconnection capacity has been secured, the participant has to enter the auction of the UKPX. If the offer of the participant is matched, according to the agreement between the power exchange and the system operator, and the British system operator is responsible for physical delivery.

Since electricity cannot be stored a high level of collaboration with the system operator is required for the good functioning of the exchange. On one hand the power exchange manages price determination, while on the other hand, the system operator is responsible for physical delivery. Technical aspects such as the capacities available for transmission at national and international levels are very important since they can have a great influence over prices. Each trading participant must be part of the balance area, or must have access to the balance area through interconnection capacities.

In practice, after matching, the power exchange transmits the trading result to the system operator. The power exchange is the counterpart in every trade and its net position is always neutral, i.e. the total volume sold always equal the total volume bought. The system operator can schedule physical flows[21] once they have received the market results.

5-4-2 Congestion management

From a technical point of view, one of the important characteristics of power exchanges in the Hybrid model is that they do not take into account technical constraints such as congestion[22] within the hub covered by the marketplace. Hence, all market participants can participate to the power exchange regardless of the place where they deliver or withdraw electricity within the hub. Such an approach has been possible in most European countries because national

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[21] See chapter 9

[22] In other models power exchanges can play an important role with respect to congestion management (see chapter 9)

networks are relatively dense. The first strength of this approach is that participants on the exchange can consider all their production and consumption capacity as a single entity allowing them to trade their electricity globally on the market. In contrast to nodal pricing, such an approach increases the size of the market by allowing a large number of players to compete. This “single-hub” approach is made possible by the transmission system operator that ensures balancing of the system and handle transmission constraints within the hub.

Concretely, the power exchange submits the result of the matching to the system operator. This schedule is balanced since on the power exchange the aggregated supply equals the aggregate demand. However, transport of electricity follows the laws of physics. Hence the transmission system operator must determine the technical feasibility of the resulting flows of electricity for the submitted pattern of supplies and demand. When a flow is not feasible, the TSO uses different protocols to create a feasible flow. The balancing market is one of these protocol. These aspects are totally ignored by the power exchanges. This model is made possible by the fact that within each hub, which corresponds to one country[23], the transmission constraints are relatively low (EC, 2001g)[24].

5-5 Power exchange and others markets

5-5-1 Interactions PX-bilateral market

Power exchanges and the bilateral markets (OTC) are rivals, yet complementary and interdependent. They are rivals because the coexistence of power exchanges and bilateral markets allows competition between the two types of market (Gjerde, 2002). From a participant’s point of view this competition is beneficial. Since power exchanges are voluntary markets, players can always use the bilateral market whenever the costs of trading on the organized market are too high. Hence if the cost of using an exchange does not reflect a real advantage, trading can be conducted outside the exchange. Such a system

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[23] Except Nord pool

[24] The limits of this approach are discussed in chapter 9.

ensures that the power exchanges do not charge too high prices for their services.

The concept of transaction costs has been introduced by Coase (1937) n economic theory and developed by many economists such as Alchiam & Demsetz (1972), Williamson (1979), and Milgrom and Roberts (1991). Analyses of transaction costs have tried to explain why some transactions are organized within the firm and others in the market. For the purpose of this section, the transaction costs that are considered are related to two different markets: organized markets, i.e. the power exchange and bilateral markets. A complete estimation and comparison of these costs is beyond the scope of this work, the objective here is to present the main determinants of these costs.

From a market participant point of view, the choice between using the OTC market or a power exchange for spot trading is directly related to the difference between the transaction cost of using the exchange (C_{px}) and the transaction cost incurred with an OTC day-ahead transaction (C_{otc}). How those costs might be estimated is presented in table 5-1. Assuming that in a perfectly arbitraged market the spot price on the power exchange is equal to the spot price on the bilateral market, when $C_{px} > C_{otc}$ the market participant will use the OTC market and when $C_{px} < C_{otc}$ the participant will trade on the power exchange. The transaction costs are composed of two main elements[25] on a power exchange: the transaction fee and the time spent. On the OTC, market the transaction costs are related to the time spent and the risk and disadvantages of spot trading on a bilateral basis.

Calculating the transaction costs of using the power exchange is relatively straightforward. The transaction fees define the costs of using the exchange. On most power exchanges this cost is related to the volume of transaction (table 5-2

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[25] Annual fee and entrance fee are not taken into account since they can be considered as sunk costs: they are paid for a year regardless of the volume of trading.

gives some example of transaction fees). Time spent refers to the time required to make the transaction. While it is quite difficult to estimate the cost related to “time spent” in money terms[26], it is easy to compare how much time is required to make exactly the same deal on the power exchange’ s spot market compared to the OTC’s spot market. On a power exchange the time required to close a transaction is very low since the contract terms, i.e. payment, delivery area, settlement, are already defined by the power exchange. Hence the time spent to obtain a contract on a power exchange is mainly the time necessary to place bids on the Internet interface. However on the OTC market the contract terms have to be negotiated for any new transaction. Even with standard bilateral contracts, simply filling in and checking the contract is more time consuming that placing bids on the power exchanges[27].

The OTC markets also involve searching costs, i.e. each buyer has to find a seller and vice versa. This searching phase increases the time necessary for closing a transaction. Additionally when two parties have met they have to determine the price for the transaction, this process induces bargaining costs (Williansom, 1979). Two others disadvantages of bilateral markets for spot trading should be included in the transaction costs. One, a premium for credit risk must be included. On a power exchange, credit risks are covered by the exchange. On the bilateral markets the recent collapse of Enron[28] has shown that credit risk is a very important issue. Two, there is the cost associated with the problem of “non-anonymity” on the bilateral market. Indeed the fact that on a power exchange the position of each company is confidential can be very valuable, especially when the market is tight. Hence it can be argued that, for a player, revealing its position to other players represent an additional cost of using the bilateral market.

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[26] Number of hours time number of people time average salary of peoples involved can be a first indicator

[27] The standard contract defined by the European Association of Energy Trader contains 50 pages, see http://www.efet.org

[28] See http://specials.ft.com/enron/ for more information on the impact of Enron’s collapse

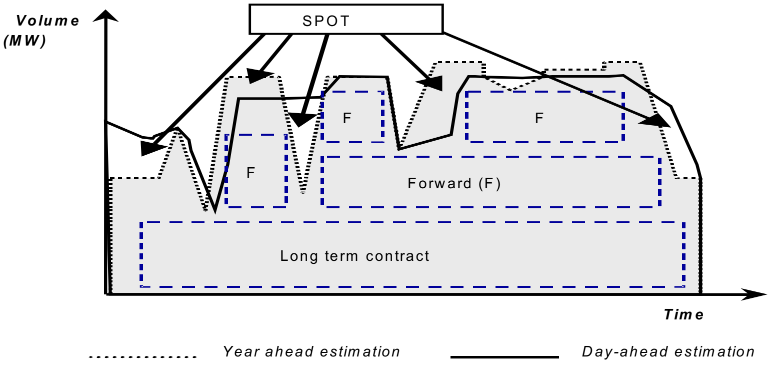
Table 5-2: Cost of trading

Power exchange	**Bilateral market**
• Time spent - Placing bids	• Time spent - Searching costs - Contract definition - Bargaining costs - Premium for credit risk - Premium for "non-anonymity" - …
• Transaction fee - APX: 18 €/MWh - LPX: 4 €/MWh - Nord pool : 3 €/MWh	

Source: APX, LPX, Nord pool

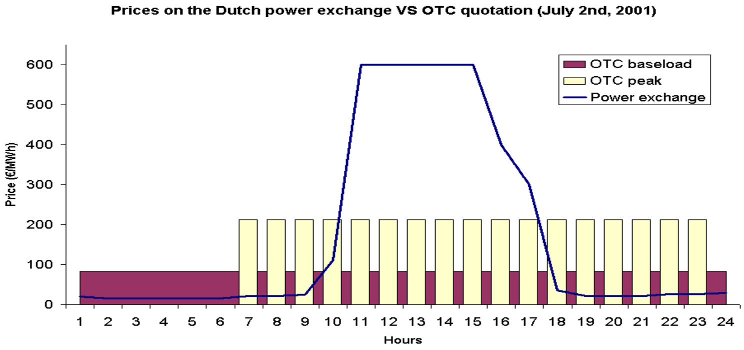
Bilateral markets and power exchanges are complementary because competition is limited between the two types of markets to day-ahead trading. Market participants mainly use the OTC market for forward contracts, which cover longer periods than one hour and are traded a long time in advance. For instance, a large consumer of electricity will contract different long term and forward contracts for its own consumption with respect to its estimation of its load curve one year in advance (figure 5-4). Since, day-ahead estimation are more precise than year-ahead estimations, any market participant may use the power exchange to adjust its portfolio.

Figure 5-4: Spot Trading and bilateral contracts



Power exchanges are complementary to OTC because they quote hourly prices while OTC prices are usually quoted for 2-3 periods (baseload, peak, off-peak). Hence, even if power exchanges only represent a small part of the total market they provide additional information about the market situation on an hourly basis. This information is especially relevant due to the large change in market conditions that may occur at very short notice. An example where information provided by the power exchange gives a better idea of market conditions than just the OTC quotation is shown in figure 5-5.

Figure 5-5: Additional information provided by a PX compared to OTC quotation



Source: APX, European Power Daily[29]

Power exchanges and bilateral markets are interdependent for two reasons. One, in the case of the OTC day-ahead market, the price between the power exchange and the bilateral market must be very close[30] otherwise arbitrage will occurs, i.e. buyers will go to the "low price market" and sellers to the "high price market" increasing the price on the first one and decreasing the price on the second one until they equal. Two, in the case of OTC excluding day-ahead, any contract sold or purchase on the bilateral market can be renegotiated on the

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[29] European Power Daily , Volume 3, Issue 127, (July 03, 2001)

[30] See chapter 7 for empirical estimations

power exchange. Hence, participants “overcontracted” or “undercontracted” on the bilateral market can use the power exchange to balance their position.

5-5-2 Interactions PX -balancing market

So far little research has been done on the question of the interaction between power exchanges and balancing markets in Europe. The relationships between power exchanges and balancing markets depends mainly on the design of these two markets. However, there is a direct link between the level of demand and the level of capacity offered on the balancing market. Additional production capacity and possible consumption decreases, which are available but have not been matched either on the bilateral market or on a power exchange, can (or must[31]) be offered on the balancing market (Lapuerta, 2001). For instance, a producer with an installed capacity of 1000 MW may have sold only 980 MWh for hour H and to maximize its revenue might offer its remaining producing capacity on the balancing market (table 5-3).

Table 5-3: Example of contractual position for a peak hour

Contract Type	Volume
• Baseload 3 year	200
• Baseload 1 year	200
• Baseload 6 month	100
• Peak load 3 Year	200
• Peak load 1 Year	200
• Peak load Day ahead	30
• Matched on the PX	50
• **Not Matched on the PX**	**20**
Total	1 000

In this example, a part of the volume offered on the power exchange has not been matched (20 MWh) due to a low level of demand or to a too high price being asked. Hence, the results of the power exchange have a direct influence on the balancing market. If there is a high demand on the PX (involving high

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[31] For instance the Dutch grid code requires that generators with more than 60 MW capacity should bid available unused capacity into the balancing market

prices), a lot of capacity will be sold on the PX and little capacity will be available for the balancing market leading to high prices on this market. Similarly, during period of low demand, typically off peak hours, prices are low on the power exchange due to a large amount of production capacity being available, which in turn involve low prices on the balancing market. Hence, similar to the relationship Power exchange-bilateral market, prices on balancing market and power exchanges needs to be very close otherwise arbitrage will occur[32].

5-5-3 Interactions PX –Cross border trade mechanisms

Most power exchanges do not differentiate between companies located within the delivery area of the power exchange and companies from outside this area. Hence, foreign operators willing to buy or sell on the exchange have to handle reserving interconnection capacity as they usually handle for bilateral trade. In general power exchanges are not involved in the management of interconnector capacity. However in Europe two exceptions exists: Nord pool and the Amsterdam Power Exchange. In Scandinavian countries, interconnection capacity are not allocated via a separated auction but directly by Nord pool[33] which handles congestion between countries by using market splitting.

In the Netherlands, the management of interconnector capacity is done by a specific entity, i.e. the TSO auction office[34], which regroups four Transmission System Operators (TenneT for the Netherlands, Elia for Belgium and E.on netz and RWE net for Germany). All available interconnector capacity is auctioned at the TSO Auction office, through a Day, Month and Year auction. Separate auctions are held for both directions on each Interconnector. A feature of the Dutch system is that parties who acquire import capacity at the daily auction are obliged, in accordance with Article 5.6.12.1 of the Grid Code, to trade the

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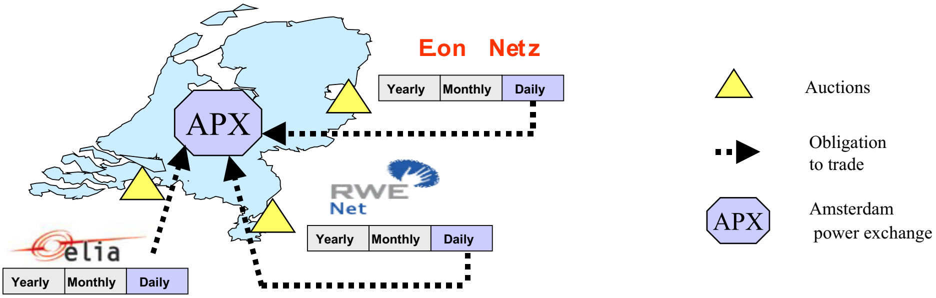
[32] See the Enron's trading strategies for examples of arbitrage (chapter 6)

[33] See chapter 9 for detailed description

[34] See http://www.tso-auction.org/

electricity transmitted on the Dutch side through the Amsterdam Power Exchange.

Figure 5-5: Relationship PX-cross-border trade in the Netherlands



The object of this design was to promote market liquidity and transparency by supporting the power exchange[35]. This rule creates a direct relationship between the exchange and the daily auction for interconnector capacity. The shortcomings of this approach are discussed in terms of strategy on the exchange in chapter 6, and in terms of market design in chapter 9.

5-6 Conclusion

We have presented the way power exchanges function in general in this chapter. The different rules for bidding and the price formation mechanisms have been described. Since the heart of power exchanges is organized via auctions, auctions theory is of particular interest for analyzing power exchanges functions. Unfortunately, understanding of multi-unit auction is not well developed and has limited theoretical foundations. Subsequently, we presented the different interactions between power exchanges and others types of markets. Identification of the main aspects of how a power exchange functions is a necessary step to provide us with the "rules of the game". The next step of the

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[35] Comment 36 of the Dutch electricity regulator accompanying Article 5.6.12.1, available at http://www.nma-dte.nl/

analysis is to understand what types of behavior take place in such marketplaces.

Chapter 6

Participants' behaviors on power exchanges

In this chapter we look at the very important issue of participant behavior on power exchanges. We first present briefly an overview of the behavior of firms in economic theory and in electricity markets in general. The strengths and limits of these approaches for the analysis of power exchanges as marketplaces are then discussed. Trading behaviors depending on the nature of participants are analyzed, and then bidding behaviors that represent concretely how players interact on the power exchange are described. Examples of specific bidding related to marketplace design, the problem of market power and examples of arbitrage strategies based on Enron memos are presented to illustrate actual behavior in electricity markets.

6-1 Introduction to firm's behaviors

6-1-1 Introduction

The concept of a firm's behavior, also referred as conduct or strategy, has different meanings in the economic literature. This concept can be divided into two main categories. One, neoclassical theory considers profit maximization as the only possible behavior. Two, since in practice profit maximization may not be the only motivation for behavior, other types of behaviors are considered.

6-1-2 Economic theory of firm's behaviors

In most economic models the behavior of firms is limited to profit maximization. Hence in perfect competition and monopoly models, firms will produce the quantity at which marginal cost equals marginal revenue. In a perfectly competitive framework, the conduct of a firm is restricted to a minimum: in the short run the firm can only respond to market price by producing a quantity that maximizes profits and in the long run if the firm is making loses it will leave the industry. In the monopoly case, the monopolist will choose the price output combination such that marginal cost equal marginal revenue[1].

Since perfect competition and monopoly are two specific limited cases, they rarely exist in practice and the range of a firm's strategies is wider that just profit maximization. Firms can develop different strategies in imperfectly competitive markets (Scherer and Ross, 1990). Industrial organization defines several types of conduct such as product differentiation, advertising, predatory pricing, price discrimination, merger and acquisition, collusion etc. Product differentiation is one of the most studied types of behavior of a firm (Chamberlin, 1933; Bain, 1968). The objective of product differentiation is to avoid competition, by making the product special for consumers[2]. Advertising is another classical strategy of firms (Stigler, 1961). For instance advertising can be use to increase barriers to

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[1] See chapter 4

[2] This strategy can involve either change in the product characteristics or investment in advertising to change the public's perception of the product.

entry by building up consumer *loyalty* or *inertia*[3] (Kaldor, 1950). Predatory pricing is traditionally related to a strategy carried out by a dominant firm, which will fix its price below the average variable cost (Areeda and Turner, 1975). The objective of such strategy is to drive other firms out of the market. Price discrimination[4] is related to the ability of a firm to sell the same product at varying prices. Mergers and Acquisitions (M&A) are certainly the most visible part of a firm's behaviors. M&A occur for a myriad of reasons and few topics in industrial organizations arouse more passionate debate (Scherer and Ross, 1990). Reinforcement of market power, elimination of competitors, achievement of economics of scales/scopes are classically cited as some of the many objectives of M&A. Finally collusion is an attractive option for firms who are aware of each others actions. *Overt* collusion and *tacit*[5] collusion aim to reduce competition and to obtain charge higher prices than if competitive pricing is operating.

6-1-3 Why behaviours on PX cannot be directly studied

An analysis of participant behavior on a power exchange must take into account the fact that a power exchange is a fringe market, i.e. power exchange are voluntary and only represent a part of the market, i.e. day-ahead trading. For this reason the behavior of a firm on a power exchange represents only a small part of its overall strategy and overall activity. Since power exchanges are organized markets for spot trading with specific rules the behavior of firms on these markets is limited to sale and purchase bids. Hence any firm's strategies of diversification or advertising, for instance, are meaningless from the point of view of a power exchange. It does not mean that firms, which participate in trading on the power exchange, cannot have these kinds of strategies, but that due to the very specific functioning and purpose of power exchanges these strategies are not visible on power exchanges only.

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[3] *Loyalty* is defined as a rational preference, whereas *inertia* involves routine buying.

[4] See chapter 3 (section 3-3-3)

[5] *Overt* collusion is characterized by a formal agreement also called a cartel, *tacit* collusion may occur when for instance, in an oligopoly, firms followi the price fixed by a leader.

Box 6-1: Predatory pricing on power exchange

Is predatory pricing a credible strategy on a power exchange?

While most strategies considered in industrial organization are not well suited for power exchanges due to the specific nature of these markets, predatory pricing might appear to be a possible behavior of a participant. Indeed by fixing bids at very low prices on the power exchange, a firm may expect to be able to drive out others participants and then charge a higher price later.

Such strategy is not credible for three reasons. One, since most electricity contracts are traded on the OTC market on a long-term basis, only a small part of the total market is traded on the power exchange. It is therefore unlikely that a company charging a very low price will be able to cover the entire market on the power exchange. Thus, in a marginal price auction the very low bid will not determine the market-clearing price, which strongly reduce the impact of such strategy.

Two, even if a firm is able to fix the market clearing price of the power exchange below the competitive level, and thus drive out the others competitors from the PX, it will not be able to enjoy its monopoly position. Since power exchanges are voluntary markets, as soon as the firm tries to charge higher prices on the power exchange, buyers will leave the power exchange and use the bilateral market.

Three, even if a firm tries to bid at very low prices, it will always face other participants that will bid at a price of zero (see section 6-3-2). Participants who overcontract on the OTC market and know that they will not be able to consume what they contracted will try to get rid of their extra volume. Since this volumes represents a sunk cost for them they are willing to sell this electricity regardless of any cost consideration. Then, in a marginal price auction, bidding under average production costs will not be sufficient to drive out competitors because some participants bid at a price of zero.

Most strategies described above, with the exception of pricing strategies or collusion, can be easily observable from outside a company, bids on an exchange are not. For practical reasons, an analysis of a firm's behavior in an economic study is often limited by the availability of data. Indeed, strategies such as M&A or advertising are easily observable. In both cases the firms involved in these types of strategy will communicate with the outside world and the information that is published can be used for analysis. In the case of power exchanges the action of each participant is confidential and commercially sensitive. By definition, organized marketplaces provide anonymous places for trading. Anonymity allows market participants to balance their portfolio without revealing their position to the outside world. Power exchanges avoid the risk of discrimination ensuring confidentiality of each participant's trade, and in doing so ensure that realized transactions are based only on objective economic criteria.

Though for economic analysis, publication of market participants' bids and transacted volumes would strongly improve the level of transparency and understanding of the functioning of these markets, from a competition point of view, information openness is not always suitable since it may facilitate, overt or tacit, collusion. If every market participant knows the pricing strategy of every other firm, there is little opportunity for gaining market share by price-cutting. Any attempt from an individual player would be discovered by the competitor and would be met with an aggressive answer. Hence, availability of pricing information may facilitate collusion and should be discouraged.

The confidentiality of bids and realized transactions per participant does not allow direct analysis of participant's behaviors on power exchanges. However possible trading strategies can be described based on experience in the United Kingdom and in California. A first range of "classical" strategies can be identified according to the type of market participants (section 6-2) assuming that pure traders, i.e. without physical assets, large consumers and producers use power exchanges differently. A second aspect of trading strategies is related to the details of bidding behaviors (section 6-3).

6-2 Trading strategies involving a power exchange

6-2-1 Introduction

Participants on a power exchanges can use a number of different trading strategies. A first approach consists of analyzing possible strategies according to the nature of players. The first obvious category is composed of electricity producers defined as players owning production capacity and which represent the sale-side of the market. The second category includes distribution companies and large industrial consumers which constitute the demand-side of the market. Finally there are pure traders, without physical assets, these players act on both side of the market. For simplicity we will ignore here the fact that, in practice, generators may act as traders and that large consumers, distribution companies and traders may also have production assets.

6-2-2 Producers

Most producers trade in long and medium-term markets so they can plan production and maintenance plans and from time to time use a power exchange to cover specific needs. Hence, the basic use of a power exchange for a producer of electricity includes three strategies: selling additional capacity, buying when "overcontracted" on the bilateral market or facing an unexpected outage, and buying when prices on the market are lower than production cost.

The first and most common strategy on a power exchange for a producer is to sell day-ahead their available extra-production capacity. Thus producers are typical sellers which means that, in general they sell most of the time. For example, assume a power producer with a production capacity of 1000 MW that has already sold 930 MWh[6] on the bilateral market. Since the producer has some production capacity left, according to the hypothesis of profit maximization, the difference between the two values represents the volume the producer will offer to the power exchange (70MWh). The price asked (P_a) is determined by the production costs (C_p) of such extra production[7]. If the market-clearing price (MCP) is lower than P_a then the producer will not sell any volume on the power exchange. If the MCP is higher than the P_a, then the producer will sell part or all of its extra volume.

Conversely if the producer has sold more on the bilateral market than what it is able to produce, it will enter the market on the purchase side to fulfil its obligation. If the producer has no possibilities to renegotiate part of the volume it can not produce, the price it is ready to pay may be very high, to avoid imbalances charges. Such a situation may also occur when a generator faces a forced outage[8] or a change in availability which decreases its production capacity.

Table 6-1: Basic behaviors of producers on a power exchange

Strategy	**Motive**
Sell	Not fully contracted on OTC (volume available day-ahead)
Buy	Overcontracted on OTC (e.g. face unexpected outage)
Buy	MCP< production cost

A producer will buy on a power exchange when the MCP is lower than its production costs (C_p). When a producer can buy electricity on the market at a lower price than its production cost instead of producing it, it will buy electricity on the market. In such cases, a producer's profitability will be improved if it meets its contractual obligations with power sourced from the market rather than produced by its own power station. This can occur for instance when fuel costs increase.

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[6] See previous chapter, table 5-3 for details

[7] In general in "imperfect markets" the relationship between the price asked and the production cost can be defined by: $(P_a) = (C_p) +$ margin

[8] A generator that does not have control over its fuel supply, e.g. wind turbine or gas-fired plant with interruptible supply, may also use power exchange to adjust its position day-ahead.

Hence, in typical bidding, a producer will place a "buy order" for low-price (lower than C_p) power while placing "sale order" for high prices (higher than C_p).

6-2-3 Large consumers

Industrial consumers and distribution companies are large consumers of electricity. While the first buy electricity on the wholesale market for industrial processes, the second buy electricity for selling on the retail market. For the purpose of this section we will consider them together as *large consumers*. As for electricity producers three basic strategies can be defined for large consumers and these form an exact symmetry of producer's strategies.

Large consumers of electricity, that have not contracted for enough electricity in advance ("undercontracted"), on the bilateral market, to meet their load, will enter the power exchange to buy the extra volumes they need. This situation occurs when the large consumer has underestimated its real consumption needs. For instance, on abnormally hot days a distribution company will need additional power to respond to an increase in demand, related to an intensive use of air conditioning. A large industrial consumer which needs to increase its level of activity for a couple of days may also use the power exchange to buy additional power.

Since the price of electricity on a power exchange is normally higher and at least more volatile than the electricity price in a long term bilateral contract, risk-adverse consumers have a great incentive to "overcontract" on the bilateral market. In doing so, they avoid the risk and uncertainty of having to buy on the power exchange's spot market[9]. Such strategy is especially relevant during the startup phase of a power exchange[10]. Large consumers will become sellers on the power exchange when they have contracted too much on the bilateral market

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[9] In market characterized by a low level of liquidity, any large increase of demand might cause a great increase of price.

[10] On a mature power exchange the level of liquidity ensures that an increase of demand from one party does not affect largely the equilibrium price.

with respect to their expected consumption. Moreover, just as producers which might face forced outages of a power plant, large consumers may face forced decrease in their consumption, e.g. workers strike, forced maintenance of a factory, cancellation of a large order etc. In these cases selling on the power exchange represent a way to get rid of the extra volume contracted on the bilateral market and to avoid balancing charges.

Table 6-2: Basic behaviors of large consumers on a power exchange

Strategy	Motive
Buy	Undercontracted on OTC (e.g. underestimation of needs)
Sell	Overcontracted on OTC (e.g. face unexpected decrease of needs)
Sell	MCP> opportunity cost of not consuming

In the presence of high prices on the market large consumers may decide voluntary to decrease their consumption in order to sell on the power exchange. Such behavior is directly related to the elasticity of demand of each consumer. Thus when the MCP is higher than the opportunity cost of not consuming, a consumer will become a seller on the power exchange. For instance, during the Californian crisis, it was more profitable for some aluminium factories to stop their operation and sell the electricity they had contracted to the power exchange (Borenstein, 2001). Moreover, with the development of load management services, distribution companies can decrease the consumption of some of their customers, in exchange of financial counterparts, and sell the power to the exchange.

6-2-4 Traders

As for any market, electricity traders bring liquidity to the market. For instance, at one instant there might be no buyer willing to buy electricity from a generator. Traders provide liquidity by filling this gap and purchasing the electricity with the intent to sell it at a higher price later. This traditional function of trading is rather limited in electricity market because electricity cannot be stored: a trader cannot buy electricity at hour 1 and resell it at hour 12. For this reason this kind of arbitrage does not occur on power exchanges.

Table 6-3: Basic behaviors of traders on a power exchange

Strategy	**Motive**
Buy-Sell	Act on behalf of a large consumer
Buy	Price PX_A < Price PX_B (aim to resell on PX_B)
Sell	Price PX_A > Price PX_B (has already buy on on PX_B)
Buy	Price PX < Price OTC (aim to resell on OTC)
Sell	Price PX > Price OTC (sell OTC contract)

However two basic behaviors of traders on a power exchanges can be identified. One, they act on behalf of other market participants who asked them to sell or buy their electricity. This is the case for industrial consumers that do not want to act directly on the power exchange. There are two reasons for such a decision. The consumer or the supplier might be a too small player to act directly on the power exchange. For industrial consumers the trading of electricity does not represent their core business; therefore they do not have the expertise to participate on a power exchange nor are they willing to build their own trading floor which will involve costs they do not wish to incur. Thus such players use traders to manage their electricity portfolio. Traders act then as "aggregators" and reduce risk for their consumers[11].

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[11] Assuming that the risk to a group of participants is less than the sum of the risks to each individually ,i.e. different groups might offset each other's demand variations

Traders also act as arbiters between markets[12], to do this they regularly switch position depending on the price spread between markets. Such arbitrage may be achieved between markets, e.g. OTC markets, balancing markets, power exchanges, or between countries. For instance, arbitrage can be carried out for bilateral contracts and the power exchange. A trader will buy a baseload contract for a defined period at a fix price and will resell it per hours on the power exchange expecting that the average price of the power exchange would be higher than the price paid for the bilateral contract.

Traders can also buy electricity in a cheap area and resell it on the power exchange. This type of operation is becoming increasingly important in Europe where cross-border trade is booming. For instance, a trader can buy electricity on a power exchange in Germany and resell it in the Netherlands or buy on the French bilateral market and sell on a power exchange in the United Kingdom. In doing so, the trader lowers prices in high-priced areas and increases prices in low-priced areas. This behavior augments the efficiency of these markets and in the absence of transmission constraints this behavior creates a single equilibrium price.

6-3 Bidding behaviors

6-3-1 Introduction

Bidding behavior represents concretely how players act to reach a strategy. In most academic research so far, the analysis of bidding strategies has been limited to generators in the context of power pools (Wolak, 1999). The main literature available concerns the England and Wales pool (Green and Newbery, 1992, Vickers and Yarrow, 1991) and the California power market (Puller, 2001; Harvey and Hogan, 2001; Joskow and Kahn, 2001) which have both been abolished. In the literature, the analysis of bidding behavior is mainly limited to comparison between bids and costs of power plants over time (Brealey and

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[12] See Enron memo (section 6-4-3)

Lapuerta, 1997; Wolfram, 1998). In its strict definition any bid superior to cost[13] can be considered to be a strategic bid, hence, in general analysis of bidding strategy is related to market power[14]. The important differences between the power pool model and the hybrid model strongly reduce the interest of this literature[15]. Most analysis are based on oligopoly competition-game theory models assuming most of the time that a generator's optimal bidding strategy will depend on the bidding behavior of all its competitors[16]. In practice, due to the voluntary nature of power exchanges it is more likely that players are unable to anticipate accurately the behavior of competitors[17]. Participants tend to use the power exchange with respect to their position on the other markets and also to the rules governing the power exchange. The publication of the Enron memos[18] has shown that in practice, in presence of multiple markets, bidding strategies can be overly complex to take advantage of market rules and (bad) market design. Since bidding strategies on power exchanges are not publicly available information, an analysis of actual the bidding strategy of a player cannot be done. However, some well-known principles can be described as can some possible strategies related to the design of existing European power exchanges.

6-3-2 Classical bidding behaviors

Five classical bidding behaviors for power exchange participants can be identified: selling (at least) at marginal cost, buying at the "utility" value, selling at a zero price, buying at the maximum price, and simultaneous buying and selling, i.e. "double side bidding". For most of the strategies, the nature of the price formation mechanism, a uniform price auction, is fundamental.

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[13] Short-term marginal costs (STMC) or long-term marginal costs (LTMC) are considered in the literature depending on the assumptions made by the authors. In the short term, the capital cost associated with delivering an additional unit is fixed. It is therefore possible to measure marginal cost excluding capital cost (STMC). In the long term, capital cost also needs to be recovered which increases marginal costs (LTMC)

[14] See 6-4-2

[15] See chapter 2

[16] See 4-4-6

[17] While in a power pool competition is restricted to main generators, in a power exchange every participants market participants may compete on both sides of the market

[18] See 6-4-3

Selling at marginal cost, or at least at marginal cost, is the first basic bidding strategy. The short-term decision rule for a generator is whether it can cover its variable costs (Lopez, 2001). Hence, if the MCP is equal or above its variable cost of producing, a producer will sell, below it will not. Producers rely on period where they will not be the marginal bidder to recover their fixed costs. Buying at the "utility" value on a power exchange is the corresponding buying strategy. The utility value is related to the value a consumer attaches to the consumption of additional power. For a large industrial consumer, for which electricity represents a large part of its costs, the utility value is the maximum price it is willing to pay for electricity. Above this price it is more profitable to not consume.

Due to the technical aspects of electricity production and peculiarities of electricity markets/marketplaces design, others bidding strategies have emerged in practice. One classical bidding behavior of a seller is to sell its electricity at a price of zero. This type of bidding has become well known since the start of organized electricity markets and is not specific to power exchanges. Such behavior has four main explanations: the existence of baseload power plants, low variable costs technology, sunk costs related to other contracts and arbitrage between non-coordinated markets. These four reasons have the same objective: to sell at any price to balance portfolio. Indeed, by bidding at a zero price, sellers maximize their chance of being matched on the power exchange. They rely on other players to determine the market price since in a uniform price auction every one receives the market-clearing price. This is related to the fact that electricity cannot be stored and the existence of baseload power plants which cannot easily reduce their level of production ("must-run"). Producers owning such types of units are almost forced to bid at a zero price[19]. This is also the case for instance, with nuclear power plants which are characterized by high fixed costs and almost insignificant variables costs (Wolfram, 1998).

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[19] Note that most of capacity of these power plants are likely to be contracted on the bilateral market via long term contracts

Another motivation for bidding at a price of zero is the existence of a long position on the OTC market. Take for example, a railway company facing a 50% reduction of its activity for a couple of days, e.g. due to a strike or following extraordinary storm, this company will be "overcontracted" and will need to get rid of the extra volume it bought previously on the bilateral market. In order to avoid imbalance charges this company will be willing to sell this electricity at any price, give it away. In this situation the price paid on the bilateral market does not enter into account. Hence, the most likely bidding strategy for this company is to bid at a zero price. Finally, bidding at a zero price is a necessary strategy in non-coordinated markets[20]. This strategy is illustrated in box 6-2 with an actual example. In such a marketplace design, the timing of markets creates a strong incentive to bid at a zero price regardless of any cost consideration.

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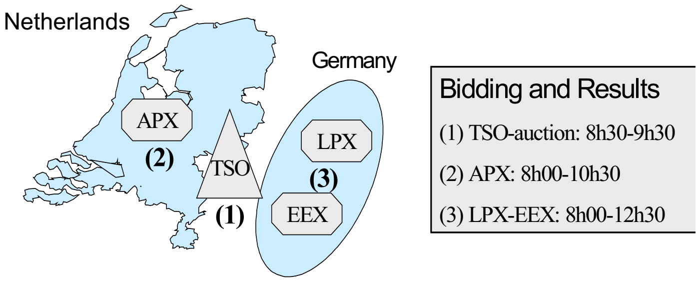
[20] The issue of coordinated markets and transmission pricing is discussed in chapter 9

Box 6-2: Why bidding at zero in non-coordinated markets: the APX-LPX example

The Dutch market, importing 17% of estimated consumption, is the market most reliant on cross-border trade of all major European markets. Available interconnector capacity is auctioned separately from the power exchange. On a day-ahead basis, trading arbitrage can be done between the Dutch power exchange (APX), and the German power exchange (LPX-EEX). Since these three markets are not coordinated their timeline influences trading, and especially bidding strategies. The timeline of these markets is important since it has a practical impact on the arbitrage possibilities between the markets. The key aspects of the timing of these markets are their trading period and their closure hour. The different timings of these markets are shown below in figure 6-1.

Figure 6-1: Timing of markets



Assuming that on average electricity prices in Germany are lower than in the Netherlands, classical arbitrage behaviors consists of first buying interconnector capacity on the TSO auction from Germany to the Netherlands, second selling power on the APX and finally buying the corresponding volume on one of the German exchanges. An arbitrageur will bid as follow to maximize the probability to be matched on each market:

- (1) TSO Auction: obtain interconnector capacity
- (2) APX: selling at zero or at minimum allowed price
- (3) LPX-EEX: buying at maximum allowed price

In so doing the arbitrageur will maximize its probability of being matched on each market while receiving and paying market-clearing prices. Such behavior is the most rational in situation of uncertainty, because not being matched on one market means facing imbalance charges. For instance, if a pure trader has obtain interconnector capacity and has sold electricity on the Dutch power exchange but has not secure power on the German market it will be unable to cover its contractual commitments.

Bidding for buying at the maximum price is in many ways symmetrical to the previous strategy of selling at a zero price. First large consumers that are "undercontracted" on the bilateral market outage with respect to their day-ahead anticipated consumption or a producer facing an unforced outage, will bid at a maximum price to maximize their chance of being matched on the market. Bidding at the maximum allowed price is also a rational behavior in non-coordinated markets (box 6-2)

Buying and selling simultaneously corresponds to a "composite" strategy which take advantage of the flexibility of a player. Such strategy is simply a combination of possible behaviors as described in the previous section. Keeping in mind that day-ahead spot markets represent only a small part of the total production/consumption of players, participants that have the possibility to modify their needs at short notice can value this flexibility on the market. A "flexible" producer[21] will buy from the market if the MCP is lower than its production cost and will sell if the MCP is higher. A flexible consumer[22]will sell to the market if the spread between the MCP and the price previously negotiated on the OTC market is superior to the opportunity cost of not consuming. Since MCP is defined on a power exchange after submission of bids, each participant must take into account the different scenario within its bids. An example of possible double-side bid is provided in box 6-3.

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[21] For instance a generator using a gas turbine or having an option contract with a consumer that can decrease its consumption

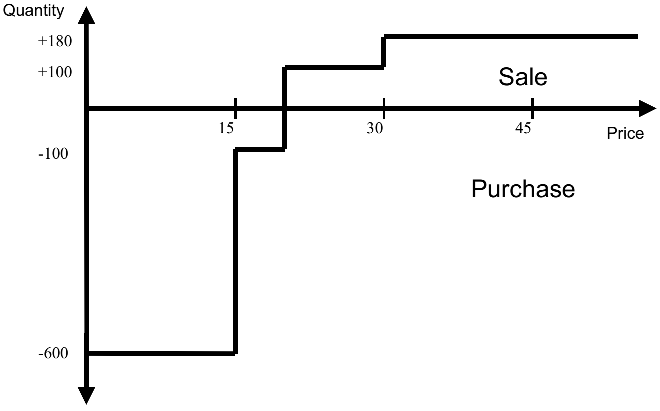
[22] For instance large green house

Box 6-3: A simple double-side bid

A producer has two generation units with respective production capacities of 500 and 200 MW and respective linear variable costs of 15 and 20 Euro/MWh*. For hour X, this producer has contracted on the bilateral market different sale contracts for a total volume of 600 MWh at an average price of 20 Euro/MWh. Moreover, one customer of this producer has agreed to decrease its consumption up to 80 MWh for a price of 10 Euro/MWh**. Hence, if the price on the market is very high the producer can sell some extra volume on the market rather than to this customer. Base on this information the generator will bid as follow:

- If the MCP is below 15 Euro/MWh, the producer will buy totally from the market (600MWh) to cover its bilateral contracts and not use its own assets
- If the MCP is between 15 and 20 Euro/MWh, the producer will produce 500 MWh with its cheapest unit, nothing with the other one and will only buy 100 from the market
- If the MCP is between 20 and 30 Euro/MWh the producer will sell 100 MWh corresponding to the available capacity not contracted
- If the MCP is higher than 30 Euro/MWh the producer will sell 180 MWh, adding the volume not consumed by its customer***.

Graphical representation



* In this example we do not take into account any fixed cost or starting cost

**In that case the producer pay the customer for its non-consumption

*** If the MCP is 50, the producer will pay 800 Euro (80*10) to the customer and will receive 4000 (80*50) from the power exchange. The profit of this operation will be then 4000-800-1600 (production cost80*20) =1600 Euro

6-4 Examples of specific bidding on power exchange related to market/marketplace design

6-4-1 Strategies related to the regulatory framework: examples from the Dutch case

A peculiarity of the Dutch electricity market design is the obligation for parties who acquired interconnector capacity at the daily auction for importing to the Netherlands to trade the electricity through the Dutch Power Exchange (article 5.6.12.1, Dutch Grid Code[23]). The first formulation of the grid code[24] involved two possible interpretations, which in turn involved different bidding behaviors from market participants on the power exchange. The point here is how to interpret "*obliged to trade […] through the APX*"[25]*.* Indeed the wording is such that it is unclear whether the related energy should be traded through (strong interpretation), or just offered on the APX (weak interpretation). Traded obviously means being matched (or sold) on the exchange; however no market participant can make sure to sell its electricity on the exchange since whether a transaction takes place or not depends on the supply and the demand of the market. Moreover, a seller should not be forced to sell below the price that it wants to charge. Secondly even if a seller bids at the minimum authorized price, a seller might not sell all its power if the MCP equals the minimum price[26]. The interpretation of this rule is problematic for these reasons.

An illustration of a first possible bidding behavior is given in box 6-2. A player who has obtained interconnector capacity and secured power from abroad will bid at the minimum authorized price to maximize its chance of being matched, expecting than the MCP will be higher or at least equal to the price of interconnector capacity plus the price of energy abroad. Now consider the case of a market participant that wants to import spot power for its own consumption or to cover any contractual agreement and not only to sell the power to the

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[23] See 5-5-3

[24] *"Parties to whom import capacity has been allocated at the daily auction are obliged to trade the electricity transmitted on the Dutch side through the Amsterdam Power Exchange"*

[25] We do not discuss here the following version of the grid code which has amended this article (for more information on that, see www.nma-dte.nl/en/default.htm)

exchange. For instance, if a player is facing a forced outage in the Netherlands it might be willing to secure one day in advance the corresponding amount of power on the German market and to import it through the interconnector. This player will do so if the price of power in Germany plus the price of the interconnector is lower than its prediction for the Dutch spot price (both OTC and PX). In the absence of article 5.6.12.1, such player would not use the Dutch power exchange. However due to this specific rule the player has to "trade" on the power exchange. Depending on the interpretation of this article two different bidding behaviors may occur which we call: "self-buy" and "cap-sell".

"Self-buy" behavior corresponds to the behavior of a participant which has made a "strong" interpretation of the Grid code, i.e. all volume obtained must be sold on the exchange. In order to respect the code and the desire of this player to use the electricity imported for its own needs, this player will simultaneously sell and buy back on the exchange. In other words the player will buy its own electricity on the market. In terms of bidding behaviors such strategy will involve a composite bid for selling at a low price and buying at a high price. In practice this player will make a sell bid for a quantity X of electricity at the minimum authorized price and a buy bid for the same quantity at the maximum authorized price. For every MCP between these two unlikely limits, this player will sell all its power and buy it back. In doing so, the player respect the Grid code and can use the electricity bought on the exchange for its own needs.

At the opposite a "cap-sell" corresponds to the behavior of a participant that has a "weak" interpretation of the Grid code, i.e. all volume obtained have to be offered on the exchange. In this case, a participant willing to use the interconnection capacity obtained on the daily auction for its bilateral obligation will offer the corresponding volume at the highest price possible (price cap). In doing so, it will fulfill its obligation to offer on the exchange. However since it will not be matched it will then use the obtain volume for its own need without

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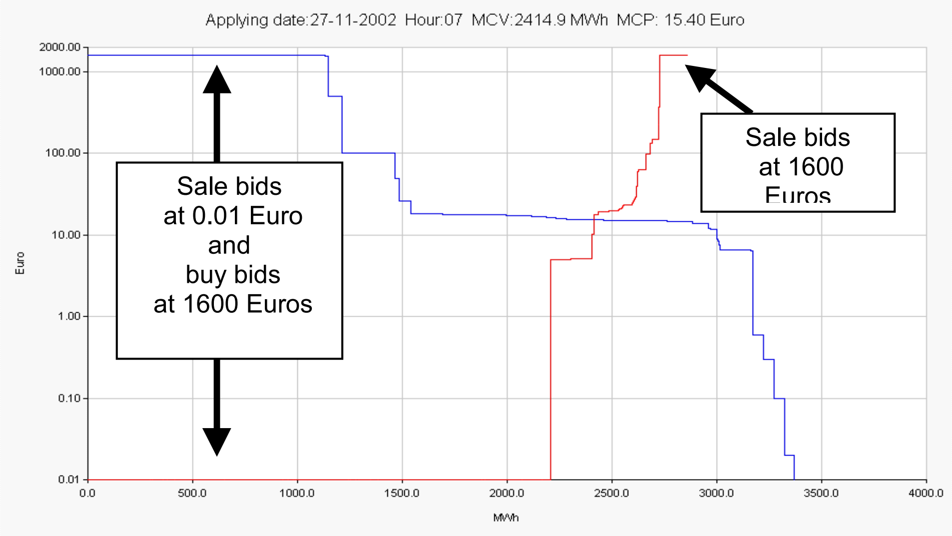
[26] In that case a prorata rule is used

breaking the law. The bid will only be a sale bid at the maximum authorized price.

Figure 6-1: Example of bids on the APX



Source: APX

These two examples show the influence of market design on the bidding behavior on a power exchange. Indeed "self-buy" and "cap-sell" bidding strategies appear to be especially odd strategies only from a power exchange point of view. Yet once the design of the exchange and article 5.6.12.1 are taken into account, the rationale of these strategies can be understood.

6-4-2 Strategic bidding: the issue of market power

Market power is certainly the most discussed issue in the recent literature on participant's behaviors in electricity markets and represents therefore an important concern with respect to power exchanges. Market power is defined as the ability to unilaterally manipulate prices. Both California and England and Wales have experienced such behaviors. In California, market power was presented as an important reason of the crisis (Wolak, 2002b), while in the UK it was one for the main reason for the introduction of a totally new market design (Sweeting, 2000). The case of California (box 6-4)[27] is especially interesting because economists are divided about the impact of market power when explaining the crisis. Several studies concluded that generators were able to exercise market power (Borenstein *et al*, 2002; Joskow and Kahn, 2002). However, other studies dispute these conclusions and show that such empirical studies suffer from significant shortcomings (Harvey and Hogan, 2001; Falk 1998). Likewise the Federal Energy Regulation Commission (FERC) has found strong evidences for the exercise of market power in the prices prevailing in the real-time market and in the power exchange, but faced difficulties when trying to identify the individual participants responsible of such abuse (FERC, 2003).

The introduction of competition in the electricity industry has produced multiple interdependent markets which have been described as "*an extremely complicated non-cooperative game with a very high-dimensional strategy space"* (Wolak, 1999), and it is the peculiarities of the electricity markets that make it possible for market participants to influence market prices. In oligopolistic competition theory[28], market participants can influence market functioning via two variables: price (Bertrand) and quantity (Cournot). In order to increase markets prices players can decrease supply (withholding of capacity), increase demand (market mix strategy), or sell at very high prices (strategic bidding also called economic withholding). We will now provide some illustrations of this behaviour in the context of European markets with respect to power exchanges.

Withholding capacity is certainly the most well known strategic behaviour in electricity markets that is used to abuse market power. We can identify three types of withholding capacity behaviors. One: withholding capacity can consist of decreasing supply and profiting from high prices for the rest of the production. This is the classic form of withholding capacity where a generator, by decreasing

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[27] See also appendix 1

supply from one power plant, profits from high prices from other production facilities. The profitability of this strategy increases with the size of the player's market share.

Two: consists of the strategy of withholding capacity on one market to force buyers to go to other markets, where prices are usually higher. For instance, a player able to withhold enough capacity from the bilateral market may force buyers to go to the power exchange where prices are usually higher due to inefficient arbitrage mechanisms between the two markets. Furthermore by withholding capacity on both the OTC and on the power exchange a player can cause a general shortage in the market. The player acting this way would be aware of this fact and would offer electricity at an inflated price in the balancing market.

Three: the last type of capacity withholding is linked to the market for interconnection capacity. A player can buy a large amount of interconnector capacity to protect a market for cross-border trade. This generator can either decide to use this capacity while offering high prices or decide to block the capacity to make sure that no one else will use it to protect its market from others competitors. Moreover, it can be profitable for a generator to withhold output at a specific location to modify transmission constraints (Borenstein *et al*, 1996; 2000; Oren, 1997; Stoft, 1998). For instance, it may be profitable for a generator to modify its output at one node to create congestion and increase prices from transmission contracts (Joskow and Tirole, 2000).

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[28] See chapter 4

Box 6-4: Strategic behavior in California's electricity wholesale industry: did it cause the crisis?

During the California electricity crisis, repeated allegations were made of strategic behavior by generators, both local and out-of-state. Detailed and elaborate investigations into the causes of the crisis followed. So far it has remained unclear if, and if so, what type of strategic behavior took place in California's electricity market and to what extent strategic behavior may have contributed to the electricity crisis. However, strong indications have been found that suggest that the following types of strategic behavior played a part in California's electricity crisis*.

Withholding capacity

The withholding of vital generation capacity in California's electricity market is said to have been one of the causes that led to and made California's energy crisis worse during the winter of 2000 and spring of 2001. During the final months of 2000 especially, strategic withholding of generation seems to have taken place (Joskow and Kahn, 2001). The unprecedented amount of power plant outages during the winter and spring of 2000-2001, at times 16,000 MW, or nearly 35% of California's total generation capacity – roughly double the typical historical forced outage rates, strongly suggests the occurrence of strategic behavior (GAO, 2000; Joskow and Kahn, 2001; Joskow, 2001). Evidence points towards privately owned out-of-state generators such as Enron and Reliant, and to some public entities. Furthermore, withholding in California's natural gas market, which supplies more than 50% of California's electricity industry, also seems to have played a role (CSA, 2001; Faruqui *et al*, 2001).

Strategic bidding

California's market structure stimulated a shift in the amount of power that was traded in the day-ahead market to the more unpredictable and volatile real-time spot market. This strongly increased the volatility of the prices in the real-time market. As California's electricity shortages became more acute, the amounts of energy traded in the day ahead market declined to the point that the California independent system operator was unable to procure enough electricity reserves in the real-time market to cover California's load. This forced the system operator to make out-of-market purchases at far higher prices, which further drove up electricity prices, resulting in vicious cycle (CSA, 2001).

* See also appendix 1.

Generators can also exploit their market power using a *mix of market strategies*. While the first kind of strategies describe above (decreasing supply) are the most obvious, increasing demand is less evident but can lead to a comparable increase in prices. Due to the confidentiality of the OTC market many players may use the power exchange price index as a reference for their bilateral contract. This relationship between the two markets can lead into specific strategies. Take for instance a player that sells part of its OTC indexed on the power exchange price. This player can take advantage of buying electricity on the power exchange to increase the price on this market because this price variation will increase its revenue on the OTC market. This strategy is profitable when the volume on the power exchange is low compared to the volume on the OTC market, when some player have a large market share in both markets, and when arbitrage between market is difficult. These three conditions are present in most European electricity markets.

Finally, the last type of strategy is to use *strategic bidding* to exploit temporary market power. The analysis of strategic bidding behaviour is mainly limited to a comparison of bids and costs of power plants over time (Brealey and Lapuerta 1997, Wolfram 1998). Hence, in its strict definition any bid superior to cost[29] can be considered to be a strategic bid. As in other electricity markets, the use of excessively high bids on the power exchange can be done in order to increase market price. For instance, for buyers that are short in the OTC market the power exchange represents the last place to buy electricity before going to the expensive (and risky) balancing market. For these players very high purchase bids may appear to be the only way to escape the balancing market. Suppliers which are aware of the tightness of the market can then bid at prices higher than the competitive level. This kind of behavior is possible due to the inelasticity of

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[29] The literature, depending on the assumptions made by the authors considers short-term marginal costs (STMC) or long-term marginal costs (LTMC). In the short term, the capital costs associated with delivering an additional unit are fixed. It is therefore possible to measure marginal costs excluding capital costs (STMC). However in the long term, capital costs also need to be recovered which increases marginal costs (LTMC)

the demand in electricity markets and the low possibilities for arbitrage between markets.

Strategic bidding can also depend on the type of auctions used. With respect to power exchanges design, the choice between the different options, one-sided auctions versus two-sided auctions, marginal bid versus pay-as-bid etc,[30] can mitigate or facilitate the exercise of market power. For instance, one-sided auctions obviously facilitate the exercise of market power since they limit demand response. However for some others aspects of marketplace design, the choice between different options with respect to their impact on market power, is more controversial. This is the case for the choice between pricing rules (or auction design). Following the Californian crisis and the introduction of NETA in the UK, investigations have started to determine whether the choice between marginal bid versus pay-as-bid might have an impact on market power. While marginal pricing based on an auction is the rule in most European power exchanges but also in most electricity markets around the world (Shuttleworth and McKenzie, 2002), following the Californian crisis and the introduction of NETA investigation have started to determine whether the choice between the two systems might have an impact on market power (Kahn *et al*, 2001; Currie 2000; Bower, 2001). The starting point in the debate on the impact on market power between pay-as bid and marginal pricing auction is that marginal price auctions may facilitate the exercise of market power (Brennan, 2001). The question is whether generators should be allowed to offer different amounts of electricity at different prices rather than all of their output at a single price. The point is that if generators are allowed to offer different amounts at different prices, they have an incentive to offer a small amount of their output at a very high price. The reason for this is that if their high bid is accepted they will receive the high price for all their output while if the bid is rejected the lose involved will not be significant due to the low volume involved. In the analysis of both types of auction, no evidence emerged to support which auction design would systematically produce lower prices and thus

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[30] See chapter 3

mitigate market power. However, pay-as-bid auctions appear to be less suitable in general because they may create significant entry barrier, which penalizes small players and thus may facilitate market power in the long run by deterring entry.

6-4-3 Arbitrage strategies: lessons from the Enron's memos

The publication of the Enron memos[31], written by Enron's lawyers in December 2000, has been largely represented in the press as evidences of market manipulation by market participants during the California crisis[32]. However, detailed analysis of the memos reveals that the vast majority of the strategies described were standard arbitrage strategies and at worse most of them increased market efficiency (Falk, 2002). While it is unclear whether the remaining strategies actually served to increase prices and, if yes, to what extent (Wolak, 2002; Hildebrandt, 2002), they clearly show how poor market design creates perverse incentives (Taylor and VanDoren, 2002). Since arbitrage strategies used in power exchanges at present in Europe are not directly observable, the Enron strategies are of particular interest because they provide a good illustration of sophisticated market behaviours in complex electricity markets[33].

In general, as one would expect, Enron's strategies (box 6-5) were aimed at taking advantage of price differences between markets or in time. This is the normal behaviour of traders in any market who try buy low in one place, or at a given time, and sell high in another place, or a another time. Such behaviour increases market efficiency because it reallocates goods from places where they are plentiful to places where they are scarce. For instance "Ricochet" and "Fat Boy" were two strategies used by Enron to exploit prices discrepancies between the real-time market and the day-ahead market. However other strategies such

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[31] The first is from the law firm Stoel Rives and is the most complete. The second is from the law firm Brobeck and explains the first memo. They are both available at www.ferc.gov

[32] Los Angeles Times, May7/2002; USA Today, May 7/2002; St. Petersburg Times, May 8/2002;

[33] See appendix 1 for a description of California's market design and discussion

as "Load Shift", "Death Star", and "Wheel Out", though it is unlikely that they had a significant effect on efficiency, clearly show how Enron took advantage of specific weakness in market design.

Box 6-5: The principal Enron's strategies

"Fat Boy":
Arbitrage between Real-time and Day-ahead markets by overstating load in the real-time market.

"Export of California power":
Arbitrage between location by buying in California day-ahead and selling outside California when prices outside California exceed the price cap of the day-ahead market.

"Death Star":
Arbitrage between transmission pricing system by simultaneously scheduling a transaction from A to B and from B to A.

"Load Shift":
Artificially creating congestion and get paid for relieving it.

"Get Shorty":
Arbitrage between Real-time and Day-ahead markets by selling ancillary services in the day-ahead market and buying them back in the real time market.

"Wheel Out":
Scheduling transactions on a transmission line already out or full and receiving payment for being rejected.

"Ricochet":
Arbitrage between Real-time and Day-ahead markets by buying power from the PX exporting it to a party in neighbouring countries and importing it back to sell the energy to the ISO market where no price caps are in place.

Several of Enron's strategies had the objective to take advantage of or avoiding the price cap that applied to transactions within the California market and arbitrage the spread between the PX's market and the ISO's market. California imposed day-ahead price caps of $250 to mitigate price spikes and abuse of market power, but prices were not capped in neighbouring countries. For instance, on December 5, 2000 prices increased to $1200 per MWh in the Pacific Northwest while they were limited to $250 in California. In such a situation it was rational for any market participant to buy as much as possible in California and sell it in the Pacific Northwest. This strategy was called "Export of California power". It has been argued that such a strategy exacerbated the supply shortage in California. This is true, however this is a simple rational arbitrage strategy, i.e. when prices outside California are above the price cap, there is no reason to sell power in California. In this case the design of the market was directly responsible for decreasing available generation in California.

The "Ricochet" strategy described in Enron's memo goes further. Since, no price caps were in place in the ISO real time market and because this market was crucial to system reliability, Enron traders were buying power from the PX exporting it to a party in a neighbouring State and importing it back to sell to the ISO market. Again this strategy is a classical arbitrage strategy aiming to take advantage of the spread between the PX and the ISO market. In a well-designed market such strategy would not have been profitable because the ISO price and the PX price should be equal or at least very close. However the existence of a price cap in the day-ahead market and not in the real time market made such strategy interesting when Enron estimated that the market clearing price on the real-time market would be higher than the price cap on the day-ahead market.

In the real-time market, participants wishing to supply generation had to claim a corresponding load. When Enron expected that prices in the real-time market would be higher than in the day-ahead market, they voluntarily overstated their load. If their expectation were correct they received the ISO real-time price. This strategy called "Fat boy", or "increasing" load into the real-time market, is illustrated in the memo as follows: *"Enron will submit a day-ahead schedule showing 1000 MW of generation scheduled for delivery to Enron Energy Services. The ISO receives the schedule, which says "1000 MW of generation"* *and "1000 MW of load" […] In real-time, Enron sends 1000 MW of generation, but Enron Energy Services only draws 500 MW. The ISO's meter shows that Enron made a net contribution to the grid of 500MW, and so the ISO pays Enron 500 times the Dec*[34] *prices".* Again, in a well-designed market such a strategy would not have been profitable because the ISO price and the PX price would be equal or at least very close.

Besides strategies aimed at arbitrage of the spread between the PX's market and the ISO's market, several strategies described in the memos took direct advantage of the inefficient transmission pricing system of the California market design. For instance, the idea of the "Load shift" strategy was to create artificially congestion and to get paid for relieving it. For this purpose they would schedule moving power through a congested interconnector. Then, in real-time Enron would cancel the transaction and receive money from the ISO which would pay Enron for relieving congestion. The arbitrage opportunity existed because congestion payments for relieving congestion could exceed electricity prices. According to the Enron memo, this strategy produced about $30 millions of profits in 2000 which shows that it was particularly profitable to do this. It is unclear to what extent such a strategy influences market prices. On one hand, this strategy potentially increased prices in the day-ahead market by raising congestion prices. On the other this strategy can not affect real time prices because they are determined only after a company has restated the loads correctly (Falk, 2002). Hence, in a well-designed market such strategy would not have been a problem because players facing high prices in the day-ahead-market would have buy power in the real-time market. However, the market design did not allow investor-owned utilities to do this because they were required to buy on the power exchange.

The description of the "Death Star" strategy is different and contradictory between the two memos. According to the first memo, the "Death Star" strategy

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[34] Real-time price for contribution to grid

allowed Enron *"to get paid for moving energy to relieve congestion without actually moving any energy or relieving any congestion"* while according to the second memo *"congestion was relieved and energy did flow through otherwise under-utilised paths".* In fact "Death Star" is a generic name for a whole types of strategies. These strategies are the most disparaged because they aim to capture congestion payments from imaginary transactions (McCullough, 2002). In the first memo, the "Death Star" strategy is described as follows: assuming that congestion was anticipated from California-Oregon-Border (COB) to Lake Mead, Enron's trader would scheduled a transaction from Lake Mead to COB and collect congestion payments because the energy travel in the opposite direction of congestion. Second, Enron buys transmission in the congested direction (from COB to Lake Mead) which net the transaction. The ISO could not see that the same energy was exported and imported simultaneously because the transmission line from COB to Lake Mead is outside the ISO's control area. This strategy was profitable due to different system for transmission pricing depending on the direction: *"Enron is not subject to payment of congestion charges because transmission charges for the COB to Lake Mead line are assessed based on imbedded costs".* Hence, this strategy was made directly possible due to two design problems. One, the ISO's control area is limited and thus it is unaware of what happen outside its area. Two congestion charges were not priced consistently.

The "Wheel out" strategy is certainly one of the simplest strategies used by Enron for taking advantage of bad market design with respect to transmission pricing: because a first-come first-served system was applied for transmission capacity rather than a bidding process, Enron scheduled transaction on transmission lines which were out or already full. This scheduling was rejected by the ISO and Enron received payments for not being allowed to move power through this interconnection when in fact they had never attempt to send any energy.

In conclusion, the recent publication of the Enron memos shows how market/marketplace design can influence behaviours of market participants. However it is worth noting that the vast majority of the strategies were, one available to all markets participants, two, that most of them were standard arbitrage strategies as opposed with abuse of market power that would not have been profitable in a well-designed market, and three, these strategies were known to the market monitoring committees of the CAISO and the power exchange well before the publication of the memos (Wolak, 2002). Two important aspects are at the centre of most strategies in this example: separation between real-time market and power exchanges, and inefficient transmission pricing mechanisms. Whatever the impact of the Enron strategies had on the market, they shed light on some examples of market intelligence and shows how sophisticated trading strategies can be to take advantage of market design, i.e. of unclear or poor market/marketplace rules.

Finally, the Enron memos illustrate one, how the complexity of electricity markets result in sophisticated market behaviours, and two, how players may take advantage of bad rules and poor market design. In a European market where the power exchanges and other markets have been designed separately, one can reasonably assume a similar set of complex arbitrage trading strategies will take place using power exchanges.

6-5 Conclusion

In conclusion, attention in this chapter was focused on how market participants use power exchanges. A typology of strategies according to the nature of players and different types of bidding behaviors was defined to help us understand the diversity and complexity of behaviors on power exchanges. This chapter shows that the nature of electricity markets and market design involves market participants using complex strategies. These strategies are largely influenced by market/marketplace design. A major concern is the several opportunities for the exercise of market power by market participants. Moreover, an analysis of

Enron's memos has showed how the complexity of electricity markets results in sophisticated market behaviors with respect to arbitrage strategies between markets. Unfortunately, in Europe these strategies cannot be directly observed, though the results of these behaviors on competition can be analyzed through analyzing market structure and outcomes of these markets.

Chapter 7

Competition and power exchanges

It has been shown that the individual behavior of players on power exchanges is not directly observable in the previous chapter, however it is possible to look at the result of this behavior for competition. In this chapter we start with the traditional approach for analyzing competition, i.e. analysis of market structure. Two types of market structure are analyzed: market structure in generation and level of interconnection, and market structure on power exchanges. This analysis highlights the low level of interconnection between countries with respect to national demand and important differences between the "physical" market structure, generators, and the "commercial" market structure, participants on the exchanges. Finally competition on power exchanges is estimated via an analysis of prices and volumes developments on different exchanges.

7-1 Defining competition

7-1-1 Origins and general definition of competition

The Oxford English Dictionary defines competition as *“the action of endeavoring to gain what another endeavors to gain at the same time”*. While Adam Smith is often presented as the founder of the concept of competition (Clark, 1961), the exact origin of this concept can be traced back to earlier work. A decade before the publication of the *Wealth of Nations* authors like Hume and Turgot were already using the concept of competition. According to McNulty (1967) the work of Sir James Steuart should be considered to be the first complete work on competition while the analysis of Adam Smith “only” represents a fundamental step:

“Probably the most complete pre-Smith analysis of competition was that of Sir James Steuart, who stressed that competition might exist among either buyers or sellers (Steuart, 1767).[…]. Rather than considering Adam Smith as the progenitor of a concept whose refinement came at the hands of a group of successors, it is more accurate, as far as the history of competition is concerned, to think of Smith’s work as marking the end of one era and the beginning of an other.” (McNulty, 1967)

According to Smith competition is the vital mechanism, the invisible hand, which control the pursuit of each individuals self-interest (Smith, 1776). Hence competition is a process of responding to a new force and a method of reaching a new equilibrium (Stigler, 1957).

“The strict meaning of competition seems to be the racing of one person against another, with special reference to bidding for the sale or purchase of anything. […]In modern economic theory, a market is said to be competitive, when the number of firms selling a homogeneous commodity is so large, and each firm’s market share is so small, that no individual firm finds itself able to influence

appreciably the commodity price by varying the quantity of output it sells“ (Marshall, 1890).

In this chapter we first present issues relating to the analysis of competition in electricity markets with respect to previous work and the peculiarities of these markets. We use a traditional approach to analyze competition; i.e. we analyze market structures. Two types of market structure are analyzed: market structure in generation and level of interconnection, market structure on power exchanges. Such an analysis shows the low level of interconnection between countries with respect to national demand and important differences between the “physical” market structure, generators, and the “commercial” market structure, participants on the exchanges. Finally competition on power exchanges is estimated with an empirical analysis of prices and volumes developments on different power exchanges.

7-1-2 Analyzing competition in European electricity markets

The analysis of competition in electricity markets in general, i.e. not only power exchanges, is confronted with many difficulties. While all electrons are the same, electricity must be distinguished by time and place. A MWh on a summer weekend night cannot be substituted with a MWh at noon on a winter weekday. Moreover due to possible transmission constraints, it is not always possible to substitute electricity at one location with electricity at another location. The key characteristic of electricity is that electricity cannot be stored and supply and demand must be balanced in real time (Stoft, 2002). Another aspect is related to the market structure of the electricity industry which has been historically organized through vertically integrated monopolies. From a technical point of view, electricity generation is a complicated production process, non-convex costs, operating constraints etc, that creates inter-temporal links in production costs (Bushnell and Savaria, 2002). Finally due to market/marketplace design and regulatory frameworks a method used to analyze competition in one country might be totally non-relevant for another country.

Analyses made in the US have shown that the electricity industry also presents some advantages for the analyst, compared to other industries, which can be used for competition analysis[1]. For instance, production capacities are well defined and to a large extent these data are publicly available. Hence, good estimates of data necessary to estimate short run marginal costs for each production unit are available. These are primarily data concerning the efficiency levels of generation units, and start up costs. Furthermore, total demand on the grid can be measured with great accuracy. Such accessibility of data allows the construction of competitive price benchmarks (Borenstein *et al*, 1999). These benchmark prices can be defined as the price that would result if all firms acted as price-taking firms, i.e. no exercise of market power (Newbery, 1995). Comparing realized prices with a competitive benchmark is a widely accepted and interesting method for estimating the level of competition (Joskow and Kahn, 2001), the open question is: Do economists have the ability to calculate accurately this competitive benchmark? For instance, the complexities of the production process and the role of market design create significant uncertainties about the accuracy of benchmark measures (Harvey and Hogan, 2002).

In continental Europe analysis of competition in the electricity industry has been little used. The first obvious reason is the very recent opening to competition of the industry compared to the US. It is quite premature, if not impossible, to assess the level of competition over a very short period. Second, due to the different levels (and delays) in implementation of the EU Directive between countries, most studies that have been done have been mainly national. For these reasons, most of the analysis done so far has focused on the creation of a single electricity market and on the creation of market mechanisms. Hence there is very little literature on analysis of competition in Europe, and none about competition on power exchanges, because obviously, analyzing competition make little sense in the absence of a market. Instead, most studies have focused

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[1] See chapter 4, section 4-4-3

on the implementation of the EU Directive 96/92 into national law rather than on the level of competition[2].

7-1-3 Estimating competition in electricity power exchanges: market structure and prices analysis

Traditional analyses of competition are based mainly on the structure-conduct-performance paradigm (Bain, 1951; 1956). According to this approach, it is the structure of the market that determines its performance, via the conduct of its participants. In line with this paradigm the degree of concentration in a market has long been considered to be one of its major structural characteristics and analysis of market structure then becomes a key indicator of the level of competition. While it is now recognized at both a theoretical and an empirical level that the SCP approach is overly simplistic (Farrell and Shapiro, 1990), in practice, national competition authorities, the US Federal Energy Regulatory Commission, and the European Commission's DGIV put a lot of emphasis on the analysis of market structure and concentration ratios (Hoehn *et al*, 1999)[3].

For the purpose of this work we will use concentration measures as a starting point for the analysis. In this chapter we will consider market structure from a national level point of view, because European power exchanges are marketplaces which provides national prices index, however, so that we can take into account potential competition from neighboring countries we will also consider interconnector capacities. The first traditional approach for analyzing competition consists of calculating the level of concentration based on installed capacity of generators per country. Since delivery areas of power exchanges are defined nationally, such measure gives an interesting proxy of the conditions underlying the functioning of each exchange (section 7-2). Although taking into account the most important part of the market structure, this measure overlooks

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[2] See chapter 10

[3] This might be partly due to, one ,from a practical point of view, the fact that these measures are relatively easy to collect and two, from a theoretical point of view, the fact that research in economic theory has until now failed to provide any other robust alternative approach

a part of the market structure with respect to power exchanges because it does not account for interconnections; for this reason, other indicators will be discussed. The nature and number of competitors on power exchanges and other relevant indicators will also be analyzed (section 7-3). We end this chapter with a first attempt to estimate the level of competition on power exchanges based on direct price analysis (section 7-4). Analysis of power exchange's prices together with the respective quantities sold, and market structure can provide a significant amount of information on the level of competition.

7-2 Competitors in generation and interconnections

7-2-1 Introduction

As a starting point for the analysis, in this section we focus on the two fundamental underlying elements of any electricity market which influence the development of competition in general, and the functioning of electricity power exchanges in particular, i.e. the level of concentration in generation and the level of interconnection capacity. In terms of generation structure, European countries can be divided into three distinct categories of markets: a single dominant player, a few dominant players, and no dominant player. For the purpose of this work we focus on countries where power exchanges have started to operate and were fully operational for the year 2002. Powernext, the French power exchange falls in the first category. The Dutch and German power exchanges fall in the second category. Finally the Nordic countries' exchange and the British exchange fall in the last category. As a starting point, table 7-1 gives a general overview of the market structure of major European electricity markets regardless to interconnection using the Hirschman-Herfindahl index (HHI)[4]. We will go into the details of the five markets analyzed in the following sections where in addition to market structure in generation we will also consider the role of interconnectors[5].

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[4] The HHI is an index of market concentration. It sums the square of the market shares of individual participants and gives then, a first approximation for the distribution of the shares throughout the market. The HHI index ranges between 1 for an atomistic market and 10.000 for a pure monopoly.

[5] It is worth noting that in this chapter we do not take into account joint ownership which is a factor that can influence market power. Moreover, the elasticity of the residual demand curve, i.e. the elasticity of the market demand curve minus the supply of all the other firms, is ignored. However using it represents

Table 7-1: Generation market structure in Europe

Country	Players	% installed capacity	HHI
Germany			
	RWE	28	
	E.on	22	
	Vattenfall	15	
	EnBW	4	**1509**
	others	31	
Austria			
	Vorbund	48	
	EVN	8	
	Wlemstrom	7	**2417**
	others	37	
Belgium			
	Electrabel	86	**7396**
	others	14	
Spain			
	Endesa	44	
	Iberdrola	31	
	Union Fenosa	12	
	Electra de Viesgo	5	
	Hidrocantabrico	4	**3082**
	others	4	
France			
	EDF	88	
	CNR	3	
	SNET	2	**7757**
	others	7	
Italy			
	Enel	65	
	Edison	8	
	Eni	1	**4290**
	others	26	
Nordic Countries			
	Vattenfall (Sweden)	16	
	Fortum (Finland)	12	
	Stakraft (Norway)	10	
	Sydkraft (Sweden)	7	
	Birka energi (Sweden)	5	
	Energi E2 (Denmark)	4	
	UPM-Kymmene (Finland)	5	**600**
	others	38	
Netherlands			
	EPZ	20	
	Electrabel	23	
	Reliant	17	
	E.on	9	**1299**
	others	31	
UK			
	British Energy	15	
	Innogy	10	
	*Powergen**	14	
	Scottisch Power	6	
	London electricity	6	
	Scottish & Southern	4	**609**
	others	45	

**include former asset TXU (2908)*

Source: Companies annual reports (2001)

another method to estimate potential market power. In particular, un-concentrated market by the HHI measure can offer considerable opportunities for market power if the elasticity of the residual demand

7-2-2 A market with a single dominant player: Powernext

The hub of delivery of the French power exchange is characterized by the domination of Electricité De France (EDF) and a low level of competition from abroad. EDF owns about 90% of installed generation capacity, and in 2000 EDF covered about 97% of French consumption. An important feature of EDF generation capacity is the large share held by nuclear technology which represent about 55% of French installed capacity[6]. On the French territory, the two main rivals of EDF are Compagnie National du Rhone (CNR) and Société Nationale d'Electricité Thermique (SNET) which own respectively 4% and 2% of installed capacity. The level of competition between these three players is quite difficult to assess. On one hand in 2000, EDF held 19% SNET and 16,7% of CNR which reinforce the position of EDF in France. On the other, due to the strategic position of these two companies, foreign companies have expressed an interest for CNR and SNET. Endesa acquired a 30% stake in SNET in 2000 while in 2001, CNR set up a joint venture with Electrabel for power sales. However, due to the overwhelming position of EDF in terms of generation, the roles of CNR and SNET on the wholesale market are rather limited.

In addition to CNR and SNET, an important source of wholesale power that is available in France is related to the "virtual capacity" auctioned by EDF. The European Commission has approved the acquisition by EDF of a stake in EnBW on the condition that EDF make 6.000 MW of its generation capacity available to competitors for a five year period[7]. While the power plants are still owned and run by EDF, this allows some new entrants to secure generation capacity within France. Such an initiative, while improving the competitive structure of the French market a little has been criticized for not being the same as asset divestiture (Finon, 2002).

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curve is low. See chapter 10 for more on that.

[6] RTE (2002)

[7] European Commission Decision of 7 February 2001, Case COMP/M.1853 - EDF/EnBW) Official Journal L 059 , 28/02/2002 P. 0001 – 0017

Finally due to the market structure of the French market one may expect a main source of competition to come from neighboring countries (CRE, 2000; 2001). This was recognized by the French Regulator in its annual report "*in the next few years competition with EDF will result more from the action of foreign operators than from the presence of important producers installed in the national territory*"[8]. The French network is interconnected with the UK (2000 MW), Italy-Switzerland (5400 MW), Germany-Belgium (2100 MW) and Spain (1100 MW)[9]. The aggregated available interconnector capacity can only cover less than 10% of national consumption[10], however due the low production costs of nuclear power plants, France, through EDF, is the largest European exporter with a total volume of 72.6 TWh in 2001. In contrast imports were quite modest in comparison to a volume of 4.2 TWh, showing that competition from abroad is relatively limited.

Table 7-2: Installed generation and interconnection in France (2002)

Player/interconnection	Installed capacity/ available interconnection	%
EDF	102810	80,87%
CNR	2937	2,31%
SNET	2600	2,05%
Total main generators	***108347***	***85,23%***
Others generators	7780	6,12%
From Spain	1000	0,79%
From Italy	1800	1,42%
From Switzerland	4100	3,23%
From Germany / Belgium	2100	1,65%
From UK	2000	1,57%
Total interconnection	***11000***	***8,65%***
Total	127127	100%

In conclusion, from a production point of view the dominance of EDF and the low volumes of import, despite the level of interconnection (8.65%), represent two strong limitations for the development of trading on the French power exchange.

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[8] Commission de Régulation de l'Electricité, *Annual report 2000*

[9] UCTE, *European Interconnection: State of the Art 2002*, the figures mentioned are available capacity opposed to technical installed capacity (see chapter 9 for more on this)

[10] ETSO. *Indicative values for net transfer capacities (NTC) in Europe*, available at http://www.etso-net.org/media/download/

A summary of the underlying conditions of functioning of the French power exchange is given in table 7-2 above.

7-2-3 Markets with a few dominant players: APX and LPX-EEX

The Dutch and German markets are characterized by the existence of a few dominant players and important cross-border flows. In this section we identify the main electricity producers for these two markets and the level of interconnector capacity. Obviously such market structures are intrinsically more favorable for the development of competition than the French structure, and in turn, for the development of electricity trading and liquidity on the APX and LPX-EEX power exchanges.

Table 7-3: Installed generation and interconnection in the Netherlands (2002)

Player/interconnection	Installed capacity/ available interconnection	%
EPZ	4086	17,34%
Electrabel	4647	19,72%
Reliant	3476	14,75%
E.on	1770	7,51%
Total main generators	***13979***	***59,31%***
Others	5991	25,42%
From Belgium	1312	5,57%
From Germany	2288	9,71%
Total interconnection	***3600***	***15,27%***
Total	23570	100%

In the Netherlands, four players own 61% of the installed capacity (Electrabel, 23%; EPZ, 20%; Reliant, 17%; E.on11%)[11] while decentralized production, led by cogeneration plants, represents the rest of installed capacity. In Germany, four players represent a significant part of the market with 68% of installed capacity (RWE, 28%; E.on, 22%; Enbw/EDF, 4%; Vattenfall, 15%)[12].

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[11] *Dutch wholesale power market review*, Elan Energy Consulting, May 2002

[12] *European power trading 2002*, Prospex research Ltd., June 2002

In both countries cross-border trade is significant. In the Netherlands interconnector capacity represents a share of 18% of the total national installed capacity[13]. Such a level of interconnection makes the Netherlands one of the most well connected countries in continental Europe alongside Austria (22%) and Belgium (18%)[14]. Germany is the largest trading partner. In 2001, 16.8TWh were imported from Germany for 0.4 TWh exported[15]. Transactions with Belgium are usually more balanced with 4.5 TWh of imports for 3.6 TWh of exports.

Table 7-4: Installed generation and interconnection in Germany (2002)

Player/interconnection	Installed capacity/ available interconnection	%
RWE	32187	25,17%
E.on	24881	19,46%
*Vattenfall**	14209	11,11%
EnBW	10768	8,42%
Total main generators	***82045***	***64,16%***
Others	37380	29,23%
From Denmark	1200	0,94%
From Sweden	460	0,36%
From France	2350	1,84%
From Austria	1850	1,45%
From Switzerland	1450	1,13%
From Netherlands	1150	0,90%
Total interconnection	***8460***	***6,62%***
Total	127885	100%

**=VEAG (7479)+HEW (3727)+BEWAG (3003)*

Due to its central position, the German market is interconnected with nine countries. However the total share of available interconnector capacity related to the national installed capacity is approximately 10%[16] which limits the level of potential competition from abroad. Some major patterns for the use of the interconnectors can be identified. One, due to large the hydro system in Austria and Switzerland, cross-border trade with Germany is related to seasonal hydro

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[13] *Electricity liberalization indicators in Europe*, A report to the European commission DG Tren, October 2001,p 144

[14] Ibid.

[15] TenneT, *Annual Report 2001*

[16] Including Poland, and Czech Republic

conditions. Two, large imports are related to large excess in France's nuclear power. Three, in contrast Germany exports large volumes to the Netherlands (see above), where, due to the production park structures, mainly conventional thermal units, prices are traditionally higher. The underlying conditions of the functioning of the Dutch and German power exchanges are summarized in tables 7-3 and 7-4 above.

7-2-4 Market with no dominant player: UKPX and Nord pool

The United Kingdom and the Nordic region, Norway, Sweden, Finland and Denmark, share two characteristics: the level of consumption, respectively 344 TWh and 359 TWh for 2001, and a low level of concentration in generation compared to other countries. In the UK, the three biggest utilities own only 39% of the installed generation capacity (British Energy, 15%; Powergen, 14%; Innogy, 10%). In the Nordic Region the three largest power producers own 38% of the total installed capacity (Vattenfall, 16%; Fortum, 12%; Statkraft, 10%)[17].

Cross-border trading is strongly limited for the UK. The level of interconnection of the UK market with foreign countries is the lowest in Europe with a share of 3% related to national installed capacity. The main connection is a subsea link with France (2000 MW). The UK is also connected with the Republic of Ireland by a 600 MW interconnector. Like Germany the UK imports traditionally cheap electricity from France. However following the introduction of NETA and an important drop in price in 2001, UK imports dropped during period of high prices in Continental Europe.

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[17] *European power trading 2002*, Prospex research Ltd, June 2002

Table 7-5: Installed generation and interconnection in the UK (2002)

Player/interconnection	Installed capacity/ available interconnection	%
British Energy	11533	14,21%
Innogy	7731	9,53%
Powergen	10744	13,24%
Scottisch Power	4790	5,90%
London electricity	4803	5,92%
Scottish & Southern	3832	4,72%
Total main generators	***43433***	***53,53%***
Others	35536	43,80%
From France	2000	2,46%
From Ireland	170	0,21%
Total interconnection	***2170***	***2,67%***
Total	81139	100%

**include former asset TXU (2908)*

In contrast, within the Nord pool area, the level of interconnection represents at least 20% of each national installed capacity which allows substantial competition between the four countries[18] but is rather limited with others countries (table 7-5). In 2001 the level of cross-border trade in the Nordic countries reached 14% of regional consumption[19]. Norway and Sweden, with large hydro capacity, are substantial exporters when hydro conditions are good. Finland is a regular importer from others Nordic countries and Russia. Denmark, which mainly uses thermal technology, exports when hydro conditions are poor in neighboring countries and imports when hydro conditions are good. Moreover, in addition Nordic countries are also connected to countries outside the Nordic area. Finland is connected to Russia (1160MW), Denmark is connected to Germany (1950 MW), Norway to Russia (50 MW), Sweden to Germany (600 MW) and Poland (600 MW)[20]. Such a high level of interconnection between the countries of the Nordic Area and between the Nordic Countries and neighboring countries represents a favorable factor for the development of competition since it increases the number of competitors.

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[18] Nordel, *Annual Report 2001*

[19] Ibid.

[20] Ibid.

Table 7-6: Installed generation and interconnection in the Nordic area (2002)

Player/interconnection	Installed capacity/ available interconnection	%
Vattenfall (Sweden)	13680	16,12%
Fortum (Finland)	10163	11,98%
Stakraft (Norway)	8815	10,39%
Sydkraft (Sweden)	5900	6,95%
Birka energi (Sweden)	4250	5,01%
Energi E2 (Denmark)	3740	4,41%
UPM-Kymmene (Finland)	4231	4,99%
Total main generators	***50779***	***59,84%***
Others	32769	38,62%
From Germany (Denmark)	940	1,11%
From Germany (Sweden)	370	0,44%
Total interconnection	***1310***	***1,54%***
Total	84858	100%

In both countries, the low level of concentration represents an attractive starting situation for the development of a power exchange and trading in general. However the Nordic area possesses an additional advantage compare to the UK, this is related to the high level of interconnection. In the UK, interconnections with foreign countries are almost insignificant. The underlying conditions of functioning of the Nordic and British power exchanges are summarized in tables 7-5 and 7-6.

7-2-5 Conclusion

Market concentration in generation represents a first useful indicator that cannot be ignored for analyzing competition[21]. Even if this indicator is particularly simplistic it can be used as a starting point for the analysis. For this purpose, comparison and combination of this measure with others indicators is a practical approach. In this section we have combined the traditional national market concentration approach with an analysis of the level of interconnector capacity. This approach allows us to take into account potential competition from abroad which, in some cases might play an important role, figures 7-1 and 7-2 show the

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[21] See chapter 10 for discussion of the shortcomings of market concentration analysis

market share of the two largest generators for each power exchange with respect to interconnector capacity.

Figure 7-1: Market share of the two largest generators and interconnection (%)

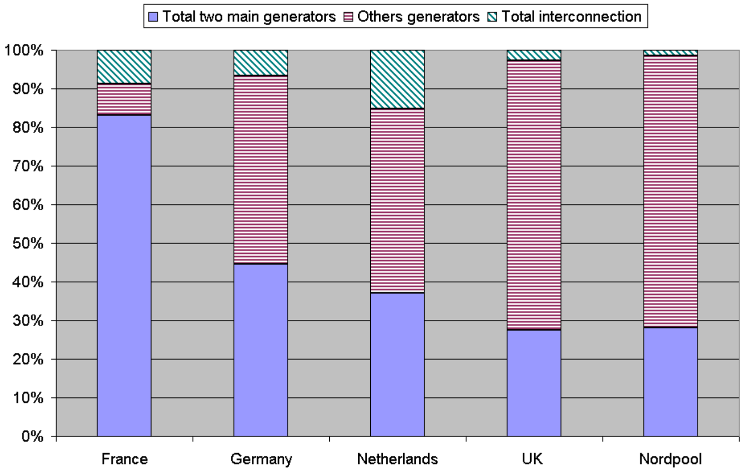
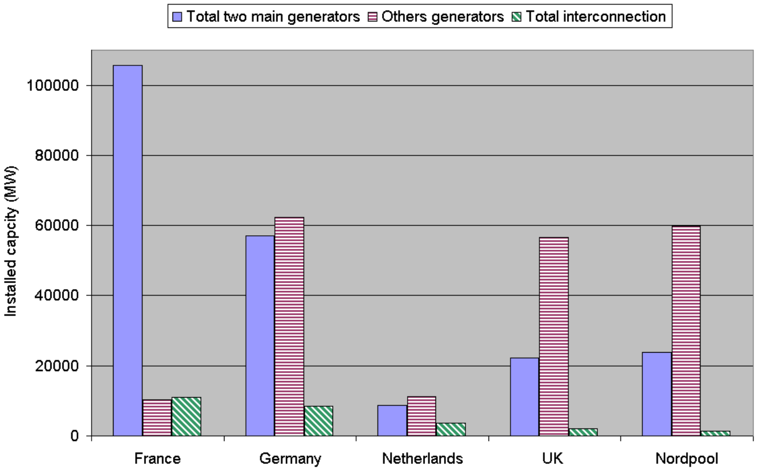


Figure 7-2: Market share of the two largest generators and interconnection (MW)



The concentration of supply and/or the low level of interconnection capacity is a common characteristic of many European national electricity markets. In such a context, competition may fail to develop and market prices may stay above competitive level (Olsen and Skytte, 2000). In December 2001, the European Commission recognized the importance of this issue in its report *“First report on the implementation of the internal electricity and gas market”* (EC, 2001a), however no solutions were put forward.

7-3 Competitors on power exchanges

7-3-1 Introduction

The previous section has showed that the number of electricity producers in many countries is relatively low. However, competition on power exchange is not limited to energy producers. Other players such as energy traders, large industrial consumers and distribution companies play an important role on power exchanges[22]. A good analysis of the role of players on power exchanges would consist of looking at the trading pattern of each participant, however, since information on trade per participants is confidential, and therefore not available, in this section we consider the number and nature of participants on different exchanges.

7-3-2 Number and nature of competitors

The total number of players on each power exchange with respect to their original country are identified in table 7-7, while table 7-6 shows the repartition of player with respect to their nature, i.e. producer, distributor, trader etc. Before going into the details of the analysis it is worth noting that, from a practical point of view, such analysis is confronted with three main difficulties. Power exchanges provide a list of their participants on their websites, but they do not differentiate between *registered members* and *active members*. Indeed, some players are members of power exchanges but participate in little, or not, to trading. Powernext is an exception, in its activity assessment 2001-2002[23], the French power exchange differentiated between the two categories: the exchange has approved 32 members but only 25 are active members. This gap is due to companies that have joined the exchange but have not started to trade. Such

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[22] See chapter 6

information is not available for the other exchanges. Table 7-7 only considers registered members.

The second difficulty is related to the *identifying the company behind the participant name*. Indeed, on most exchanges a number of different daughters companies are represented from the same Mother Company. For instance, Fortum Direct Ltd. and Fortum Energy Plus, Scottish power (UK) plc and Scottish power trading energy trading Ltd. are all members of UKPX. Enel Produzione SpA and Enel Trade S.p.A , BP Energie (Deutschland) GmbH and BP Gas Marketing Limited are all registered on LPX-EEX. Finally Electrabel NV and Electrabel Nederland NV are registered as two different members on APX. Such multiplication of subsidiary companies is a real challenge for those trying to identify players. The question is whether two subsidiaries which belong to the same Mother Company can actually be considered to be competitors.

Finally, *defining the activity* of each player, as presented in table 7-6, is sometime ambiguous. Indeed, electricity players are rarely limited to only one activity. For instance all major producers in Europe have developed a "sales departments", in charge of selling the production of their assets, and a trading department which carries out all kinds of arbitrage, like a pure trader[24]. In order to take into account this aspect, the nature of a player is defined with respect to its main activity in the country considered. Hence, E.on is considered to be a producer on LPX but a trader on Powernext since E.on has production capacity in Germany but not in France. For the same reason, Electrabel is considered to be a producer on APX but a trader on UKPX.

The number of players on the exchanges considered range from 35 for Powernext to 111 for LPX[25] at the end of the year 2002. The average number of participant is thus 61 which represents a large difference with the number of producer in each countries. With the exception of France, a minimum of 50% of

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[23] Powernext, *Activity Assessment 2001-2002*

[24] i.e. without physical assets

the players are national players; on the APX 50% of the participants are “national” players, 54% on LPX, 63% on UKPX and 90% on Nord pool. Since power exchanges are markets for physical delivery such a feature is not surprising. The limited presence of French participants on Powernext has two reasons. One, EDF is not only the main producer it is also the main distribution company with a market share in distribution comparable to its market share in production. Two, for French players, the law governing energy trading is ambiguous and it restricts “pure trading” to 20% of production[26]. The remaining players on the different power exchanges are international traders coming from others neighboring countries.

The nature of players on power exchanges also presents interesting information with respect to the nature of competition. As can be seen in table 7-6, in the majority of cases traders represent the largest share of participants. These traders can be separated into two categories. The first one consists of pure traders without any physical assets based on the model of (now defunct) Enron. The second category is composed of the trading department of the large producers such as E.on, RWE, EDF, Endesa or Enel which do not have assets in the hub of delivery of the exchanges under consideration.

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[25] For Nordpool (91), only players active on the spot market (Elspot) are considered

[26] Décret 2000-1069 du 30 octobre 2000 relatif à l’activité d’achat pour revente aux clients éligibles.

Table 7-7: Total number of players on European power exchanges and nationality (2002)

	APX		EEX-LPX		Powernext		UKPX		Nord pool	
	Number	*%*	Number	*%*	Number	*%*	Number	*%*	Number	*%*
Denmark			4	*4%*					7	***8%***
Finland	1	*3%*					2	*4%*	17	***19%***
Germany	3	*9%*	60	***54%***	7	*28%*	1	*2%*	2	*2%*
UK	3	*9%*	13	*12%*	5	*20%*	29	***63%***	4	*4%*
Norway	2	*6%*	1	*1%*	1	*4%*	1	*2%*	37	***41%***
Sweden	1	*3%*					1	*2%*	21	***23%***
Switzerland		*0%*	12	*11%*	4	*16%*			1	*1%*
Netherlands	16	***50%***	5	*5%*					2	*2%*
Belgium	1	*3%*	1	*1%*	1	*4%*				
United States	2	*6%*					2	*4%*		
France	2	*6%*	1	*1%*	1	***4%***	3	*7%*		
Spain	1	*3%*	3	*3%*	2	*8%*				
Austria			7	*6%*	1	*4%*				
Italy			3	*3%*	3	*12%*	1	*2%*		
Scotland							6	*13%*		
Luxembourg			1	*1%*						
Total	32	*100%*	111	*100%*	25	*100%*	46	*100%*	91	*100%*

Source: UKPX-Powernext-LPX-APX-Nord pool, 2002 (hereafter Power exchanges, 2002)

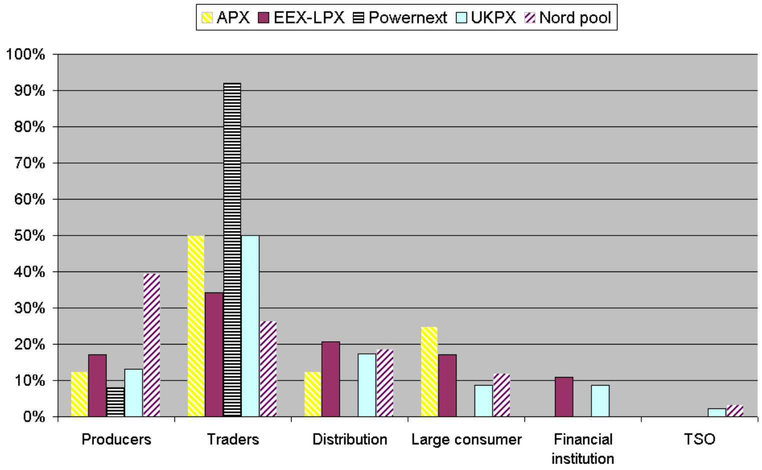
The percentage of producers is logically related to the market structure in generation. On Nord pool 40% of the participants are generators, only 8% on Powernext. On APX, EEX-LPX and UKPX the share of producers is comparable with values between 13% and 17%. Interestingly, financial institutions such as Goldman Sachs International, Credit Suisse First Boston or Deutsche Bank are members of power exchanges. However, it is unlikely that these players participate in physical spot trading, it is more likely that these players are members to monitor closely developments in electricity trading with intention of offering their expertise when financial trading, based on the power exchange price, takes off. Finally, in the UK and in the Nordic Region Transmission System Operators are members of the exchange which shows that TSO may use the power exchange for their own needs.

Table 7-8: Nature of players on European power exchanges (2002)

	APX	EEX-LPX	Powernext	UKPX	Nord pool
Producers	13%	17%	8%	13%	40%
Traders	50%	34%	92%	50%	26%
Distribution	13%	21%	0%	17%	19%
Large consumer	25%	17%	0%	9%	12%
Financial institution	0%	11%	0%	9%	0%
TSO	0%	0%	0%	2%	3%
Total	100%	100%	100%	100%	100%

Source: Power exchanges, 2002

Figure 7-3: Nature of player on European power exchanges (2002)



Source: Power exchanges, 2002

7-3-3 International players

Beside the number of player on each exchange, it is also interesting to identify players that are active on many exchanges. Indeed such players are naturally in the best position to identify market inefficiency and exploit market gaps. Players which are members of at least three of the five exchanges considered are given in Table 7-9. This table identifies 22 players that were registered on a minimum of three exchanges in 2002.

Table 7-9: Players members of three exchanges and more (2002)

	Main trading office	APX	EEX-LPX	Powernext	UKPX	Nord pool	Total
Electrabel	Belgium	X	X	X	X	X	5
Fortum	Finland	X	X		X	X	4
TotalFinaElf	France	X	X	X	X	X	5
E.on	Germany	X	X	X		X	4
EnBW	Germany	X	X	X			3
RWE	Germany	X	X	X	X		4
Enel	Italy		X	X		X	3
Nuon	Netherlands	X	X			X	3
Norsk Hydro	Norway	X	X	X		X	4
Statkraft	Norway	X	X	X		X	4
Endesa	Spain	X	X	X			3
Vattenfall	Sweden	X			X	X	3
Atel	Switzerland	X	X	X			3
Cargill	Switzerland		X	X		X	3
Aquila	UK	X	X	X	X	X	5
Duke Energy	UK		X	X	X	X	4
Dynegy	UK	X	X		X	X	4
EDF	UK	X	X	X	X	X	5
El Paso	UK	X	X		X	X	4
Entergy	UK	X	X		X		3
PowerGen	UK	X			X	X	3
TXU	UK	X	X	X	X	X	5
Total		**19**	**20**	**15**	**13**	**17**	**84**

Source: Power exchanges, 2002

Table 7-9 shows clearly that all the major producers are present on most exchanges and do not limit themselves to their national historical market. In some cases, geographic proximity remains a relevant criterion. For instance E.on and EnBw (Germany) are not present in the UK nor is Endesa. However such consideration tend to be increasingly less relevant. Indeed, most players are present on most exchanges. Besides the producers, the others international players are pure electricity traders such as TXU or Dynegy mainly based in the UK. The first open question concerns the traders' level of activity on the different exchanges, i.e. large market share or just registered member. Secondly when a non-asset based trader sells on a power exchange electricity that was bought from a generator on the bilateral market, can it be said to be competing with generators.

Moreover, it is worth noting that table 7-9 relates to data for 2002, following the collapse of Enron, a large number of pure trader (non-asset based) players have left the European market. This is the case for TXU, Entergy, El Paso, Dynegy, Duke energy, and Aquila. Hence, recent developments have led to a decrease in the importance of this type of player (Newbery *et al*, 2003).

7-4 Prices and volumes analysis

7-4-1 Introduction

Comparison of electricity prices is a classical approach that can be used for analyzing the level of competition in electricity markets. However in Europe most analysis have used retails prices to different user groups collected by Eurostat (EC, 2001a; 2002) rather than wholesale prices prevailing on power exchanges. Furthermore when power exchange prices have been used the analysis has only considered one or two markets (Lange *et al*, 2002; Galli and Armstrong, 2002).

In this section we estimate the level of competition on power exchanges based on direct price analysis. Analysis of power exchange prices together with the respective quantities sold can provide a significant amount of information on the level of competition. We compare price and volume evolution for the year 2002 which was the first full year of operation on the French and British power exchanges. The existence of exchanges in five majors EU electricity markets in 2002 (Netherlands, United Kingdom, France, Germany and Nordic countries) allows us to carry out such analysis for the first time.

We identify several distinguishing features of prices and volumes on these different exchanges in the following sections. Because demand differs widely between days (weekdays/weekend) and hours (peak/off-peak) and since electricity is a non-storable good, prices and volumes vary over time, and this involves an important level of volatility. In this chapter we analyze this volatility with respect to the temporal properties of electricity prices, and the variation of volumes traded on the different exchanges while the relationships between exchanges are analyzed in the following chapter. We first present the different data used for the analysis, then, the question of prices differences and volatility is addressed. The temporal properties of electricity prices are analyzed, finally, relationships between prices and volumes are presented.

7-4-2 Data

The data used in this study consists of hourly prices and volumes taken from five power exchanges (APX, LPX, Powernext, Nord pool[27], and UKPX) for year 2002. The locations, the power exchanges analyzed, the nature of the data and the sources used in the analysis are given in table 7-10.

Table 7-10: Data collected

Location	Source	data	Website
UK			
	UKPX	Half hourly price/volume	www.ukpx.co.uk
France			
	Powernext	Hourly price/volume	www.powernext.fr
Germany			
	LPX	Hourly price/volume	www.lpx.de
Netherlands			
	APX	Hourly price/volume	www.apx.nl
Nordic countries			
	Nordpool	Hourly price	www.nordpool.no

Source: Power exchanges, 2002

The time series contain hourly electricity prices traded on a day-ahead basis for delivery on the any of the 8760 hours of the year 2002. Daily prices were calculated using a simple arithmetic average. Where necessary, prices were converted to Euros using an average exchange rate prevailing for the period studied.

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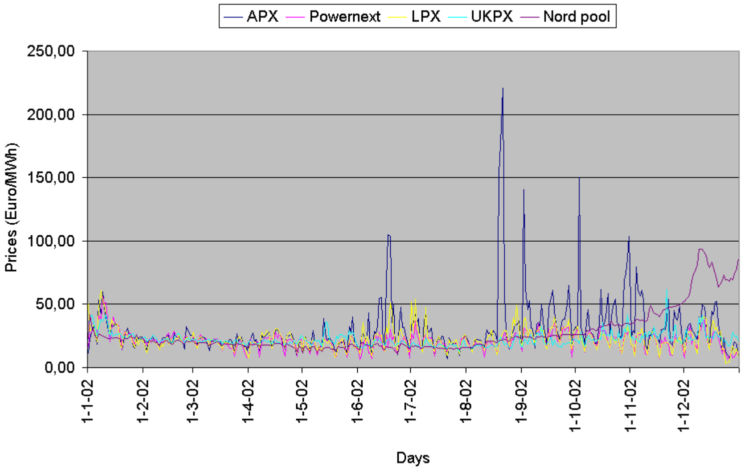
[27] Volumes for Nord pool were not collected since this exchange defines different hubs, due to market splitting, (See chapter 9) and thus it make little sense to aggregate those volumes

7-4-2 Price differences and volatility

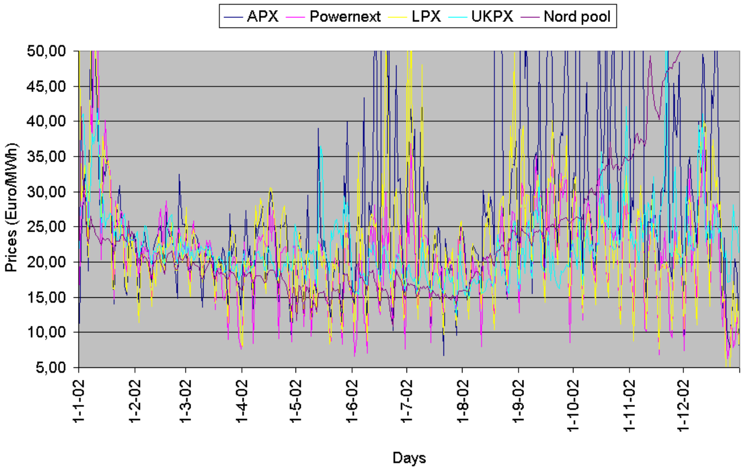
As for any other commodity, electricity is subject to the law of supply and demand, i.e. when demand increases prices tend to go up. Since electricity cannot be stored, no substitutes exists and demand varies widely over time, electricity prices are extremely volatile (table 7-11). The daily average prices on the five power exchanges are showed in figures 7-4a, and 7-4b. The annual daily average price and standard deviation of prices four the five power exchanges[28] are given in table 7-12. Several interesting facts emerge from these figures. One, as found in previous studies on the behavior of electricity spot prices (Wolak, 1997; Knittel and Roberts, 2001), one of the most striking features of these prices is their tremendous volatility across days within the week. Two, as can been seen, day-ahead prices may vary widely between the different geographic locations. These price differences between countries and the volatility of prices have different causes.

Figure 7-4a: Daily average prices (2002)



Source: Power exchanges, 2002

Figure 7-4b: Daily average prices (2002)



Source: Power exchanges, 2002

The first reason for price differences is related to generation technologies, i.e. nuclear, hydro, coal, gas etc. The nature of generation technologies is the most important variable with respect to differences in marginal costs. For instance, gas fired generation represent over 50% of Dutch installed capacity, but just 15% in Germany and 1% in France. In France, generation is largely dominated by nuclear plants while in Germany coal and nuclear plants represent the two major technologies used. Prices in France are the lowest despite the dominance of one player. This is mainly due to the generation structure which is essentially based on nuclear technology. Prices on the APX are on average 40% higher than prices on Powernext (table 7-12). The nature of technology has an impact on variable cost, e.g. gas power plants have high variable costs and low fixed costs while nuclear plant have low variable costs and high fixed costs. Thus the differences in fuel prices between countries represent an important reason for price differences.

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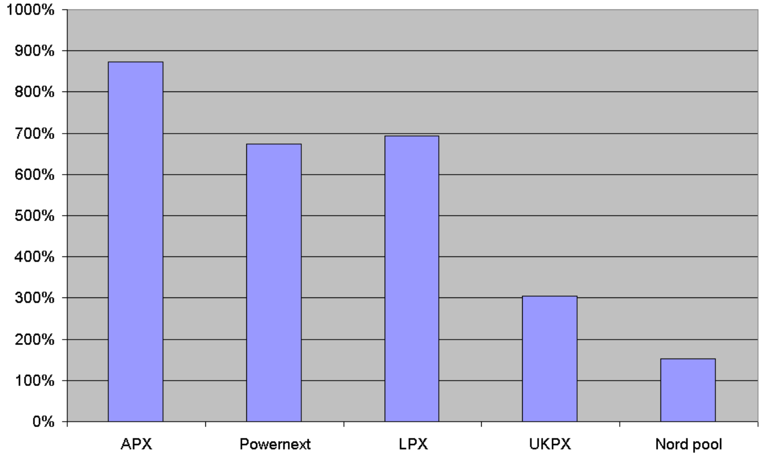
[28] Four locations within Nord pool are presented

The structure of demand and transmission constraints also plays an important role. The proportion of residential and commercial consumers with respect to the proportion of industrial consumers can also explain higher or lower variations between peak and off-peak demand. In the absence of transmission constraints simple arbitrage would tend to cause electricity prices to converge[29].

Figures 7-4a and 7-4b also indicate that price volatility on most exchanges is high and that price spikes occurred regularly throughout 2002, in figure 7-5 volatility is measured by the annualized standard deviation of daily changes in baseload prices relative to average baseload prices.

Figure 7-5: comparative daily volatility



Source: Power exchanges, 2002

Volatility in electricity power exchanges is especially high for APX, Powernext and LPX (above 600%) and less important for UKPX (300%) and Nord pool (150%). APX has seen repeated price spikes that have not been equaled on any other exchange, most of the others markets also experienced important spikes to

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[29] See chapter 8 and 9 for more on this.

lesser extent. Several reasons for "normal" [30] volatility (and price spikes) can be identified:

- Unexpected plant outages
- Unexpected decreases in available interconnection capacity
- Low elasticity of demand
- Unusual high/low temperatures
- Poor hydro conditions
- Volatility of fuel prices
- Market manipulation/market power

Table 7-11: Summary statistic power exchanges (2002)

	Mean	Median	Maximum	Minimum	Std. Dev.
APX BASE	34,60	27,98	220,85	7,84	24,24
POWERNEXT BASE	23,49	22,83	55,85	6,24	6,30
LPX BASE	25,26	23,94	61,00	3,47	8,06
UKPX BASE	23,05	21,72	61,77	15,17	5,73
DK BASE	27,38	24,44	88,47	9,06	11,32
SWEDEN BASE	28,36	23,06	93,32	11,48	16,42
NORDPOOL BASE	27,38	20,85	93,43	11,75	16,96
NORWAY BASE	26,91	20,50	94,17	12,26	17,31

Source: Power exchanges, 2002

The annual daily average price and standard deviation of prices for the five power exchanges are given in table 7-11, four locations within Nord pool are presented. In Nord pool hydro conditions are the primary price driver. The end of 2002 was marked by an important increase in prices due to poor hydro conditions which dropped reservoir levels to their lowest point in 10 years[31]. In addition to a lack of precipitation in 2002 that pushed Norwegian and Swedish reservoir levels well below their seasonal norms, a number of plant outage compounded the situation[32] resulting in dramatic price increases, above 50 Euro/MWh in December. Unseasonably cold weather was an important factor of

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[30] By opposition with abuse of market power as a reason for volatility and for price spikes

[31] Heren Report, *European Electricity Markets*, December 2002

price increase across northwest Europe in the end of 2002. Price spikes in June on the APX, average daily price over 100 Euro/MWh on June 19th, have been caused by a combination of line congestion, high temperatures, plant outages, cooling water problems and congestion on the border between France and Belgium[33]. Price spikes over 40 Euro/MWh in Germany were attributed to unplanned nuclear plant outages[34]. On Powernext the main reason for price spikes in January and December, above 40 and 30 Euro/MWh respectively, was a spell of extremely cold weather in Europe.

Others external factors can also have an impact on electricity spot price. For instance, the fall of Enron in December 2001 was presented as an important reason for the high volatility of electricity prices at the beginning of 2002. Similar, concerns over the credit-worthiness of some other US players and the withdrawal of some of them were cited has a contributive factor to some prices spikes. Workers strikes, bank holidays, and things such as national football games can also represent possible explanations for temporary price spikes. Nevertheless, the most important part of volatility is directly related to seasonality. These aspects are discussed in the following sections.

7-4-3 Temporal properties: weekends/weekdays

Light is shed on the importance of temporal properties with respect to weekdays and weekends in figures 7-6a 7-6b and 7-7. To facilitate readability a constant term was applied to the different series on figure 7-6a compared to figure 7-4a while only weekdays are considered in figure 7-6b. The annual daily average price during weeks, weekdays and weekends and standard deviation of prices for the five power exchanges are presented in figure 7-7.

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[32] Heren Report, *European Electricity Markets*, November 2002
[33] Platts *European Power Daily*, June 2002; Heren Report, *European Electricity Markets*, June 2002
[34] Heren Report, *European Electricity Markets*, July 2002

As presented in the previous section, price volatility on most exchanges is high. However, an important part of the volatility suggested is simply related to changes in demand. Prices on three exchanges, Powernext, LPX and APX, present important seasonality features implying that cyclical factors play an important role in price variations. An important factor is related to the difference in demand between weekends and weekdays. These differences in demand are due to the fact that load levels are lower during weekends than during the week. In order to isolate this pattern, in figure 7-6b only weekdays are taken into account and thus clearly shows this seasonal effect when compared to figure 7-6a. Hence, weekend prices are significantly lower, on average, than prices for the rest of the week (figure 7-7). The prices analyzed for the five power exchanges differed on average by 35% between weekdays and weekends.

Figure 7-6a: Seasonality of daily average prices

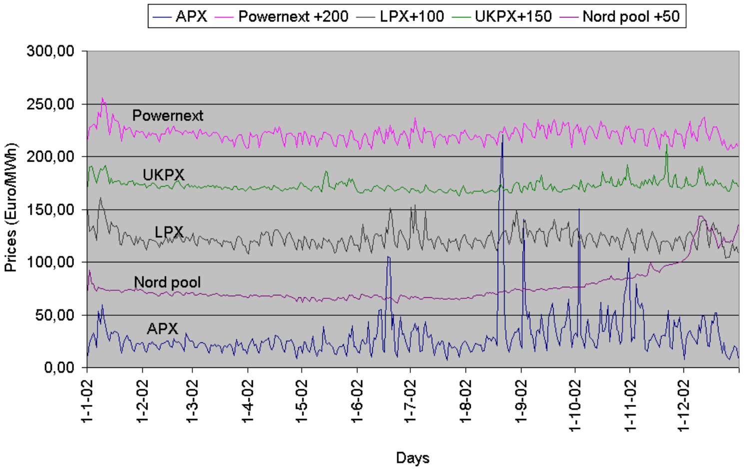
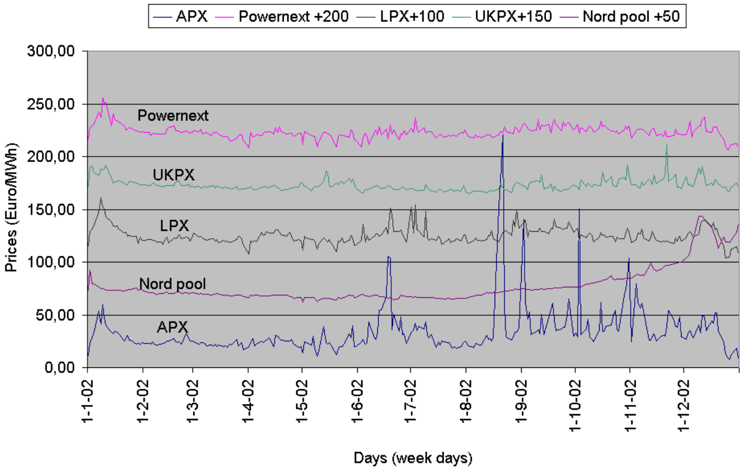


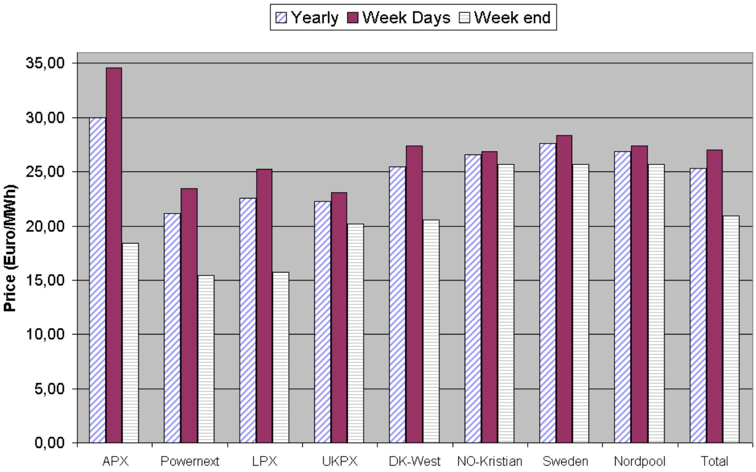
Figure 7-6b: Daily average prices weekdays



Source: Power exchanges, 2002

Average daily electricity prices measured in Euro per megawatt hour for the all week, weekdays and weekends are presented in figure 7-7. From figure 7-6 it can be seen that such price differences vary significantly between the exchanges. The price difference between weekdays and weekends is extremely high for APX (prices during weekends are 50% lower than during weekdays). On Powernext and LPX this difference is approximately 35%. In the UK this difference is lower (12%). Finally, within the Nord pool area this pattern is present to different extents. Norway has the lowest difference (less than 5%) while Denmark has the largest (24%). In Norway, prices are relatively stable over time because electricity is largely used for residential space heating which does not vary between weekdays and weekends. In contrast in the Netherlands industrial and commercial consumers represent a larger part of the demand compared to residential consumers, typically industrial and commercial demand drops during weekends while residential demand is more stable. Such variations shows that prices on power exchanges follow the pattern of demand with respect to weekday and weekend consumption but that some national peculiarities remains.

Figure 7-7: Averages prices 2002

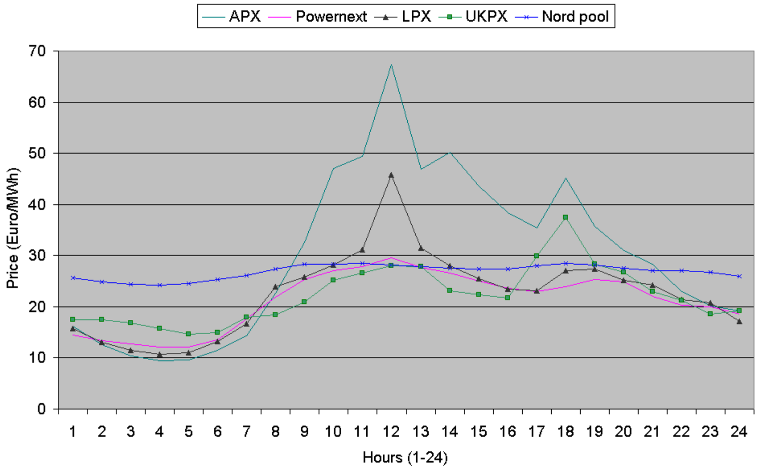


Source: Power exchanges, 2002

7-4-4 Temporal properties: peak/off peak

During the day, since demand varies sharply, prices vary sharply from hour to hour within the day. Hence, there is a marked difference between off-peak and peak hours. Annual average of hourly prices for each hour of the day are plotted in figure 7-7. This figure highlights the correlation between the price traded on the exchange and the structure of electricity consumption and important seasonal components can be identified from this figure. As expected, price begins to increase early in the morning, as the populace wakes up and work activity begins. Hence, prices are especially low during nights and increase regularly from 5.00 until 12.00 which is consistent with the daily variations in electricity consumption. Prices begin to fall at the end of workdays following the decrease in demand.

Figure 7-7: Average prices per hour



Source: Power exchanges, 2002

However the scope of such price variations differs between the different locations. On Nord pool, prices are relatively stable over the day while on APX, LPX and UKPX prices give rise to daily spikes. For instance, a characteristic spike at 11.00 (hour 12) on APX and LPX can be identified as well as a second spike at 18.00 on APX and UKPX when residential demand increase and working activity remains high. It highlights the close correlation between the price traded on the exchange and the structure of electricity consumption during the day. In conclusion just as with the weekdays/weekend variation in demand, the seasonality of prices on power exchanges follows the patterns of demand, but again some national peculiarities exist.

7-4-5 Volumes developments

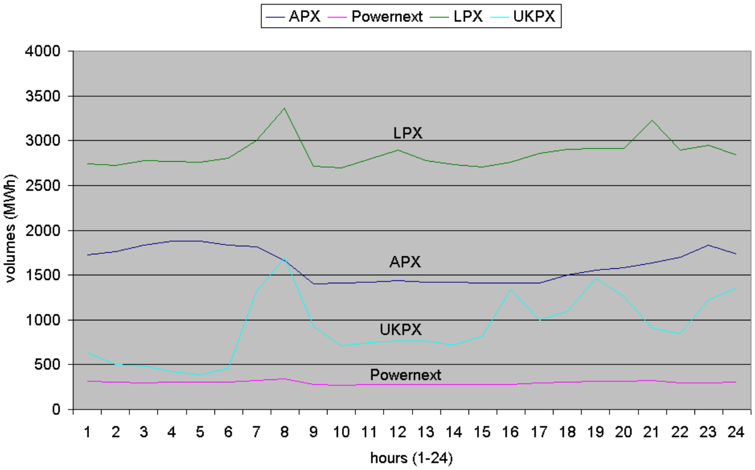
In mandatory pool models the development of volume is meaningless, i.e. all electricity transactions go through the pool and thus volumes traded on the pool are proportional to the size of the market. However, power exchanges are optional day-ahead markets in competition with OTC markets. The issue of volume traded is fundamental for exchanges since it indicates the representativeness of the power exchanges with respect to the rest of the market. A classical way to look at the importance of power exchanges with respect to the global wholesale market is to calculate the percentage of volume traded on the exchanges compared to total electricity consumption (table 7-14). These figures show important differences ranging from 0.7% (France) to 29.7% (Nordic countries) between the five exchanges considered.

Table 7-14: “Market shares” of power exchanges

Country	Consumption (2000, TWh)	Exchange (% of consumption)
Germany	502	4.7%
France	409	0.7%
Scandinavia	368	29.7%
UK	310	1.4%
Netherlands	101	12.8%

Source: Claxton (2003)

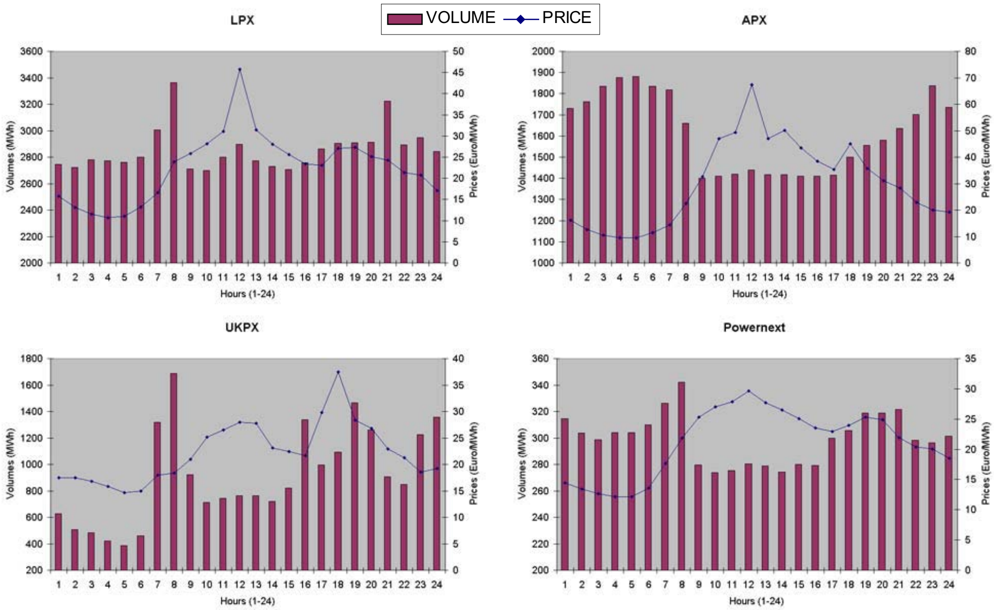
Figure 7-8: Average volume per hour



Source: Power exchanges, 2002

The focus in figures 7-8 and 7-9 is on volume traded on the different APX, LPX, UKPX and Powernext. Average hourly volumes are plotted in figure 7-8 while the relationship between prices and volumes for each exchange is presented in figure 7-9. As already presented on table 7-14, one of the most striking feature is the large difference between volumes traded on each exchange. While Germany and France are comparable countries in terms of electricity consumption, volumes on LPX are almost ten times higher than on Powernext. Similarly, while the UK market is about four times larger than the Dutch market, volumes on the APX are about two times larger than on the UKPX.

Figure 7-9: prices VS volumes



Source: Power exchanges, 2002

There are many alternative explanations for these differences, some of them can be directly related to the market structures presented in the previous section of this chapter. For instance, one, the low volumes on Powernext are mainly due to a lack of competitors in France compared to Germany. Two, the nature of generation technologies used can also explain such differences. The dominance of large inflexible power plants, nuclear, is ill suited for spot trading compared to small flexible units, combined cycles. Three, market/marketplace design can also influence the level of volume traded. This is obviously the case in the Netherlands where all day-ahead imports have to go through the APX[35].

Comparing price evolution and volumes provides interesting information on the functioning of these markets, averages prices and volumes per hour for the four exchanges are plotted in figure 7-9[36]. An interesting conclusion that can be drawn from this figure is that volumes traded on power exchanges are negatively correlated to demand. Indeed volumes traded during peak hours are generally lower than volumes traded during off-peak hours. This is especially striking for Powernext and APX and to less extent for UKPX. Hence volumes are inversely proportional to prices. In others words, while the level of demand, and thus of prices, is the highest during the afternoon, the level of traded volumes is paradoxically low compared to volume traded during the night. This illustrates the scarcity of supply during these hours and is due to the fact that power exchanges are voluntary market, i.e. a large part of peak consumption is covered by bilateral contracts.

On three exchanges (UKPX, LPX, Powernext) large volumes are traded just before the start of the peak period (hour 7 and 8) and suddenly drop for the following hours. This phenomenon can be explained by the fact that during this period many power stations are ramping up for peak hours. Thus their output is progressively increasing. Generators in this period sell their power on the exchange because it is difficult for them to contract on the bilateral market for variable quantities and over short period of time, i.e. 1 or 2 hours. In the following hours volumes decrease on the exchange because the generators have sold their output on the bilateral market. In conclusion, the design of current wholesale electricity markets appears to exacerbate the volatility of prices during peak hours on power exchanges due to the voluntary characteristic of power exchanges.

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[35] See chapter 5, section 5-5-3

[36] Note that for the sake of readability the scales (prices and volumes) are different

7-5 Conclusion

The classical approaches of competition analysis based on market structure are a necessary starting point at a conceptual level. They are adequate for estimating the underlying conditions of functioning of these marketplaces but are not entirely satisfactory for electricity power exchanges; levels of interconnections were taken into account to improve these indicators. This analysis has showed that market structure and level of interconnection differ widely between the five countries analyzed. Moreover, competition on a power exchange is not limited to energy producers and cross border trades, other players such as energy traders, large industrial consumers and distribution companies play an important role on power exchanges.

A comparison of electricity prices was used to analyze the level of competition in electricity power exchanges. As in others studies of deregulated markets, we found strong deterministic cycles including, intraday and day of week effects. In general several similarities have been shown between price developments on the different power exchanges studied especially with respect to the variations of demand over time. However, some differences between countries remain such as the volumes traded on these markets.

Chapter 8

Power exchanges and market integration

While the focus of chapters 5, 6 and 7 is the power exchange spot market, i.e. power exchanges as national marketplaces, ignoring the question of market design, in this chapter and in chapters 9 and 10, we consider the role of power exchanges within the global design of a European electricity market, i.e. power exchanges as institutions. An important aspect of the creation of a common market is the opening up to competition of national electricity markets which are for most of them dominated by national monopolies. Since market structures in these markets are historically heavily concentrated in most European countries, the creation of a common market appears to be a good solution for diluting national market power. In this chapter we aim to test the level of market integration based on power exchanges prices. Two econometric analyses are done using power exchanges prices of major European electricity markets. The methodology used for estimating the level of market integration is described. Then an analysis based on simple price correlation is made. A second analysis is done to deal with the drawbacks of the above approach, using regression models. Finally, the empirical results are analyzed.

8-1 The creation of a common market

8-1-1 Introduction

The functioning of power exchanges as marketplaces defined for a limited area, mainly a national area, was analyzed in the previous chapters. However, keeping in mind the final objective of the European Commission is to create an integrated market international trade and a more generally European-wide market design needs to be considered (Smeers, 2001a). In such a context power exchanges can be considered as institutions that form part of the overall European market design. While in part 2 of the thesis the analysis focused on the functioning of electricity power exchanges as national market places, in this part the role of power exchanges within the general design of competitive wholesale electricity markets at the European level is analyzed. The clear objective of the liberalization process is "*to ensure that the implementation of the electricity directive does not result in 15 liberalized but separate and rather isolated electricity markets, thereby falling to create one common market*" (EC, 2002). The political and economical motives for the creation of a single European-wide electricity markets were presented in chapter 2. The purpose of this chapter is to test the existence of such integrated market, to do so we use power exchanges prices or more precisely the relationships between power exchanges' prices.

Spatial prices relationships constitute an important indicator for market integration. In economic theory, market definition is often based on such relationships. For instance, according to Cournot (1838) *"Economists understood by the term Market, not any particular market place in which things are bought and sold, but the whole of any region in which buyers and sellers are in such free intercourse with one another that the prices of the same goods tend to equality easily and quickly".* Similarly Stigler (1969) defines a market as an *"area within which the price of a good tends to uniformity allowances being made for transportation costs".* In practice, when analyzing price relationships price correlation is frequently used to determine whether two geographic areas are in the same economic market. In an integrated market, one would expect to find a high correlation between price levels. The concept of market integration is directly related to market efficiency. An efficient market is one where the prices always reflect all available information, hence the efficient market hypothesis implies that all publicly available information is fully reflected in prices at any location.

In this chapter we first discuss the limits of previous works on market integration. For this purpose we present in details the analysis of Bower (2002b) which can be considered to be a real primer on market integration in European wholesale electricity markets. Subsequently we discuss the limits of his analysis, which allow us to present the contribution of our work which represent a first attempt to estimate the level of market integration in 2002. Second, two econometric analysis are done using power exchange prices of five main European markets (UK, France, Germany, Netherlands, and Nordic countries). The first analysis is a simple price correlation analysis. Subsequently, due to the drawbacks of such an approach two others approaches, cointegration and regression analysis, are considered. Finally the results of our analysis are presented.

8-1-2 Previous analysis on market integration

Several studies in the literature have provided empirical evidences about market integration in Europe in different sectors. Amongst them a large number has been done for topics such as the European Monetary Union (Artis and Taylor, 1988; MacDonald and Taylor, 1991), the financial retails markets (Sander and Kleimeier, 2001; Schüler and Heineman, 2001) or natural gas (Asche *et al*, 2000). However, with the exception of Bower (2002b), little empirical work has been carried out with respect to the extent of the wholesale market for electricity in Europe. In this section we present the main findings and limits of the analysis of Bower (2002b) and present the contribution of our study.

The main results of Bower’s analysis of European wholesale electricity prices in 15 locations by the end of 2001 are given in summary in table 8-1. Ten of these locations are within the Nordic countries area (zonal prices determined by Nord Pool for Finland, Denmark, Sweden and Norway[1]), one in UK, one in Spain, two in Germany and one in the Netherlands. Bower uses simple arithmetic daily prices averages. Two analytical techniques are used: simple correlation and cointegration.

Table 8-1: Main results of Bower's analysis

	Norway (Kristians)		Sweden (Stockholm)		Denmark (West)		Nord Pool (System)		UK (Pool/UKPX)		Spain (OMEL)		Germany (1) (EEX)		Germany (2) (LPX)	
	Cor	*Coi*	Cor	*Coi*	Cor	*Coi*	Cor	*Coi*	Cor	*Coi*	Cor	*Coi*	Cor	*Coi*	Cor	*Coi*
Norway	1	-														
Sweden	0,96	*-55,04*	1	-												
Denmark	0,78	*-27,02*	0,77	*-53,30*	1	-										
Nord Pool	0,99	*-159,2*	0,97	*-70,93*	0,78	*-26,53*	1	-								
UK	0,18	*-6,54*	0,19	*-7,25*	0,26	*-7,26*	0,18	*-6,78*	1	-						
Spain	0,29	*-1,33*	0,33	*-0,10*	0,37	*-2,38*	0,29	*-1,15*	0,4	*-1,1*	1	-				
Germany (1)	0,16	*-2,30*	0,20	*-4,15*	0,21	*-4,03*	0,19	*-2,91*	0,28	*-8,76*	0,26	*-9,05*	1	-		
Germany (2)	0,16	*-2,71*	0,25	*-4,78*	0,25	*-4,99*	0,19	*-3,26*	0,27	*-8,72*	0,34	*-8,3*	0,36	*-22,21*	1	-
Netherlands	0,14	*-2,49*	0,18	*-3,63*	0,22	*-5,78*	0,15	*-2,77*	0,26	*-5,42*	0,27	*-7,2*	0,60	*-14,61*	0,29	*-10,72*

Source: Bower (2002)

Note 1: Cor stands for correlation analysis, Coi for cointegration analysis
Note 2: Critical values for cointegration analysis are: 15 -3.944; 5% -3.363; 10% -3.064

The first contribution made by Bower was the development of a systematic and rigorous methodology for the analysis of wholesale spot prices in Europe. Based on wholesales prices provided by different "power exchanges"[2] this work represents a real primer regarding empirical evidences of market integration at the wholesale level. Such an analysis was not possible before 2001 as many organised wholesale markets did not start to operate until 2000 and 2001[3]. Bower's analysis reveals that there were significant prices differences between locations resulting in potential arbitrage opportunities. Bower concludes that within the Nord Pool area price correlation was high while correlation with other European market was low. Conversely, the prices in Spain were not correlated to other European electricity markets based on both techniques (correlation and cointegration). With regard to the other countries, UK, Germany and the

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[1] See chapter 9 for details

[2] Except for Spanish market which cannot be considered as a power exchange (see chapter 2) and for the UK where data from the pool have been used until the 26th of March (UKPX started on the 27th of March)

Netherlands, Bower's conclusion is mitigated. Simple correlation analysis shows a very low level of correlation between these countries. However cointegration analysis shows relative cointegration between Germany, Sweden, Finland and Denmark and between Nord Pool, UK, Netherlands and Germany.

The second contribution of Bower's work is to show the inefficiency of the actual transmission pricing mechanism. Indeed by using the locational spot price model framework developed by Schweppe *et al* (1988)[4], he showed an important difference between theoretical prices of congestion and actual prices being charged by transmission system operators. The empirical evidences clearly shows large differences between prices in locations using explicit auctions for interconnector capacity while implicit auctions (Nord pool) appears to be quite efficient[5].

Finally the last part of Bower's analysis concerning the exercising of market power by generating firms and the solution suggested[6], although interesting, is less convincing. While the approach used (Lerner index) is certainly the most well recognised for its robustness, the estimation of generation costs is questionable (box 8-1). However for the purpose of this chapter we will not go into the details of the limits of the market power identification approach of Bower's analysis, here we will focus on the first part of Bower's work.

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[3] See chapter 2

[4] See chapter 9

[5] This issue is discussed in details in chapter 9

[6] Breaking up dominant generators

Box 8-1: Limits of Bower's analysis with respect to market power

The first limit of the Bower's approach, found in the estimation of the Lerner index, is his use of the same generation cost for all countries (23,80$/MWh). Such an estimation overlooks the important differences between the generation cost structures in the countries studied. Norway relies almost exclusively on hydropower while Denmark in turn relies on conventional thermal power (Hjalmarsson, 2000). In contrast the market structure in generation for the UK, Spain and Germany is highly diversified with technologies ranging from nuclear, conventional thermal units, hydro plants and to less extent wind energy (Bergman *et al*, 1999). Finally the Netherlands relies mainly on gas-fired plants (Arentsen *et al*, 1997) which are strongly dependent on gas prices. Depending on type of generation, for instance on hydro conditions or on gas prices, generation cost between countries may vary widely. It is therefore not surprising that all the Lerner indexes for the Nordic countries are negative yet they are very high for the Netherlands. Bower argues that the 10 Euro/MWh range in mean locational prices *"is too wide to be explained by generation costs technologies"*, this is not totally true since the cost of a hydro plant and that of a gas power plant can easily exceed this range. Some differentiation in generation cost with respect to national generation structures is thus missing in Bower's work.

The second limit relates to using a simple figure as a benchmark for generation cost, this ignores dynamics, e.g. starting costs. This is especially important for hourly spot markets where flexibility of generation plays a fundamental role.

Finally when dealing with Germany, Bower concluded that prices did not indicate any exercise of market power. However due the network access conditions and "imperfect" unbundling, Brunekreeft (2001) has showed a specific type of exercise of market power where major utilities could compensate for low wholesale prices (the PX price) by charging high access charges to the network for third parties.

8-1-3 Shortcomings of Bower's analysis and corrective proposals

The Bower's analysis is confronted with three categories of limits. The first category is exogenous, mainly due to the availability of data for the year 2001. The second category is endogenous related to choices made by the author. Finally, the last limit is related to the assumption that electricity price time series are similar to other commodities, i.e. the price series are non-stationary. We discuss these three categories of limits in this section and suggest improvements that will be used for our analysis (for the year 2002) in the next section.

An important limit of Bower's analysis is related to the availability of data for three countries: France, Italy and UK. The absence of France in the analysis definitely represents the most important limits of this work, due essentially to the central geographical position of France and its interconnections with neighbouring countries, i.e. Spain, UK, Belgium, Germany, Switzerland, and Italy. The French power exchange started operation in November 2001. Trading volumes in the first months of operation of any exchanges are always low[7] due to the learning experiences of participants, it is thus perfectly understandable that it would not have been reasonable to include one month of French prices in the analysis. An important contribution of our work is the consideration of the French power exchange's prices for the year 2002.

The absence of Italy damages Bower's analysis because this market is the fifth largest one in Europe, after respectively Germany, France, the Nordic Region, and the UK but before Spain. Again this absence is due to the fact that no organised wholesale market in Italy was in operation in 2001. While the launch of an organised market was planned for 2002, this has been postponed and thus no figures are as yet available for 2002. Our analysis will therefore also ignore the Italian market. However this market is of less importance for our analysis as in contrast to France the geographical position of Italy is not central and interconnection with other main markets is limited.

The case of the UK is different from the two previous cases. The New Electricity Trading Arrangements (NETA) was introduced from 27 March 2001. NETA were introduced to address some of the fundamental weakness of the pool (OFGEM, 2001)[8]. Hence in Bower's analysis for the three first months of data pool prices

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[7] See chapter 7

[8] See also chapter 2, box 2-1

were used while for the rest of the year UKPX prices were used. Due to the large difference between the two institutional arrangements, e.g. the pool was mandatory with no demand participation while UKPX is voluntary with demand participation, the time series for the UK does not appear to be consistent. This is not the case for the year 2002, when UKPX was in operation for the full year.

The second category of limits relates to choices made by the author. These limits are related to the choices of the wholesale locations, the absence of comparison with bilateral prices and the fact that Bower's analysis overlooks the important aspect of seasonality. First, two thirds (10 out of 15) of the prices are located in the Nordic countries which overestimate the importance of such market in Europe and add a lot of calculation for little supplementary information. For this reason in our analysis we will consider only four prices for the Nord Pool area. Second the choice of Spain is arguable for two reasons. The market design of the Spanish market might better be considered to be a pool rather than a power exchange[9] which make comparison with other market place difficult. Hence for consistency it appears worthwhile to not consider the Spanish market. Secondly, since Spain is only directly (and weakly) connected to France, the Spanish market is rather isolated from the rest of the European markets and, as shown in the results, arbitrage with other markets are unlikely to occur on a regular basis. For these two reasons, it is difficult to compare prices from the Spanish market with prices from other exchanges. However, to allow comparison, we will consider this market.

It is worth noting that Bower does not refers at all to prices from bilateral markets (OTC) whereas these markets represent the largest share of European electricity trading. For this reason and for the sake of completeness it appears important, before drawing any conclusion on the level of market integration, to realise some analysis based on bilateral market prices. Such an analysis is by definition difficult because prices from bilateral markets are usually not available and are

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[9] See chapter 2

difficult to compare. However some indexes are regularly published. Therefore, we will use these indexes for two purposes. First they will allow us to estimate the level of integration at a national level between national bilateral markets and national power exchanges. Second, they will allow us to compare the level of market integration, based on power exchanges, with the one based on bilateral markets.

The use of daily averages for the full period though providing a workable proxy for the analysis, suffers from ignoring price variations with respect to seasonality within the week (weekdays/ week-end). Seasonality is a cyclical factor that occurs on a regular basis and it can strongly influence the result of an analysis. As showed in chapter 7 prices on power exchanges present important seasonality aspects. Indeed price differs in average by 35% between weekdays and weekends. Hence, it is likely that a large part of the correlation between locations in Bower's analysis is related to seasonal components rather than real integration between markets. This aspect has been totally overlooked and represents a serious limitation. In order to eliminate the seasonal component we only consider prices during weekdays. Thus a question that is not addressed deals with the possible different levels of integration of markets with respect to levels of demand. The point here is that, the level of demand directly influences the level of congestion which in turn has an impact on market integration. Thus, in our analysis we will first use daily averages, which will allow us to compare our result with Bower's results, but we will also use "peak prices" indexes to reflect the different level of demand.

While the use of cointegration is one of the most commonly used methods for testing market integration in applied economics, from an econometric point of view such an approach requires specific time series properties of the data. In this respect Bower's analysis is limited due to the fact that he did not test the properties of the data but assumed that electricity prices time series were non-stationary. If this assumption appears to be wrong, the cointegration approach makes little sense and others approaches should be considered. For this reason we will first test the properties of the data so we can choose the most appropriate method.

In sum, our analysis contributes to the discussion by extending the analysis of Bower made for the year 2001. Our analysis will make four new contributions to the literature:

- An analysis of the year 2002, first year where exchanges in France and in the UK where operational
- Include France, central geographic position
- Reduce the impact of seasonality, weekdays/weekends; baseload/peakload
- Compare power exchanges prices with bilateral markets, national and international integration

8-2 Test for market integration

8-2-1 Data and hypothesis

The data used in this study consists of hourly prices from five power exchanges, APX, LPX, Powernext, Nord pool, and UKPX, previously presented in chapter 7, one power pool, Omel, and daily prices from the bilateral market for the whole of year 2002. Power exchanges prices were taken directly from power exchanges' website and OTC spot prices from *Platts European Power Daily*[10] publication. For the Nordic countries we use the "system price"[11] and three regional prices: Denmark West, Norway-Kristiansand and Sweden. Over this period, there are 365 days with 24 observations per day (8760 prices) for the five power exchanges considered. Daily average prices for the different markets were calculated for the purpose of this work, since seasonality is an important characteristic of hourly prices[12] and since bilateral prices are only quoted on a

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[10] Research assistance with collecting data from Nathalie De Barstch from the French Energy Regulatory Commission (CRE) and from Sylvia de Hoop from the Dutch Energy Regulatory office (DTe) is gratefully acknowledged.

[11] The "system prices" is an equilibrium price for the global Nordic countries regardless to bottlenecks and capacity restriction on the grid.

[12] See chapter 7

daily basis. Moreover due to the important difference in demand between weeks and weekends we only consider weekdays which represents 261 observations for each of the six organized markets. The two types of price series utilised are summarized in table 8-2.

Table 8-2: Data collected

Location	Source	data	Website
UK			
	UKPX	Hourly price/volume	www.ukpx.co.uk
	OTC	Base/peak	www.Platts.com
France			
	Powernext	Hourly price/volume	www.powernext.fr
	OTC	Base/peak	www.Platts.com
Germany			
	LPX	Hourly price/volume	www.lpx.de
	OTC	Base/peak	www.Platts.com
Netherlands			
	APX	Hourly price/volume	www.apx.nl
	OTC	Base/peak	www.Platts.com
Nordic countries			
	System	Hourly price	www.nordpool.no
	Denmark West	Hourly price	www.nordpool.no
	Norway-Kristiansand	Hourly price	www.nordpool.no
	Sweden	Hourly price	www.nordpool.no
Spain			
	Omel	Hourly price	www.omel.es

There is not just one price for the bilateral market, since these transactions consist of taylor-made contracts traded bilaterally when contrasted to power exchanges. First bilateral trade by definition is achieved between two players and the prices are only known by the parties involved. Second in these markets contracts are not standards which makes aggregation a difficult exercise: How does one aggregate a six month baseload contract with a two weeks peak hours contract? Prices on this market can only be estimated by using an aggregated index. In Europe traders then usually use the prices provided by *Platts*. This company contacts a subset of different market participants which provide them the price of their bilateral transactions. Specific transactions involving names of companies, quantities and price are confidential, so they are aggregated to build an anonymous index. Based on this information *Platts* publishes an average price which is recognized by most professionals as a good indicator of bilateral prices. The prices are broken down into many categories: peak prices, baseload prices, week ahead and year ahead. For each category a high and a low price are reported. Whereas Platts report a high and a low price for each market for each day, in this work we use a simple arithmetic average of high and low price for base and peak[13] to give a spot bilateral price.

Summary statistics of power exchanges prices were presented in table 7-11. More details statistic for both power exchanges and bilateral electricity prices including baseload and peak prices are given in table 8-3. As can been seen, the properties of bilateral prices are similar in some ways to those of power exchanges. For example the average power exchange prices are comparable in magnitude to the averages of bilateral prices for most countries. Nevertheless, the standard deviations of bilateral prices are generally lower than the corresponding standard deviation of power exchanges prices. This implies that bilateral prices tend to be less volatile than power exchanges prices. In particular, maximum and minimum prices are typically respectively lower and higher in the bilateral market than on power exchanges.

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[13] Peak: 7h00-19-00 (or hour 8 to hour 19), Base 0h00-0h00 (or hour 1 to hour 24)

Table 8-3: Summary statistic power exchanges and bilateral markets (2002)

	Mean	Median	Maximum	Minimum	Std. Dev.
APX BASE	34,60	27,98	220,85	7,84	24,24
APX PEAK	44,93	35,10	324,53	9,80	35,85
DK BASE	27,38	24,44	88,47	9,06	11,32
FRA OTC BASE	23,92	22,75	65,00	7,50	6,37
FRA OTC PEAK	30,66	28,35	110,00	10,00	9,45
GER OTC BASE	25,39	23,88	70,00	7,73	7,07
GER OTC PEAK	33,34	31,55	110,00	9,75	10,64
LPX BASE	25,26	23,94	61,00	3,47	8,06
LPX PEAK	32,44	29,95	89,81	4,14	12,25
NL OTC BASE	32,28	26,63	177,50	8,25	18,79
NL OTC PEAK	44,15	35,50	255,00	12,75	27,41
NORDPOOL BASE	27,38	20,85	93,43	11,75	16,96
NORWAY BASE	26,91	20,50	94,17	12,26	17,31
OMEL BASE	41,03	40,65	106,97	5,66	12,87
POWERNEXT BASE	23,49	22,83	55,85	6,24	6,30
POWERNEXT PEAK	29,26	27,76	76,99	7,00	8,84
SWEDEN BASE	28,36	23,06	93,32	11,48	16,42
UK OTC BASE	26,58	24,92	56,04	16,71	7,07
UK OTC PEAK	33,88	29,51	100,16	19,61	12,06
UKPX BASE	23,05	21,72	61,77	15,17	5,73
UKPX PEAK	26,08	23,76	82,75	17,72	7,65

Using the above data, the two tests developed below are based on the idea that in a fully integrated European-wide electricity market, price between locations should only differ due to transmission constraints and arbitrage should safeguard that prices move in tandem. Hence, if two markets are integrated, prices in the two regions should move quite closely in tandem. This means that any shock of supply or demand in one location should be transmitted to the other regions because electricity coming from abroad can be considered as a perfect substitute for national production within the limit of transmission constraints. Two econometric approaches for testing time series relationships are in common use, the correlation and the “regression/cointegration” approach. We use these two different methods to test the level of integration of European electricity markets. The methodology used and results of these two approaches are given in the rest of this chapter.

8-2-2 Methodology: Correlation analysis

The most widely used measure of market interdependence is “simple” (or linear) correlation analysis. Even in a perfectly integrated market, prices can differ because of transport costs or transaction costs or because of temporary demand or supply or demand shocks, so correlation will be less than one. However, correlation analysis is especially well-suited as a starting point for estimating the level of market integration. Indeed the correlation coefficient between two time series price data can be used to determine whether these two markets are integrated (Stigler and Sherwin, 1985). Two variables are said to be correlated if a change in one variable is associated with change in the other. If two series have a correlation of 1, they are perfectly correlated: as one moves up, the other one moves up. If they have a correlation of –1, as one moves up, the other moves down. If two sets of numbers have a correlation close to zero, they are said to be non-correlated. Coefficients were calculated according to equation 8-1 for the first analysis correlation:

$$\rho_{x,y} = \frac{Cov(X,Y)}{\sigma_x \cdot \sigma_y} \qquad (8\text{-}1)$$

where

$$-1 \leq \rho_{x,y} \leq 1 \qquad (8\text{-}2)$$

and

$$Cov(X,Y) = \frac{1}{n}\sum_{i=1}^{n}(x_i - \mu_x)(y_i - \mu_y) \qquad (8\text{-}3)$$

Concerning electricity markets, the classical weaknesses of correlation analysis are (or can be) avoided. For instance, one drawback of correlation analysis is that a misleadingly low correlation coefficient can arise because one price series responds to another with a significant lag. Since electricity is non-storable such a lag problem cannot occur in electricity markets, e.g. a price spike on one market at 12.00 due to unusual weather conditions is unlikely to affect prices on another market later on. A misleading high correlation can occur if the prices in two locations are subject to a common influence. This is the case in electricity markets because intra-day and week seasonality is important[14]. We partially eliminated the impact of such seasonality by using weekdays data and daily averages rather than hourly prices.

While Bower's analysis only used this method for power exchanges' prices, including weekends, we have applied this method both to power exchanges and bilateral markets. This allows us to estimate three level of market integration: the national levels between power exchanges and bilateral markets, the international level between power exchanges, and finally between the different national bilateral markets. The results of this analysis are presented in section 8-3.

8-2-3 Methodology: classical regression and cointegration analysis?

An alternative method to simple correlation analysis can be use to test the level of market integration of electricity market based on the locational spot price framework developed by Schweppe *et al* (1988) and extended by Hogan (1992), and used in Bower's analysis. This method uses a rather simple standard model of an integrated market. The underlying idea is that in an integrated market prices between locations should equal prices in other location plus the price of transmission. Such model can be defined as follows:

$$Y_t = T_t + X_t \qquad (8\text{-}4)$$

where Y_t is the price at location Y at time t, X_t the price at location X at time t, and T_t the price for transmission between X and Y at time t. Estimation of this model is straightforward and can be realized using regression models according to standard ordinary least square (OLS) method:

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[14] See chapter 7

$$Y = c + bX \qquad (8\text{-}5)$$

where

$$b = \frac{n\sum XY - (\sum X)\cdot(\sum Y)}{n\sum X^2 - (\sum X)^2} \qquad (8\text{-}6)$$

$$c = \frac{\sum Y}{n} - b\frac{\sum X}{n} \qquad (8\text{-}7)$$

n= total number of observations in the sample

Regression models are commonly used as a quantitative way to determine underlying trend and price relationships. A linear regression trend line uses the OLS method to plot a straight line through prices to minimize the distances between the prices and the resulting trend line. Such an estimation makes sense only if the data are stationary time series, i.e. contain a constant mean, variance, and autocovariance. If the different time series are stationary OLS can be use to estimate the level of interdependence between prices. However, in the presence of non-stationary time series[15] classical OLS regressions may lead to spurious or nonsense regressions. In other words, if a variable contains a unit root it is non-stationary and unless it combines with other non-stationary series to form a stationary cointegration relationship, a simple regression of the series can falsely imply the existence of a meaningful economic relationship. For instance if two time series grow with time they can be correlated even if there is absolutely no relationship between them[16]. Such regressions often include important autocorrelation as indicated by a low Durbin-Watson[17] statistic.

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[15] A non-stationary time series posses unit root which mean that the effect of shocks persit indefinitely.

[16] Examples of spurious regression characterized by high correlation coefficient but a low Durbin Watson: Egyptian infant mortality rate, annual data on gross aggregate income of American farmers and total Honduran money supply (1971-1990); US Export Index and annual data on Australian males' life expectancy (1960-1990); US Defense Expenditure and annual data on Population of South African (1971-1990). (source: http://halweb.uc3m.es/esp/Personal/personas/jgonzalo/teaching/jgonzalo.html)

[17] The Durbin-Watson test is used to measure autocorelation which occurs when the disturbances in one period are correlated from one or more of the preceding periods (see appendix 2 for details).

The concern about spurious regressions in time series gave rise to the concept of cointegration (Granger and Newbold, 1974; Phillips, 1986). Spurious regression happen when time series are dominated by long term trends or important seasonal components. The concept of cointegration was first introduced in the econometric literature by Granger (1981) and was further extended by Engle and Granger (1987). This concept is based on the idea that, although economic time series exhibit non-stationary behaviour, an appropriate linear combination between trending variables can remove the trend component and, hence, the time-series can be cointegrated. In economic terms, cointegration implies that there is an equilibrium prices relationship toward which prices gravitate. The interest of cointegration lies in the fact that it allows to look for the existence of an equilibrium relationship among time series even if each series is individually non-stationary. The Engle-Granger residual based test is one of the most commonly used for testing cointegration. This test contain two steps: estimation of a cointegrating regression by applying Ordinary Least Squares (OLS) on the levels of the variables included, and testing for stationarity of the residuals using Augmented Dickey-Fuller (ADF) tests[18].

The choice between the two methods involves a primary analysis to figure out if the series are stationary or not, using unit root tests. If the series are stationary OLS regression can be used, if the series are non-stationary cointegration should be used. Concretely, before testing for cointegration, it is necessary to test for the existence of a unit root in each price time series. If the time series are non-stationary cointegration analysis can be used. Subsequently if the prices studied are found to be co-integrated it will mean that prices will be tied in the long run. It is worth noting that the primary test for unit root was not conducted by Bower because he assumed that the behaviour of electricity prices is comparable to other commodity or financial markets which are mainly non-stationary. Such an assumption represents an important shortcoming because electricity markets

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[18] ADF tests of stationarity of residuals are different from ADF tests of whether a variable is stationary. In the case of ADF test of residuals these residuals are generated by regression. Hence, critical values are

have many peculiarities which might involve electricity prices behaving differently from others markets. From an econometric perspective, appropriate definition of the nature of price series is a vital issue because misspecification of a random walk as a stationary process, or the other way around, has a major effect on the statistical analysis of the data (Perron, 1989; Hamilton 1989). Concretely, it is necessary to figure out if the series are stationary or not because cointegration analysis cannot be used if any series is stationary.

The second method of our study is as follows.

1) Establish the time series properties of the individual series, using ADF tests (box-8-2), to determine the use of the appropriate method.
2) Consider the price relationships, regression if the data are stationary, cointegration if the data are non-stationary, between pairs of locations.
3) Compare with the result of correlation analysis and Bower's analysis
4) Conclude on the level of integration of the "European electricity market"

The results of this analysis are presented in section 8-4.

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different from those used for ADF tests for stationarity of a variable.

Box 8-2: The ADF Test

The issue of trend stationarity versus difference stationarity is critical for the analysis of time series. The theory of cointegration emphasises the need for pre-test time series for unit roots (Hendry and Juselius, 2000). There is a large literature on testing for unit root theory (McKinnon, 1994; Hamilton, 1994; Stock, 1994; Lardic and Mignon, 2002). For the purpose of this work we consider the approach suggested by Dickey and Fuller (1979; 1981).

Consider the case in which the price series Y_t can be described by the following equation:

$$Y_t = \alpha + \beta t + \rho Y_{t-1} + \varepsilon_t \qquad \text{(8-8)}$$

Where Y is the variable under investigation, t is a linear time trend, and ε_t is a random error term. The Augmented Dickey Fuller (ADF) test is carried out by expanding equation (8-8) to include lag, *p* is the number of lag, changes in Y_t as follow:

$$Y_t = \alpha + \beta_t + \rho Y_{t-1} + \sum_{j=1}^{p} \lambda_j \Delta y_{t-j} + \varepsilon_t \qquad \text{(8-9)}$$

Using OLS, one first runs the unrestricted regression:

$$Y_t - Y_{t-1} = \alpha + \beta t + (\rho - 1) Y_{t-1} + \sum_{j=1}^{p} \lambda_j \Delta Y_{t-j} \qquad \text{(8-10)}$$

and then the restricted regression

$$Y_t - Y_{t-1} = \alpha + \sum_{j=1}^{p} \lambda_j \Delta Y_{t-j} \qquad \text{(8-11)}$$

Then a standard *F* ratio is calculated to test whether the restriction (β=0, ρ=1) hold using the distribution.

Source: Pindyck and Rubinfeld (1998)

8-3 Results of linear correlation analysis

In an integrated electricity market, one would expect to find a high correlation across the market between prices. A really integrated market should provide price correlation in the individual underlying markets. The price differences should only reflect physical congestion between markets. Many correlation calculations between different prices were done as a test. These correlation calculations were done between different locations and between different types of contracts from January 2002 to December 2002. The different physical markets under study are directly or indirectly physically interconnected (ETSO, 1999). One would expect to see a high level of correlation between the prices on these markets. However the simple correlations reported in table 8-4 do not support the idea of a single integrated European electricity market but rather the existence of different regional markets. Several interesting conclusions emerge from these results with respect to the level of market integration at the national levels between power exchanges and bilateral markets, at the international level between power exchanges, and finally between the different national bilateral markets.

First in general, a high correlation (80% in average including both base and peak periods) has been found at the national level between OTC prices and power exchanges for the four markets where OTC prices were computed (France, Germany, Netherlands and UK). Such a result is consistent with the analysis given in part 2 of this thesis (chapters 5-6-7) which has showed that power exchanges have been developed and designed at national levels. Furthermore, it shows that despite a relatively small traded volume, power exchanges prices are representative of the overall wholesale market since change in one market is associated in change in the other market. In other words, at national level arbitrages between the two markets safeguard that prices move together. Moreover no significant differences in correlation were found at the national level using base or peak prices for OTC and power exchanges, 82% of correlation between “base OTC” and “base power exchanges” and 79% between “peak

OTC" and "peak power exchanges" on average. We can thus conclude that **the level of integration at the national level is high** between power exchanges and bilateral markets.

Second, at the international level, this analysis reveals the existence of two "supra-national" markets, Norway-Sweden-Denmark, and France-Germany, and three rather isolated markets, Spain, Netherlands, and UK. Similar to Bower we found evidences that prices between Norway and Sweden were almost perfectly correlated (99%) and to less extent that all prices within the Nord pool locations were also highly correlated as indicated by correlation coefficients above 70%, 74% between Norway and Denmark, 77% between Sweden and Denmark. This means that supply or demand shocks in any Nord pool location have a direct impact on other Nord pool locations. This result is consistent with the general idea that the Nordic market is highly integrated[19]. In contrast, locational prices within the Nord pool area appear to be totally isolated from the other European power exchanges prices. Surprisingly the Nord pool system price is more correlated with the UKPX price (35%) than with the LPX price (7%) in spite of no cross-border transmission capacity between UK and Nord pool and the existence of interconnection between Nord pool and Germany, through Denmark and Sweden, but this coefficient remain too low to be significant. Similar correlation with France (6%) and Netherlands (7%) are also very low. Finally, the negative correlation with Spain (-45%) shows a total separation between these two markets. Hence these results indicates that there was a high level of integration between Norway, Sweden, and Denmark in 2002 forming an **integrated Nordic market**. However, this market was rather isolated from all other locations outside the Nordic countries.

A second "supra-national" market can be identified that is made up of France and Germany, based on power exchanges prices and bilateral prices. These two markets show high correlation, 75% on average. Such correlation shows that

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[19] See chapter 9 for more details on Nord pool

important arbitrages exist between these two countries. As they are directly connected such result appears to be logical[20]. However it is worth noting that the interconnections between France and Germany have historically been a one-way connection for EDF to export cheap (nuclear) electricity to Germany. Furthermore the low level of liquidity in the French market make it difficult for any company other than EDF to take advantage of arbitrage possibilities between the two markets. In conclusion, this analysis highlights an **important level of integration between France and Germany** but the possible domination of EDF on the arbitrage remains an open question.

The analysis also highlights that for all the other locations there is little correlation for either power exchange prices or bilateral prices during the period in focus, with correlation between locations generally below 40%. For instance, despite the central geographic position of France and beyond the correlation between France and Germany, electricity prices on the French power exchange appear to be weakly correlated with prices from neighboring exchanges: 51% with Omel, 41% with UKPX, 29% with APX. Similarly correlation between the UK markets and all others location are mainly below 40%. Therefore, this analysis shows a **very low level of integration between most European locations**.

In summary, several interesting facts emerge from this first analysis. First a high level of integration at the national level between power exchanges and bilateral markets has been observed. Second, two “supra-national” markets have been identified. Finally the more general conclusion that can be drawn from this analysis is that with some regional exceptions, European electricity prices are not correlated which shows inefficiency of arbitrage mechanisms and a low level of market integration.

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[20] See chapter 9 for a presentation of the allocation mechanism of interconnector capacity between France and Germany

Table 8-4: Results of correlation analysis

	FraOTC base	Powernex base	FraOTC peak	Powernex peak	GerOTC base	LPX base	GerOTC peak	LPX peak	NLOTC base	APX base	NLOTC peak	APX peak	UKOTC base	UKPX base	UKOTC peak	UKPX peak	Omel base	Nordpool base	DK-West base	Norway base	Sweden base
FraOTC base	1,00																				
Powernext base	0,87	1,00																			
FraOTC peak	0,96	0,81	1,00																		
Powernext peak	0,83	0,97	0,80	1,00																	
GerOTC base	**0,90**	**0,81**	**0,88**	**0,78**	1,00																
LPX base	**0,76**	**0,75**	**0,69**	**0,73**	0,83	1,00															
GerOTC peak	**0,84**	**0,73**	**0,85**	**0,74**	0,97	0,80	1,00														
LPX peak	**0,67**	**0,66**	**0,63**	**0,67**	0,78	0,97	0,78	1,00													
NLOTC base	0,31	0,33	0,34	0,36	0,37	0,35	0,39	0,36	1,00												
APX base	0,25	0,29	0,28	0,33	0,33	0,32	0,35	0,33	0,89	1,00											
NLOTC peak	0,27	0,28	0,31	0,33	0,35	0,32	0,38	0,34	0,96	0,90	1,00										
APX peak	0,23	0,27	0,26	0,30	0,30	0,29	0,32	0,31	0,89	0,99	0,90	1,00									
UKOTC base	**0,52**	0,48	**0,55**	0,48	0,37	0,27	0,34	0,23	0,25	0,18	0,21	0,17	1,00								
UKPX base	0,41	0,41	0,42	0,39	0,29	0,25	0,26	0,20	0,20	0,12	0,16	0,12	0,72	1,00							
UKOTC peak	0,45	0,42	0,49	0,45	0,33	0,25	0,33	0,23	0,26	0,20	0,25	0,20	0,95	0,68	1,00						
UKPX peak	0,39	0,38	0,41	0,38	0,27	0,24	0,26	0,21	0,23	0,14	0,19	0,14	0,70	0,99	0,68	1,00					
Omel base	0,47	**0,51**	0,40	0,44	0,42	0,38	0,38	0,33	0,01	0,01	-0,03	-0,01	0,12	0,15	0,05	0,12	1,00				
Nordpool base	0,11	0,06	0,17	0,11	0,06	0,02	0,06	0,02	0,09	0,07	0,12	0,08	0,42	0,35	0,41	0,34	-0,45	1,00			
DK-West base	0,32	0,31	0,34	0,37	0,33	0,34	0,32	0,34	0,36	0,29	0,37	0,28	0,42	0,35	0,45	0,36	-0,30	0,75	1,00		
Norway base	0,11	0,06	0,16	0,11	0,06	0,01	0,05	0,00	0,08	0,06	0,10	0,07	0,42	0,35	0,41	0,34	-0,45	0,99	**0,74**	1,00	
Sweden base	0,12	0,06	0,18	0,12	0,08	0,05	0,09	0,05	0,12	0,09	0,15	0,10	0,40	0,34	0,41	0,33	-0,45	0,99	**0,77**	**0,99**	1,00

LEGENDA

>0.5	National integration
> 0,5	International integration
< 0,5	No integration

8-4 Results of regression analysis

8-4-1 Unit root test

In Bower's analysis the assumption was made that the data were non-stationary time series. While such a characteristic has been observed for most economic variables, it is a fundamental prerequisite to test such hypothesis for electricity prices to choose the appropriate method to use for an analysis. Indeed, due to the peculiarities of electricity markets such hypothesis may be non-suitable for electricity prices. Hence, before any econometric analysis can be carried out, it is necessary to investigate the time series properties of the data. We need to distinguish between the stationary and stochastic component, for this purpose, the Augmented Dickey-Fuller test was performed for each price series[21]. The results are reported in table 8-5. To save space in this section, the details of all test results are displayed in appendix 2.

Table 8-5: Summary of ADF unit root tests

Serie	ADF Test Statistic	Unit root* (5%)
Powernext	-6,837230	No
LPX	-7,164452	No
APX	-8,182311	No
UKPX	-7,607387	No
OMEL	-3,135941	No
DK-West	-6,419316	No
NORDPOOL	1,152283	Yes
NORWAY	1,786610	Yes
SWEDEN	0,056822	Yes

*MacKinnon critical values for rejection of hypothesis of a unit root.

1% Critical Value	-3,4571
5% Critical Value	-2,8728
10% Critical Value	-2,5727

If the ADF statistic is not significant we fail to reject the null hypothesis of stationarity and can conclude that the series are non-stationary. Surprisingly, according to the ADF test for unit root, the hypothesis of stationarity can be rejected only for three series, Nord pool, Norway, and Sweden, while for the six other series, Powernext, LPX, APX, UKPX, Omel, and Denmark, this hypothesis cannot be rejected. Hence most prices series were found to be stationary. These results of unit root tests are of primary importance because they show that electricity spot prices do not behave like most others economic time series which are generally non-stationary. As such cointegration analysis will be invalid, because in the presence of stationary series cointegration analysis will always find prices to be cointegrated.

Based upon the above results the alternative approach to test for market integration is regression analysis, i.e. regressing price series on each other using the standard OLS method. This approach appears well suited because due to the nature of these markets, short-term, and the nature of electricity, non-storable, the relationship between prices should be instantaneous rather than containing lags (e.g. ARMA models[22]).

8-4-2 Results of regression

Since the data are stationary time series, estimation of our model (equation 8-5) can be done using the standard OLS method. In order to focus on the most important relationships, the regression analysis only considers markets which are directly connected, e.g. France-Spain as opposed to Germany-UK, assuming that markets are better integrated when they are closer. The results of the regression analysis ranging R-squared in decreasing order are given in table 8-6[23]. This statistic is important because it measures the strength of the association between the two variables by indicating the percentage of variation in one location that is explained by the other location.

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[21] Two different numbers of lags (zero and four) have been used. They both end up with similar results. For the sake of brevity only the results of the first estimation are presented.

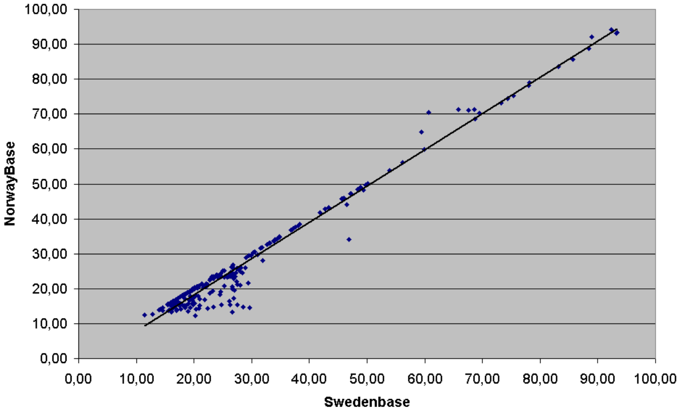
[22] AutoRegressive Moving average see Box and Jenkins (1970)

Table 8-6: Summary of regression analysis

Dependent variable (Y)	Variable (X)	Constant (c)	Coefficient (b)	R-squared	Durbin-Watson
NORWAYBASE	SWEDENBASE	-2,57755	1,039818	0,972605	0,625035
DKWESTBASE	SWEDENBASE	12,33978	0,530569	0,592542	1,196392
POWERNEXTBASE	LPXBASE	8,76749	0,583019	0,555816	1,380904
DKWESTBASE	NORWAYBASE	14,39116	0,482891	0,545649	1,140531
POWERNEXTBASE	OMELBASE	13,28181	0,248835	0,258207	0,816145
POWERNEXTBASE	UKPXBASE	13,12157	0,449886	0,167365	0,841305
LPXBASE	DKWESTBASE	18,62080	0,242315	0,115740	0,665690
APXBASE	LPXBASE	10,42515	0,957349	0,101347	0,950483
POWERNEXTBASE	APXBASE	20,84045	0,076639	0,086854	0,698207

The R-Squared allows us to separate the results in three categories: very high relationships, high relationships and no relationships. First, as in the previous analysis, the regression between Norway and Sweden prices (figure 8-1) indicates a very high level of integration between these two markets. Indeed the estimated R-squared indicates that 97% of price variation at one location is explained by price variation at the other location. Moreover the slope of the regression is close to one which demonstrate a high level of arbitrage between these two markets.

Figure 8-1: Regression Norway-Sweden



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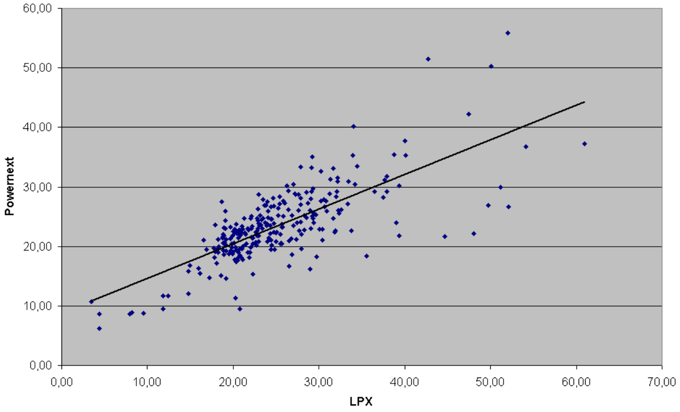
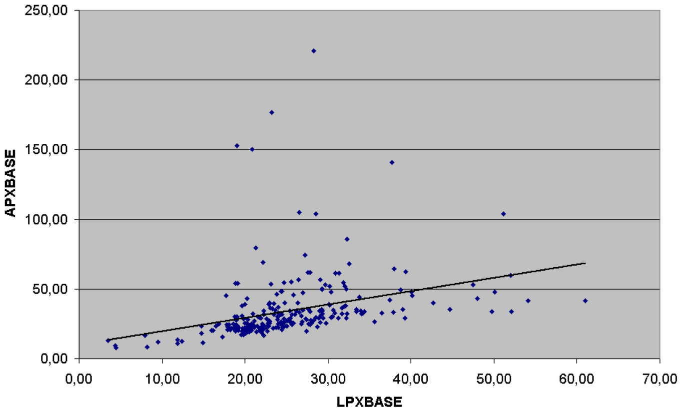
[23] See appendix 2 for details of regression analysis

Figure 8-2: Regression Powernext-LPX



Second, to a lesser extent Denmark appears to be relatively well integrated with Norway and Sweden while France and Germany also present a high R-squared (>55%). However compared to the previous case (Norway-Sweden) which can be considered as an example of effective integration, these markets appears has imperfectly integrated.

Figure 8-3: Regression APX-LPX



Finally, the other regression results suggest that no real relationships exist between numerous locations since none of the estimated coefficients are significant although these markets are physically connected (figure 8-3). For instance the estimated R-squared is lower than 20% for four relationships, France-UK, Germany-Denmark, Netherlands-Germany, France-Netherlands. It appears that price variations in several locations do not affect prices in neighbouring locations (figures 8-4, 8-5). In conclusion, just as with the correlation analysis the OLS estimation results based on power exchanges prices are unambiguous. There seems to be very few relationships between the different markets. These results indicate that so far there exists no single European electricity market although there is some evidence for local integration.

Figure 8-4: Regression Powernext-UKPX

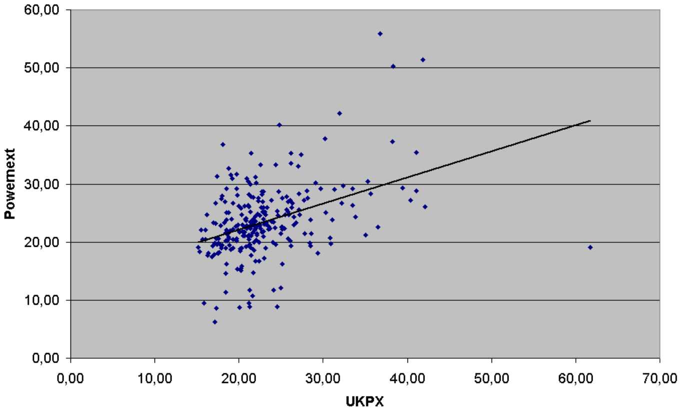
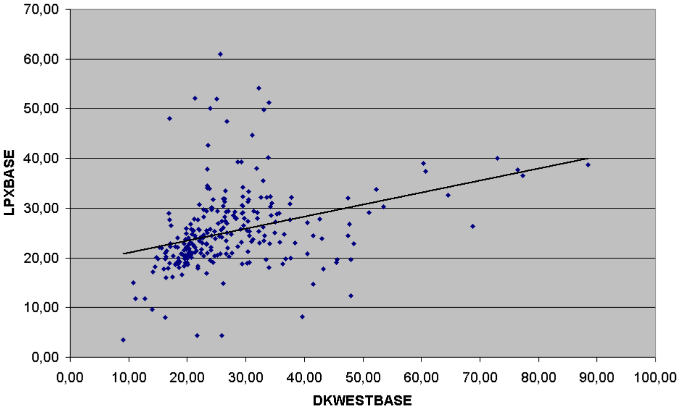


Figure 8-5: Regression LPX-Denmark



8-5 Conclusion

The extent to which electricity prices in the different countries are related is of considerable interest from a market definition perspective. In this chapter we have considered prices in several European locations during the year 2002 to test the level of market integration of electricity markets in accordance with the objective of the liberalization process to create a single European market. In principle, in an integrated electricity market, one would expect to find a high correlation across the market between prices. However the results presented here give limited support to this assumption of a single “European electricity market”.

Taken together, our econometric evidence points in one direction: the European electricity market is not integrated. In particular it has been possible to identify different markets. While in theory strong relationships should exist between these markets, the present sets of tests with the present set of data have provided only weak support for this theory. First, correlation analysis between prices considered in location pairs proved to be low in general. This holds true for both types of spot market, i.e. power exchanges/bilateral markets, and for both types of periods, i.e. base/peak. However, this analysis has allow us to demonstrate a high level of integration at the national level between power exchanges and bilateral markets and to identify two regional markets and three isolated markets.

Second, while cointegration analysis is the most commonly used method for measuring market integration, the nature of the data did not allow us to use this method because this test requires non-stationary time series. Indeed, primary tests on time series properties have showed that electricity price behaviors are different from classical commodity prices which are usually non-stationary. Hence, classical regression has been used and this provided primary evidences that although the goal of the liberalization process is to create an integrated European-wide market, the process so far has resulted in the creation of different national markets that still need to be integrated.

From this analysis, a question emerges: What are the reasons for this lack of integration? In the following chapter we try to answer this question and argue that the lack of market integration which mean a lack of efficient arbitrage between markets is directly related to market design and especially to the existence of inefficient transmission pricing for cross-border trading.

Chapter 9

Power exchanges and transmission pricing

The poor level of integration between European electricity markets was demonstrated in chapter 8. The next step of the analysis is to try to explain the reasons of such low market integration. The hypothesis developed in this chapter is that the actual wholesale market design at the European level lacks efficient transmission pricing which hampers the development of an integrated market. The purpose of this chapter is not to go into the details of all approaches to transmissions pricing but rather to focus on the role of organized markets for dealing with congestion. In this chapter, we first emphasize the importance of transmission constraints in electricity networks. While at national levels dense grids have allowed most European power exchanges to be designed in a way that ignores transmission constraints, at the international level the existence of important bottlenecks make this issue critical. Different theoretical approaches to transmission pricing, nodal/zonal, and the study of actual successful examples of integrated markets, PJM/Nord pool, are presented. Using these two examples we identify possible lessons for the European market, it appears that an efficient transmission pricing mechanism is a fundamental cornerstone for such markets. The inadequacy of the actual transmission pricing mechanisms between European countries is discussed. Some empirical evidence of inefficient pricing between European countries is provided in the last part of this chapter.

9-1 Transmission pricing

9-1-1 Introduction

The creation of an integrated market is confronted with the fact that transmission capacity between countries is limited[1]. In such a context trading arrangements regarding transmission represent one of the most complex, but also one of the most important, issues of market design. While there is a general agreement among academic practitioners and policy makers that direct and non-discriminatory access to the transmission grid is an essential centerpiece for a competitive electricity market, in Europe little attention has been paid to instituting direct access.

In continental Europe, two levels of transmission pricing can be identified, a national level and an international level. When pricing transmission at the national level, the lake model, also called copper plate or postage stamp approach, is mainly used, i.e. generators “pour in“ electrons and consumers “draw out “ electrons (Albers, 2001). This model is a zonal model, each country is a single zone[2], is relevant when there are no transmissions constraints. The justification for such a model is that national network are very dense in most European Members States. Access to interconnectors is an essential element of the Trans-European network and it is a fundamental condition for the creation of the internal electricity market. The existence of interconnection is an important factor for international competition since it allows consumers to import electricity from Members States with lower electricity prices. Moreover in Members States, characterized by a dominant incumbent, interconnectors are the only source of competition and choice for consumers[3].

An important problem with power exchange is that they offer a price for a wide area regardless of the location of producers. Buyers on a power exchange only

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[1] See chapter 7

[2] Note that regional zones are delineated within the United Kingdom and in the Nordic countries

[3] See chapter 7

buy energy and have to add the price of transport. In most European countries the charges for transmission are regulated and do not take into account the location of generating companies. Because of this transmission system operators may face difficulties in insuring physical delivery of power when congestion occurs. At the national level, most European member states have dense transmission grid and excess generation capacity which allows them, in the short term, to leave the problem of efficient grid pricing for later review (Newbery, 1999). The different power exchanges ignore differences in nodal prices, and have adopted a single integrated market approach at the national level and are not directly involve in transmission pricing of interconnector capacity with neighboring countries.

The hypothesis developed in this chapter is that the actual wholesale market design at the European level lacks efficient transmission pricing which hampers the development of an integrated market and explains the low level of market integration presented in the previous chapter. The purpose of this chapter is not to go into the details of all possible approaches to transmissions pricing but rather to focus on the role of organized markets for dealing with congestion. As introduced in chapter 3 in the presence of transmission constraints, economic theory suggests the application of locational pricing[4]. In this chapter we elaborate from a theoretical point of view on the difference between the two main approaches: zonal and nodal pricing[5]. These two approaches are illustrated with two successful examples of existing markets, in Nordic countries (Nord pool) and on the east coat of the US (PJM), with particular attention paid to the role of the power exchanges. Then, the inadequacy of the actual approach followed in Europe and empirical evidence for this are discussed[6]. We compare the cost of transmission between locations, based on the result of auctions for interconnector capacity, with the difference in the prices at the locations, based

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[4] See section 3-3-4

[5] For the sake of brevity we do not consider other possible approaches such flow-based transmission approaches. For a presentation of flow-based approaches see Chao *et al* (2000) and Ruff (2000)

[6] Current discussions and proposals for changes are presented in chapter 10

on power exchanges prices. This analysis shows that from a theoretical and an empirical point of view the actual transmission pricing mechanism is inefficient and it is a fundamental missing piece of the actual European market design.

9-1-2 Transmission constraints

Due to its physical features electricity flows regardless of contract between generators and consumers. The main determinant factor of electricity flow is transmission constraints. Transmission constraints arise on transmission networks from time to time, due to changing patterns and costs in generation and demand. Due to the complex interactions in the electricity transmission network, loop flows, physical limits and reliability constraints, transmission constraints represent a significant challenge for the creation of competitive electricity markets. In a meshed network, characterized by the existence of several interconnected lines, electrons do not only flow on the line directly connecting the generation point with the load point they also flow on other parallel lines in accordance with the law of least resistance (Kirschoff's law). Hence, it is a physical fact that, in a meshed system, the flow along any transmission line at any time depends upon the all other flows in the system at that time (Turvey, 2001). Due to these loop flows identification of a specific transaction is impossible. For this reason, transmission constraints represents one of the most complicated issues in electricity market design (Hogan, 1995).

At national levels most European power exchanges have been designed as if they were operating in an unconstrained network[7]. In an unconstrained network, the transmission capacity is considered to be infinite, i.e. the transport of electricity is a secondary issue. Electricity can be produced at a location and consumed at another one without any risk for the system. In such a system price differs across location only by the marginal costs of power losses in transmission. However, marginal losses on high voltage transmission grids are relatively small

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[7] See chapter 5, section 5-4-2

and represent only a few percent of the cost of delivered power. Hence, in such a system the price of power is the same at any location. In practice, unconstrained networks do not exist since they involve over-investment which is not an economic optimum[8]. Hence an optimal level of capacity for transport capacity involves transmission constraints, or congestion. While at national levels the dense networks have allowed the creation of a single hub regardless of transmission constraints, at the international level the weak interconnections between countries make congestion management a fundamental issue.

The capacity of transmission lines and the way transmission is priced determine the degree to which generators in different locations compete (Borenstein *et al*, 2000). Due to the existence of transmission constraints between countries, transmission capacity is a scare good and needs to be allocated. Economic theory recommends that market mechanisms are used to do this. In theory, the marginal cost of transmission between two locations should equal the difference in the prices at the two locations (Schweppe *et al*, 1988). From a practical point of view, experience has showed that an organized market for electricity is an institution which can be used to support the market mechanisms for dealing with transmission constraints.

9-1-3 Zonal versus nodal[9]

In most European countries, power exchanges provide a single price for the hub of their country. For this reason the existing European market can be viewed as a zonal system, although a very basic form. Each zone consists of a country. No intra-country zone exists even if congestion can occur within the country. Moreover this zonal system is incomplete because the existing coordination

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[8] Since the demand for electricity vary widely between "super" peak hours and off peak periods, it is wasteful to build expensive capacity that will be use only for a couple of hours during the year

[9] When describing transmission pricing system, the term 'nodal' pricing is conventionally used to describe markets with a high resolution of locational energy prices, while 'zonal' pricing is used to describe markets with one or very few locational prices.

mechanisms between countries (zones) present several shortcomings[10]. The main features of the zonal approach in contrast to the nodal approach, and the different controversies related to the zonal/nodal pricing debate are presented from a theoretical[11] point of view in this section.

In presence of transmission constraints, economic theory suggests the application of locational prices (Schweppe *et al*, 1988; Hogan, 1992). In such a system, each constrained area has its own electricity price. This approach is known as *nodal pricing* (Hogan, 1998). The nodal approach defines “area” with respect to transmission constraints. An area is defined when it does not have any internal constraints. In a very constrained area, prices are determined for each node of the network. Due to changes in physical constraints related to change in production-consumption, prices may differ between nodes. A price should be set to reflect transport constraints for each node of the physical network. The first visible effect of implementing nodal pricing rather simple zonal pricing is that the market consists of a set of prices, one for each location.

A schematic network introduced in Chao and Peck (1998) consisting of six nodes is presented in figure 9-1 to illustrate the difference between nodal and zonal approach. Grouping all nodes into one single zone (zonal price) we obtain a single zone system, which defines a single price for all of the area regardless of any transmission constraints within the zone. In contrast defining a price at each node takes into account all possible transmission constraints and defines a price at each node (nodal price). Finally a combination of the two approach can be defined using both zones and nodes (“multi-zonal” price)

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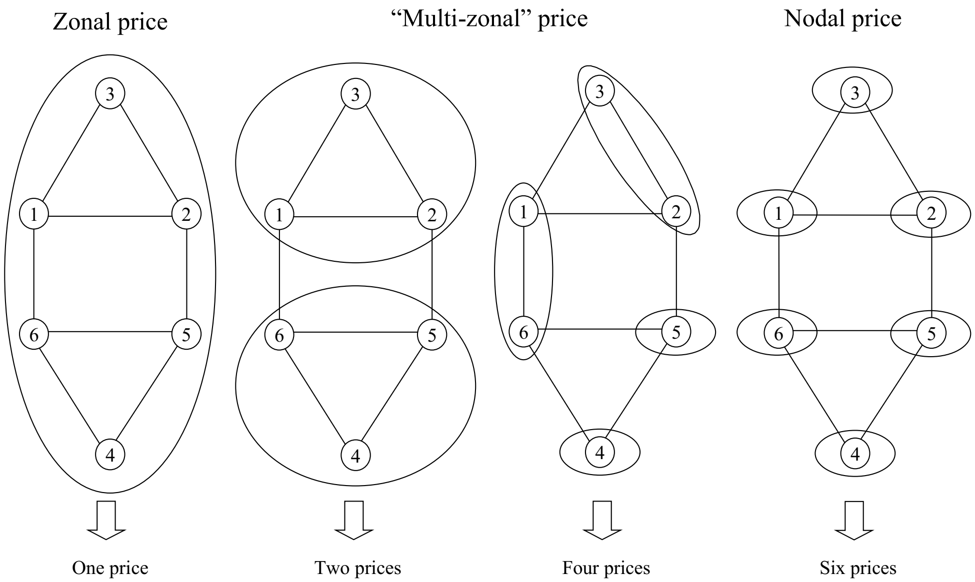
[10] See section 9-4

Figure 9-1: Locational price-illustration



With respect to transparency, the nodal approach is often criticized for its complexity and its requirement for a very high level of technical coordination between system operator and market operator. Due to the complexity of this approach an alternative method consists of aggregating many nodes into a smaller number of zones which simultaneously reduce the number of prices (Bjorndal and Jornsten, 2001). Such an approach is known as *zonal pricing* (Hogan, 1998). The use of zones rather than nodes for pricing purposes is a common simplification (Green, 1997). The zonal approach has as its main advantage, from a market participant point of view, that it is simple to operate and provides only one (zonal) or a few prices (multi-zonal) while the nodal approach require complex calculations and results in many prices. This characteristic makes the single market approach at a first glance more

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[11] Practical advantages and shortcoming of the two approaches are presented in section 9-2 based on case study

transparent and more “trading-friendly”. However, in the presence of real transmission constraints such “advantages” become problematic.

One shortcoming of zonal pricing is the problem of how to define a zone with respect to loops flows, while one major advantage of the nodal approach consists of its capacity to take into account loop flows which are a very important feature in a meshed network. Indeed, in the presence of a network with loop flows, price may differ within an unconstrained zone due to the indirect effect of “distant” constraints in neighboring zones[12]. Hence zones definition may change according to substantial differences in nodal prices within the zones[13]. It is then necessary to calculate nodal prices within a zone to assess the suitability of the zone definition (Harvey, 1996).

A second problem of the zonal approach is that there is a lack of signals on where to invest both for new generation and for new transmission capacity. Nodal pricing systems are criticized for producing complicated prices, highly volatile, and large price differences between areas which might hamper trading. Indeed, nodal prices can be higher than the marginal cost of the most expensive units reflecting the need simultaneously to increase output from expensive plants and decrease output from cheap plant to keep the system in balance. Moreover, nodal prices can be negative at constrained areas reflecting the value of a counterflow in the system, i.e. it would be cheaper to pay market players to consume electricity at some nodes in order to relieve transmission constraints. Although such a system is more complicated than a single-price system, it provides the right locational signals for new investment. For this reason, the nodal approach also offers better investment incentives, high prices areas will attract new investment in generation which in turn will lead to lower prices.

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[12] For illustration see Hogan (1998), *Competitive electricity market design: a wholesale primer,* Harvard Electricity Policy Group, p 51

[13] See box 9-2 for an example

Nodal pricing systems are often criticized for calculating too many prices which reduces transparency, however in the presence of imperfect markets bilateral trading also produces many, if not more prices. While differences between nodal prices are based on real technical constraints, differences in bilateral prices are due to different levels of bargaining power, or worst, of market power. In a bilateral system, trade at the same node can results in different prices while a nodal system ensures one price for one location for a given period (Stoft, 2002). In the zonal approach, when transmission constraints occurs within a zone, the system operator needs to intervene to resolve conflicts between contracts and technical reality, and the system operator will use a balancing mechanism that takes into account these particular constraints. Such a system therefore requires an additional mechanism where players make additional adjustment bids/offers which in fact reduce the overall transparency of the system. From an operational point of view, accurately aggregating nodes into zones first requires a knowledge of individual flows per nodes, this aggregation requires additional computation and because of this the zonal approach adds supplementary work for less accurate price signals (Hogan, 1998).

A last problem with nodal pricing points that is often mentioned is the fact that such a system is difficult to implement in practice. This argument appears particularly weak with respect to international experiences. Indeed such system has been already implemented in the east of the United States (PJM) and in New Zealand and to lesser extent in the Nordic Countries, Argentina and Chile.

An important drawback from the perspective of the market participants is that nodal pricing involves intricate calculations which reduces transparency (Deng and Oren, 1998). In practice nodal pricing computations are often compared with a “black box”. The black box is based on different models which like all models[14] are based on assumptions (security constraints, power flows…) simplifications and lot of human input. For instance, the complexity of the mathematical

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[14] See Chapter 4

algorithm can produce different equilibrium results. Hence, arbitrary choices may have to be made by the system operator between different solutions (Glachant and Pignon, 2002).

An additional concern about nodal pricing is the volatility of prices and the problem of ex-post pricing while separate auctions allow market participants to know in advance, ex-ante, the total costs of transporting electricity between two locations, nodal prices are only known ex-post. From a participant perspective, such a system involves more uncertainties which might hamper trading. Moreover, with nodal pricing, price differentials between locations can be substantial and vary widely from time to time. Such volatility can also represent an important barrier for the development of a liquid market.

Another concern with regard to nodal pricing is the fact that it does take into account the cost of operating transmission facilities. Nodal pricing is totally a function of generation costs. Hence in practice nodal prices can far exceed the redispatch cost necessary to relieve congestion (Rosenberg, 2000).

In conclusion, even if zonal pricing in providing a single price appears to be simpler and more transparent, the aggregation of nodes into a fewer number of zones is problematic in the presence of real transmission constraints and may add complexity and diminish price signal and transparency. When the system is unconstrained, the use of zonal pricing and nodal pricing is equivalent but the important question is how does the market design deal with the problems when the system is constrained. In contrast, nodal pricing is criticized when used in practice as having numerous flaws. The intense debate between advocates of each system can be illustrated as follows.

“The real impact of zonal pricing is to create more administrative rules, poorer incentives for investment, demands to pay generators not to generate power, and

proposals to "socialize" the higher costs by using the taxing power of the ISO. This is not the way of a market. ***It creates more problems than it solves****."* (Hogan ,1999).

"[nodal pricing]… ***suffers from numerous flaws****: it is divorced from the actual cost of providing transmission, it can far exceed the redispatch costs necessary to relieve congestion, and it may even provide perverse incentive to retain congestion."* (Rosenberg, 2000)

Table 9-1: Comparison of Nodal and Zonal pricing approaches

	Nodal pricing	**Zonal pricing**
Theoretically efficient without transmission constraints	Yes	Yes
Theoretically efficient with intra-zone transmission constraints	Yes	No
"Trading -friendly"	No	Yes

In sum, from a purely theoretical point of view the nodal approach, lavishly praised by Hogan, appears to be more suitable than the zonal approach. However, applying such approach in practice meet some difficulties. Practical experiences and empirical studies suggest that a compromise that combines the best of both approaches represents a workable solution (Tabors, 1999). Such a compromise is used in the Nordic countries (9-2-1). In PJM, though nodal prices are used (9-2-2), some empirical studies have shown that zonal prices in this market would capture most of transmission constraints with much simpler system[15]. Hence, the debate between the two approaches continues with respect to economic theory and practical applications. In the following section we

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[15] See box 9-2 for an example

illustrate the functioning of these two approaches by elaborating on these two practical examples.

9-2 Case studies: the Nordic countries and PJM

9-2-1 The "Zonal"[16] approach: the Nordic countries

The analysis presented in chapter 8 showed a low level of integration between most locations within Europe, though within the Nord pool area, price changes at one location were generally highly correlated with price changes at other Nord pool locations. In this section we argue that such a good level of market integration is directly related to market design, especially with respect to the articulation between power exchanges and transmission pricing.

Table 9-2: Key figures for the Nordic electricity system 2001

		Denmark	Finland	Iceland	Norway	Sweden	**Nordel**
Installed capacity	MW	12 480	16 827	1 427	27 893	31 721	**90 348**
Generation	GWh	36 009	71 645	8 028	121 872	157 803	**395 357**
Imports	GWh	8 603	12 790	-	10 753	11 167	**43 313**
Export	GWh	9 180	2 831	-	7 161	18 458	**37 630**
Total consumption	GWh	35 432	81 604	8028	125464	150512	**401040**

Source: Nord pool

The Nordic countries, Norway, Sweden, Finland and Denmark, present a very interesting example of how a power exchange is used for dealing with congestion. First, it is worth noting that two methods are used simultaneously to deal with congestion: market-splitting, also called implicit auctions, for cross-border congestion and counter trading[17] for internal constraints in Sweden, Denmark, Finland and for some congestion within Norway (Johnsen *et al*, 1999).

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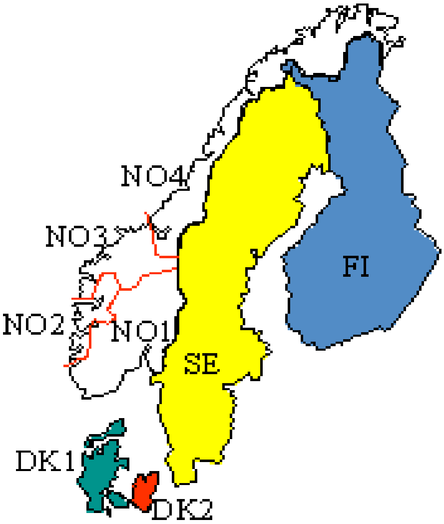
[16] While nodal pricing refers to a system where prices at each node of the network can vary, under zonal pricing, nodal prices are aggregated across several zones. In the Nordic countries zones may varies. Hence the distinction between nodal and zonal pricing is less clearly defined. For the sake of brevity, we refer to the Nordic system as zonal "pricing".

[17] Under Counter trading, congestion is eliminated by the system operator who chooses counterparties on one or both sides of the congestion to reduce capacity demand, either by buying in the high price area and selling in the low price area or by securing demand reduction in the high price area.

For the sake of the discussion we will only consider the market-splitting mechanism because it deals with cross border flow while counter trading is only use at the national level. Nord pool was primarily the Norwegian market, Denmark, Finland and Sweden joining progressively later. Currently Nord pool covers five areas, Norway, Sweden, Finland, East Denmark and West Denmark and potentially up to eight congestion zones since Norway may be divided into four zones (figure 9-2). In general, due to a weak level of interconnection between countries with respect to national grid density, the first determinants of congestion zones are national borders (Gronli, 2001). Secondly within Norway different zones are defined due to internal bottlenecks.

Figure 9-2: Zone definition for Nord pool



Source: Nord pool

Like all European power exchanges, Nord Pool is a non-mandatory marketplace for physical day-ahead trades. Hence market participants can choose between using the power exchange or contracting on a bilateral basis, however, an important feature of Nord pool is a ban on players entering into physical[18] bilateral contracts between zones. For inter-zones transactions, sellers have to sell in their generation area and buyers have to buy in their consumption area through Nord pool. Nord pool is therefore mandatory for physical cross-border trades. Concretely, buyers have to specify their withdrawal zone and sellers their injection zone day-ahead, to allow the system operators to check the feasibility of transactions.

Congestions between zones are handled by Nord pool through the *market-splitting* mechanism. The main characteristic of market splitting is that transmission constraints and energy are coupled and traded simultaneously[19]. The objective of such system is to ensure that transmission capacity is allocated with respect to energy trading requirements. In such a system Nord pool collects bids for specific grid input and consummations points to assess the physical flows that would be created. If acceptance of all the bids does not create congestion, all input and consumption points form a single zone. However, if the flows create congestion, the area is then "split" into different zones with respect to congested interconnectors and new market prices are determined for each zone. At the same time, the system ensures that, for every hour, all interconnector capacity is used in accordance with the price differentials.

Concretely, in the first phase Nord pool, as a power exchange, calculates the system price, which is the price that could have been obtained if it was possible to accommodate all the transmission demands on the interconnector between the two areas. Then, the exchange checks whether this price will enable transmission between the areas over and above the capacity on the interconnector. If no restrictions are encountered, the system price will be the valid current price in both areas. This situation corresponds to the case where no transmission constraints occur.

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[18] In contrast to financial contracts such as Contracts for Differences or financials contracts traded on "Eltermin", the financial market.

[19] ETSO discussion paper, *Coordinated use of PXs for congestion management*, February 2002

In the presence of transmission constraints between two areas, the exchange will split the whole market into two areas and repeat the price calculation separately in the two areas. The price in one area will therefore be higher than in the other. The exchange will then purchase in the low price area and sell in the high price area. The increased demand in the low price area will in turn raise the price in that area. Correspondingly, the price in the high price area will fall when the amount of available power increases. This will be done until the amount of electricity bought and sold reaches the maximum capacity of the interconnector. The revenues of these operations are collected by Nord pool and paid back to the TSOs.

Market splitting indicates the local value of electricity. This mechanism relies on a liquid organized spot market within each zone. The use of market-splitting gives a central position to the power exchange: all physical trade between zones has to go via the exchange. There is only one exchange for all areas defining different prices, in contrast to continental Europe where each zone (country) has its own exchange which defines one price. Finally, zones are clearly defined, and may change, with respect to transmission constraints and are based on the TSO's load-flow calculations.

The Nordic system is often presented as a very sophisticated example of zonal pricing. However since the system operator has the possibility to change the definition of zones daily or hourly with respect to transmission constraints, this system can be better described as a nodal pricing system. Indeed, Nord pool is continuously investigating new ways of dividing up the joint Nordic electricity market according to structural bottlenecks in the grid and independently of national borders to reflect actual physical constraints in the grid and thus provide market players with better signals as to where surplus and shortfall areas are located[20].

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[20] Nordel 2001, Annual Report, *Congestion management in the electric power system*

With 10 years of experience of a competitive market, the overall output of the Nord pool system is generally considered to be successful (Midttum, 1997; Gjerde, 2002). This system is of particular interest for the rest of Europe because it involves collaboration between several countries. One of the key elements of its success is the development of a common cross-border mechanism managed by a common institution formed by the system operators that directly run the power exchange. Hence the example of Nord pool is a concrete application of how a power exchange may play a central role in the creation of an integrated market.

9-2-2 The nodal approach: PJM

The PJM (Pennsylvania-New Jersey-Maryland) market is the largest centrally dispatched control area in North America (figure 9-3) and is often cited as one of the leading example of a successful competitive electricity market. Similar to Nord pool, PJM provides an interesting example of market design where organized markets and transmission pricing are integrated and are at the heart of the functioning of the electricity market. PJM reaches into eight states and the District of Columbia in North America. It serves about 11 millions customers. The installed generating capacity in the PJM area represents about 70 000 MW.

Table 9-3: Key figures for the PJM electricity system 2001:

		PJM
Installed capacity	MW	67,269
Generating Units		594
Peak Load	MW	64,127
Annual Energy	MW	298,011

Source: PJM Annual reports 2001

PJM combines the power exchange and the system operator. Similar to Nord pool[21], PJM operates several markets, although different in detail: two generating

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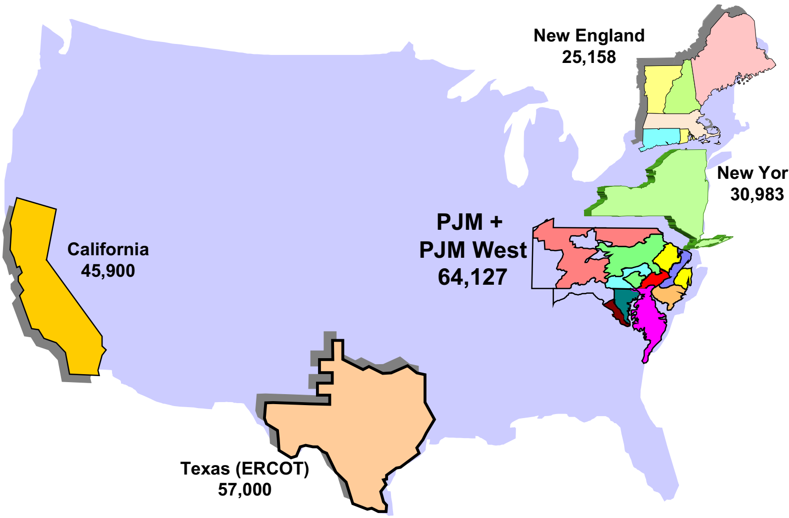
[21] See chapter 2, Box 2-2

capacity credit markets (daily and long term), two energy markets (day-ahead and real time), a financial transmission entitlements market and an ancillary services market.

PJM started operation of its spot market in 1997. At that time the spot market provided a single price for the entire PJM region. Hence, the PJM area was treated as one zone with hypothetical unconstrained dispatch. In situation of congestion, some generators were constrained on, while others were constrained off. The main drawback of this method was that generators constrained off were paid nothing, even though they had bids below the system price. The cost incurred by using more expensive generation was socialized into a charge applied to all loads.

Figure 9-3: Major markets in the US (peak load)



Source: PJM

The single price system proved quickly to be problematic as it was unable to reflect adequately locational value of energy throughout the market related to transmission constraints. For this reason PJM switched from a single price system to a locational marginal pricing (LMP)[22] methodology. In November 1997, the Federal Energy Regulatory Commission (FERC) approved locational marginal pricing for transmission congestion for PJM[23]. Since 1998, PJM has determined hourly Locational Marginal Prices (LMPs) on a nodal basis which reflects the underlying cost of the energy and the marginal cost of transmission congestion. The energy market represents the cornerstone of the PJM system.

Concretely, PJM collects bilateral schedules and voluntary bids from market participants. Based on these schedules and bids, PJM determines an optimal dispatch for power flows and the associated locational marginal prices. PJM calculates (and publishes) the five minutes marginal prices at each node which are then aggregated on an hourly basis and used for energy transmission pricing[24]. PJM provides prices for approximately 2000 locations.

In order to allow financial hedging against price differences between locations, the LMP system is accompanied by a system of transmission rights (Hogan, 1992) called fixed transmission rights (FTRs) since 1999. FTRs entitle the holder to receive compensation for transmission congestion charges that arise from locational differences in the hourly market prices (the LMPs) resulting from the dispatch of generators out of merit in order to relieve congestion. FTRs are financial transmission rights rather than physical transmission rights[25], they do not represent a right to the physical delivery of power, but they do ensure that access is financially firm. FTRs represent a financial hedge against the ex-post-calculated locational prices. PJM also facilitates the trading of FTRs by running monthly FTR auctions that allow participants to adjust their FTR positions.

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[22] LMP= Generation marginal cost + transmission congestion cost + cost of marginal losses

[23] FERC order, Docket No. OA97-261-000, issued 25 November 1997

[24] See www.pjm.com for locational current and historical LMP information

[25] See section 9-3-3

In conclusion, the example of PJM is of particular interest because it first worked with single zonal pricing and collapsed due to transmission constraints. Subsequently PJM adopted a nodal pricing system which appeared, from an economic theory point of view, to be the most efficient approach and has delivered in practice successful outcomes. PJM's successful experience with nodal pricing system shows the practical feasibility of such a system and the relevance of nodal pricing for concrete applications. Similar to Nord pool, the key elements of success at PJM are the development of a transmission pricing mechanism integrated with the market operation.

Box 9-1: Would "multi-zonal" pricing be a simpler approach for PJM?

Though the single zonal price system has proved to be problematic and was replaced by nodal pricing in 1998, it has been argued that a multi-zones approach would have been sufficient to capture major transmission constraints and would have avoided *the "unnecessarily cumbersome and complex aspects of nodal pricing"* (Tabors, 1999). In order to compare the relevance of nodal pricing compared to zonal pricing, different authors have estimated the additional value of calculating hundreds of nodal prices versus aggregating these nodal prices in a small number of zones. For instance, Hogan and Tabors have used actual nodal prices calculated by PJM and have tried to identify the existence of nodes with the same prices. The basic principle for aggregating two nodes into a single zone is that the two nodes should always have the same price. From a methodological point of view such a calculation consists of first identifying nodes with the same averages prices and same standard deviation. We present the finding of these two studies below.

Hogan (1999) has argued that nodal pricing is the truly simple approach for PJM because the location of constraints is unpredictable. Hogan made the calculations for six months, since the criterion of no differences in prices may be too strict, he used a threshold of $1 for aggregating two nodes into one zone and found that 94 zones would have been necessary in April 1998, 83 in May, 75 in June, 57 in July, 52 in August and 64 in September. Thus he found the number and also the geographical definitions of the zones differed monthly. This result proved for Hogan that zonal pricing for PJM would not produce real simplification.

Tabors (1999) argues that a smaller number of zones would capture the most important transmission constraints, he argues that the threshold of $1 used by Hogan is too strict with respect to the average zonal price, $1 represent less than 5% of the average zonal price, and to uncertainties due to the used of a model for calculating nodal prices. Using a 10% of average zonal price criterion would mean that less than 10 zones would be able to capture 98% of the variations in majors transmission constraints proving that a zonal system

9-2-3 What can be learned from these two examples?

A common characteristic of Nord pool and PJM is the direct relationship between system operators and a single institution (power exchange) that organizes market operations. In Europe most power exchanges are independent[26] entities, from their respective system operators, in Nord pool and PJM the two functions, power exchange and system operator, are integrated, i.e. technical constraints are taken into consideration in the functioning of the marketplace. Such integration allows transmission constraints and energy trading to be taking into account simultaneously. According to Hogan (1995) this type of integration is essential since it allows efficient dispatch and efficient pricing.

Nord pool and PJM are multinationals with one market operator acting for a whole area regardless of national boundaries. In others words, division of the market into zones/nodes is defined by actual physical bottlenecks and not by national borders. The two marketplaces calculate, from a technical point of view, the physical feasibility of proposed trades. In the absence of congestion the two marketplaces define a single price zone, when congestion occurs the markets are split into different zones/nodes according to transmission constraints which result in different locational prices. Due to the relative “simplicity”, radial network opposed to meshed network with numerous loop flows, of the network in the Nordic Countries, it is possible to determine a small number of zones. Hence market-splitting may be effective in areas where constrained flow gates are easily identifiable, e.g. North-South, but would probably operate poorly in continental Europe where the constrained flow-gates change too often (Smeers, 2001). In PJM, which is a most complex network, the existence of numerous loop flows requires more locational prices to be determined.

The size of the underlying networks (90 0000 MW of installed capacity in the Nordic Countries for 64 000 MW in PJM) appears to be relatively low compared to the size of the Continental European Market. For instance, the installed capacity in Nordic countries is 20% inferior to installed capacity in France alone (116 000 MW) while the PJM system has a smaller load than England and Wales. The open question is whether it is possible, from a technical point of view,

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[26] With the exception of APX which has been taken over by the Dutch system operator. However the APX does not deal with any technical constraints. To less extent the French TSO is a shareholder of Powernext.

for a many times larger system, to implement the integrated approach used in the two examples studied.

The market structure of Nord pool and PJM, number of players, number of power plants, technology used etc, of these two markets also represents an important condition for the development of these markets. A part of Nord pool's success can be attributed to the existence of important hydropower generators and the presence of numerous players[27]. Hydropower allows electricity to be stored which is not possible with other technologies. At the same time, the low level of concentration in generation has favored the development of competition and restricted possible market power. Similar, PJM does not have a high level of market concentration in comparison to most others markets.[28] Indeed the average annual HHI for PJM in 2000 was 1270[29] which is generally considered to be moderately concentrated.

In sum, though Nord pool and PJM have adopted market design models which differ in details, they share some common characteristics. Identifying such characteristics and comparing then with the actual European market design is of particular interest because it might provide guidance for further changes in the European market design. One, in Nord pool and PJM the size of the underlying networks is relatively small compared to the overall European market. Two, Nord pool and PJM are characterized by a low level of concentration which obviously is a facilitating factor for the development of competition. Three, participation is mandatory for transaction subject to transmission constraints. Four, the most important characteristic of the two markets is that a single institution is used to combine the function of system operation (TSOs) and market operation (power exchange). This type of integration appears to be fundamental to market functioning, regardless of any choice between a nodal or a zonal approach, in the sense that it allows the marketplace to take into consideration transmission

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[27] See chapter 7

[28] The Brattle Group (1998), "PJM market competition evaluation white paper", October1998

pricing which represents a key aspect of market design. We therefore investigate the functioning of transmission pricing in continental Europe in the following section.

9-3 Transmission pricing in the EU

9-3-1 Introduction

Historically, European electricity networks were built to serve national "markets", and not a European market, therefore only about 8-10% of national consumptions originates from cross-border trading (EC, 2001a). Congestion is relatively prevalent on interconnectors because they were not built to facilitate large electricity flows between countries as is being encouraged by the EC's liberalization process. Originally, their main purpose was to allow exchange of power between countries for the purpose of system stability. The existing prices differences between national markets have increase the demand for interconnector capacity, EC competition law does not prescribe any particular method for the calculations of transmission prices (Albers, 2001), only unfair selling prices or others unfair trading conditions are prohibited following article 82 of the EC treaty. In the event of cross-border disputes, the competition rules of the Treaty apply.

Moreover, the EU Directive 96/92 does not contain any specific rule for the allocation of interconnector capacity, which is considered to be a key issue for the implementation of a truly internal electricity market. The Directive[30] only established the general principles of open access to cross-border transmission capacity. Following these principles each Members States was free to choose how they will implement transmission pricing mechanisms and interconnectors access arrangements nationally. Paradoxically, this implies that in practice, the design of the internal European power market has been decided at the respective national levels (Boisseleau and Hakvoort, 2003), and, due to this freedom granted by the Directive different kinds of arrangements have emerged.

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[29] PJM 2000, "PJM Interconnection State of the Market Report 2000", www.pjm.com

Subsequently, the actual European electricity market is presently characterized by a patchwork of national and bilateral arrangements (Hancher, 1997; Glachant and Finon, 2000).

In contrast to Nord pool and PJM, presented in the previous sections, in continental Europe, transmission constraints and energy trading are treated separately and the system operator ensures physical delivery of trade on the exchange regardless of any possible physical congestion involved in these transactions. We will now identify the technical characteristics and the institutional framework of transmission pricing in Europe and we shed some light on the choice that was made to separate transport and energy (9-3-2) which has led to a system of physical transmission rights being put into place. We show that the physical nature of transmission rights hampers the development of an integrated European-wide market (9-3-3). Finally the drawbacks related to the methods used to allocate these transmission rights are addressed (9-3-4). We argue that these three related aspects, separation energy/transport→physical rights→allocation methods, represent a fundamental barrier to the creation of an integrated market in Europe due to the existence of serious transmission constraints at the European level [31]. This is illustrated using empirical evidences in the last section (9-4).

9-3-2 Technical system and institutional framework

Before addressing the functioning of the actual system in Europe with respect to transmission pricing and power exchanges, it is helpful to describe from a technical point of view, the structure of the European electricity network. Electricity networks are generally divided into four categories according to voltage levels. The first level is the extra high voltage network (380 kv/220kv) which represent the backbone of any electricity network. The extra high voltage network connects most of the large power plants and large industrial consumers.

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[30] Further work by the European commission is discussed in chapter 10

[31] In contrast to national levels where transmission constraints are relatively limited

The second network level (150kv/110kv) connects medium power plants and medium industrial consumers. The third network level (50kv-10kv) connects small power plants and small industrial consumers. Finally, the last network level (0.4kv) connects very small power plants and domestic consumers. All these different levels of networks are connected together using transformers. The extra high voltage network is used for the long distance transport of electricity and for connecting national networks, this level of network is the most important with respect to cross-border trade.

Technical co-operation has already existed for many years between the different European countries in order to ensure the operation of the interconnected system. This co-operation is founded in data exchange for planning purpose (Vasconcelos, 2002). In the past, cross-border transactions were realized according to the technical and economic rules defined by Association of Transmission Organization (ATO[32]) such as UCPTE or Nordel (figure 9-4). These transactions were limited to owners of the high-voltage grids and final customers had no access to the interconnection. Following the Directive 96/92, eligible customers and other type of players, e.g. traders, distribution companies, were allowed to have access to transmission network.

Each TSO, created following the liberalization process, is part of an ATO within which they agree to coordinate their activities. Due to the importance of cross-border trade for the creation of a single electricity market, the four ATO created the European Association of Electricity Transmission System Operators (ETSO) in 1999. ETSO is composed of 32 independent TSO companies from the 15 countries of the European Union plus Norway and Switzerland. This association works mainly on network access conditions at the European level, e.g. congestion management methods, cross-border transmission capacity definition

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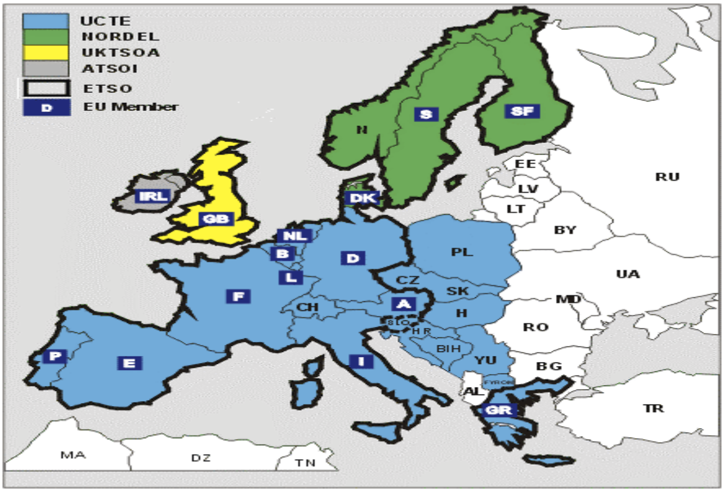
[32] To some extent, the concept of ATO is similar to the concept of Regional Transmission Organization (RTO) in the US

etc[33]. However the actual mechanisms for allocation of interconnectors are defined bilaterally regardless of the physical impact of a transaction between to countries on the network of neighboring countries[34].

Figure 9-4: European Association of Transmission Organizations.



Source: UCTE

In conclusion, the existence of several system operators and the separation between energy (product) and transport (service) characterizes the actual market design of the European electricity market(s) with respect to transmission pricing. From an institutional point of view, and in contrast to PJM and Nord pool, all European networks are operated by different national or local transmission system operators who deal with transmission pricing while markets for energy are separated and left to bilateral transactions and power exchanges. Due to this separation between transport and energy a system of physical transmission

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[33] For instance, ETSO introduced in 2002 a pan-European border fee scheme for cross-border trade (ETSO *Proposal for a Temporary Cross-border Tariff Mechanism 3 September 2001)*

[34] Current discussions and proposals for change of the actual system such as for instance the use of joint-auction mechanisms are presented in chapter 10

rights has been put in place and this presents important drawbacks that hamper the development of an integrated European-wide market.

9-3-3 The nature of transmission rights

An important feature of market design in Europe is the separation of the energy market, the power exchange and bilateral market, from the market for transportation, transmission pricing. Transmission pricing combines two types of mechanisms with respect to national and international congestion. At national levels congestion is not priced, but socialized ex-post on a cost-basis to firm users of the system. Hence at a national level in Europe congestion is managed by national TSO according to national rules and not by market-mechanisms.

In practice, at the international level allocation of interconnector capacity for cross-border exchanges implies that interconnection capacities are defined in advance by the involved TSOs and that market participants should acquire capacity before contracting the energy. While details of allocation procedures differ between interconnections[35], cross-border exchanges share a common characteristic in the sense that they all use a physical transmission rights system (PTRs). Indeed, the separation of energy and transport has led to the creation of physical transmission rights. In this system, the physical capacity of each interconnector is first defined. ETSO has published a set of net transfer capacities (NTC) for each European interconnection (ETSO, 1999; ETSO 2001c). The system operators create rights to use this capacity and allocate them in some way, using allocation methods, to market participants. These PTRs are rights that allow their holder to use a congested interconnector. Within this framework, market participants conduct their trades insulated from the details of system operation. Such a system allows ex-ante (before actual delivery) pricing which make the market simpler and (apparently[36]) transparent. From a theoretical point of view such an approach is questionable since the separation of

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[35] See 9-3-4

[36] See 9-1-3

energy flows, resulting from trade, and transmission capacity, resulting from network capacity calculations, easily results in inefficient allocation of the available capacity because the real capacity available can only be determined once physical flows are known (Ruff, 2001). This approach is, in general, opposed to the Financial Rights (FTRs) approach.

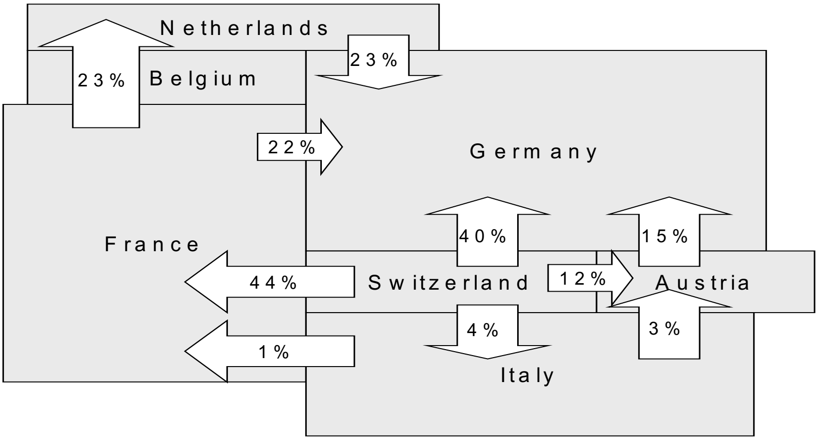
The major difference between the physical transmission rights approach and the financial transmission rights approach is in the way the final settlement is reached and the impact the systems have on the value of transmission rights (Green, 1998). In the PTRs system, the price of transmission is set in advance by market participants while in the FTRs system prices are determined ex-post by the TSO that administer the power exchange and operate the transmission system (like PJM) and payments are made to right holders.

Table 9-4: FTRs and PTRs

Financial Transmission Rights (FTRs)	**Physical Transmission Rights (PTRs)**
- Guarantees the holder the financial equivalent of using the transmission right, but not the physical certainty - The value is independent of actual flows, and depends on congestion on the system - Do not affect the way the system operator dispatches the system	- The right to inject a certain amount of power at point A and take it out at point B - The holders are guaranteed the scheduling certainty for their right - Do affect the way the system operator dispatches the system

An important drawback of the PTR approach is related to the assumption that electricity can be directed to follow a particular path in the network, this breaches the physical laws (Kirschoff) that dictate the flow of electricity (Hunt, 2002). Due to important differences in production costs and prices between national markets, the liberalization process has created an important demand for interconnector capacity and thus for physical transmission rights. For instance, based on the actual European market design a trader wishing to sell 100 MWh from Switzerland and Germany will secure the corresponding interconnector capacity between the two countries (100 MW) through a firm physical capacity right, regardless of any physical impact of such a transaction on neighboring countries. In practice such a transaction has an effect on the Austrian, Italian, French, Belgian and Dutch network (figure 9-6). Hence, when there are too many transactions the difference between the contract path and the actual flows may be really large. National system operators are well aware of this problem and to ensure that interconnectors are not overload they reduce available capacity which results in very inefficient usage of the system.

Figure 9-6: Difference between physical flows and contractual paths: example from a transaction between Switzerland and Germany



Source: RTE

Furthermore, since electricity does not follow the contracted path, transmission system operators face transit flows on their network which involve costs. To compensate the system operators, ETSO has developed a compensating mechanism for loop flows or transit costs (ETSO, 2000; ETSO, 2001g). The practical problem is that it is technically not possible to identify participants who cause transit and therefore to identify who should pay for the cost of transit; and it is difficult to estimate this cost accurately. A nodal system would remove this difficulty but this approach has not been considered by ETSO (Smeers, 2001).

With respect to market power, PTRs introduce the possibility for dominant players to withhold these rights from the market, which will reduce competition (Borenstein *et al*, 2000). For instance a generator can buy transmission rights to import within its national market and not use them in order to restrict access to its competitors (Joskow and Tirole, 1999). Furthermore, since until now physical rights have been defined regardless of to the impact that flow on the interconnector considered has on other interconnectors, players who are aware of the impact their behavior will have on transmission constraints may take advantage of this system. For instance, if a player owns generation assets at node A and B of a three nodes network, it may increase generation at node A relative to a competitive scenario if the loop flows created reduce the total energy delivered and increase prices at node B (Hogan, 1997).

Another important issue related to PTRs is the problem of “pan-caking”[37]. For example, a Spanish supplier wishing to sell electricity in the Netherlands, while allowed to do so under the electricity Directive, may face difficulty in competing with local generators because it would have to pay for transmission capacity in France, Belgium and in the Netherlands.

In conclusion the use of physical rights present serious limitations, one they reduce available interconnector capacity this results in very inefficient usage of the system and, two physical rights fail to take into account loops flows. Three, even under the, relatively unrealistic, assumption that transmission system operators can accurately estimate actual network use, the actual methods applied to allocate transmission rights lack harmonization, co-ordination and efficient design.

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[37] “pan-caking” corresponds to an addition of charges for power transmission crossing several borders

9-3-4 Allocation methods for physical rights

The EU Directive 96/92 only established general principles for open access to cross-border transmission capacity[38]. Each Member State was free to implement a system for national transmission pricing and for access arrangements to cross-border capacity. Due to this freedom it is not surprising to encounter a range of bilateral arrangements for the allocation of cross-border capacity. Subsequently, the actual European electricity market is characterized by a patchwork of national and bilateral arrangements with respect to the allocation of PTRs.

Many methods exist to handle congestion on power lines, that is several mechanisms can be use to allocate physical transmission rights. In order to deal with the fundamental issue of transmission pricing at the international level, the European Commission initiated the European Regulatory Forum for electricity[39] in 1998. The forum, which does not have any regulatory powers, is a platform for discussion about the progress of the implementation of the Directive with particular attention being paid to cross-border trade. The forum has identified two majors categories of allocation methods: market-based methods and non-market based methods. Market-based methods rely on market mechanisms to allocate transmission rights while non-market based methods rely on administrative rules. For the sake of brevity we will only consider three major types of non-market based mechanisms and one type of market-based approach[40].

While the European Commission has explicitly mentioned its preference for market-based mechanisms for the allocation of interconnector capacity (EC,

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[38] On this issue, the new Directive 2003/54/EC and especially the new regulation No 1228/2003 on conditions for access to the network for cross-border exchanges in electricity are discussed in chapter 10, section 10-2-2

[39] This bi-annual forum is attended by national regulatory authorities, member states, the European Commission and organizations representing the transmission system operators (ETSO), generators, electricity traders, consumers and power exchanges. The forum was set up to discuss issues regarding the creation of a truly internal electricity market that are not addressed in the Electricity Directive. See http://europa.eu.int/comm/energy/en/elec_single_market/ florence/index_en.html.

[40] An extensive discussion on congestion management methods in Europe can be find in Knops *et al* (2001) and De Vries and Hakvoort (2001)

2001d), in practice non-market-based system are still used for several interconnections (table 9-5). By definition, these methods allocate transmission capacity following criteria that are not based on any kind of market mechanism. For instance, to allocate transmission rights at one location, one can simply give the rights to those who first apply to use them. This method is called “first-come, first-serve”. One can also distinguish between different types of contracts and, for instance, give the rights to those with the longest-running contracts. This method is called “type of contract” allocation. Another method is to allocate scarce capacity “pro rata”, which means that all applicants receive an equal percentage of the total amount of capacity they apply for.

Table 9-5: Example of the diverse methods applied for the allocation of cross-border capacity: the case of France

Location:	**Allocation frequency***	**Method 1**	**Method 2**
France to UK	d, m, q, y,	call for tender	auction
UK to France	d, m, q, y,	call for tender	auction
France to Italy	d, m, y,	long term contracts	prorata
Italy to France	d, m, y,	long term contracts	prorata
France to Germany	d	list of priority	prorata
Germany to France	d	prorata	-
France to Belgium	d.m	first come first serve	prorata
Belgium to France	d	prorata	-
France to Spain	d	first come first serve	prorata
Spain to France	d	prorata	-

*daily, weekly, monthly, quaterly, yearly

Source: RTE

Non-market-based methods suffer several drawbacks with respect to economic efficiency. These methods do not provide any price signal and thus suffer from a lack of transparency. Moreover these methods discriminate against new entrants. Finally, in the presence of “imperfect unbundling” between the utilities and network operation (e.g. Germany), there is a high risk that the system operator will discriminate in favor of its own interests in supply. “Type of contract” allocation generally favors large long-term contracts. Hence, long term contracts signed before the new regulatory framework allow incumbent generators to control a large part of interconnection capacity and limit possibilities for new comers. “Pro-rata” methods work poorly in the presence of a large excess in demand with respect to available capacity. In a pro-rata system players integrate the fact that they will receive only a small part of what they will ask into their bids. They thus have incentives to ask for many times what their real needs are, which can lead to distorted results. Moreover the capacity attributed to each participant may become so small that is no longer commercially interesting (Albers, 2001). This method also discriminates against small players. Since these methods are not compatible with an efficient market, the Member States decided at the sixth Electricity Regulatory Forum in Florence meeting that the allocation of transmission rights for scarce interconnector capacity should be based upon market-based mechanisms (EERF, 2002).

While several market-based methods have been considered in Europe, e.g. explicit auction, implicit auction, market splitting, counter trading, redispatching, joint auction, in practice the most popular market-based option for congestion management in Europe is explicit auctions (ETSO, 1999; ETSO, 2001a, 2001b, 2001e, 2001f). In an explicit auction of interconnector capacity, the TSOs of the systems between which congestion exists sell their interconnector capacity to the highest bidder. Variations in auction design are possible with regard to bidding mechanisms, the time periods which are auctioned (days, weeks, months, years) and the firmness of capacity rights (see box 9-2 for an example). Auctions are interesting because they provide a transparent market-based allocation method. Such a method allows players who value the capacity the most to use it. It is worth noting that auctions are allocation methods above all, thus they work in situation of congestion and “non-congestion”[41].

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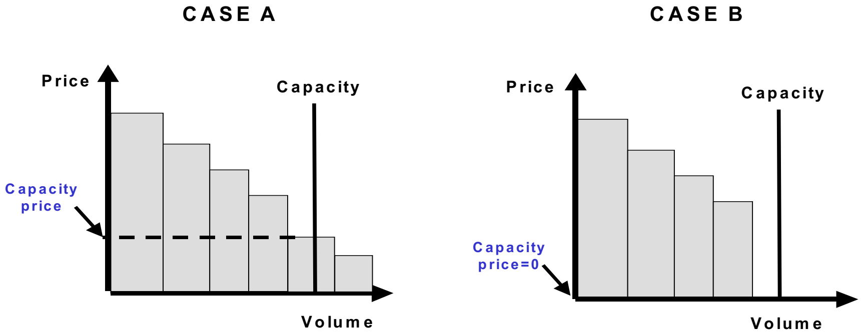
[41] See Case B box 9-2, figure 9-5

Box 9-2: Price formation mechanism for interconnector auction

The first step in the price formation mechanism is to determine the available capacity. The different system operators determine the available capacity in accordance with applicable laws and regulations. As soon as this capacity is defined the auction office informs market parties. Market participants wishing to acquire capacity then have to submit their bids, volume and prices, to the auction office. If the total amount of capacity asked by participants exceeds the available capacity (figure 9-5, Case A), all the highest bids, that when aggregated do not exceed the available capacity, are accepted. The remainder of capacity is awarded to the bidder that has submitted the next highest bid. This last bidder will only receive part of the capacity it requested. The price of the capacity corresponds to this lowest accepted bid, and every party will pay the same price. If the total amount of capacity requested by participants is equal to or lower than the available capacity the clearing price is zero (figure 2, Case B). In other words, when there is no congestion the price of interconnection capacity is zero.

Figure 9-5: Price determination mechanism



Due to the relatively low level of interconnection capacity at the European level, several TSO have chosen auctions to allocate the "remaining"[42] cross-border capacity. Although auctions present a significant improvement compared to non-market-based mechanisms they still present important drawbacks. A classical criticism of auctions is that they allow TSO to extract profits from congestion. Hence, auctioning interconnector capacity may create perverse incentives

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[42] The rest of the capacity consists of that allocated to long term contracts signed before the new regulatory framework

especially in the presence of vertically integrated suppliers and network operators. Since congestion creates revenues for the system operator, it has no incentive to make new investments in interconnection capacity as these will involve a reduction in its revenues. In the presence of a vertically integrated supplier and network operator, the supplier has the incentive to influence national market prices to allow it to rise extra revenues from congestion. Therefore auctioning of capacity in some circumstances can be criticized as an abuse of dominant position (Albers, 2001). These two weaknesses can be handled by clear unbundling of supply and network operations, as clearly stated in the EU Directive, and by forcing TSO to not consider congestion rent as a profit, for example by forcing them to use it for new investment in capacity or to reduce costs for cross-border transactions.

A real problem with bilateral auction is that they allocate physical rights for transmission. As presented above, TSOs define available interconnector capacity *ex-ante*. However the real available capacity can only be determined once physical flows are known due to loop flows, contingencies and deviations from expected estimations of the available capacity. For this reason, the available capacity defined by the TSO, and auctioned, is lower than the real available capacity because it is necessary to take into account a rather high safety margin. Thus the separation between energy flow and transmission capacity is artificial and this results in an inefficient mechanism. Moreover, from a practical point of view, this separation increases risk for market players, as trader have to buy interconnector capacity before the spot prices are known.

Even assuming that system operators are able to define accurate levels of available interconnector capacity, the last category of flaws regarding pricing of interconnector capacity is related to the detail of their practical implementation. In practice, the capacity of a large number of interconnectors is still allocated according to non-market-based mechanisms. Moreover, when market-based mechanisms are used they are often used in combination with non-market-based mechanisms, i.e. one part of available capacity is allocated via auction while the remaining part is allocated via non-market-based mechanisms. For instance, for the capacity of a single interconnector, one part can be allocated to long term contracts signed before the new regulatory framework, another part can be allocated using to pro-rata rationing and a last part allocated according to auction. Added to this, auctions are run simultaneously but separately in each direction, from country A to country B and from B to A. Such a system does not allow netting between the two directions and does not reflect the physical characteristics of electricity flows, i.e. two flows in opposite directions cancel each other. Finally, the design of the auction also represents an important issue in the sense that a poorly designed auction can hamper efficient arbitrage (box 9-3).

Box 9-3: The interconnection France-UK: a poorly designed auction?

The auction between France and UK represents an interesting example of a poorly designed auction. One, the auction is a pay-as-bid auction, which mean that the rights for using the auction are allocated to the highest bidders at the price they offer. As discussed in chapter 4 the choice for such type of auction has important drawbacks. For instance, pays-as-bid auction can have an important impact on the behavior of market participants and may be discriminatory toward new entrants. Further the capacity does not have a unique price and thus the different participants do not pay the same price.

Two, the definition for the time period of the daily auction is a daily period of 24 hours from 23.00 to 23.00 UK local time. Hence, while prices vary widely over the day, players willing to arbitrage these two markets cannot do it on an hourly basis and are forced to buy capacity for a day at an average daily price. Such characteristics reduce trading possibilities and discourage participation from small players who may want arbitrage between specific hours. This is especially important because for instance, the price difference between the two markets can be positive during the night and negative during day. Hence, such system favors large players who are more likely to be able to arbitrage the markets. This lack flexibility is unlikely to favor arbitrage.

Three, all bids are subject to a reserve price of 3 Euro/MWday. The existence of such a reservation price represents a barrier to trade since in a market with low margin, it may be higher than spread between the two markets, this combined with the lack of netting limit arbitrages possibilities.

In conclusion, although the Member States decided at the sixth Electricity Regulatory Forum in Florence meeting that their allocation procedures should comply with an agreed set of rules based on market mechanisms, in practice different methods are still being used and non market-based methods remains in many cases. Moreover, beyond the shortcoming of explicit auctions and non-market-based mechanisms, the total capacity of a single interconnector can be allocated according to different methods which reduces transparency and may favor incumbents. Finally, the total separation of transmission pricing mechanisms from the operation of energy markets, power exchanges in particular, does not allow efficient usage of transmission capacity. Hence, an important weakness of the actual market design based on bilateral auction is that it ignores the implications of trade on one path of the network for the rest of the network.

9-4 Empirical evidences of inefficient transmission pricing

9-4-1 Introduction

A first measure of the efficiency of actual transmission pricing between countries can be done using hourly interconnector auctions results[43]. Thus in this section such an analysis is done using the following explicit auctions: Germany-Netherlands, Germany-Denmark, Belgium-Netherlands, and UK-France. The data used in this section are hourly results of interconnectors auctions[44]. Such an analysis will shed light on the problem of netting, i.e. power flows in opposite directions “net” each other. For this purpose we have looked the results of explicit auctions and identified the number of occurrence where within a single hour two prices, from A to B and from B to A, for physical rights coexists despite a lack of economic sense. Such situations reveal economic inefficiencies since in theory the price level of the auction should equal the difference between the two locations. In other words, no positive price should exist from the expensive location to the cheap location because no players will transport electricity from a

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[43] or daily in the case of the auction between France and the United Kingdom

high-price to a low price area will all the corresponding losses entailed in such an action.

We will then compare the results of the auction with price differentials between power exchanges. Since there is no power exchange in Belgium this analysis could only be done for three cases, Germany-Netherlands, Germany-Denmark, and UK-France. The idea is to compare price differentials between exchanges and auctions results for interconnection capacity which link the respective exchanges to asses the efficiency of the actual cross-border transmission pricing scheme and power exchanges prices. In an efficient market these two values should be equal. To the extent that they are not, indicates the inefficiency of the actual transmission pricing system. Concretely, we first estimated the theoretical interconnector price between the locations using power exchanges prices according to formula 9-1:

$$T_t = Y_t - X_t \qquad (9\text{-}1)$$

where T_t is the theoretical price for transmission between X and Y at time t, Y_t the price at location Y at time t and X_t the price at location X at time t. In the absence of transmission constraint Y_t equal X_t , and T_t equal zero. For different locations, we compared T_t with the actual results of the auction (R_t). While in theory only one price for transmission exists, from the cheap location to the expensive location, the design of the auction, e.g. no netting and/or reservation prices, produces on several occasion prices in both directions. For this reason, when X_t is higher than Y_t we use the result of the auction from Y to X and when X_t is lower than Y_t we use the result of the auction from X to Y (table 9-6). In an efficient market T_t and R_t should be equal and the difference between T_t and R_t measures the level of (in)efficiency (E_t) of the system. For instance if the price of UKPX at time t is higher than the price of Powernext at time t, i.e. the difference

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[44] Germany-Netherlands/Belgium-Netherlands: www.TSO-auction.org; Germany-Denmark: www.eltra.dk; UK-France: www.rte-france.com

UKPX minus Powernext is positive, we use the result of the auction France-UK. This is consistent with the locational model where, in theory, the result of the auction UK-France should equal zero and thus it makes little sense to use it. Our results are then split into two categories:

Table 9-6 Efficiency measure

	Theoritical price (Tt)	Actual price (Rt)	Efficiency measure (Et)
If Yt > Xt	Yt-Xt	Auction from X to Y	Tt-Rt
If Yt < Xt	Xt-Yt	Auction from Y to X	Tt-Rt
If Yt = Xt		No congestion	

9-4-2 The problem of netting

Netting of opposite direction flows has two main advantages compared to separate auctions for import and export. One it gives more capacity to the market, assuming that the TSO can rely on the flows in both directions really taking place. Two, it ensures that the price of the interconnection is only for one direction, i.e. from the cheap location to the expensive location. In order to illustrate the inefficiency of separated two-direction auctions, we computed the number of occurrence where two prices, from A to B and from B to A, coexisted. These results are presented in table 9-7 for the year 2002. The first analysis shows that in 3% to 70% of the hours in 2002, auction results led to inefficient outcomes, i.e. one positive price in each direction.

Table 9-7: The inefficiency of separated two-direction auctions

	Fra-UK	Bel-Nl	Ger-Nl	Ger-Den
Frequency	47*	229	6147	4435
%	13%	3%	70%	51%
Frequency (> Pr)**	31	139	2993	1557
%	8%	2%	34%	18%

** This auction is a daily auction ** Pr is the resevation price*

However due to the existence of reservation prices, positive prices can occur even in absence of congestion in one direction. For this reason the second part of table 9-7 only shows the number of occurrences when two prices coexisted and when both prices were higher than the reservation price. As expected the number of hours where two prices coexisted decreased significantly, for instance, from 70% to 34% between Germany and the Netherlands. The fact that some players bought interconnector capacity at the reservation price, almost for free, can be a rational behaviour in a situation governed by uncertainties. Indeed, it can be interpreted as an option to move power from one location to the other if prices differences move a direction opposite to that expected. However, once this has been taken into account the results shows clearly that the auction results are inconsistent with what one would expect in an efficient market for a significant number of hours, ranging from 2% to 34%. Hence, the design of the auction characterised by the absence of netting induces significant economic losses.

9-4-3 France-UK

An analysis of the results from the auction of transmission capacity between France and the UK requires that specific attention is given due to the design of this auction[45]. Since this auction is a daily pay-as-bid auction, the other auctions considered are hourly marginal price auctions, several prices can exists and are expressed in Euro/MW per day[46]. In order to allow comparison with a theoretical price we first had to estimate an average price for each day. This average price is a volume-weighted average of prices. For example on the 11th of January 2002 the results of the auction from France to the UK were the following:

- 100 MW at 4,16 Euro/day
- 25 MW at 3,06 Euro/ day
- 25 MW at 3 Euro/ day
- 100 MW at 3 Euro/ day

Hence the actual average price per MW per day was calculated as follows:

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[45] See box 9-3

[46] In contrast to Euro/MW per hour for the other auctions

$[(100\times4,16)+(25\times3,06)+(25\times3)+(100\times3)]\div(100+25+25+100)=3,47$ Euro/MWd

The average price per hour is:

$3,47\div24=0,14$ Euro/MW

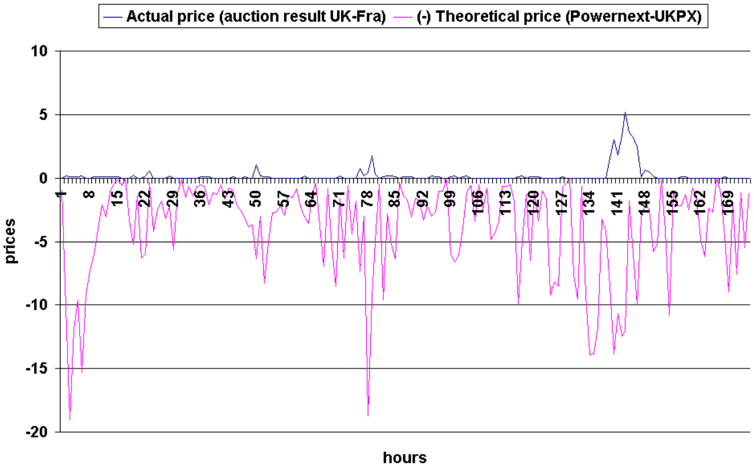
Once the average actual price was determined for both directions (France-UK, UK-France), we considered the sign of the spread between UKPX prices and Powernext prices to allowed us to choose the relevant auction result for our comparison. The daily average prices of UKPX were higher than the daily average prices of Powernext for 191 days and lower for 174 days in the year 2002. The results of our efficiency estimation are presented in table 9-8.

Table 9-8: Efficiency of the France-UK interconnection pricing

	Occurence	Mean (Tt)	Std Dv (Tt)	Mean (Rt)	Std Dv (Rt)	Mean (Et)
UKPX > Powernext	191	5,66	0,95	3,77	6,09	1,89
UKPX < Powernext	174	4,02	3,80	0,21	0,68	3,81
UKPX = Powernext	0	-	-	-	-	-

Table 9-8 shows that when the price of UKPX was higher than the price of Powernext the average difference between the two exchanges was 5,66 Euro/MWh while the average price for interconnection capacity was 3,77 Euro/MWh. The difference between these two prices represents the extent of inefficiency of transmission pricing from France to the UK. Figure 9-7 illustrates the opposite case, UKPX<Powernext, at a finer level, actual daily prices resulting from the auction and theoretical prices multiplied by minus one to give the opposite have been plotted. If the theoretical and actual prices were equal for each day, this graph would show perfect symmetry between the two curves. The extent of the asymmetry between the two curves indicates the extent of inefficiency of the mechanism.

Figure 9-7: Actual prices and theoretical prices (case: UKPX<Powernext)



These results show that market participants are able to secure interconnection capacity at a lower price than the theoretical price in both directions. This can be interpreted as serious lack of competition for acquiring transmission rights, and this is consistent with the results of the auction which shows that very few players are competing. The pay-as-bid system allows the number of bidders accepted for each day to be identified, and during the year 2002 on average about 1,6 bids per day were accepted. Even, under the assumption that each player only made one bid these results show clearly that in practice very little competition takes place at the auction. The highest difference of 3,81 Euro/MW between theoretical price and actual prices (from France to UK) reflect that, with the exception of EDF, very few players are able to export electricity from France to the UK on a short-term basis. In the opposite direction, more competition seems to take place but the actual outcome of the auction remains lower than one would expect in an efficient market. This indicates that in both directions the actual system is inefficient since markets participants have been able to secure capacity below its arbitrage value and hence increase trading profits.

9-4-4 Germany-Netherlands

The interconnections between Germany and the Netherlands are of particular interest for three reasons. One, prices in the Netherlands are significantly higher than in neighboring countries which creates important opportunities for cross-border trading[47] and thus a high demand for interconnection capacity. Two, the comparison of exchanges prices is especially relevant because a specificity of the Dutch system is that parties who acquired import capacity on the daily auction are obliged to trade the electricity transmitted on the Dutch side through the Dutch Power Exchange[48]. Three, in practice, two auctions exist between Germany and the Netherlands (E.on-TenneT and RWE-TenneT[49]) while it would appear simpler to combine E.on-TenneT's and RWE-TenneT's capacity to form a generic "Germany-TenneT" capacity.

In contrast to the UK-France interconnection, the short-term capacity between Germany and the Netherlands is allocated according to an hourly marginal price auction. This design allows us to investigate the efficiency of the mechanism at a finer level by using hourly prices rather than daily prices. Such a level is better since electricity prices vary widely within the days and it is thus likely that price spread between markets also differs within the days. Due to the existence of two auctions we first compared the outcome of these two auctions for the year 2002. Since these two auctions have exactly the same design, auction format, timing, price formation mechanism etc, and that they both allow market participants to move power from Germany to the Netherlands, they could be considered as perfect substitutes. As such one would expect that prices at the two auctions would be equal for any period. However as shown in figure 9-8, though the two prices behave similarly and are often the same, the results of the two auctions are not always equal revealing a first level of inefficiency.

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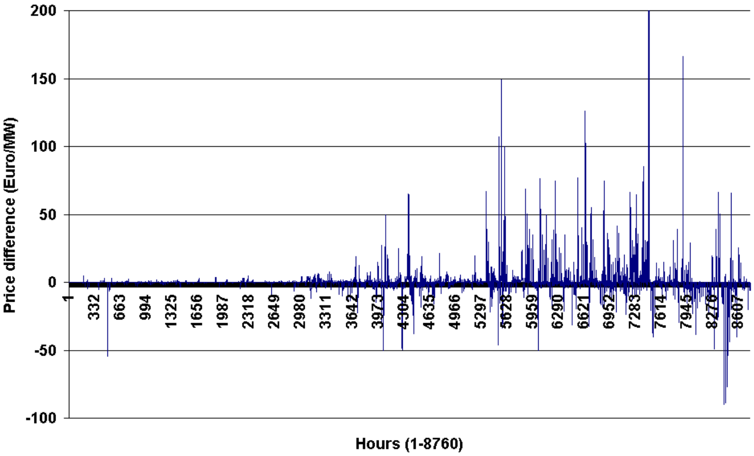
[47] Price differences can be largely attributed to differences in system marginal cost, domination of gas-fired in the Netherlands, coal and nuclear in Germany. See chapter 7

[48] See chapter 5

[49] See www.TSO-auction.org

Figure 9-8: Difference between E.on-TenneT and RWE-TenneT (E.on minus RWE)



On average the difference between the two auctions was 1,47 Euro/MW. As can been seen, such a difference is largely due to some “spikes” in differences. The largest difference was observed on the 7th of November at hour 15 where the price E.on to TenneT was 555,01 Euro/MW and the price RWE to TenneT was 50,08 Euro/MW showing important inefficiency in the arbitrage mechanism between the two auctions.

A second level of inefficiency was estimated by comparing the hourly results of the auctions with electricity prices differences from the APX and the LPX. The results of the comparison between theoretical and actual prices for the interconnection capacity are presented in table 9-9.

Table 9-9: Efficiency of the Germany-Netherlands interconnection pricing

	Occurence	Mean (Tt)	Std Dv (Tt)	Mean (Rt)	Std Dv (Rt)	Mean (Et)
LPX > APX	3842	3,96	8,39	0,04	0,09	3,92
LPX < APX	4912	16,36	46,43	12,58	35,23	3,78
LPX = APX	6	-	-	-	-	-

These results show that, surprisingly, the arbitrage between Germany and the Netherlands is not just in one direction. Indeed for 3842 hours during the year it was profitable to buy electricity in the Netherlands and sell it in Germany, i.e. 44% of the time. However the average of the theoretical price for interconnection shows clearly that when the APX price is higher than the LPX price the price difference is on average higher (16,36 Euro/MWh) than in the other direction (3,96 Euro/MWh). Similar to the auction between France and UK, these results show that in both directions, market participants are able to secure interconnection capacity at a lower price than the theoretical price. This is measured by E_t which, in both directions, is close to 4 Euro/MW (3.92 and 3.78). A first reason for this difference is related to the separation of the energy markets, i.e. the power exchanges, from the market for transportation, i.e. capacity auction[50]. This has important consequences in terms of “timing”. Timing refers to the period when trading is allowed, i.e. when buyers and sellers are allowed to submit bids, and when results are communicated to market participants. The prices for capacity are determined via the auction based on the expectation of market participants about spreads between the two energy markets. The prices cannot be adjusted if the results of the power exchanges, which are known later, are different. This design means it is therefore likely that differences will occurs between theoretical prices and actual prices. What is important is the extent of this difference.

Without access to the data per players it is quite difficult to identify the reasons for such lack of competition. However one major issue concerning this auction is the fact that both RWE and E.on are vertically integrated with their grids and TSOs. One can speculate that these two players may have access to confidential information about biding behaviors of others participants. The important point is that what price vertically integrated utilities pay for interconnection capacity is half

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[50] See 9-3-3

of the price that other players pay because half of the revenue[51] of the auction goes to the German "TSOs" which they own. The fact that a significant part of the revenues of the auction goes back to some of the market participants may distort competition.

9-4-5 Germany-Denmark

The interconnection between Germany and Denmark also represents an interesting example since it links together the Nord pool area and the largest continental market. For this purpose we use the price from the German power exchange (LPX) and the price produced by Nord pool for Denmark West (hereafter Nord pool DK).

Table 9-10: Efficiency of the Germany-Denmark interconnection pricing

	Occurence	Mean (Tt)	Std Dv (Tt)	Mean (Rt)	Std Dv (Rt)	Mean (Et)
LPX > nordpool DK	3566	7,39	15,88	5,42	20,48	1,97
LPX < nordpool DK	5194	9,96	13,94	3,63	7,48	6,33
LPX = nordpool DK	0	-	-	-	-	-

The hourly prices of LPX were higher than the daily average prices of Nord pool DK for 3566 hours and lower for 5194 hours for the year 2002. Table 9-10 shows that when the price of LPX was higher than the price of Nord pool DK the average difference between the two exchanges was 7,39 Euro/MWh while the average price for interconnection capacity was 5,42 Euro/MWh. The high standard deviation of theoretical prices reflects important volatility for certain hours on both exchanges. From Denmark to Germany, the price for transmission was on average 1,97 Euro/MW lower than its theoretical value and 6,33 Euro/MW lower from Germany to Denmark. This indicates that on average, players exporting electricity from the German exchange to Nord pool DK, when it was profitable to do so, made 6,33 Euro/MWh of extra profit.

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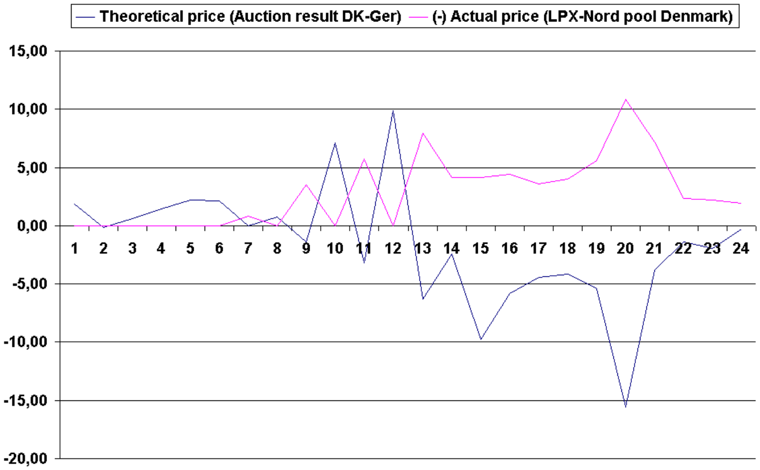
[51] The other half goes to the Dutch System operator

Figure 9-9 illustrates these results. Using an example (the 27th of March 2002), this graph plots the theoretical prices and the of the actual prices time minus one. The extent of the asymmetry shows the important differences between actual prices and theoretical prices. For hours 12 and 17 the prices on LPX were 41,42 and 22,28 Euro/MWh and the prices in Denmark were respectively 51,29 and 17,81 Euro/MWh. In the first case it was profitable to buy electricity in Germany and sell it to Denmark and vice versa in the second case. In the second case the difference between the theoretical price (4,47) and the actual price (3,56) indicates some inefficiency but this is relatively low. However, in the first case the difference is huge. While the theoretical price should have been 9,87 Euro/MW for moving electricity from Germany to Denmark, the actual price was 0.

Figure 9-9: Actual prices and theoretical prices (example: 27/02/2002)



Again these results suggest that the auction does not work properly. Similar to the previous example, timing of the auction and timing of the power exchange may explain part of the difference. However, only an analysis of the details data per player would allows us clearly to understand the reason for these differences between theoretical and actual prices. Without such confidential information, one may only point out the fact that the auction on the German side is handle by E.on Netz. In Germany system operation is left to vertically integrated utilities and no national system operator has been created. Hence, as for the auction between the Netherlands and Germany, one may speculate that the lack of neutrality of the organization that runs the auction has an impact on the extent of competition.

9-4-6 Conclusion

The empirical analysis illustrates the fundamental flaws of separating markets for interconnections and markets for energy. One, in all cases the absence of netting results in the existence within a few hours of two prices, from A to B and from B to A, for physical rights against any economic logic. Two, a comparison of the results of the auction with price differentials between power exchanges reveals significant inefficiencies. In particular this analysis shows that market participants were able to secure capacity below its arbitrage value. Such inefficiencies do no exist in systems such as Nord pool and PJM because transmission pricing and energy markets are integrated through a centralized power exchange, i.e. there are no transmission rights, there is only an energy market which takes into account directly the problem of transmission constraints. Thus, it appears that the actual design of European electricity markets based on the separation of transmission pricing and energy markets represents an important reason for the poor level of integration at the European level.

9-5 Conclusion

In this chapter we have shown the importance of transmission pricing in electricity markets. In this respect economic theory of transmission pricing provides interesting guidance, although the debate between academics continues as to which approach is the best, i.e. nodal or zonal. Moreover successful examples such as Nord pool and PJM show that there is not only one model which works. However with respect to the role of organized markets, it appears to be fundamental that a single institution should combine system operations (TSOs) and market operations (power exchanges) regardless of the choice made between nodal and zonal system. Such an integration allows the marketplace to handle transmission pricing and thus use transmission capacity efficiently.

In Europe transmission pricing and energy trading are treated separately bringing into play a physical transmission rights system. Such a system presents serious limitations with respect to efficient usage of the system and loops flows. Moreover, although the Member States have decided at the sixth Electricity Regulatory Forum in Florence meeting that their allocation procedures should comply with an agreed set of rules on congestion management based on market-based mechanisms, in practice several non-market based methods are still being used. Finally, when market-based mechanisms are used, empirical evidence suggests that their outcome is far from what can be expected in an efficient market.

In conclusion, despite the goodwill of the parties attending the Florence forum, the fact that the Directive 96/92 lacks a design for handling cross-border congestion has led to the creation of a non-harmonized patchwork of (mainly) non-market-based methods. Moreover, the separation between transmission and energy markets has led to inefficient transmission pricing and appears to be a fundamental reason for the poor level of integration between European electricity markets. Several measures needs to be taken to improve the functioning of the market with respect to market design but also with respect to “market regulation” in general. These aspects are discussed in chapter 10.

Chapter 10

Power exchanges: cornerstone for "market" regulation

The absence of an effective market design at the European level, coupled with the patchwork of electricity markets operating at the national level has been shown fundamentally to affect the creation of an integrated electricity market within the EU. In this chapter we analyze the role of power exchanges for achieving this goal. We will consider a broad definition of regulation which includes promoting competition through market design and preventing unfair trading practices through market monitoring. We emphasize the importance of power exchanges for monitoring market performance and market design developments. We present the interests and drawbacks of the recent works realized by the European Commission and other European associations such as the European association of transmission system operators and council of European energy regulators with respect to power exchanges. Finally we present some guidelines for the creation of a "European" framework for market regulation based on effective market monitoring using power exchanges that in turn will help effective market design to develop.

10-1 Redefining regulation

10-1-1 Introduction

The process of introducing competition in electricity markets is often called a "deregulation process", a term which can be interpreted at a first glance, as the removal of any form of regulation. However developments in wholesale electricity markets shows that the introduction of competition in electricity markets requires the setting up of new types of regulation. The term "regulation" is commonly used in the literature and in practice, but how it is defined and used can vary widely. With respect to economic literature (Baumol *et al*, 1982) and to electricity markets, "regulation" is commonly used to define the regulation of the natural monopoly elements[1]. However regulation has a broader meaning. The Oxford Dictionary of Economics defines regulation as:

"A rule individuals or firms are obliged to follow: or the procedure for deciding and enforcing such rules […] These may be designed to promote public health and safety […] They may be designed to promote competition and prevent unfair trading practices […] In the last resort regulation relies on legal sanctions […]"

For the purpose of this chapter we use this broad definition of regulation which includes promoting competition, preventing unfair trading practices and in the last resort using legal sanctions. In this section we will briefly present the "traditional" concept of regulation with respect to regulation of the natural monopoly (10-1-2). Going into the details of this concept as they apply to electricity markets is beyond the scope of this work, however it is useful to provide an outline of the main principles. Subsequently, we argue that to achieve competitive electricity markets it is necessary to consider a broader definition of regulation including "market" regulation and not only "monopoly" regulation (10-1-3). The purpose of "market regulation" is not to (re) introduce price controls or any other type of direct regulation but rather to establish the rules of the game through "ex-ante regulation", i.e. market design, supervising the functioning of the markets through "continuous regulation", i.e. market monitoring, and ensuring competitive outcomes through "ex-post regulation", i.e. antitrust policy. We do not elaborate on the latter because once the specificity of the electricity industry is recognized, the way antitrust policy deals with dominant market positions should be similar to other industries.

We first elaborate on the issue of ex-ante regulation applied to the European electricity markets and show that this part of regulation has been, and is still being, widely overlooked in the liberalization process. In particular we focus on the recent work realized by the European Commission and other European association such as the European association of transmission system operators and council of European energy regulators with respect to power exchanges. Though power exchanges are often mentioned in these works, their potential role has not been fully recognized (section 10-2). Subsequently, we suggest how power exchanges can be used to implement market regulation in Europe by facilitating market monitoring. Finally several recommendations with respect to designing a really integrated market based on power exchanges are presented (section 10-3).

10-1-2 "Classical" regulation

The economic literature on utility regulation concentrates on the regulation of the natural monopoly elements. Hence, a large amount of the literature has focused on the definition of the natural monopoly concept (Schamalensee, 1979; Braeutigam, 1989; Viscusi *et al*, 1992). The purpose of regulation in the electricity sector is to prevent natural monopolies abusing their market power (Joskow and Schmalensee, 1983; Littlechild, 2001). Before liberalization the vertically integrated utilities were subject to regulation as a whole. After

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[1] After liberalization, the "classical" natural monopoly elements in the electricity industry are energy transmission and distribution grids because the cost of two or more firms building a grid to serve the same customer would be prohibitive.

liberalization the main purpose of regulation has become the distribution and transmission of electricity while production and sales have become competitive ("deregulated") businesses.

According to Baumol and Sidak (1994) the purpose of regulation is *"protection of the public from the detrimental consequences of inadequacies of competition".* The main problem faced by regulators is the asymmetry of information between the regulator and the regulated utility (Loeb and Magat, 1979; Baron and Myerson, 1982, Laffont and Tirole 1993; Shleifer, 1985). The regulator is always confronted with information disadvantage concerning the true costs of the firm it has to regulate.

In practice, *rates of return* and *price cap* regulation represent the two basic regulatory schemes for controlling prices (Berg *et al*, 1998). Under rate of return regulation the regulator defines a set of rate that ensure the firm will recover incurred expenses plus a risk-adjusted return on its rate based. The flaws of such regulation are well known. The most important one relates to over-investment incentives when the rate of return exceeds the cost of capital because revenues are linked to costs (Averch and Johnson, 1962). Price cap regulation guarantees prices rather than returns (Littlechild, 1983). Under price-cap regulation, also known as CPI-X schemes, the regulator defines an initial maximal price, the price-cap, at which the regulated firm can sell its service[2]. The regulator may allow the price-cap to be adjusted over time by a predetermined adjustment factor, the efficiency factor, external to the firm to simulate the pattern of competitive markets. The main issue in price-cap regulation is thus the determination of the level of the price-cap and the value of the efficiency factor.

In conclusion, regulation of the natural monopoly is dominant in the literature covering the concept of "regulation" in the electricity industry. From a theoretical point of view the discussion focuses on the different interests and drawbacks of the two main approaches, i.e. rate of return versus price-cap, and on the constraints faced by the regulators, i.e. asymmetry of information. Numerous comparative studies reveal the differences in applying these concepts in practice (Joskow and Rose, 1989; Gilbert and Kahn, 1996; Midttun, 1997). Yet little attention has been paid to regulation in a broader sense with respect to designing and monitoring markets.

10-1-3 “Market” regulation

“Market” regulation as mentioned above refers to promoting competition, preventing unfair trading practices and at the last resort defines legal sanctions. Concretely market regulation consists firstly of defining the rules of the game, and secondly enforcing obligations and monitoring performance (figure 10-1). Such regulations are necessary in electricity markets for two reasons. First because electricity is physically different from all other commodities but also, and this is the most important reason, because the well functioning of any market, e.g. commodities, stock exchanges, labor markets etc, involves a minimum level of regulation. For instance, financial markets which are often cited as the most competitive markets are heavily regulated[3].

Figure 10-1: “Market” regulation

In contrast to most goods and commodities where markets have existed for some time, in some cases centuries, and have evolved over the years, electricity

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[2] The regulated firm’s price increase is limited to the rate of inflation, estimated by the Consumer Price Index (CPI), less an agree efficiency factor (“X”) based on expected productivity improvement. Hence the price cap scheme restricts price increases to “CPI-X”.

[3] See for instance the impressive amount of rules governing the New York Stock exchange, available at www.nyse.com/regulation/

markets were created in the last decade of the twentieth century following political decisions to liberalize markets. As a start to this process a set of regulation principles, dealing with the "market design of the industry structure"[4], was adopted. The focus of early regulations was on the separation of production from transport and third party access to the network. In Europe these principles can be found in the electricity Directive 96/92[5]. However, regulations concerning the detail rules of the market design and monitoring principles are missing in this document. In Chapters 8 and 9 we have shown that the emergence of power exchanges at national levels, and the absence of a common consistent market design at the European level with respect especially to transmission pricing, represent an important reason for the low level of integration found in the European electricity markets. A first important part of market regulation is to produce a market design which can be considered as ex-ante regulation because the design process must be done before any interaction on behalf of market participants. The threat of market power due to a high level of concentration[6] and the inter-temporal features of electricity gives rise to a need to monitor performance and this represents a fundamental step before sanctions can be brought for possible abuse of market power. Since designing electricity markets is a controversial issue, as showed by the theoretical debates and the international experience, effective market monitoring will require the efficiency of the market design to be assessed on a regular basis. With time this should give rise to proposals for corrective measures. This regulation can be considered as continuous regulation because it analyzes on a regular basis the outcomes of markets.

From an intellectual point of view it would appear logical to start with market design, then market monitoring, and based on the outcome of the monitoring, improve the market design. This is the logical sequence when starting from scratch. However in practice, regulation bodies do not start from scratch they are

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[4] See chapter 3

[5] See chapter 2

confronted with the actual conditions, i.e. actual market designs, and need to consider these initials aspects. Hence, accurate market monitoring of the actual situation needs to be considered first. Subsequently, based on the outcome of market monitoring, the regulatory bodies can go on to improve the market design. Since it is difficult to get every thing right at the outset, it is worth noting that these two aspects of market regulation are dynamically interrelated, i.e. after an improvement in market design, monitoring is again necessary to assess the performance of the new market design which in turn may lead to recommendations for further changes in the market design and so on.

10-2 Difficulties for designing and monitoring markets in Europe

10-2-1 Introduction

To date, little attention has been paid to market regulation in Europe and most work has focused on implementing the EU electricity Directive 96/92. However, market design and market monitoring are important for the creation of well-functioning markets. In particular it is important to keep in mind how these two aspects of market "regulation" are dynamically interrelated, i.e. market design must pay attention to potential behaviors of market participants and the monitoring of these behaviors is a necessary step for the identification of design flaws and proposals for corrective measures. In focusing only on legal aspects the EU Directive has overlooked these aspects. Indeed, the Directive provides *"a framework is the loosest sense of the word: its objectives are laid down in general terminology and moreover, Member States are given a substantial degree of choice in how they are about introducing more competition into their electricity markets. Indeed the margin is so substantial that it would seem possible for the determined anti-market countries to avoid introducing any meaningful degree of competition at all"* (Hancher, 1997). Thus, in the absence of any guidelines on what the European electricity market should look like, an integrated market has failed to develop[7] and this can largely be attribute to the

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[6] See chapter 7

[7] See chapter 8

fact that market design, e.g. the rules and functioning of wholesale markets, transmission pricing etc, have not receive due attention[8].

In the face of this lack of guidelines a large part of the electricity market design, e.g. power exchanges, has been done at the national level and left to the principle of subsidiarity. The central problem is that, in presence of different designs in each country, national markets may be hard to integrate as their varying designs will prevent this (Smeers, 2001a). Nonetheless, important efforts have been produced at the European level mainly by the association of transmission system operator (ETSO), the association of regulators (CEER) and through reports the European Commission has commissioned to assess the implementation of the Directive and to suggest recommendations for improvements. Roughly speaking works by ETSO and CEER discuss issues that are not addressed in the Directive, while work by the European Commission provides analysis on the progress of the liberalization process.

The Directive deals with primary conditions necessary for the creation of a market, unbundling, TPA etc. Since it is difficult to get everything right at the outset and since dealing with details of market design make little sense before addressing the primary conditions, one would expect that work produced after the implementation of the Directive would have pay attention to the issue of market design. Unfortunately, the EU Commission has focused mainly on the implementation of the Directive without paying attention on the issue of market design. While the "Florence process"[9] did not address the issue of market design in general but focused only on one specific issue of market design: cross-border trade, i.e. international congestion management and compensation mechanisms for cross-border flows. Moreover, it is worth noting that the recommendations defined in these works have no legal power and thus their implementation is voluntary due to the absence of any legal authority to impose them. Thus while

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[8] See chapter 9

market design at the European level was not addressed in the Directive of 1996, most of the recommendations which have followed firstly they have not addressed all issues related to market design. Secondly in the absence of any legal power they have failed to impose common features on the European electricity markets.

In this section we look at the EC and Florence process work, which have followed the Directive and shed some light on their shortcomings with respect to market design and the potential role of power exchanges at the European level (10-2-2). Since one practical way to detect problems in market design is to ensure effective market monitoring, we shows that the approach followed by the European Commission to supervise the development of the liberalization process is poorly suited for assessing the creation of an integrated electricity market (10-2-3). Finally, we analyze recent work by the EC and by ETSO which provides interesting insights into what will be the next important issues on the agenda of the European liberalization process and the expected role of power exchanges (10-2-4).

10-2-2 Actual market designing: EC and Florence process

The problems related to the creation of a European electricity market were first identified by the European Commission in their second report on harmonization requirements (EC, 1999). While the first report only addressed the issues of energy taxation and environmental aspects (EC, 1998), the second report recognize that there might be areas *"which are not specifically address by the Directive, but nevertheless might require harmonization or at least which deserve regulatory attention to guarantee the proper and efficient functioning of the internal electricity market"* (EC, 1999). For this purpose the report focuses on three issues: the risk of creating 15 liberalized but separate markets, the need for regulation of electricity networks at the European level, and the need to ensure a

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[9] The "Florence process" is a forum convened by the European Commission to monitor and discuss the implementation of the Directive

level playing field at the European level. With respect to market design, two aspects of the report are of particular interests.

One, according to the EC, the central issue in the creation of a single electricity market is limited in terms of market design to access to interconnection capacity, while others aspects of market design, e.g. trading arrangements, wholesale market design, marketplace design, balancing mechanisms, power exchanges etc, are not mentioned. The assumption here is that a harmonized European framework for cross-border trading would be sufficient for the creation of an integrated market. However the report is silent on the other aspects of market design especially those at national level, e.g. power exchanges. Hence the main criticism that can be made is that it may make little sense to coordinate the different national markets if their design does not permit this to be done (Smeers, 2001b). For instance assuming a harmonized and efficient framework for cross-border trading at the European level, it appears difficult to integrate a market with a pool (e.g. Spain), with one with a voluntary exchange (e.g. France) and one without any organized marketplace (e.g. Belgium). The main assumption of the EC behind this report is that dealing with cross-border trade is sufficient to create an integrated market while the other aspects of market design are not mentioned. Hence with respect to market design at the European level it is worth noting that all attention and effort has been focused on cross-border trades.

The second interesting aspect of this report is the fact that it sheds light on what are seen as the two alternative approaches for dealing with harmonization issues. The first approach can be defined, as a "consensus" approach while the second one is a more traditional "legal" approach. In the consensus approach, the EC relies on consultation between parties and tries to reach a unanimous consensus. The second approach is more traditional since the EC will use regulatory instruments via for instance the creation of a "European Regulator". The advantages and disadvantages of these two approaches are also well described in this report.

At a first glance, the consensus approach appears to be faster because it does not require the creation of new institutions, treaties or rules. However such approach has two major drawbacks. First it requires that all parties agree, which means all Member States and the Commission. This is difficult, as demonstrated by the several years of considerable negotiations required to reach unanimous agreement before the first Directive was defined. It is thus difficult to determine how long such a process will take. Second assuming that unanimous agreements can be reached on specific points the question is whether the decisions would be applied. Indeed without there being a legal authority empowered to enforce application of the decisions it would be left to the Member States, and if a Member State refused to apply a decision, the EC would not have the legal power to impose it.

The "legal" approach would require the creation of new regulatory instruments at the Community level. In contrast to the consensus approach this approach would require new institutions that will first need to be defined and second, to be approved by the different authorities such as the European Council, the European Parliament and the Members States. The main disadvantage of this process is that it could take years of negotiations to be finalized. The major advantage is that once such a new instrument was in place, it would provide the EC with the clear power of a legal authority specifically designed to impose decisions at the European level. The EC does not present any preference between the two approaches in the second report (EC, 1999). However the following shows that in practice, a clear choice has been made in favor of the consensus approach to "designing" the European electricity market.

In response to the problem of cross-border trading, the EC initiated the creation of the European energy regulatory forum (EERF), also called the "Florence forum". In this forum, representatives from the council of European energy regulators (CEER), from the European transmission system operators (ETSO), from network users (Eurelectric), from the European federation of energy traders

(EFET), and other interested parties, market participants, power exchanges etc, discuss issues regarding the creation of the European electricity market. This forum does not address the issue of market design in general but focuses only on one specific issue of market design: cross-border trade, i.e. international congestion management and compensation mechanisms for cross-border flows. ETSO has produced several papers on this topic examining different approaches to solving the problems (ETSO, 1999; 2000a-b; 2001a-g; 2002a-c). of congestion management and compensation mechanisms for loop flows.

Two aspects of ETSO work are of particular interest with respect to the role of power exchange in market design. One, it appears that, according to ETSO, the role of power exchanges should be limited. While they have examined different approaches to congestion management, such as auctions, market splitting, redispatching etc, the nodal pricing approach has received no attention. It is surprising that the experiences of PJM, which provide an interesting solution for dealing with transmission pricing, have totally been left out of the discussion. Furthermore market-splitting which is as a simplified approach to nodal pricing has been rejected because it was thought to be impracticable. Two, the separation of energy and transport which gives rise to a need to define Net Transfer Capacity (ETSO, 2000a) is regularly presented as a problem because these capacities depend on the transactions that use them. While this problem has been recognized in several ETSO papers (ETSO, 1999; 2001c-f), the logical solution, combining these two products, is not considered.

Four years after the starting of the consensus process, and well aware of its limits, its failure with respect to cross-border trade has lead the European Commission to reconsider this approach and move towards the "legal" approach. The EC did not choose this approach in 1998 because it argued that it would requires new institutions which would take times to create. However, the real reason is certainly that the EC did not really have choice in the matter. In particular, the different parties present at the Florence process, but also the member States were against the creation of such an "EU regulator" which would have reduced their power and would have diminished their control on the decision process. However, in the face of a lack of power to implement the decisions made through the Florence process, the European Commission has made two legislation proposals amending the Directive 96/92 (EC, 2002a) and on conditions for access to networks for cross-border exchanges (EC, 2002b). These are largely based on the Florence process but give legislative power to the EC to implement the reforms. From a legal point of view, these legislation proposals are Regulations[10] which, if adopted, would be directly applicable in all Member States. The issue of congestion management is addressed explicitly (article 6) but it is presented in very general terms e.g. congestion must be addressed on a non-discriminatory, transparent, open manner. Thus, although this work represents a very important step in the market design process, it remains limited because again it only takes into account general principles for cross-border transactions and appears to be rather incomplete regarding any perspective for creating a real integrated market.

In conclusion, the EC and others interested parties have not address the issue of market design in general and have paid little attention to the role of power exchanges focusing instead on the harmonization of cross-border trading arrangements. Hence, in the absence of a real market design approach, the process of harmonization can be considered to be an "ersatz" form of market design. While the "consensus" approach was suppose to be faster, due to it not requiring the creation of new institutions and especially not a "European Regulator", it has proved to be relatively inefficient because any decision making has required a lot of time due to the need to reach a consensus within the interested parties. More importantly the outcomes of this consensus process have not been followed by implementation due to the absence of any legally enforcing power. The best illustration is the issue of the use of market-based

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[10] By opposition with Directives which must be transposed into national legislation, permitting Member States to make different interpretations and involving a time lag up to two years.

mechanisms for allocating transmission capacity which has been clearly recognized as a necessity since March 2000 (EERF, 2000b) but has not been implemented at most borders (EFET, 2003). The EC has been well aware of these difficulties since 1999 and recognized the problems of the efficiency of this approach in 2001. The Florence process is described as an "*effective tool in developing consensus on highly complicated issues*" but "*suffers from a number of disadvantages when it is necessary to reach concrete decision*" (EC, 2001a). Three disadvantages are identified: the forum only meets twice a year, full consensus is required, and no procedures exist to implement the decisions. While the two legislative proposals amended in 2002 and the EC Strategy Paper[11] represent an interesting step with respect to the creation of a common European market design, many aspects are still not addressed. An explanation of why the EC has not addressed most of the market design aspects can be found in the way the monitoring of the liberalization process has been done to date.

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[11] See 10-2-4

Box 10-1: Regulation No 1228/2003 on conditions for access to the network for cross-border exchanges in electricity

On 26 June 2003, the European Commission published Directive 2003/54/EC concerning common rules for the internal market in electricity (See box 2-1), and Regulation No 1228/2003 on conditions for access to the network for cross-border exchanges in electricity. Regulation (EC) No 1228/2003 is of particular importance for the allocation of interconnector capacity in that it contains new rules on cross-border exchange in electricity. This regulation is aimed at setting fair rules for cross border exchanges in electricity. The objective of this regulation is to harmonize cross-border transmission charges and the allocation of available interconnection capacities. This regulation is divided into three parts: compensation mechanisms for cross-border flows, harmonized principles on cross-border transmission charges, and allocation of available interconnector capacity. By definition this regulation does need to be implemented, it applies. Article 3 of the regulation defines the rules for compensation between TSO. This article states that TSO should be paid for cross-border flows, by source and destination but no extra charge should be paid for transits. According to Article 4 transmission should not be distant related, but can be location related. Article 6 states that no additional cross border tariff should be added, except in the case of congestion. Article 7 treats the issue of merchant interconnectors, which can be exempted for several rules, but the exemption must be granted by the national regulator, this is rather unclear since, by definition, a new interconnector involve at least two regulators.

This new regulation represents an important step forward but remains rather vague. For instance TSO are required to offer unused capacity but the fact that TSO must offer capacity does not ensure that the capacity would be actually used. With respect to netting, which is now required, where feasible, under the new regulation, the regulation leaves an important freedom for TSO to interpret the word "feasible". Finally the annex of the regulation provides guidelines for congestion management. These guidelines represent a step forward but they are presented in very general terms e.g. congestion must be addressed in a non-discriminatory, transparent, open manner. Finally the main limit of this regulation is that it keeps the separation between transport and energy. This requires determining available capacity in advance which remains problematic.

10-2-3 Actual market monitoring

According to the article 25 of the electricity Directive 96/92, the European Commission has to submit reports to the Council and to the European parliament concerning harmonization requirements and, if necessary, harmonization proposals for the internal market for electricity. The first report in February 1998 covered the issue of promoting renewable energy and harmonizing taxation regimes (EC, 1998). The second report in April 1999 looked at two important issues: the obstacles for cross-border trade and the problem of ensuring a level playing field in the European electricity market (EC, 1999). In this report the problem of implementing the Directive with respect to creating 15 separate, and rather isolated markets instead of a single market was identified as a major issue. This report taken in conjunction with the Commission staff working papers (EC, 2001a; EC, 2002a), and the communications from the Commission to the Council and European Parliament (EC, 2000a; EC, 2001b-e), represents the monitoring that has been done to date of the internal electricity market(s). However these works focus mainly on measuring the level of liberalization within markets following the principles defined in the Directive but say little about competition in an integrated European Electricity market. Thus just as the harmonization process of cross-border trade mechanism that can be considered to be an ersatz of market design, the monitoring of the liberalization process can be seen as an ersatz of market/competition monitoring.

The European Commission uses several indicators to monitor the liberalization process within the electricity market, however, these indicators only measure the level of liberalization which is different from the real degree of competition. Indeed, the main indicators are directly related to the implementation of the Directive, e.g. legal opening, the number of customers who have changed suppliers, unbundling and third party access. Additionally others indicators such as customer switching, price changes, market concentration, the existence of standardized wholesale markets, i.e. power pools, power exchanges, are also used to monitor the impact of the liberalization process on competition. While providing interesting insights, most of these indicators appear rather ill-suited or at least incomplete for efficient monitoring of electricity markets with respect to competition, market design and more generally the creation of a really integrated, competitive, market.

The European Commission has develop a *"set of indicators intended to measure the impact of liberalization on European electricity markets*" and aiming "*to identify the principal drivers for effective competition*" (EC, 2001f) to monitor the liberalization process. This important work, developed by a consortium of consultant and academics[12], is representative of the indicators used by the Commission. This analysis provides interesting insights about the liberalization process in Europe having established a robust methodology. However a large majority of these indicators have proved to be relatively uninformative regarding the real extent of competition.

The first indicator used by the European Commission to assess the level of liberalization is the "legal opening rate"[13]. This indicator measures the share of consumers who can choose between different suppliers. For instance, some markets present a legal opening rate of 100% that mean that they are totally open, e.g. Germany, United Kingdom, Sweden, while others present lower opening rates showing that some categories of consumers do not have the freedom to choose between different energy suppliers, e.g. Netherlands, France, Belgium. The limitation of this indicator is that it overlooks practical provisions which can favor or deter competition. For instance, if a market is totally open but if conditions to access to the grid are non-transparent and discriminatory real competition may fail to develop, despite "theoretical opening". A market with a low opening may be more competitive by ensuring easy access for eligible customers. For this reason, to be effective, market opening needs to be

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[12] led by Oxera, and supported by the Netherlands Energy research Foundation (ECN), the Energy System Analysis and Planing Group (ESAP) and the ATOM Center from Pantheon Sorbonne University (ATOM).

accompanied by several others factors. Thus, these thresholds are a poor indicator of the level of competition because competition requires a real choice for customers and not just an eligible status.

A second widely used indicator is the "switching rate". The idea behind this indicator is that in a competitive market eligible customers will switch to suppliers who offer better prices than their historical supplier. The first limit of this indicator is related to the lack of information available, i.e. obviously incumbents are reluctant to communicate the number of consumers they have lost. Second, a low level of switching does not necessary reflect the absence of competition because eligible consumers can simply threaten their supplier that they will switch and then renegotiate their contracts at a better price. Such behavior which directly results from the intensification of competition is not taken into account by switching rate.

Changes in prices are another indicator used frequently by the EC. Yet, analysis of price changes is relatively difficult because several elements differ between countries, e.g. taxes, environmental efforts, technologies used etc. Moreover prices changes are relative measures expressed as a percentage, therefore they do not account for an initial level. For instance, industry electricity prices[14] in the United Kingdom fell by 19 % between January 1999 and July 2001 while they fell by 4% in France. Nonetheless, it is hard to say, based on these measures, that competition was stronger in the UK than in France because prices were respectively 59 and 50 Euro/MWh in 1999 and were equal to 48 Euro/MWh in both countries in 2001.

One indicator used in these studies is the existence of wholesale organized markets, e.g. power exchanges. Though it is true that *"they contributes to the development of a transparent market price"* (EC, 2002), their existence provides

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[13] See chapter 2, figure 2-1

[14] Eurostat category Ig: Consumption of 24000 MWh/year

little information on the extent of competition. For instance, if one player is able to determine the market-clearing price or if several players collude the fact that an exchange exists is meaningless. It is just a marketplace where competition is expected to occur, it does not necessary mean that competition is actually taking place.

It would be unfair to say that all indicators presented in the report commissioned by the Commission (EC, 2001f), defining "Energy liberalization indicators in Europe", provide little information on competition. Indeed, four interesting indicators with respect to competition analysis are mentioned. The first one, market concentration is based on installed capacity, and despite its shortcomings it represents an interesting starting point, but only a starting point (see 10-3-3). The three others indicators that are of particular interest are number of participants that can set the system marginal price on the organized market, volume traded by non-domestic members on the organized market, and volumes and prices on the bilateral market.

In a competitive market no single player should be able systematically to set the market price. Hence identifying which players are setting the price on the power exchange provides interesting information on the extent of competition by allowing differentiation between a low level of competition in markets where one or a few players set the prices and from competitive markets where a large number of players can set the price. Similarly the volumes of electricity traded by non-domestic members appears to be an important indicator on the real role of international competition. Finally, analyzing the volumes and prices, and ideally the market share of each participants, in the bilateral market allows us to gain a detailed understanding of the actual role of each market participant. Unfortunately, though mentioned, these indicators are not used because providing them requires data considered as commercially confidential and thus not available to the EC.

In conclusion, the actual form of monitoring carried out by the European Commission to supervise the development of the liberalization process is poorly suited for assessing competition in an integrated electricity market. Amongst the numerous indicators, regularly monitored by the EC, market concentration is the only one that provides some information about competition, and this is rather poor with respect to the stakes of the liberalization process and the creation of a competitive European-wide electricity market. Finally, although mentioned, the interesting competition indicators based on power exchanges have not been used due to the EC's lack of power to access relevant information.

10-2-4 The proposals: coordinate auctions/Strategy paper

Recent works by the ETSO and the European Commission have provided interesting insights into what will be the next important issues on the agenda of the European electricity liberalization process with respect to market design and the potential role of power exchanges. But these works also illustrate the lack of a clear perspective on what the European electricity market should look like. The ETSO proposals consider two approaches, the use of coordinated auctions and market splitting/market coupling for allocating interconnector capacity. The different reports and discussion papers put out by ETSO present interesting approaches because they share the objective of improving the use of actual interconnections by taking into account several technical problems, e.g. parallel flows in meshed networks. The EC strategy paper is interesting because it recognizes the difficulties of market integration and provides some guidelines for market design which rely strongly on power exchanges and a timetable for implementation. Finally it is worth noting that, while to different extent, these works recognize the potential role that power exchanges may play in facilitating the creation of a European market.

Since 2000, ETSO has published a set of documents aimed at promoting progress on the issue of congestion management. Two types of congestion management methods have been discussed both aimed at developing a harmonized framework at the European level. One proposal aims to extend the bilateral auction, between two countries, e.g. A and B, to "multilateral" auctions that take into account the impact of transactions between more than two interconnected countries. For example in the case of four countries, the impact of a transaction between country A and country B on transactions between A and C, A and D, B and C, B and D, and C and D. This method is called "coordinate auctioning" (ETSO, 2001a; 2002b). The second approach considers the use of power exchanges for congestion management (ETSO, 2001b). This method is based on the market-splitting principles used in the Nordic area[15].

The starting point of the ETSO proposal on coordinated auctions is based on two relevant criticism of bilateral auctions, i.e. separate auctions increase complexity for market participants and do not reflect the impact of parallel flows in a meshed network because the definition of interconnector capacities cannot be calculated separately. The idea behind this mechanism is that coordinating the allocation procedures will allow a better use of the network by netting flows in opposite direction and reflecting the physical realities of loop flows. However, though such a mechanism would bring a large improvement over bilateral auctions, it retains several of the problems of the current methods used in Europe[16]. One, the principle of separation between energy and transport remains. Hence, market participants would still be required to enter into different transactions for energy, e.g. a power exchange, and transport, e.g. an auction. Two, the overall mechanism is based on the very restrictive assumption that zones can be defined[17]. Three, the major shortcoming of this approach is that the coordinate auction only uses the data of participants that are willing to use interconnection capacities and thus the impact of intra-zones production on interconnector capacities is not considered.

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[15] See chapter 9

[16] Ibid.

[17] Ibid.

The second approach considered by ETSO is the use of power exchanges to deal with congestion. In the Nordic countries "market-splitting" is the expression used to defines this approach, where a single organized market is "split" when congestion occurs. However, since there is no single organized market in continental Europe but rather one organized market for each country, the use of this method for dealing with congestion is also called "market-coupling". Though it is largely recognized, even by ETSO that this method functions well in the Nordic countries, ETSO has regularly express reservations about this approach. Three problems have been presented as the main obstacles for the implementation of "market splitting". The first obstacle in ETSO's view is the presence of a highly meshed network in continental Europe which influences the location and the capacity of congested lines and make it difficult to define zones.

The second problem is related to the existence of bilateral contracts between congested areas which are hardly compatible with market splitting. Finally, ETSO argues that *"electricity markets in Continental Europe are at present far from being compatible enough to implement a common market splitting system"* (ETSO, 2001b). Hence, while the logical conclusion would have been to harmonize national market design, to get rid of bilateral contracts for cross-border trade[18], and to develop a more sophisticated version of market splitting that takes into account loops flows, e.g. nodal pricing, market splitting is at present considered to be unpractical. Thus, in the absence of a harmonized market design, ETSO has favored the coordinate auction approach because it has less institutional requirements and, according to ETSO is sufficiently flexible to function in a European market where market designs differ (ETSO, 2002a).

Until now, as presented during this work, the issue of market design has been a fundamentally missing part of the work of the European Commission. However, as this thesis was being written, at the beginning of 2003, the European Commission produced a "Strategy paper" aimed at presenting a medium term

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[18] Against a fair compensation for market participants

vision on what the internal electricity market should look like. This paper was not publicly available in June 2003, but it has been widely circulated between the different organizations (CEER, ETSO, national regulators), as the intention is for this document to become a public document by the end of 2003, and finally because this document is of particular interest for this work, we will now present a brief outline of the main points and limits of this document with respect to market design and market power. The document is of particular interest because it represents the first time the EC explicitly has addressed the issue of wholesale market design for the European electricity market. Though much less developed than the "standard market design" and "wholesale power market platform" of FERC[19], this document represents an interesting starting point for discussion on what the European electricity market should look like according to the EC. Further it gives an important role to power exchanges.

A first interesting aspect of this paper is that it recognizes that the creation of a single European electricity market might not be a realistic objective in the medium term and that the developments of different regional markets may be a necessary step. Hence the strategy paper defines seven possible regional markets according to transmission constraints and possible dates for the creation of these markets (figure 10-2). Second, the paper defines the creation of wholesale markets in each Member State as a medium term objective providing a single price area which can eventually cover more than one Member State. The use of market splitting is expressly favored in contrast to ETSO which favors of coordinate auctions. The "Strategy paper" addresses the problem of market power when it is difficult to increase interconnection capacity and recommends either divestments, capacity release program, or restriction to interconnector access for dominant generating companies, and monitoring by regulators for

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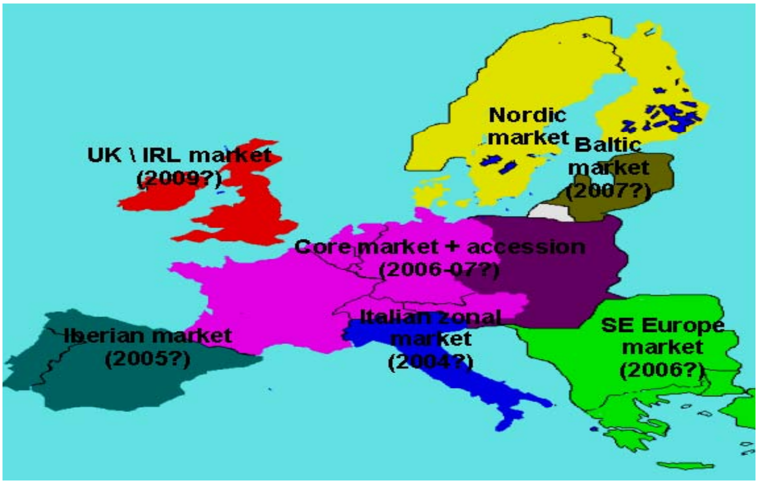
[19] See 10-3-5, Box 10-1 for more on the "Standard market design". The Strategy paper address a very large number of issues in only 20 pages, i.e. market integration, implementation of the Directive, interconnection between Members States, choice by consumers, problems of market concentration, generation adequacy, renewable energy, tax/state aid, and relations with third countries.

possible market manipulation. Finally, this paper advocates strict control on further mergers.

Figure 10-2: Potential regional electricity markets in Europe



Source: De Jong (2003)

The content of this paper can be analyzed from two different point of views. On the one hand, it represents a step forward in the process of creating a competitive European electricity market by defining a concrete outline on the EC's view on some important aspects of market design. On the other hand, however, careful analysis of the draft document presents several serious inconsistencies. Some of these inconsistencies have already been point out in the ETSO comments on this document (ETSO, 2003). For instance, the "Strategy paper" recommends simultaneously creating single price areas and the using of "market-splitting", yet, in the presence of congestion, market splitting leads to the creation of several prices. Furthermore the "Strategy paper" states that in the case of serious congestion explicit auctions might be applied rather than market splitting mechanism. However what "serious" congestion means remains unclear and one may argue that because market splitting is a more efficient solution than explicit auctions it should be especially favored when congestion is serious to optimize the use of scarce interconnector capacity. The paper also mention creating a power exchange in each Member State this antinomic with the market-splitting mechanism which requires that there is a single power exchange for the entire area.

Similar, the "Strategy paper" states that *"market structure based on obligatory pools […] should be avoided"*. It seems that an argument against mandatory pools is the incompatibility between a mandatory pool and bilateral contracts: *"Bilateral contracts for difference should always be possible to allow long term relationships between producers and suppliers".* This is particularly confusing because mandatory pools and bilateral contracts are not incompatible[20] as showed by the example of the British pool before NETA. Avoiding the obligatory feature of organized markets is not consistent with the stated preference for both market splitting and integration of balancing markets. Indeed, as noticed in the ETSO comments, market splitting as in Nordic countries implies the obligation for players to use the organized market for cross-border trading. Similar, balancing markets are always likely to be mandatory because close to the real time of delivery only the TSO know the transmission constraints.

Additionally, while defining the different regional markets appears to be a reasonable step, it faces several problems. One, it is may be interpreted as a step backwards because the initial objective was to create a single European electricity market. Two, it is unclear how these markets have been delimited. Three, the "Strategy paper" does not mention particular measures for Switzerland regardless to its central position geographically. Four, from a political point of view, it is unclear whether countries outside of the "core market" will oppose or promote this scheme which keeps them out of the major market.

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[20] See chapter 3

Beyond the fact that no reference is made to the coordinate auction proposal, which seems to show low consideration on behalf of the EC towards the preferred option of ETSO, ETSO's comments illustrate the reluctance toward detailed market design guidelines coming from the EC. This can be illustrated by the following *"The way the strategy paper is drafted gives the impression that TSOs' responsibilities are reduced to just implementing the decision of the EC, Members States and Regulators. ETSO considers necessary to address in much more detail in this paper the question of a suitable sharing of responsibilities in order to avoid unnecessary concentration of power, overregulation etc."* (ETSO, 2003). Similar, while the strategy paper recognizes the importance of market power and of market monitoring, it seems that this issue is not taken on board by ETSO as illustrated by the following: *"In our view, undue weight is put […] on market dominance or concentration and too little weight on high prices"(ETSO, 2003).*

In conclusion, recent work by ETSO and the EC illustrates a continuing lack of a clear perspective on, and consensus about, the future design of the European electricity market. One must first recognize the effort of the EC in that it has addressed, for the first time, the very complex issue of market design. Moreover the "Strategy paper" illustrates strong support from the EC for electricity power exchanges. Nevertheless the "Strategy paper" is far from providing a consistent framework. Fortunately, this paper is a draft and one may expect serious improvements on the first version after consultation with others parties. Unfortunately, this lack of consistency may also illustrate the absence of a clear perspective within the European Commission on what the European electricity market should look like, and more worryingly, a poor understanding of the different aspects of market design. If the final version does integrate major modifications it will raise concerns about the future ability and credibility of the EC to play a leading role in the "market" regulation process.

10-3 Toward European "market" regulation: the role of power exchanges

10-3-1 Introduction

The analysis of recent works by the European Commission has shown that monitoring to date has focused on the implementation of the Directive 96/92 and thus has not directly addressed the issue of market performance which is a necessary step for the improvement of market design. Monitoring of competition is mentioned in article 22 of the amended proposal for a Directive amending the Electricity and Gas Directives and amended proposal for regulation on cross-border exchanges in electricity: *"Member States shall designate one or more competent bodies as national regulatory authorities […] that shall at least be responsible for continuously monitoring the market […] in particular with respect to the level of competition"* (EC, 2003). It is unclear however, how this monitoring should take place.

In this section, since market accurate monitoring is seen as a fundamental step for market design, we suggest a practical approach for improving the actual functioning of the European electricity market based on effective monitoring of competition using power exchanges. We analyze how power exchanges can be useful for three important aspects of market monitoring, i.e. facilitating market definition, improving traditional market share analysis, and developing competition indicators. An important problem of any competition analysis is to define the relevant market, in this respect power exchanges provide interesting solutions (10-3-2). Subsequently, we discuss how classical market share analysis can be improved by using power exchanges (10-3-3). Additionally, we suggest which types of information should be combined with the information provided by power exchanges to create competition indicators (10-3-4). Finally based on this monitoring we provide several recommendations as to how power exchanges can be used to improve market design (10-3-5).

10-3-2 Power exchanges: a useful tool for defining the relevant market

The organizational complexity of the actual design of European electricity markets makes it difficult for competition authorities, regulators and governments to assess the efficiency of the functioning of their electricity market as a whole. It is necessary to define the relevant market before undertaking any further studies to estimate the level of competition and understand the reasons for the unsatisfactory output of these markets. Yet, the traditional approach, based on merger control procedure, appears to be ill suited while using power exchanges provides an interesting starting point.

Defining the relevant market provides the necessary framework for any analysis of competition. Market definition is not an end in itself but it represents the first step for any investigation where there are concerns regarding competition. The main objective of defining a market is to identify the competitors that might behave negatively with competition. The need to define markets has formed a fundamental basis of EU competition policy since its inception and has always been a pre-condition under articles 81 and 82 of the Treaty. The market definition notice provides guidance on the rules followed by the Commission to define the relevant market (EC, 1997). This notice gives three main elements that constrain the exercise of market power: demand substitutability, supply substitutability and potential competition. Demand substitutability represents the most important criteria. It refers to perfect or near perfect substitutes being readily available in a determined geographic area to which consumers can easily switch if prices increase. Supply substitutability represents the second criteria, and refers to producers who are able to switch to relevant production as a response to price increase. The potential competition criteria for market definition is not taken into account in this document. It appears as a later stage for identifying market power. In practice, the first step in market definition consists of defining the relevant product market and the relevant geographic market.

Under European regulation, the relevant product market comprises any products or services which are regarded by the buyers as interchangeable with respect to their characteristics, prices and intended use. The relevant geographic market is defined as the area in which *"the undertaking concerned are involved in the supply of relevant products or services in which the conditions of competition are sufficiently homogeneous and which can be distinguished from neighboring geographic areas because, in particular, conditions of competition are appreciably different in those areas".* In order to define these markets the commission put forward three basic sources of competitive constraint on a party: demand substitutability, supply substitutability and potential competition.

Demand substitution is estimated using the hypothetical monopolist test. This test is known as the "Small but Significant Non transitory Increase in Price" test (SSNIP). The objective of this test is to estimate the reaction of customers in response to a small (in the range of 5-10%) permanent relative price increase in the product market and areas considered. If the loss of sale resulting from substitution make the price increase unprofitable, additional substitutes and areas are included in the relevant market. The identification of a set of products and of relevant geographic area can be achieved based on this theoretical test.

Supply substitutability refers to the ability of producers or services providers to switch production to the relevant products as a response to a price increase. This substitutability capacity is only taken into account when suppliers can produce the good under consideration with respect to comparable standards in terms of effectiveness and immediacy. The notice states that supply side substitution should occur *"within a period that does imply a significant adjustment of existing assets"* which mean the very short term.

The traditional approach presents several limits for electricity because electricity markets differ widely from other product markets, e.g. non-storability, low demand elasticity, transmission constraints, complex market design. Using power exchanges as a basis for defining the relevant market has several advantages that take into account these peculiarities.

Since electricity cannot be stored each single period represents a different market. Power exchanges allow this aspect of competition in electricity markets to be taken into consideration, by providing prices for each single hour, they reflect the dynamic aspects of competition. For instance, careful analysis of power exchange outcomes may reveal that a specific hour or combinations of a couple of hours represents particular markets that need to be isolated. Power exchanges can thus be use to narrow down market definition.

Though power exchanges only represent a small share of the total traded volumes, prices on power exchanges are well representative of the overall situation in bilateral markets[21]. Hence, power exchanges prices can be use as an indicator for the overall electricity market. Since substitution and arbitrage can be achieved across market potential large difference between power exchange prices and other bilateral market are unlikely to remain. For instance, one contract for 10 MWh baseload power for the following day contracted on the bilateral market can be considered to be a good substitute for 24 purchase contracts, i.e. one for each hour, on a power exchange.

Finally, using power exchanges markets helps us to take into account the fact that actual electricity markets are composed of more players than just national generators[22]. For instance pure traders and foreign generators without asset in the delivery area of the power exchange can play a very important role in the market. They can arbitrage between different types of OTC contracts, between OTC and power exchanges, or between power exchanges through the markets for interconnection capacities. Power exchanges are thus a good indicator of the

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[21] See chapter 8
[22] See chapter 7

relevant geographical market because they allow the suppliers who are able to compete in the market to be identified.

10-3-3 Using power exchanges to improve traditional market share analysis

When a relevant market has been defined, a classical way to tackle market power is to estimate the level of concentration of this market. This approach is derived from the "Structure-Conduct-Performance" (SCP) paradigm[23], which states that market structure determines the behavior of participants and market outcome. From an intellectual point of view it appears logical that concentrated markets are more vulnerable to price manipulation and market power than less concentrated markets. Though traditional market share analysis present several shortcomings for electricity markets in general (Rosen and Williams, 1999), using this approach for power exchanges provides interesting insights into the extent of competition and is thus a useful step to start.

In their report issued in November 1997 on generator market power in England and Wales, the Brattle Group compares different values of the HHI[24] index of generator market power calculated by Littlechild, Newbery and Joskow (Brealey and Lapuerta, 1997). *"Professor Littlechild, has cited a figure of 1,750 as the divided line between a moderately concentrated and a highly concentrated market. Newbery and Green have estimated that an HHI of 2,000 could have eliminated most of the inefficiencies of a duopoly in generation. Finally, Joskow has argued that HHI figures above 2,500 indicate so severe risks of market power that regulatory intervention would be justified".* In Europe due to the dominant position of the incumbents a HHI index on the production side above 3.600, i.e. with a dominant player having more than 60% of installed capacity is common. This is a major concern for competition, since under European Union

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[23] See chapter 1

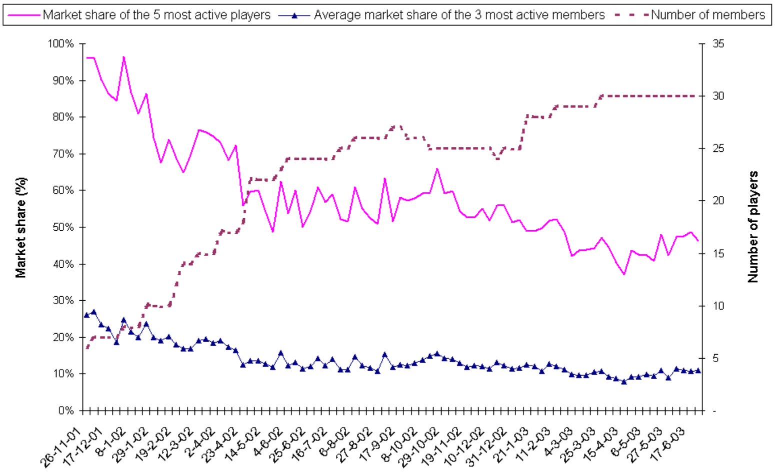
[24] See chapter 7

competition law, a market share above 40% is usually considered to be dominant.

In this example, and in general, market shares calculations in electricity markets have been realized from a production side point of view. Using installed capacity is the simplest methods. The greatest advantage of this approach is that it only consists of making an inventory of installed power in a defined area and calculating the market share of each player. This method is often used since it is easy to calculate, i.e. based on technical data, and reflects the basic conditions of the market. However this method can be criticize because it does not account for power plants that have been put out of production or that can not produce 100% of their theoretical capacity, and for power plants that have different levels of production over time. Ii also sometime hard to relate installed capacity with volumes sold. The main problem with concentration measure based on installed capacity is the fact that they are static measures that do not reflect the flexibility of production necessary to cope with the seasonal patterns of electricity demand.

Using power exchanges to calculate market shares provides some interesting solutions for these problems. First calculating market shares based on power exchange markets has the advantage of being able to take into consideration the fact that actual electricity markets are composed of more players than national generators. For instance, market share of pure traders and foreign generators without assets in the delivery area of the power exchange provide interesting information on the extent of the competition faced by national generators. Hence, if traded volumes of non-domestic members represent a significant share of the total, this would show a relatively good level of competition. In Europe, only the French power exchange publishes information about market share on the exchange (figure 10-3). Such information provides interesting information about the extent of competition on the exchange and the credibility of the price index. It can be seen that the role of EDF in the price determination process appears not to be significant which reinforce the credibility of Powernext. Yet the number of participants has increased on a regular basis, the market share of the most active members has decreased strongly since Powernext started operation and is now relatively low

Figure 10-3: Weekly market share of the most active members



Source: Powernext

In practice, electricity players do not intervene in the market per power plant but per company. This portfolio approach makes it difficult to assess the relationship between physical flow and economical transactions. Hence using data from the transactions on the power exchange allows us to identify the actions of individual participants. Most generators have developed trading activities around their assets. Thus calculating market share on the power exchange on both sides, i.e. buyer and sellers, may allow us for instance to identify a generator that might be a buyer in a market when prices are lower than its production costs.

Finally, since power exchange spot markets provide 24 markets per day, i.e. one for each hour, they also provide the possibility to calculate concentration measure for each key time period and thus provide a dynamic estimation of competition in contrast to the static HHI which is based on installed capacity.

While calculating 24 HHI indexes per day might hamper the possibility to reach a robust conclusion, analysts should be able to weight these HHI to define aggregate HHI indexes, e.g. peak-off peak/weekdays-weekends, or to focus on specific hours, e.g. super peak hour and compare them over time. Thus, defining a set of HHI based on traded volumes on the power exchanges will allow market monitoring units to identify if any individual players has market power in any given time period.

10-3-4 Power exchanges: competition indicators for effective market monitoring

Due to their complexity, as illustrated in California by the Enron's memos[25], concentration measures do no suffice for analyzing competition in electricity markets. Amongst the most important issues that HHI does not account for, are aggressive bidding, withholding capacity, tacit collusion and complex rules manipulations. For these reasons, though HHI based on volume traded on power exchange provide a good starting point they need to be completed to recognize important problems related to market power analysis in electricity markets. The existence of an organized market such as an official power exchange facilitates the task of market monitoring units (MMU) because it can provide a large amount of information, in contrast to bilateral markets, that can be use to analyze competition. The question is then how can we use power exchange data to perform an adequate analysis.

A practical way to perform an analysis is to compare actual data with what would be expected in a well functioning market. A significant amount of analysis can be done based on power exchanges and others type of public information. For instance, a simple indicator is an estimation of the relationship between system load and prices on the power exchange. Indeed, one would expect that prices are higher during points of high demand than during periods of low demand.

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[25] See chapter 6 and appendix 1

Systematically monitoring this relationship across time appears to be a good way to test whether market outcomes reflect markets conditions.

Analyzing resilience on power exchanges, i.e. the sensitivity of the market-clearing price to incremental demand, provides interesting insights into the level of liquidity on a market. Indeed, estimating the impact of different values of additional demand on market prices is a good indicator of the sensitivity of a market to potential market manipulation. For instance, if a small additional demand of 5 MW dramatically increase prices, this reflects a low level of competition where almost any player can influence prices. In contrast, if a large additional demand order has a low impact on prices this indicates that no player can individually influence prices.

The price-cost markup index is a more sophisticated indicator of competition. The goal of the markup index is to estimate the difference between the observed market price and what might be expected in a competitive market. The price-cost markup index is defined here as the difference between market price (MP) and marginal cost (MC), divided by market price (=MP–MC)/MP). The central assumption behind this reasoning is that in theory market price should be determined by the marginal cost of the marginal. This method has been widely used in California for estimating market power[26] and is regularly used by the MMU of PJM (PJM, 2003). Such indicators provide a fundamental benchmark, i.e. relationship price/cost, and should be considered for this reason.

As the publicly available information is mainly aggregated, it does not suffice for effective monitoring by the MMU, which needs more detailed information to ensure effective monitoring. The information produced by power exchanges is particularly interesting because it allows the MMU to assess the behavior of individual participants, in particular, the data on individual bids and individually traded volumes allow it to construct several interesting indicators.

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[26] See appendix 1

To be effective the MMU should have access to individual bids on the organized markets which would allow it to determine which players can set the system marginal price. On wholesale short term markets, such as power exchanges, market power depends on a firm's capacity to modify the short run marginal costs of generation in each hour of the day and the ability to withhold part of its production capacity. Then estimating market power in generation requires an analysis of a firm's plant production costs and especially its capacity to meet demand during peak hours when the market is tight. Since, the last accepted bids fixes the price on power exchanges, the price offered by the last bidder is a relevant indicator of the existence of a dominant position. Thus, the systematic identification of the players that set the market-clearing price on power exchanges provides information about the level of competition because a real indicator of market power is not just a firm's market share it is also its ability to control the clearing price. For example if one player sets the price on the power exchange 90% of the time, this would indicate a lack of competition and strongly suggest the existence of market power.

Power exchanges can also be used to analyze the problem of withholding capacity. Withholding capacity is certainly the most well known strategic behaviour in electricity markets to abuse market power. The traditional form of withholding capacity consists of decreasing supply and profiting from the high prices for other production. The profitability of such a strategy can be tested using power exchanges. To test this the MMU needs to run several simulations based on actual bids and add or withdraw supply bids, such simulations will allow the MMU to estimate how changes in supply influence the profits of the different players and thus facilitate the detection of market power. Another simulation approach consists of removing the bids of one player and estimating the impact on prices and volumes. If the changes are significant, this would not show automatically that the player is abusing market power but it would show that the player has potential market power and thus specific attention should be paid to its behaviour.

In periods of high demand, suppliers that are aware of the tightness of the market may use excessively high bids on the power exchange to increase market price. Such behavior is known as aggressive bidding or economic withholding. For buyers who are short in the OTC market the power exchange represents the last place to buy electricity before going to the expensive (and risky) balancing market. Hence, an analysis, by the MMU over time, of bids is a practical way to identify such behavior. If such behavior is detected, the MMU can undertake further investigations and determine whether the higher bids where justified or whether they were an abuse of market power.

Due to the confidential nature of the data used, the details of the work of market monitoring units should remain restricted because revealing information on players at the level of individuals participants would be commercially sensitive and might favor collusion. For instance, the purpose monitoring is not to publish which participant is setting the price for any particular hour, but rather to get insights into the real extent of competition. Hence, an MMU could publish anonymously the number of participants that were able to set up the price on the power exchange for a defined period and the number of occurrence. As a rule, an MMU should publish the results of its findings in a format that does not allow individuals participants to be identified.

Finally, one of the most difficult aspects of monitoring electricity markets is defining the boundaries of the market[27]. Indeed, once an electricity market has been defined, it is extremely difficult to take import and export with neighboring countries into account. Although the net amount of electricity entering or leaving a pre-defined market can be measured, it is almost impossible to identify the exact origin and the cost of that power. This problem is of particular relevance in Europe where the development of cross-border trade is significant. Thus, although a significant part of market monitoring can be done at national level, it is also necessary to monitor the electricity markets at a supra-national level.

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[27] See 10-3-2

Indeed, purely national monitoring make little sense in the presence of international players competing simultaneously in several markets. Hence, focusing only on one power exchange is unlikely to capture all the subtleties of market participant’ strategies[28].

Table 10-1: Competition indicators and power exchanges

Indicators based on public information	Indicators based on information available to MMU
•PX prices Vs system load •PX prices/volumes developments •Comparison OTC/Power exchange/Balancing prices •Difference actual prices/theoretical prices •Deepness of the market (based on aggregate bids curves) •Level of integration with neighbouring markets •PX prices Vs costs •Resilience •Impact of scheduled/unplanned outage/ maintenance on interconnector on PX prices •Evolution of congestion Vs price of congestion	•Individual market share on PX traded volumes •Who set the price on the PX •Marginal unit ownership Vs who set the price on PX •Market share of non-domestic producers on PX •Level of liquidity •Volume traded Vs Load per player •Who use interconnection capacity •Reserve margin Vs PX prices •Profitability of withholding capacity on PX •Impact of change of design •Level of demand response on the PX

Since power exchanges are now in place in most European countries, combining the analysis of different exchanges would provide interesting information about participants behaviors. For instance, studying the behavior of players on two exchanges would help indicate the extent of arbitrage between two exchanges. In the case where there is low arbitrage, despite a price difference, a European market monitoring unit that combines the work of the different national MMU might investigate the reasons for such inefficiency. This could reveal incompatible marketplace design, e.g. different products or incompatible trading periods.

In conclusion, the existence of organized markets, such as an official power exchange, facilitates the task of MMU because they provide a large amount of information that a monitor can then use to analyze competition on a market.

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[28] To this respect, the strategies “export of California power” and “Death Star” described in the Enron’s memos are good illustrations of how players can take advantage of a system if monitoring is limited to national markets (see chapter 6).

Access to relevant information is crucial for both the development of competition and effective market monitoring. With regards to monitoring, it appears suitable for more information to become publicly available while still maintaining confidentiality with regards to any detailed information that the MMU may access. Power exchanges are very interesting for monitors because they help MMU to obtain the information necessary to develop indicators of competition (table 10-1). Such indicators are vital for assessing market performance. Market monitoring, in that it helps to identify market design flaws and anti-competitive behavior, plays an important role in terms of preventing market power abuse by players. Close monitoring discourage players from acting anti-competitively since players know monitoring units are "watching" them. Such monitoring also reinforces confidence in the fairness of the market because market participants know that unfair practices will be detected and sanctions taken against abusive players.

10-3-5 Recommendations: power exchanges as a basis for a market regulation framework

Based on the economic theory of electricity markets and successful international experiences one might be tempted to make just one recommendation to create a single European electricity market. This recommendation would be to merge the different national system operators and power exchanges to create a single European system operator that would implement nodal pricing at a European level. Yet, although such a system appears likely to be the only one able to take into consideration technical aspects and ensure economic efficiency, such a recommendation will be of little use. This is because it will be seen as such a dramatic change with respect to the approach followed to date that it will be considered to be "practically" unfeasible, which would be true in the short term at short notice, and thus rejected by the different parties. Hence, we suggest a step by step approach to an integrated European market based on power exchanges.

Since wholesale marketplace/market design was overlooked in the liberalization process for the European electricity market, the initial step that needs to be considered is a detail assessment of the actual situation. To do this we need to make a detail analysis of the different national market designs, i.e. trading arrangements, grid codes, functioning of bilateral market/power exchange/balancing mechanisms/allocation methods for interconnector capacity. We need to estimate the level of market integration based on power exchanges and extend the work presented in this thesis. Such an analysis would shed light on the diversity of national market designs and provide the European Commission with solid empirical evidences for further reforms of the electricity market and a first benchmark for evaluating progress.

Recommendation 1: *The European Commission should realize a detail analysis of the actual European wholesale electricity market design and the level of market integration using power exchanges*

Subsequently the European Commission should consider the different alternative for market designs. Ideally, the choice between market designs should be made in favor of the model that delivers the best performance. A comparison of the costs and benefits of each model with respect to market structure, i.e. number of players, barrier to entry, excess capacity, interconnections etc; market design, i.e. mandatory pool, voluntary exchange, nodal pricing, zonal pricing, auction mechanisms etc; and institutional features, i.e. ownership, regulation, market governance, environmental constraint etc, appears to be the best approach. However, in practice a cost benefit analysis would face a major difficulty as noted by Newbery (2000): *"Given the large number of possible factors that might explain differences in performance of different trading arrangements, and the short time period over which most have been tested and adjusted, the empirical evidence is far from decisive as to which design suits which set of circumstances. The debate has therefore been largely driven by a priori arguments, analogies or the expectations of different special interest groups who see opportunities for gain from changes of the existing system".* One way of comparing the differences in performance of different market design would be to identify clearly the different alternatives by comparing, for instance, the different theoretical models and the international experiences. Many models of market design already exist and many variations are possible. It is important to recognize that no model is perfect because electricity markets are imperfect and complex (Ruff, 1999). Though it is unlikely that such a comparison would end with the identification of a perfect model, it would allow us to define some critical principles of successful models that need to be followed and should sort out and allow us to dismiss fallacious approaches. In this respect, determining the role of power exchanges in the successful examples of Nord pool and PJM and their role in the failure of the California market should allow to identify several fundamental success factors.

Recommendation 2: *The European Commission and the different interested parties (ETSO, CEER…) should consider the different alternatives for market design to identify the critical principles of well-functioning markets with respect to the role of power exchanges*

Despite the variety of market designs, one important characteristic of most well functioning electricity markets is that a single institution combines system operation (TSOs) and market operation (power exchange). Such integration or at least a high level of collaboration is fundamental because it allows the marketplace to take into consideration transmission constraints which represent a key aspect of market design in electricity markets. Moreover, since in Europe the balancing markets are managed by system operators and day-ahead markets by power exchanges, a high level of coordination between the two entities is necessary to avoid incompatible rules between the two markets that may distort competition. Such collaboration is necessary to coordinate congestion management and synchronize the functioning of day-ahead market with balancing markets.

Recommendation 3: C*ollaboration between the different power exchanges (PX-PX) and the different transmission system operators (TSO-TSO) but also between the PX and TSO (PX-TSO) needs to be encouraged and developed*

Market-based mechanisms have been recognized in the Florence process since 2000 as the most efficient way to allocate interconnection capacities. Although bilateral auctions for the allocation of physical transmission right are not an optimal solution, they nevertheless represent a real step forward compared to first-in first-served and prorata methods. Indeed, non-market-based approaches which give away valuable transmission rights, should be eliminated. Once the amended EU electricity Directive of 2003 and Regulation No 1228/2003 (See box 10-1) come into force, the allocation of all interconnector capacities based on auction will signal the beginning of the standardization of market design. Moreover it is necessary that these auctions are managed by independent system operators, in contrast to vertically integrated utilities, to ensure the neutrality of the mechanism. Once such mechanisms are in place netting should be encouraged to maximize available capacity.

Recommendation 4: *In the short-term market-based mechanisms for congestion management managed by independent system operators should be implemented, netting should be encouraged, and compatibility with power exchanges should be respected*

In the medium term, the integration of transport and energy must be considered to maximize the utilization of interconnector capacity and locational pricing (nodal or at least zonal) should be encouraged. Ex-ante determination of interconnector capacity results in inefficient allocation of the available capacity because the real capacity available can only be determined once physical flows are known. Hence the separation of transport and energy does not maximize the utilization of the network because the available capacity defined by the TSO, and auctioned, is lower than the real available capacity which force the TSO to take into account a substantial safety margin. Although most national networks are very dense, which has allowed most European Members States to ignore transmission constraints at the national level, locational pricing based on power exchanges at a national level should be considered. The main reasons for this are to optimize the utilization of congested interconnectors and to provide a signal for new investment in generation and networks.

Recommendation 5: *In the medium term improvement of the efficiency of transmission pricing by integrating transport and energy and moving towards locational pricing through better collaboration between power exchanges and system operator needs to be considered*

One practical way to improve the functioning of the actual European electricity market(s) is to increase the level of information available. The "Open Access Same Time Information System" (OASIS) required by FERC provides a good example. Such a system covers a large range of operational information, e.g. day ahead scheduled outages, transmission line real time scheduled outages, transmission line real time actual outages, scheduled flows, real time events, real time actual load, demand forecast etc. The two key benefits of increasing market transparency are one, it removes asymmetries between players which is fundamental for the creation of a one level playing field, and two, it facilitates market monitoring.

Recommendation 6: *The level of transparency of electricity markets should be improved by system operators and power exchanges by publishing relevant information*

In markets characterised by short-term inelasticity of demand, a concentrated structure and a design in transitional phases, opportunities for abuse of market power represent a major threat for the development of competition. Above all, it is worth noting that the first necessary condition for competition is the presence of a competitive market structure. Though market design plays an important role in the creation of a competitive market it does not solve the problem of concentration that exist in most European markets. Until now, the European Commission has been powerless to block large mergers and acquisitions. Across Europe, electricity markets are already very concentrated with a growing trend towards further concentrations. For instance, despite the fact that EDF was already the largest player in Europe, the European Commission was unable to prevent this company gaining shares in Austrian, Italian, British and German companies. Even worse, EDF has been able to increase its market share in France by buying a French co-generation company (Dalkia). Similarly, the impotence of national competition authorities has been recently illustrated with the German merger between E.on and Rurhrgas. The EU Commission was relatively silent on this 'mega-fusion' simply because this merger did not fall under the current EU competition law. At a national level, competition authorities are often reluctant to challenge such mergers because the concept of a "national champion" able to compete on the European market appears appealing – regardless of the threat it represents for a well functioning (national) market. Competition needs players and therefore further concentration should be carefully evaluated.

Though market design cannot solve problems of market structure, poorly designed markets may facilitate the abuse of market power by, for instance, restricting entry or limiting demand response. Since electricity markets are very complex and highly dynamic, classical indicators, e.g. HHI based on installed capacity, and traditional competition laws are poorly suited to address this issue (See 10-3-2). Careful market design can help to mitigate market power by improving transparency, facilitating competition and optimizing the use of network. Hence the different aspects of market structure need to be carefully considered and new indicators of competition determined, e.g. system load VS prices, price-cost markup index, the number of participants that are able to set up the price etc.

Recommendation 7: *Pursue initiatives to address the issue of market power by considering the impact of market design on market power and developing "competition indicators" using power exchanges*

A continuing challenge in electricity market regulation is how to design the market and analyze the level of competition. Continuous monitoring by specialized entities, i.e. Market Monitoring Units (MMU) at the national level is suitable for this purpose. Using power exchanges, MMU should perform analysis of the development of competition and provide recommendations regarding how to improve market performance, for instance by recommending changes in market design. Additionally, a European Market Monitoring Unit should be created to combine the different national analysis and to address the issues that involve more than one national market.

Recommendation 8: *Create a European Market Monitoring Unit and national MMU for effective monitoring of competition and market design*

Market monitoring is of little use if it only identifies problems and is not backed up by regulatory authorities that can implement and enforce recommendations to fix the problems. This is especially important because it is difficult to get everything right at the outset. Hence procedures to fix electricity market design and market performance problems are suitable. Unfortunately, the EU Directive(s) and traditional competition laws are currently inadequate for this purpose.

Concretely, the different regulatory authorities need to define what the European market should look like. Political, economic and governmental differences make it impossible to replicate at a European level the approaches used at national levels and elsewhere around the world. Nevertheless some critical principles of successful processes can be identified and need to be followed. Clear principles with respect to market design should be defined and measures should be adopted to facilitate competition in electricity markets at a European level. For this purpose, a uniform policy approach is necessary which will define a precise market regulation framework, i.e. market design and market monitoring. This is the purpose of the "Strategy paper" but, as we have seen, this remains a very incomplete draft, and it appears unlikely that in it present state it will suffice to create an integrated market[29].

If the level of integration remains low, which is likely to occur due to the lack of a harmonized market design, the European Commission should, in the medium

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[29] See 10-2-4

term, present a market regulation framework. Such a framework would define the main features of the design of the European electricity market not just for cross-border trade but also for the detailed principles of market design in each Member State.

Such a problem is also a central issue in the United States where in the absence of a clear consensus on what markets should look like the initial approach of the FERC for electricity restructuring was to let each market develop its own design. This thinking was capture by the phrase: *"let a thousand flowers bloom"*. This process resulted in the creation of several flawed designs. Hence, in testimony before the US Senate committee on energy and natural resources, Pat Wood, Chairman of FERC stated that wholesale power markets in the US have *"many of the worst features of both regulated and competitive markets, and few of the benefits of either"*. Having faced the failure of the *"let a thousand flowers bloom"* approach, FERC issued its proposed rule for a Standard Market Design (box 10-2) which has recently been replaced by the Wholesale Power Market Platform.

Using input from the different MMU, a European framework would recognize that the creation of a single market needs not only harmonization of cross-border mechanisms but also to create compatible national market designs. Power exchanges are important tools in this case since they represent an important part of each national market design. An extension of the European Commission authority might be opposed by many Member States but makes sense because international transactions are crucial for the creation of a single electricity market, and market design flaws in one country are likely to have adverse effects on other countries. Although, it appears to be difficult to standardize market design in each State at short notice, it appears to be necessary to standardize at least wholesale pricing and transmission rules at the European level. In the absence, to date, of recognition for the importance of market design, it is unlikely that such framework would be perceived as necessary by the different parties. On the contrary it would be seen as overregulation and to be incompatible with the principle of subsiduarity. However, if in a couple of years facts shows that a real integrated market has failed to emerge, one may expect support for more draconian measures using such a framework.

Recommendation 9: *In the medium term, the European Commission needs to define a market design framework clarifying the role of power exchanges for the European electricity market: a market design Directive?*

Box 10-2: Market Regulation: the approach of FERC

In 2002, the Federal Energy Regulatory Commission's (FERC) Order No. 2000 set in motion the voluntary formation of regional transmission organizations (RTOs). Unhappy with the progress to date on RTO formation and in an effort to foster seamless transmission and wholesale energy markets, FERC issued its proposed rule on Standard Market Design (SMD) in the Notice of proposed Rulemaking (NOPR). The proposed SMD rule would require the mandatory formation of Independent Transmission Providers (ITPs) that will implement and administer the new SMD. The aim of this proposal was to create: genuine wholesale competition, an efficient transmission system, proper pricing signals for investment in transmission, generation facilities and demand reductions and more customer options. Moreover market monitoring and market power mitigation are also key features.

Some key elements of the SMD proposal are presented below:

- **Transmission constraints → Locational Marginal Pricing (LMP)**

LMP (nodal pricing) should be used to manage transmission congestion

- **Volatility → Bilateral contracts**

The SMD includes reliance on financial bilateral contracts that limit the effect of potential volatility

- **Short term trading → An independent Transmission Provider (ITP)**

The ITP will establish short-term and ancillary services markets.

- **Security of supply → A resource adequacy requirement**

Requirement on load-serving entities to ensure that they have adequate capacity to serve their load plus a minimum reserve margin

- **Market power → Monitoring and mitigation procedures**

Special attention should be given to market power through monitoring of bids (when relevant), possible withholding of capacity, and implementation of a safety-net cap.

The SMD proposal represents a significant step forward to enhance competition in American's electricity markets. While some details are missing and need to be further discussed (Hogan, 2002), this proposal provides a consistent starting-point-framework taking into account both market design and market monitoring that appeared necessary to support a competitive electricity market. However after consultation with different parties several modifications were made to take into consideration the concerns of opponents in the Southeast and Northwest. The SMD became the Wholesale Power market Platform (WPMP) in April 2003. In recasting the SMD proposal as the WPMP, FERC allowed some flexibility in the implementation. The open questions now are : How long will it take to implement the WPMP? Will States regulators accept it? To what extent will the different implementation be compatible?

10-4 Conclusion

A continuing challenge in electricity market regulation is how to design the market and analyze the level of competition. The short-term inelasticity of demand, the concentrated structure of most electricity markets and the relatively poor design of electricity markets in transitional phases represent important concerns with respect to competition. For this reason market monitoring is necessary. To date the European Commission has focused its monitoring on the implementation of the Directive and not paid due attention to wholesale market design and wholesale market performance. Moreover, recent work by the EC and ETSO seems to show a lack of a clear perspective on what the European electricity market should look like.

In order to move forward we have suggested a practical approach for improving the actual functioning of the European electricity markets using power exchanges. We have showed how power exchanges can be used to facilitate the problem of market definition and improve traditional market share analysis. We have then suggest how power exchanges can facilitate the construction of competition indicators to ensure effective market monitoring and identify potential market design improvements. In this respect the existence of power exchanges, in contrast to purely bilateral markets, facilitates the work of monitoring units by aggregating a large amount of information about participant behavior and providing details data on the evolution of supply and demand.

This work shows that only opening access to interconnection capacities is not sufficient to create an integrated market, it also requires designing the market that facilitate competition. In the absence of specific guidelines for market design, this has been carried out at a national level which has resulted in different arrangements. However, one important feature of actual market design is the existence of power exchanges in most Members States. These marketplaces have been able to develop good indicators of their respective national markets and thus can be used as a starting point for the development of an integrated market. Concretely, additional measures need to be taken to favor the creation of a European electricity market such as the creation of a consistent framework for market regulation. Market design and market monitoring need to be recognized as two essential elements for the well functioning of electricity markets. In Europe the liberalization process has overlooked these two issues. The focus has been on the legal aspects (liberalization) rather than economic aspects (competition).

The Directive 96/92 represents a significant step toward the creation of competitive markets, i.e. it has induced dramatic changes in the electricity industry, but it has not provide guidance on the question of what the market should look like. Liberalization is only one step in the process, alone it cannot deliver the expected benefits of a single integrated European-wide electricity market. The peculiarities of electricity markets need to be recognized. This involves designing the market at a European level rather than at a national level, and installing committees that are well equipped to perform effective monitoring. Since power exchanges are an important part of the actual market design they represent an interesting tool for this market monitoring process, and because it is hard to get everything right at the outset, this monitoring will allow monitoring committees to make recommendations for further improvements of the market design.

In conclusion, the definition of a clear and consistent market regulation framework by the EC appears to be a fundamental step in the sense that it will provide the necessary basis for negotiation with all interested parties to move from the actual situation, characterized by a low level of integration, to the creation of a real European wide market. The definition of such a framework is a complex task because no model is perfect. However, a detail analysis by monitoring committees using power exchanges can be utilized to provide solid empirical evidences that can be used to help regulatory bodies in the definition of such a framework.

Chapter 11

Conclusion

11-1 Research results

The creation of competitive electricity markets raises complex economic and public policy issues that are not amendable to an easy solution(s). Contrasted results of international experiences show the difficulty of the task. In this context, this work presents a first attempt to analyze the role of power exchanges in the creation of a single competitive European electricity market. We have tried to combine the contribution of general economic theory, more precisely of industrial organization, with the available literature on electricity markets and have used as many lessons as possible drawn from international experiences in the field.

In the first part of this work (chapters 2-3-4) we have presented the current developments of electricity markets in Europe and the different theoretical approaches in the literature. In this part we have seen that the emergence of organized markets, such as electricity power exchanges, is an important feature of the design of the actual European electricity market, though not mentioned in the initial electricity Directive. Hence, paradoxically the design of the “European” electricity market has been left to each national country (chapter 2). We have then identified three levels of market design. Interestingly, it appears that only the general level of market design (industry structure, i.e. unbundling, third party access, market opening) has been addressed by the Directive 96/92 and that the two other levels (wholesale market design and marketplace design) have not been considered (chapter 3). Subsequently, we have presented an overview of the alternative market models present in the economic literature and their applications in electricity markets. We have divided the analysis into two parts: power exchanges as organized marketplaces (part 2) and power exchanges as part of the wholesale market design (part 3). The survey of existing literature showed that little work has been done, to date, on this issue in Europe due mainly to the fact that most power exchanges have only recently been created. Hence one of the main interests of this work has been to look at a very recent and important issue of the European liberalization process, i.e. the creation of organized marketplaces, that is power exchanges, and to provide an analysis at the European level. To date most existing works have been conducted at the national level. This makes this work a primer on several aspects with all interest and (unfortunately) shortcomings of a primer.

Since little attention has been paid to the role of power exchanges in Europe, the second part of this work (chapters 5-6-7) starts with a detailed description of the functioning of electricity power exchanges as marketplaces with special attention to the price determination process. We have presented the different types of product traded on power exchanges and how prices are determined based on player's bids. The contributions and shortcomings of auction theory have been discussed. Since spot trades on a power exchange lead to physical delivery we have identified the relationship between these two aspects. In contrast with other models power exchanges in Europe do not take into account technical constraints such as congestion within the hub they cover (chapter 5). Subsequently, we focused our attention on how market participants use power exchanges. A typology of strategies according to the nature of players and different types of bidding behaviors were defined, and an analysis of arbitrage strategies described in the Enron memos was presented to help us understand the diversity and complexity of behaviors on power exchanges (chapter 6). Finally, since individual behavior on power exchanges is not directly observable we looked at the results of such behavior on competition through an analysis of two types of market structure and a direct analysis of price and volumes traded on several major power exchanges in Europe. Such analysis shows the low level of interconnection between countries with respect to national demand and important differences between the "physical" market structure (generators) and the "commercial" market structure (participants on the exchanges) and also the difference between countries. The direct analysis of price and volumes showed strong deterministic cycles including, intraday and day of week effects. In general several similarities between price developments on the different power exchanges studied, especially with respect to the variations of demand over time, were identified. However, some differences between countries remain such as the volumes traded on these markets (chapter 7).

While the focus of the second part of this work was the individual functioning of power exchanges, the third part of this work (chapters 8-9-10) deal with the role of power exchanges at the European level. Using different quantitative techniques, we tested the level of integration of the European market for the year 2002. Our study made four new contributions to the literature by analysing wholesale prices for the year 2002, the first year when power exchanges in France and in the UK were operational, which allowed us to take into account the central geographical position of France. We reduced the impact of seasonality by differentiating different periods (weekdays/weekends; baseload/peakload.) We estimated different levels of integration (national and international) by comparing results based on power exchange prices with bilateral market prices. The analysis demonstrated that a good level of integration exists at the national level between power exchanges and bilateral markets while the level of integration at the international level is relatively low. This shows that power exchange prices provide a reliable source of information for price developments in national markets and that the objective of an integrated market has not been reached (chapter 8). In the following chapter we tried to explain the reasons for such low market integration. The hypothesis we developed is that the actual wholesale market design at the European level lacks efficient transmission pricing which hampers the development of an integrated market. Comparison with international experiences showed that it appears to be fundamental to electricity markets that a single institution combines system operation (TSOs) and market operation (power exchange). In Europe transmission pricing and energy trading are treated separately, leading to the need for a physical transmission rights system. Such a system presents serious limitations with respect to efficient usage of the system and loop flows. This finding is supported by empirical evidence that suggests that the outcome of actual transmission pricing, based on separated auctions of interconnector capacity, is far from what should be expected in an efficient market (chapter 9). Several measures need to be taken with respect to market design and with respect to “market regulation” in general to improve the functioning of the market. We thus considered a broad definition of regulation which included promoting competition through market design and preventing unfair trading practices through market monitoring. In markets characterised by short-term inelasticity of demand, a concentrated structure and a design in transitional phases, opportunities for abuse of market power represent the main reasons for effective market monitoring. The Directive 96/92 defines a very basic framework for the creation of a European electricity market but does not provide guidance on the details of what the market should look like. To date the European Commission has focused its monitoring on the implementation of the Directive and has not paid due attention to wholesale market design and wholesale market performance. Moreover, recent work by the EC and ETSO seems to show a lack of a clear perspective on what the European electricity market should look like. To move forward, we have suggested a practical approach, and recommendations for improving the actual functioning of the European electricity market, by defining what kind of indicators need to be constructed using power exchanges as a source of information to ensure effective market monitoring and to improve market design (chapter 10).

11-2 Follow up research

This works shows how the lack of market design represents a barrier to the construction of a single European electricity market. This issue has been widely overlooked in Europe. An important body of theoretical literature is available in the US on this topic but few applications to the European context are available[1]. Market design is a very recent issue that covers a wide area of topics. Our approach has combined empirical observations, international comparisons and theoretical literature. As such, it will hopefully pave the way for further research and can always be extended. It can be completed using other approaches such

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[1] In this respect, the paper of Boucher and Smeers (2001) and Smeers (2001a) should be noted as exceptions that represent the principal and most valuable contributions on the topic

as simulations of how market participants behave and the use of models to estimate market outcomes. Moreover, several theoretical questions and practical problems are still unsolved. Further research may include:

- Power exchanges are organized around auctions to determine prices. However, little is known about the relationships between auction format and bidding behavior. Further research into auction theory should help us to understand how bidding formats affect the degree of competition. Moreover, the advantages of other types of auctions other than marginal pricing and pay-as-bid should be considered (e.g. Vickrey auctions).

- Actual European electricity markets are a combination of several markets (power exchanges, OTC, balancing markets, and auctions for interconnector capacities). As showed by the Enron memos the existence of several markets opens these markets to a large range of behaviors. It would be interesting to investigate to what extent such a combination of markets affects the behavior of participants with respect to the relationships between the different markets. Modeling might be considered for this purpose.

- In parallel to the creation of an integrated electricity market, the European Commission is dealing with other important issues such as the promotion of renewable energies, the Kyoto protocol, and the question of a public/universal service level, which may have important impacts on the functioning of wholesale markets. For instance, it would be interesting to analyze the impact of incentive mechanisms for the promotion of renewable energy sources on competition to avoid systems that create distortion of competition.

- The central role of a transmission operator is a common feature in different market designs for creating wholesale competitive markets, and one of the fundamental assumptions is its neutrality and efficiency. However due to its monopoly position, the strategic behavior of the TSO should be considered and the extent of its neutrality should be challenged.

- The analysis presented in this work focuses on the major power exchanges in Europe. As soon as power exchanges exist in all European countries, it would be interesting to extend the analysis of market integration. Moreover, other econometric techniques may be considered to analyze the evolution of market integration and the efficiency of bilateral auctions for interconnector capacities.

- Some market designs incorporate market power mitigation features such as price caps, bid caps, and reserve prices in several electricity markets, due to potential market power abuse. To date there is no clear consensus as to whether such measures really mitigate market power or whether they create perverse incentives. Theoretical and empirical research in this area would be of particular interest.

11-3 Final remarks

The introduction of competition in the European electricity industry in Europe, initiated by the EU Directive 96/92, has involved a massive transformation of the industries organization but has not lead, to date, to the creation of a single market. Liberalization in the electricity industry is a complex process because it needs to account for political considerations, interest groups, technical constraints and economic efficiency aspects. An additional difficulty in Europe is that the objective is not just to introduce competition in each country, it is also to integrate the different markets. A major obstacle is the different starting points, i.e. market structure, institutions, and histories, that exist in the various countries. However, since the physics and the economics of power systems are the same, solid economics and technical expertise can be used to underpin the process of integrating the European electricity markets.

Paradoxically, while the peculiarities of electricity are well-known, e.g. non-storability and loops flows, the creation of a single European electricity market is based on the assumption that electricity is like any other good which means that no specific market design is required. To date most attention has focused on market opening and increasing of interconnector capacity while the issue of market design, which is at the heart of market functioning, has been widely overlooked. The assumption behind the European process is that opening access to networks and increasing interconnection capacities will be sufficient to create an integrated market. Such assumption appears to be incorrect. Opening access to networks alone is of little use in the absence of institutions that facilitate access to these networks and in the absence of consistent rules that facilitate trading. Increasing interconnection capacities, although it definitely would support the liberalization process by increasing the number of players competing against each other and would dilute market power, is not a realistic solution in the short and medium term for several reasons. One, interconnectors are large infrastructures that take time to build. Two, the cost of building a new line between two countries may need more investment than just that needed to put in the new line because it would require national grids to be reinforced. Three, there is the question of who will pay for such large investments when return is regulated and will be spread out over a period of 30 to 50 years. Last but not least, licensing procedures and environmental constraints make it very difficult in practice for potential investors to obtain authorization. Instead of focusing exclusively on new investments in interconnection capacities, effective market design needs to be considered because it can provide the necessary coherent scheme for trading arrangements and market institutions to support network access. On its own an efficient market design is not sufficient to create a single competitive market, because transmission constraints create separate markets, but at least efficient market design would support optimal use of the existing infrastructure.

Short-term markets provided by electricity power exchanges are of particular interest because, though imperfect, they represent the beginnings of market design. Efficient short-term markets are critical because short-run signals are essential for providing incentives for additional investments. Moreover, they facilitate trading for market participants and facilitate monitoring for public policy makers. Power exchanges are now part of the initial conditions for further reforms and represent a powerful tool that can be used to develop a really competitive European wholesale electricity market. As the role of power exchanges is likely to change significantly in the next few years, the present analysis is intended to be a useful benchmark against which to compare further changes.

In conclusion, efficient monitoring based on empirical observations and combined with theoretical considerations appears to be a well-suited approach for improving market design. An important issue in designing electricity markets is the ability of the policy makers to take into account the fact that each market is part of a larger system. In Europe especially, where the final objective is to constitute a pan-European market, each Member State should avoid designing its electricity market while disregarding developments taking place in other countries. This is particularly important with the coming EU enlargement. Finally, one risk for public policy makers, when looking at market design issues, is to consider such issues as details. Yet details matter in vital markets such as electricity markets where supply and demand interact instantaneously and continuously, and where any major failure has disastrous economic and social costs, as illustrated by the major blackout that took place in North America in 2003.

Appendix 1

The importance of "market" regulation: lessons from California

A1-1 Introduction

During spring 2000 until spring of 2001, California experienced an energy crisis that led to skyrocketing natural gas and electricity wholesale prices which culminated in a regional electricity shortage. The subsequent electricity shortage caused California's electricity system operator (CAISO), to institute 'rolling blackouts' forcibly to adjust the State's electricity demand to the available amount of electricity in the state. Furthermore, the crisis led to the bankruptcy of PG&E, the largest electricity distribution company in the state, and the California Power Exchange, California's electricity marketplace.

Large supply shocks and a large demand shock that hit the state can largely explain the electricity crisis (Taylor and VanDoren, 2001). Firstly, a lack of investment in power plants represents probably the most important reason of the crisis. While demand grew by about 5,500 MW between 1996 and 1999, generating capacity increased by only 672 MW over the same period[1]. At the same time the California economy grew steadily during that period and this led to an increase in demand. This was exacerbated by the fact that retails prices were fixed and thus Californians had no incentives to decrease their demand.

In conjunction with these two fundamental reasons a combination of several other factors played a role in the crisis. For instance, poor hydro conditions reduced the generating capacity of the hydroelectric dams while abnormally hot weather increased electricity demand for air conditioning. Additionally, due to environmental rules some power plants could not operate because they did not have emissions credits. Similarly, California's dependence on imported electricity (20% of Californian consumption) became problematic because of a growth in electricity demands in neighboring States reduced the amount these States were able to export to California. Moreover this period saw a large increase in natural gas prices which was the fuel of choice for the marginal power plants. Finally last, but not least, poor market design and abuse of market power also played a role in the crisis.

There are numerous articles detailing the Californian electricity liberalisation process (Blumstein *et al*, 2002) and the collapse of its market (Borenstein, 2001; Jurewitz, 2002). California was among the first states in the U.S. to restructure its electricity industry in accordance with the world-wide trend of liberalisation. California's restructuring process was undertaken within a record-breaking time of five years[2]. The main purpose was to reduce the relatively high electricity prices. The process was based largely upon previous experiences in gas and telecommunications restructuring, rather than on experience with other liberalised electricity markets. California began its electricity market deregulation process in the mid 1990s. Two core pieces of the new industry structure, the California Independent System Operator (CAISO) and the California Power exchange (CalPX) and their procedures and tariffs were conceived and set up within three years. When the restructured electricity market started operating on March 31 1998, it was generally considered to be one of the most liberalised electricity markets in the world.

The main facts of this crisis were a 500% increase in prices between 1999 and 2000 (Joskow, 2001), the bankruptcies of the two largest utilities, dozens of blackouts have taken place, and an increase in the energy bill estimated at about \$50 billion. The reasons for this meltdown were multiple and are summarised briefly in figure A1-1. While the issue of market power has been widely studied for this market[3], interestingly, in his statement before the US Senate Committee on Governmental Affairs[4], bad market design was cited first by Paul Joskow as a reason of the Californian crisis. According to Joskow the causes of California's

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[1] California Public Utilities Commission, "California's electricity options and Challenges", www.cpuc.ca.gov

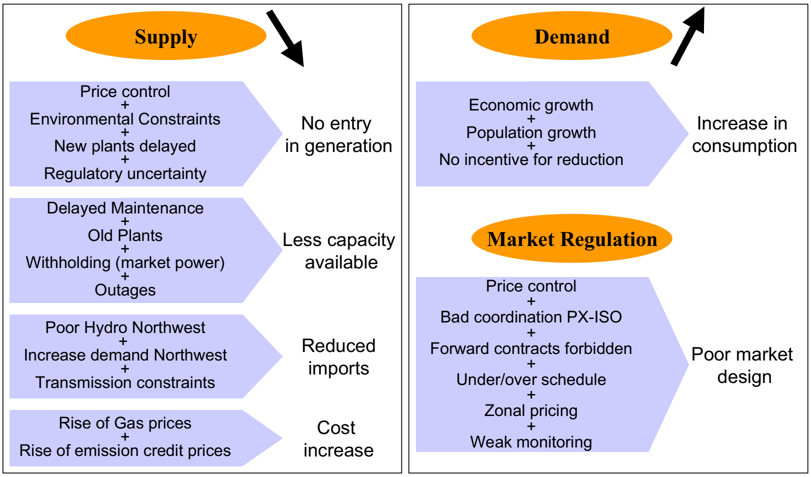
[2] Background documents about the California liberalization process are available at www.ucei.berkeley.edu/restructuring.html

[3] See chapter 6

[4] Statement of Professor Paul L. Joskow Before The Committee on Governmental Affairs

meltdown were *"complex, reflecting a combination of bad market design, bad regulatory decisions, unanticipated changes in basic supply and demand conditions, and supplier behaviors which rationally took advantage of opportunities created by these conditions to further increase market prices".*

Figure A1-1: The causes of California crisis



Beside the supply and demand shocks, three features of the California market design contributed to the crisis. These features were the freeze on retail prices, the restriction placed on long-term contracts, and the design of the PX and CAISO markets (Farmer *et al*, 2001). The first feature certainly represented the most important design flaw of the California market design, i.e. the wholesale market was deregulated while the retails markets were not and were subject to fixed prices defined for four years. Hence, distribution companies were forced to buy in an unregulated wholesale market and to sell to final customers at a regulated fixed price. The freeze on retail prices created important market distortions because suppliers could charge high prices for some periods without worrying that consumers would reduce their consumption (GAO, 2002). This feature had disastrous financials consequences for the distribution companies when, in the summer of 2000, wholesale prices rose above the fixed retail price.

United States Senate. Available at http://econ-www.mit.edu/faculty/pjoskow/papers.htm

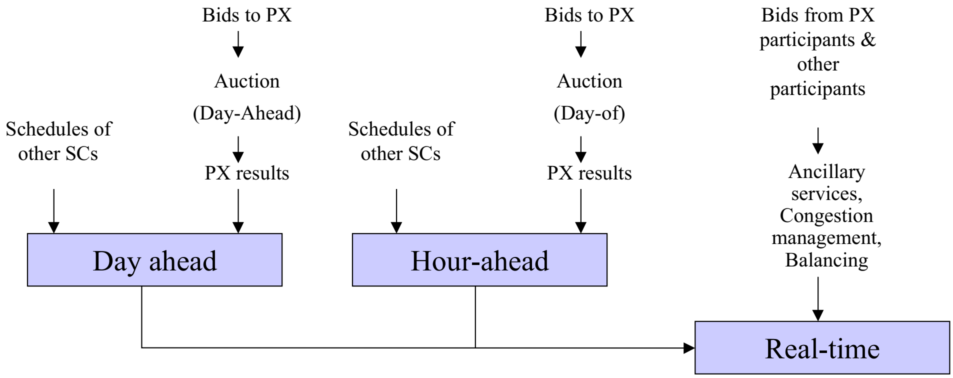
This retail price control is always cited as the most important flaw of the California market design (Smith *et al*, 2001). However, two others features which relate directly to wholesale market design also played an important role.

The aim of this appendix is not to provide a new analysis of the crisis but rather to focus on the role of wholesale market design in the meltdown of this market. We first present the main aspects of the design of the Californian market with respect to the respective roles of the power exchange, the system operator and transmission pricing (A1-2). Subsequently we pay attention to the shortcoming of this design (A1-3). Finally we summarise some key lessons that can be learnt from the Californian market for the European market (A1-4).

A1-2 Overview of the Californian market design

Similar to European electricity markets, the Californian market was organised around two primary institutions: a power exchange (CalPX) and an independent system operator (CAISO). The power exchange and ISO began operation in April 1998. The power exchange ran a day-ahead market using a one-sided bidding arrangement (as did the UK pool) for each hour with a marginal clearing price system, i.e. all bidders were receiving the same price equal to the highest accepted bid. The power exchange was also mandatory for the demand and supply of the investor-owned-utilities. The exchange handled roughly 85% of the volume of day-ahead transactions. Hence, participation to the power exchange was mandatory for some players and voluntary for some others. Similar to European markets, the power exchange provided a day-ahead market and after matching of supply of demand the PX submitted a balanced schedule to the system operator (figure A1-2). An important aspect of the California markets was the limitations on bilateral transactions. Investor-owned utilities were forced to divest much of their fossil-fuel based power plants and not permitted to sign multiyear contracts to buy part or all of the output from the plants they had just sold. Due to this prohibition, the distribution companies were required to buy almost all of the power they needed on the power exchange and on the real-time market run by the ISO. In addition to the PX, a peculiarity of the Californian market was that anyone other than investor-owned-utilities was allowed to form their own market. These markets were called scheduling co-ordinators (SCs). Note, Enron was one SCs. In fact SCs were just a way to handle physical bilateral transactions since, similar to the PX, the SCs had to submit a balanced schedule for each hour to the ISO.

Figure A1-2: Californian 's electricity market design



Source: California Power Exchange, Market Year Report to Californians, 1998-1999

Again, similar to European power exchanges, the California power exchanges ran an "energy only" market and did not take into consideration the different aspects of physical delivery. This was the responsibility of the California Independent System Operator (CAISO). The principal responsibility of CAISO was the management of the operation of the network (Alaywan, 2000)[5]. Three majors tasks can be distinguished: real time balancing, congestion management and ancillary services[6]. An important difference between the former Californian design and most European markets is the fact that the ISO was running a real-

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[5] See also www.CAISO.com for a detailed description of CAISO design and "redesign"

time market to manage the operation of the network. Hence market participants were able to change their day-ahead position by trading in the ISO's real time market. The purpose of this market commonly called a real–time or balancing market, was to price additional generation in the event of a supply shortfall and generation decreases in the event where supply exceed demand. For instance, a supplier that was scheduled to produce 100 MWh but was able only to produce 90 MWh, was forced to purchase 10 MWh from the ISO real-time market to maintain the balance between supply and demand. The ISO market was thus critical as it fell at the end of the chronological sequence of markets.

The ISO was also operating a "reserve capacity market". Through this market, the ISO purchased reserve capacities for two reasons. One the reserve capacities were used to meet unexpected demand peaks. Two they allowed the ISO to adjust production at different locations within the network to relieve congestion. The ISO also relied on several annual supply contracts with generators to ensure supply availability in constrained area.

One important controversial feature of the California market was the approach used for transmission pricing. When the ISO received schedules from the PX and the SCs it had to determine the physical feasibility of the transactions with respect to transmission constraints. Several zones were determined within the ISO system to take into account transmission constraints and possible congestion within a zone was not priced. When such a type of congestion occurred, the ISO paid above market prices to certain generators to use their output to relieve congestion[7]. Moreover due to important transmission constraints an important problem for the system operator was to make sure that where there was no substitutes for the output of a specific generator this would operate. Reliability Must-Run Contracts (RMR) were created for this purpose. These

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[6] Ancillary services cover products such as Regulation reserve, Spinning reserve, Replacement reserve, Black start…

[7] The price paid by the ISO is necessarily above-market, since there would have been no congestion if the necessary generation units had been willing to operate at the zonal market clearing price.

contracts aimed to compensate a generator forced to run for reliability purposes when the market price was below their operating costs.

In conclusion the design of the California electricity market consisted of several parallel and overlapping markets. Additionally the wholesale design was based on the idea that most co-ordination problems should be left to the market and that the role of the system operator should be as minimal as possible. Although, the design of this market was not the primary reason of the crisis, obvious mistakes contributed to California's problem by limiting market responsiveness to the extreme conditions.

A1-3 Poor market design?

The existence of retail price control is always cited as the most important flaw of the California market design. However at the wholesale level two others features of the California electricity market exacerbated the problem. One, distribution companies were not allowed to sign long term contracts to hedge their position. Two, the separation between system operation (CAISO) and power exchange (CalPX) created a complicated set of wholesale markets imperfectly coordinated with one another.

The decision to forbid long term contracts has several explanations. First following the divestiture of their generation asset the incentives for the investor-owned utilities were important for them to make contracts with the company buying the generation units. There was a fear that at first such possibility would distort the selling price of the asset and the prices for electricity. Second such contracts could be substituted for a utility ownership of the generator and would represent a threat for the creation of a competitive market. In addition, at the beginning of the market, utilities were reluctant to sign long-term contracts because long-term prices were generally higher than the spot prices of the PX.

This design appears problematic when the prices rose dramatically on the power exchange and on the CAISO market

Beside a lack of demand response and the impossibility for distribution companies to use bilateral contracts for hedging purposes, there was another important controversial issue this was the decision to separate the system operator managing transmission operations and reliability from a separate power exchange to coordinate market operation. The existence of the three markets, day-ahead, real-time and reserve, created uncertainties about which of them would have the best price and thus created even more arbitrage opportunities than would normally exist in a typical market (Taylor and VanDoren, 2001).

In particular, the low co-ordination between the PX and the ISO was an important limitation for the actual role of the ISO in the market. Hence the separation of the PX and the ISO had important consequences with respect to wholesale market design. On a short-term horizon, day-ahead, hour ahead, no distinction can be made between energy dispatch and use of transmission capacity. Thus, it was a fallacy to separate these two aspects (Chandley *et al*, 2000). Moreover the physical feature of contracts on the PX imposed constraints on real-time operation.

In theory, arbitrage between the power exchange and the real-time market would result in similar prices in both markets. However because the ISO market was run after the power exchange results, uncertainties existed about whether a generator would receive a higher price if waited for the ISO results. This is one explanation for the "INC-ing Load into the real-time market" strategy described in the Enron memos[8]. Additionally the pricing rules in the two markets were different in the respective markets of the PX and the ISO. For instance, different price caps created incentives for suppliers during high prices hours to use the ISO real-time market rather than the PX.

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[8] See chapter 6

The existence of various markets offered market participants several opportunities to arbitrage price difference across markets but also created perverse incentives for trading strategies. For instance many of market design problems have been identified as early as 1998 by the market surveillance Committee of the California ISO with regard to the market for ancillary services (Wolak *et al*, 1998): *"(1) some firms are subject to cost-based price caps while others are allowed to earn market-base rates; (2) the demand for ancillary services has been higher than anticipated; (3) the amount of each ancillary service demanded by the ISO does not depend on market prices and these demands are not procured in a rational manner; (4) perverse incentives for generator bidding behaviour have been created by reliability must-run contracts; (5) the ISO has often purchased ancillary services separately from small geographic areas, increasing the potential for the exercise of market power; (6) the ISO's dispatch practices have not been transparent to market participants; (7) the allocation of ancillary services costs to scheduling co-ordinators has been flawed".*

With respect to transmission pricing, the use of pre-determined zones for the management of transmission constraints was problematic due to the existence in some periods of intra zone constraints[9]. The day-ahead transmission market relied on incremental/decremental pairs to balance inter-zonal flows, whereas the real-time market was not confined to matched pairs. Furthermore, the SCs paid the cost of inter-zonal balancing whereas the system operator absorbed the cost of intra-zonal balancing (Chao and Wilson, 1999) which provided poor locational signals. Such an approach encouraged overscheduling of constrained transmission.

In conclusion the lack of demand response, the over reliance on the power exchange resulting from the ban on using bilateral contracts, and the inefficient transmission pricing system represent the principal shortcomings of California

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[9] See chapter 9

market's design leading to strategic incentives arising from the interaction of the PX and the ISO as illustrated by the Enron's memos[10].

A1-4 Lessons for European markets

In assessing the role of market design in the collapse of the California, one must recognise that the first lesson to be drawn from the California crisis is nothing other than an reminder of the most basic principle of Economic theory, i.e. when supply decreases and demand increases simultaneously, prices go up. Indeed a large part of the price spikes of 2000 and 2001 can be explained by factors directly related to supply and demand. Hence, in the short term for most European Member States, such situation appears to be unlikely due the existence of important reserve margins[11] and the slow increase in demand for electricity in most countries[12]. However, the several similarities between the design and regulatory environment of the former California wholesale market with actual European markets make analysis of the Californian crisis of particular interest.

First, several similarities exist in terms of design between California and most European markets: separation power exchange/system operator[13], non-harmonised transmission pricing methods (national/international)[14], regulated retails prices…etc. These aspects of California market design exacerbated extreme conditions. For this reason it is interesting for European markets to pay attention to the details of the inappropriate Californian market design which were a complementary factor to the Californian crisis. Though, a good market design might not have survived the summer 2000, it would have removed perverse incentives and would have certainly mitigated the extent of the crisis (Hogan,

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[10] See chapter 6

[11] Due to over capacity in most European countries, the reserve margin in Europe is above 30% (IEA, 2002)

[12] The projected growth in electricity demand in Europe through 2015 is below the expected rate of GDP growth, 2.6% per year (IEA, 2001)

[13] See chapter 4

2001). For instance, facing a lack of demand response, an increase of retail prices was presented as an essential element for limiting the price spikes[15] but this was not implemented. Moreover the low co-ordination between the power exchange and the system operator and the inefficient transmission pricing mechanisms, illustrated by the Enron strategies, shows that artificially separating these two functions creates artificial constraints on markets functioning.

Second, several authors (Joskow, 2001; Cramton, 2003) have argued that the fact that the Californian market design incorporated bits and pieces of alternatives market models was due to an effort to appease various interest groups. Such process led to the creation of the most complicated electricity market ever created with features beneficial to some participants, but harmful for the over-all design. Hence, it was especially difficult to make changes that would adversely impact a large group of market participants. Again this aspect is interesting for the European situation because most power exchanges to date have been created on private initiatives and most of them are owned by market participants.

Third, California had more than a dozen regulatory bodies with overlapping responsibilities (Robb and Sugalski, 2001). The State's Public Utility Commission (PUC) had not authority over municipal utilities within California, utilities in neighbouring States, or interstates transmission companies. Other agencies such as Air quality Management districts, the California Energy Commission (CEC) also had different types of conflicting regulatory power. For instance, PUC was responsible for approving of the retail prices that private utilities could charge for electricity while FERC was responsible for approving wholesale prices that producers could charge for power and use of their transmission lines. Hence, it was difficult to find which organisation was ultimately responsible because jurisdiction lines were not well defined. For instance when prices started to rise

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[14] See chapter 9

dramatically, PUC refused to raise retail prices and insisted that refunds for abuse of market power on the wholesale market (under the responsibility of FERC) would obviate the need for retail price increases (Hirst, 2001). This situation clearly made it difficult for efficient and rapid regulatory decisions to be made when the crisis started. This problem is also present in Europe, where regulatory responsibility is divided up between the European Commission, Member States, national Regulators, competition authorities, and even regional and local authorities.

Finally, the Enron memos illustrate how the complexity of electricity markets result in sophisticated market behaviors, and how players may take advantage of bad rules and poor market design. In a European market where market design has been widely overlooked by the liberalisation process, it is not unreasonable to believe that similar behaviors are taking place. Hence, due to the complexity of different market rules and grid code in the different European Members States it appears sensible to monitor closely electricity markets in order to diagnose and solve market performance and market design problems. Moreover, beyond the problems of market design, the nature of electricity markets and the existence of concentrated markets make this an issue of primary importance because they raises important concerns with respect to market power.

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[15] Manifesto on the California Crisis, January 2001, Available at www.haas.berkeley.edu/news/california_electricity_crisis.html

Appendix 2

Details of ADF unit root tests, estimates of regression models and econometric definitions

A2-1 Details of ADF unit root tests

A2-1-1 APX

```
ADF Test Statistic     -8.182311     1%   Critical Value*       -3.4571
                                     5%   Critical Value        -2.8728
                                     10% Critical Value         -2.5727
=======================================================================
*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(APX)
Method: Least Squares
Sample(adjusted): 1/02/2002 12/31/2002
Included observations: 260 after adjusting endpoints
=======================================================================
       Variable          Coefficient   Std. Error   t-Statistic   Prob.
=======================================================================
       APX(-1)            -0.412597     0.050425    -8.182311    0.0000
          C                14.30730     2.133000     6.707594    0.0000
=======================================================================
R-squared                  0.206032   Mean dependent var      -0.012462
Adjusted R-squared         0.202955   S.D. dependent var       22.02336
S.E. of regression         19.66188   Akaike info criterion    8.802903
Sum squared resid          99740.08   Schwarz criterion        8.830293
Log likelihood            -1142.377   F-statistic              66.95022
Durbin-Watson stat         2.061494   Prob(F-statistic)        0.000000
=======================================================================
```

A2-1-2 POWERNEXT

```
ADF Test Statistic     -6.837230     1%   Critical Value*       -3.4571
                                     5%   Critical Value        -2.8728
                                     10% Critical Value         -2.5727
=======================================================================
*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(POWERNEXT)
Method: Least Squares
Sample(adjusted): 1/02/2002 12/31/2002
Included observations: 260 after adjusting endpoints
=======================================================================
       Variable          Coefficient   Std. Error   t-Statistic   Prob.
=======================================================================
    POWERNEXT(-1)         -0.314990     0.046070    -6.837230    0.0000
          C                7.387138     1.122295     6.582174    0.0000
=======================================================================
R-squared                  0.153398   Mean dependent var      -0.030500
Adjusted R-squared         0.150117   S.D. dependent var       5.025643
S.E. of regression         4.633096   Akaike info criterion    5.911990
Sum squared resid          5538.119   Schwarz criterion        5.939380
Log likelihood            -766.5587   F-statistic              46.74771
Durbin-Watson stat         2.357868   Prob(F-statistic)        0.000000
=======================================================================
```

A2-1-3 OMEL

```
ADF Test Statistic    -3.135941    1%   Critical Value*      -3.4571
                                   5%   Critical Value       -2.8728
                                   10%  Critical Value       -2.5727
*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(OMEL)
Method: Least Squares
Sample(adjusted): 1/02/2002 12/31/2002
Included observations: 260 after adjusting endpoints
        Variable         Coefficient    Std. Error    t-Statistic      Prob.
        OMEL(-1)         -0.085703      0.027329      -3.135941        0.0019
        C                 3.421715      1.177312       2.906379        0.0040
R-squared                 0.036717    Mean dependent var          -0.106654
Adjusted R-squared        0.032984    S.D. dependent var           5.683145
S.E. of regression        5.588634    Akaike info criterion        6.287009
Sum squared resid         8058.070    Schwarz criterion            6.314399
Log likelihood           -815.3112    F-statistic                  9.834128
Durbin-Watson stat        2.287375    Prob(F-statistic)            0.001911
```

A2-1-4 SWEDEN

```
ADF Test Statistic     0.056822    1%   Critical Value*      -3.4571
                                   5%   Critical Value       -2.8728
                                   10%  Critical Value       -2.5727
*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(SWEDEN)
Method: Least Squares
Sample(adjusted): 1/02/2002 12/31/2002
Included observations: 260 after adjusting endpoints
        Variable         Coefficient    Std. Error    t-Statistic      Prob.
        SWEDEN(-1)        0.000771      0.013567       0.056822        0.9547
        C                 0.219257      0.439296       0.499110        0.6181
R-squared                 0.000013    Mean dependent var           0.240947
Adjusted R-squared       -0.003863    S.D. dependent var           3.499204
S.E. of regression        3.505957    Akaike info criterion        5.354467
Sum squared resid         3171.267    Schwarz criterion            5.381856
Log likelihood           -694.0807    F-statistic                  0.003229
Durbin-Watson stat        2.055828    Prob(F-statistic)            0.954731
```

A2-1-5 UKPX

```
ADF Test Statistic     -7.607387     1%   Critical Value*        -3.4571
                                     5%   Critical Value         -2.8728
                                     10%  Critical Value         -2.5727
*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(UKPX)
Method: Least Squares
Sample(adjusted): 1/02/2002 12/31/2002
Included observations: 260 after adjusting endpoints
       Variable           Coefficient    Std. Error    t-Statistic     Prob.
       UKPX(-1)            -0.366542      0.048182     -7.607387      0.0000
          C                 8.449532      1.144838      7.380545      0.0000
R-squared                   0.183214   Mean dependent var       -0.002603
Adjusted R-squared          0.180048   S.D. dependent var        4.916764
S.E. of regression          4.452188   Akaike info criterion     5.832331
Sum squared resid           5114.070   Schwarz criterion         5.859721
Log likelihood             -756.2030   F-statistic               57.87233
Durbin-Watson stat          2.155848   Prob(F-statistic)         0.000000
```

A2-1-6 LPX

```
ADF Test Statistic     -7.164452     1%   Critical Value*        -3.4571
                                     5%   Critical Value         -2.8728
                                     10%  Critical Value         -2.5727
*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LPX)
Method: Least Squares
Sample(adjusted): 1/02/2002 12/31/2002
Included observations: 260 after adjusting endpoints
       Variable           Coefficient    Std. Error    t-Statistic     Prob.
        LPX(-1)            -0.337357      0.047088     -7.164452      0.0000
          C                 8.516694      1.250304      6.811699      0.0000
R-squared                   0.165938   Mean dependent var       -0.025885
Adjusted R-squared          0.162705   S.D. dependent var        6.629751
S.E. of regression          6.066476   Akaike info criterion     6.451095
Sum squared resid           9494.950   Schwarz criterion         6.478485
Log likelihood             -836.6424   F-statistic               51.32938
Durbin-Watson stat          2.357074   Prob(F-statistic)         0.000000
```

A2-1-7 NORDPOOL

```
ADF Test Statistic    1.152283     1%   Critical Value*     -3.4571
                                   5%   Critical Value      -2.8728
                                   10%  Critical Value      -2.5727
===================================================================
*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(NORDPOOL)
Method: Least Squares
Sample(adjusted): 1/02/2002 12/31/2002
Included observations: 260 after adjusting endpoints
===================================================================
      Variable        Coefficient   Std. Error   t-Statistic   Prob.
===================================================================
    NORDPOOL(-1)       0.011325     0.009829     1.152283     0.2503
         C            -0.066385     0.312697    -0.212297     0.8320
===================================================================
R-squared              0.005120    Mean dependent var       0.241192
Adjusted R-squared     0.001264    S.D. dependent var       2.627958
S.E. of regression     2.626297    Akaike info criterion    4.776689
Sum squared resid      1779.538    Schwarz criterion        4.804079
Log likelihood        -618.9696    F-statistic              1.327757
Durbin-Watson stat     1.808746    Prob(F-statistic)        0.250271
===================================================================
```

A2-1-8 NORWAY

```
ADF Test Statistic    1.786610     1%   Critical Value*     -3.4571
                                   5%   Critical Value      -2.8728
                                   10%  Critical Value      -2.5727
===================================================================
*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(NORWAY)
Method: Least Squares
Sample(adjusted): 1/02/2002 12/31/2002
Included observations: 260 after adjusting endpoints
===================================================================
      Variable        Coefficient   Std. Error   t-Statistic   Prob.
===================================================================
     NORWAY(-1)        0.014553     0.008146     1.786610     0.0752
         C            -0.147338     0.257347    -0.572525     0.5675
===================================================================
R-squared              0.012221    Mean dependent var       0.240947
Adjusted R-squared     0.008392    S.D. dependent var       2.231713
S.E. of regression     2.222329    Akaike info criterion    4.442651
Sum squared resid      1274.197    Schwarz criterion        4.470041
Log likelihood        -575.5447    F-statistic              3.191977
Durbin-Watson stat     1.603893    Prob(F-statistic)        0.075175
===================================================================
```

A2-1-9 DK-West

```
ADF Test Statistic      -6.419316     1%  Critical Value*       -3.4571
                                      5%  Critical Value        -2.8728
                                      10% Critical Value        -2.5727
=======================================================================
*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(DK)
Method: Least Squares
Sample(adjusted): 1/02/2002 12/31/2002
Included observations: 260 after adjusting endpoints
=======================================================================
       Variable        Coefficient   Std. Error   t-Statistic    Prob.
=======================================================================
        DK(-1)          -0.273575     0.042617    -6.419316    0.0000
          C              7.589780     1.260479     6.021346    0.0000
=======================================================================
R-squared                0.137722   Mean dependent var         0.111074
Adjusted R-squared       0.134380   S.D. dependent var         8.338861
S.E. of regression       7.758366   Akaike info criterion      6.943083
Sum squared resid        15529.60   Schwarz criterion          6.970473
Log likelihood          -900.6008   F-statistic                41.20761
Durbin-Watson stat       2.420592   Prob(F-statistic)          0.000000
=======================================================================
```

A2-2 Estimates of regression models

A2-2-1 Denmark-Norway

Example: DKWESTBASE= 14,39116+ 0,482891NORWAYBASE

```
Dependent Variable: DKWESTBASE
Method: Least Squares
Sample: 1/01/2002 12/31/2002
Included observations: 261
=======================================================================
       Variable        Coefficient   Std. Error   t-Statistic    Prob.
=======================================================================
          C              14.39116     0.875519     16.43728    0.0000
     NORWAYBASE          0.482891     0.027380     17.63642    0.0000
=======================================================================
R-squared                0.545649   Mean dependent var         27.38431
Adjusted R-squared       0.543894   S.D. dependent var         11.31596
S.E. of regression       7.642299   Akaike info criterion      6.912907
Sum squared resid        15126.83   Schwarz criterion          6.940222
Log likelihood          -900.1344   F-statistic                311.0434
Durbin-Watson stat       1.140531   Prob(F-statistic)          0.000000
=======================================================================
```

A2-2-2 Denmark-Sweden

Dependent Variable: DKWESTBASE
Method: Least Squares
Sample: 1/01/2002 12/31/2002
Included observations: 261

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	12.33978	0.895323	13.78249	0.0000
SWEDENBASE	0.530569	0.027338	19.40744	0.0000

R-squared	0.592542	Mean dependent var	27.38431
Adjusted R-squared	0.590969	S.D. dependent var	11.31596
S.E. of regression	7.237180	Akaike info criterion	6.803974
Sum squared resid	13565.58	Schwarz criterion	6.831288
Log likelihood	-885.9185	F-statistic	376.6488
Durbin-Watson stat	1.196392	Prob(F-statistic)	0.000000

A2-2-3 Norway-Sweden

Dependent Variable: NORWAYBASE
Method: Least Squares
Sample: 1/01/2002 12/31/2002
Included observations: 261

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2.577545	0.355127	-7.258087	0.0000
SWEDENBASE	1.039818	0.010844	95.89144	0.0000

R-squared	0.972605	Mean dependent var	26.90702
Adjusted R-squared	0.972499	S.D. dependent var	17.31007
S.E. of regression	2.870607	Akaike info criterion	4.954557
Sum squared resid	2134.260	Schwarz criterion	4.981872
Log likelihood	-644.5697	F-statistic	9195.169
Durbin-Watson stat	0.625035	Prob(F-statistic)	0.000000

A2-2-4 Powernext-UKPX

Dependent Variable: POWERNEXTBASE
Method: Least Squares
Sample: 1/01/2002 12/31/2002
Included observations: 261

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	13.12157	1.480944	8.860274	0.0000
UKPXBASE	0.449886	0.062351	7.215318	0.0000

R-squared	0.167365	Mean dependent var	23.49248
Adjusted R-squared	0.164151	S.D. dependent var	6.303001
S.E. of regression	5.762506	Akaike info criterion	6.348255
Sum squared resid	8600.478	Schwarz criterion	6.375570
Log likelihood	-826.4473	F-statistic	52.06081
Durbin-Watson stat	0.841305	Prob(F-statistic)	0.000000

A2-2-5 Powernext--LPX

Dependent Variable: POWERNEXTBASE
Method: Least Squares
Sample: 1/01/2002 12/31/2002
Included observations: 261

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8.767489	0.858427	10.21344	0.0000
LPXBASE	0.583019	0.032385	18.00255	0.0000

R-squared	0.555816	Mean dependent var	23.49248
Adjusted R-squared	0.554101	S.D. dependent var	6.303001
S.E. of regression	4.208871	Akaike info criterion	5.719899
Sum squared resid	4588.079	Schwarz criterion	5.747213
Log likelihood	-744.4468	F-statistic	324.0919
Durbin-Watson stat	1.380904	Prob(F-statistic)	0.000000

A2-2-7 Powernext-APX

Dependent Variable: POWERNEXTBASE
Method: Least Squares
Sample: 1/01/2002 12/31/2002
Included observations: 261

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	20.84045	0.651943	31.96667	0.0000
APXBASE	0.076639	0.015441	4.963362	0.0000

R-squared	0.086854	Mean dependent var	23.49248
Adjusted R-squared	0.083329	S.D. dependent var	6.303001
S.E. of regression	6.034679	Akaike info criterion	6.440556
Sum squared resid	9432.094	Schwarz criterion	6.467870
Log likelihood	-838.4925	F-statistic	24.63496
Durbin-Watson stat	0.698207	Prob(F-statistic)	0.000001

A2-2-8 LPX-Denmark

Dependent Variable: LPXBASE
Method: Least Squares
Sample: 1/01/2002 12/31/2002
Included observations: 261

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	18.62080	1.232800	15.10448	0.0000
DKWESTBASE	0.242315	0.041618	5.822398	0.0000

R-squared	0.115740	Mean dependent var	25.25644
Adjusted R-squared	0.112326	S.D. dependent var	8.059906
S.E. of regression	7.593757	Akaike info criterion	6.900163
Sum squared resid	14935.27	Schwarz criterion	6.927478
Log likelihood	-898.4713	F-statistic	33.90032
Durbin-Watson stat	0.665690	Prob(F-statistic)	0.000000

A2-2-9 APX-LPX

Dependent Variable: APXBASE
Method: Least Squares
Sample: 1/01/2002 12/31/2002
Included observations: 261

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	10.42515	4.695331	2.220323	0.0273
LPXBASE	0.957349	0.177138	5.404533	0.0000

R-squared	0.101347	Mean dependent var	34.60437
Adjusted R-squared	0.097877	S.D. dependent var	24.23794
S.E. of regression	23.02123	Akaike info criterion	9.118344
Sum squared resid	137264.1	Schwarz criterion	9.145659
Log likelihood	-1187.944	F-statistic	29.20898
Durbin-Watson stat	0.950483	Prob(F-statistic)	0.000000

A2-3 Econometric definitions

The least squares regression coefficients **b** are computed using the standard OLS formula:

$$b = (X'X)^{-1}X'y \qquad \text{(A2-1)}$$

The coefficient c is the constant in the regression.

The **“Std.Error”** column reports the estimated standard errors of the coefficient estimates. It measures the statistical reliability of the coefficient estimates, i.e. the larger the standard errors, the more statistical noise in the estimates.

The **“t-statistic”** is computed as the ratio of an estimated coefficient to its standard error. It is used to test the hypothesis that a coefficient is equal to zero.

The column **“prob”** shows the probability of drawing a t-statistic as extreme as the one actually observed, under the assumption that the errors are normally distributed, or that the estimated coefficient are asymptotically normally distributed.

The **"R-squared"** (R^2) statistic measures the success of the regression in predicting the values of the dependent variable. R^2 Equal one if the regression fits perfectly, and zero if it fits no better than the simple mean of the dependent variable.

The **"adjusted R^2"** penalises the R^2 for the addition of repressors which do not contribute to the explanatory power of the model (An R^2 of one can be obtain if as many independent repressors as there are sample observation are included).

The **"S.E. of regression"** (Standard error of the regression) is a summary measure based on the estimated variance of the residuals.

The **"Durbin-Watson statistic"** measures the serial correlation in the residuals. This statistic uses the residual from the OLS regression procedure and is computed as follow:

$$DW = \frac{\sum_{t=2}^{T} (\varepsilon_t - \varepsilon_{t-1})^2}{\sum_{t=1}^{T} \varepsilon_t^2} \qquad \text{(A2-2)}$$

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Summary

The electricity sector worldwide is undergoing a fundamental transformation of its institutional structure as a consequence of the complex interactions of political, economic and technological forces. The way the industry is organized is changing from vertically integrated monopolies to unbundled structures that favor market mechanisms. This process in Europe, known as the liberalization process, has had a wide impact on the European electricity industry. The focus of this dissertation is an analysis of the role of electricity power exchanges in the recently liberalized electricity markets of Europe. In the context of creating "a" competitive electricity market at a European level, the key questions considered are the functioning of these power exchanges with respect to electricity characteristics, market design and regulatory framework.

In Europe, very little attention has been paid to the role of these new marketplaces and to the issue of market design in general. Hence the main purpose of this work was to analyze how these marketplaces facilitate the trading of electricity and the role they can play in the construction of a pan-European competitive electricity market. An analysis of power exchange requires taking into account the "double-duality" of such institutions. One, power exchanges are both a market and an institution. As a market they facilitate the trading of electricity and determine an equilibrium price. As an institution power exchanges have their own objectives and constraints, and play a role in the market design of the overall electricity market. Two, the relationship between electricity power exchanges and liberalization is neither linear nor one way: liberalization encourages the birth of such marketplaces yet marketplaces are more than the results of such process, they are also a driving force of the liberalization process.

This thesis is divided into three parts. The current situation in Europe and different existing theoretical approaches in the literature are presented as a starting point for the analysis in **part 1** of the thesis. The EU legal framework of the liberalization process, the role of electricity trading and the emergence of power exchanges is presented first (chapter 2). In this chapter we define a model including power exchanges which will be used as an analytical framework for the analysis. The theoretical concepts that will be used for the analysis are presented in the following two chapters. First, the different theoretical approaches of market design are presented (chapter 3). Then the economic theory models of market functioning and their application to electricity markets are discussed (chapter 4). This description led us to divide the analysis into two parts: power exchanges as organized market places (part 2 of the thesis) and power exchanges as institutions that are part of the global wholesale market design (part 3 of the thesis). In part 1 of the thesis we show that the emergence of power exchanges in Europe is a fundamental aspect of the actual design of European wholesale electricity markets; and that existing theoretical literature can provide guidance for an analysis, but that literature pertaining to the European situation is rather limited.

In **part 2** of the thesis power exchanges are considered as marketplaces with a specific type of functioning (chapter 5) which in turn involves interaction from participants (chapter 6). Finally the concrete output of these interactions is analyzed using empirical observations to estimate the level of competition on power exchanges (chapter 7). The main contribution of part 2 of the thesis is to provide a primer on the functioning of power exchanges in Europe which differ from other organized electricity markets and which have so far received little attention. Looking at the electricity markets at the European level, it can be seen that most power exchanges have been designed separately and that they have been designed to function at a national level. Keeping in mind that the objective of the liberalization process in Europe is to create a single electricity market, the results derived in part 2 of the thesis are taken as the starting point for part 3 of the thesis in which we determine if such a piecemeal design process has resulted in the creation of a single integrated electricity market.

Part 3 of the thesis begins with an empirical estimation of the level of integration of European electricity markets. The level of integration is estimated using an econometric test based on power exchanges prices (chapter 8). Such an analysis shows a low level of market integration at the European level. In the next step of the analysis an attempt is made to explain the reasons for such low market integration. The hypothesis developed is that the actual wholesale market design at the European level lacks efficient transmission pricing (chapter 9). We then present some different theoretical approaches to transmission pricing (Nodal/Zonal) and an analysis of actual successful examples of integrated markets (PJM, Nord pool). We conclude by providing some empirical evidence of inefficient transmission pricing in Europe. Finally we argue that the creation of an integrated market requires design at the European level rather than national market design (chapter 10). We present the positive points and drawbacks of the recent works realized by the European Commission and other European bodies such as the European Association of Transmission System Operators and the Council of European Energy Regulators. Finally, we emphasize the importance of “market” regulation through monitoring market design developments with particular attention paid to market power concerns. The objective of this part of the thesis is to show that design is a major missing piece of the European liberalization process; and that the issues of transmission pricing and market power especially, while fundamental to the creation of competitive electricity markets, have been widely overlooked. The concrete output of this part of the thesis is a definition of the main principles of a “European framework for market regulation” emphasizing the role of power exchanges through several recommendations for a step by step approach to the creation of an integrated market.

Samenvatting

De elektriciteitssector ondergaat wereldwijd, als gevolg van een complexe interactie tussen politieke, economische en technologische krachten, een fundamentele transformatie van institutionele structuur. De ordening van de industrie in de vorm van verticaal geïntegreerde monopolies verandert in een structuur van ontvlochten ondernemingen die via marktmechanismen met elkaar wisselwerken. Dit transformatieproces, beter bekend als de liberalisering van de elektriciteitssector, heeft een grote invloed op de Europese elektriciteitsindustrie. Dit proefschrift analyseert de rol die elektriciteitsbeurzen (*power exchanges*) spelen in de zo ontstane Europese elektriciteitsmarkt, met name met betrekking tot het functioneren van deze elektriciteitsbeurzen, het marktontwerp (*market design*) waarin beurzen hun rol kunnen vervullen en het regelgevend kader hiervoor.

In Europa is er tot nu toe weinig aandacht besteed aan het marktontwerp voor een geliberaliseerde elektriciteitsmarkt in het algemeen en de rol van elektriciteitsbeurzen daarin in het bijzonder. Dit proefschrift beoogt te analyseren hoe deze marktplaatsen de handel in elektriciteit bevorderen en welke rol zij in de vorming van een concurrerende pan-Europese elektriciteitsmarkt kunnen spelen. Bij een analyse van elektriciteitsbeurzen moet rekening gehouden worden met de inpassing van dergelijke instituties in de marktstructuur. Ten eerste zijn elektriciteitsbeurzen zowel een marktplaats als een institutie. Als marktplaats faciliteren elektriciteitsbeurzen de handel in elektriciteit en bepalen zij evenwichtsprijzen. Als instituut heeft een elektriciteitsbeurs zijn eigen doelen en beperkingen, en speelt deze een eigen rol in het functioneren van de gehele elektriciteitsmarkt. Ten tweede bestaat er ook een wisselwerking tussen elektriciteitsbeurzen en het liberaliseringsproces: Enerzijds bevordert liberalisering het ontstaan van zulke marktplaatsen, maar anderzijds zijn elektriciteitsbeurzen zelf ook een drijvende kracht achter het liberaliseringproces.

Dit proefschrift omvat drie delen. **Deel 1** beschrijft de actuele situatie van de elektriciteitssector in Europa alsmede de verschillende modellen hiervoor uit de literatuur die een uitgangspunt vormen voor de verdere analyses. Het juridische kader van het liberaliseringsproces, de rol van de elektriciteitshandel en het belang van elektriciteitsbeurzen worden in hoofdstuk 2 beschreven. Tevens biedt dit hoofdstuk een model voor de elektriciteitsmarkt dat eveneens later gebruikt wordt voor verdere analyses. De theoretische concepten die hierbij de revue passeren, worden in de daaropvolgende twee hoofdstukken nader uitgewerkt. Hoofdstuk 3 beschrijft de verschillende theoretische vormen van marktontwerp. Vervolgens bediscussieert hoofdstuk 4 enkele economische modellen voor het functioneren van markten en de toepassing hiervan op de elektriciteitsmarkt. De twee vervolgdelen van dit proefschrift sluiten overigens op de analyses van dit eerste deel aan: Deel 2 analyseert de elektriciteitsbeurzen als georganiseerde marktplaatsen, terwijl deel 3 zich richt op het analyseren van elektriciteitsbeurzen als instituties die onderdeel zijn van het algehele marktontwerp en het liberaliseringsproces. Zo toont het eerste deel van dit proefschrift dat elektriciteitsbeurzen een fundamenteel onderdeel vormen van het ontwerp van Europese groothandelsmarkten voor elektriciteit en dat, hoewel de bestaande economische literatuur wel een handvat biedt voor nadere analyse, de huidige wetenschappelijke literatuur nog slechts beperkt is ingegaan op de recente Europese elektriciteitsmarkt.

In **deel 2** van dit proefschrift worden elektriciteitsbeurzen beschouwd als marktplaatsen. Hoofdstuk 5 beschrijft de functie van elektriciteitsbeurzen in de elektriciteitsmarkt. Hoofdstuk 6 onderzoekt vervolgens de interactie tussen de participanten op dergelijke marktplaatsen. Hiertoe is het niveau van concurrentie op de verschillende Europese elektriciteitsbeurzen ingeschat op basis van empirische gegevens (hoofdstuk 7). Het hoofddoel van deel 2 is om een analyse te geven van de bestaande Europese elektriciteitsbeurzen. Hoewel deze duidelijk verschillen van de marktplaatsen in andere georganiseerde elektriciteitmarkten, is hier tot nu toe weinig aandacht voor geweest in wetenschappelijk onderzoek.

Uit de analyse van met name de Europese elektriciteitsmarkten kan geconcludeerd worden dat de meeste elektriciteitsbeurzen afzonderlijk zijn ontworpen en wel zó dat ze vooral op nationaal niveau dienden te functioneren. Met het doel van het creëren van een pan-Europese elektriciteitsmarkt in het achterhoofd, dienen de resultaten van deel 2 als basis voor het derde deel van dit proefschrift. Hierin wordt geanalyseerd in hoeverre de huidige stapsgewijze aanpak wel *kan* resulteren in één volledig geïntegreerde Europese elektriciteitmarkt.

Deel 3 van het proefschrift begint met een empirische inschatting van het niveau van integratie van de Europese elektriciteitsmarkten. Dit is gedaan door een econometrische toets uit te voeren voor de correlatie tussen de verschillende elektriciteitsmarktprijzen (hoofdstuk 8). Deze analyse laat zien dat het niveau van marktintegratie in Europa laag is. In een volgende stap is de oorzaak hiervan getracht te analyseren. Eén mogelijke reden lijkt de weinig efficiënte prijsvorming voor transmissie in het huidige Europese marktontwerp te zijn (hoofdstuk 9). Hoofdstuk 10 bespreekt vervolgens de verschillende (theoretische) prijssystemen voor transmissie (*nodal* versus *zonal*) en geeft een aantal succesvolle voorbeelden van marktintegratie (de *PJM-markt* in het noordoosten van de V.S. en *Nord pool* in Skandinavië).

De conclusie, gebaseerd op een aantal praktijkvoorbeelden, is dat het tarief voor transmissie in sommige Europese landen inderdaad op een inefficiënt niveau wordt vastgesteld. Daartegenover blijkt het voor het creëren van een volledig geïntegreerde Europese elektriciteitsmarkt – in plaats van de som van een aantal nationale markten – wel degelijk noodzakelijk te zijn dat transmissie efficiënt beprijsd wordt. De Europese Commissie en andere Europese organisaties zoals ETSO (*European Association of Transmission System Operators*) en de CEER (*Council of European Energy Regulators*) hebben inmiddels een aantal maatregelen en richtlijnen voorgesteld en (deels) geïmplementeerd met betrekking tot de tarifering van landgrensoverschrijdende transmissie. Deze worden eveneens besproken, en tevens wordt ingegaan op de belangrijke rol van marktregulering in het proces van marktintegratie. Dit betreft het maken van een marktontwerp en het monitoren van marktontwikkelingen, waarbij speciale aandacht uitgaat naar problemen betreffende marktmacht. Het doel van het derde deel is om te laten zien dat een eenduidig marktontwerp op Europees niveau een belangrijk onderdeel is in het liberaliseringsproces en dat met name het belang van marktmacht en transmissietarifering tot nu toe danig zijn onderschat. Een concreet resultaat van dit laatste deel is dan ook het beschrijven van de grondbeginselen van een Europees kader voor marktregulering, waarin de belangrijke rol van elektriciteitsbeurzen wordt benadrukt. Dit leidt tenslotte tot een aantal aanbevelingen voor een stapsgewijze aanpak voor het ontwikkelen van een volledig geïntegreerde Europese elektriciteitsmarkt.

Résumé

En Europe comme ailleurs dans le monde, l'ouverture à la concurrence du secteur électrique, résultat de complexes interactions de forces politiques, économiques et technologiques, se traduit par de nombreux changements au niveau de l'organisation industrielle de ce secteur. Traditionnellement organisé autour de monopoles verticalement intégrés, le secteur électrique évolue vers une organisation décentralisée basée sur des mécanismes de marché. Au sein de cette nouvelle organisation de marché (*market design*), l'émergence de «bourses de l'électricité» (*power exchanges*) dans la plupart des pays Européens représente un aspect majeur. Cette thèse présente une analyse du rôle de ces bourses d'électricité dans le contexte de création d'un marché commun de l'électricité au niveau Européen. Pour cela l'analyse se concentre sur le fonctionnement de ces bourses d'électricité en tenant compte des caractéristiques de l'électricité, des problèmes d'organisation économique de marché et de régulation.

En Europe, le rôle des bourses de l'électricité en tant que places de marchés et la question même d'organisation de marché en général ont été peu étudiés. Ainsi, l'objectif de cette thèse est d'analyser comment ces places de marchés facilitent le négoce d'électricité et leur rôle dans la construction d'un marché de l'électricité commun au niveau Européen. Une telle analyse nécessite de prendre en compte la «double-dualité» des bourses de l'électricité. Premièrement, une bourse de l'électricité est à la fois un marché et une institution. En tant que marché, une bourse facilite le commerce d'électricité et détermine un prix d'équilibre, résultat de la rencontre de l'offre et de la demande. En tant qu'institution, une bourse de l'électricité a ses propres objectifs et contraintes, et joue un rôle dans l'organisation globale du marché de l'électricité. Deuxièmement, le lien de causalité entre bourses de l'électricité et processus de libéralisation n'est pas unidirectionnel. Certes le processus de libéralisation est à l'origine même de la création de ces places de marché. Cependant les bourses d'électricité ne sont pas seulement un résultat du processus de libéralisation mais, une fois en place, représentent aussi un élément moteur de ce processus.

Cette thèse est divisée en trois parties. Dans un premier temps, la situation actuelle des marchés de gros électriques en Europe et les différents travaux théoriques sur le sujet sont présentés dans la **première partie** comme point de départ à l'analyse. Le contexte règlementaire européen encadrant le processus de libéralisation, le role du négoce (*trading*) d'électricité et les raisons de l'émergence de bourses d'électricité sont tout d'abord présentés (chapitre 2). Dans ce chapitre nous définissons un modèle analytique d'organisation de marché de gros comprenant une bourse de l'électricité qui sera utilisée comme modèle de référence pour la suite de l'analyse. Les deux chapitres suivants sont consacrés aux concepts théoriques et aspects technico-économiques spécifiques aux marchés électriques. Nous présentons d'une part, les différents modèles théoriques de design de marché (chapitre 3) et d'autre part les modèles économiques de fonctionnement de marché et leurs applications aux marchés électriques (chapitre 4). Ce travail nous amène à diviser notre analyse en deux parties : les bourses de l'électricité sont des marchés où plus précisément des places de marché (deuxième partie) et les bourses de l'électricité sont des institutions qui jouent un rôle dans l'organisation globale du marché de l'électricité (troisième partie). En conclusion, la première partie de cette thèse montre que l'émergence des bourses de l'électricité est un phénomène majeur qui représente un aspect fondamental du design du marché Européen et que la littérature disponible sur le sujet propose des pistes de réflexions intéressantes mais que les applications à la situation Européenne sont limitées.

Dans la **deuxième partie** de cette thèse, les bourses de l'électricité sont étudiées en tant que place de marché. Tout d'abord nous mettons en évidence les différentes règles de fonctionnement de ces places de marché (chapitre 5). Deuxièmement les différents types de comportement de la part des acteurs sont étudiés (chapitre 6). Enfin nous analysons le résultat concret de l'interaction des acteurs en terme de concurrence à travers plusieurs observations empiriques (chapitre 7). La contribution majeure de la seconde partie de ce travail est de proposer une première analyse sur le fonctionnement des bourses de l'électricité Européennes qui présentent à la fois des caractéristiques différentes des marchés organisés de l'électricité observés ailleurs dans le monde et qui jusqu'à présent, de part leur émergence récente, n'ont pas été étudiées. Dans cette partie nous observons que l'ensemble des bourses de l'électricité ont été mises en place séparément les unes des autres et que leur mode de fonctionnement est national. Cette observation représente le point de départ de la troisième partie de cette thèse dans laquelle nous cherchons à savoir si cette ensemble hétérogène de marchés juxtaposés constitue un marché commun de l'électricité conformément à l'objectif du processus de libéralisation.

La **troisième partie** de cette thèse commence par une estimation empirique du niveau d'intégration des marchés électriques Européens. Le niveau d'intégration est estimé à partir de tests économétriques utilisant les prix fournis par différentes bourses d'électricité Européennes (chapitre 8). Cette analyse montre un faible niveau d'intégration au niveau Européen. Dans le chapitre suivant nous développons l'hypothèse que ce faible niveau d'intégration est directement lié aux lacunes du système actuel de transport en ce qui concerne la gestion des congestions au niveau des capacités d'interconnection entre pays (chapitre 9). Pour ce faire nous présentons les principales approches théoriques de gestion des congestions (Nodal/Zonal) et étudions deux exemples de marchés bien intégrés (PJM, Nord pool). Enfin nous mettons en évidence les inefficacité du système actuel à travers plusieurs études de cas. Dans le dernier chapitre nous arguons que la création d'un marché Européen de l'électricité nécessite la mise en place d'une organisation du marché (*market design*) au niveau Européen et non aux différents niveaux nationaux (chapitre 10). Nous présentons pour cela les différents intérêts et limites des récents travaux sur le sujet de la Commission Européenne et de d'autres organisations telles que l'association Européenne des gestionnaires de réseaux (ETSO) ou le conseil des régulateurs de l'énergie

Européen (CEER). Nous insistons sur l'importance d'une régulation de marché s'appuyant sur un suivi de près des dévelopements du design de marché avec une attention particulière portée aux questions de pouvoir de marché. L'objectif de cette troisième partie est de montrer que le design de marché représente une pièce manquante majeure du processus de libéralisation et en particulier que les aspects transports et pouvoir de marché, bien que fondamentaux dans la création de tout marché de l'électricité, ont été relativement négligés jusqu'à présent. En conclusion nous proposons différentes pistes de réflexion sur comment utiliser les bourses de l'électricité comme élément de base à une «directive» posant des principes communs en terme de design de marché qui semble indispensable pour la construction d'un véritable marché Européen de l'électricité intégré et concurrentiel.

Publications

“The liberalization process of the European electricity market(s): an unstructured restructuring process?”, 26th International IAEE conference , June 4-7,2003, Prague, Czech Republic, conference proceedings (with Rudi Hakvoort)

“La question du marché pertinent dans le secteur électrique”, Economies et sociétés, Série “Economie de l’énergie”, EN, numéro 9, 2-3/2003, p.321-337

“The role of electricity trading and power exchanges for the construction of a common European electricity market”, International IEEE/PES Transmission & Distribution conference 2002 Asia Pacific, October 6-10, 2002, Yokohama, Japan, conference proceedings

“The relevance of the relevant market for market power in power markets”, 25th International IAEE conference, June 26-29, 2002, Aberdeen, Scotland, conference proceeding

“The role of electricity power exchanges in Europe for the construction of a common market”, Fifth international IEE conference on power system management and control, April 17-19, 2002, London, United Kingdom, conference publication No 488

“Electricity trading in Europe: Electricity power exchanges VS e-marketplaces”, DistribuTECH Europe 2001, November 6-8, 2001, Berlin, Germany, conference proceedings

“Congestion management methods and power exchanges: their significance for a liberalized electricity market and their mutual dependence”, Gas and electricity forum-Scuola Enrico Mattei-ENI, June 21-22, 2001, Milan, Italy, conference proceedings (with Laurens De Vries)

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Curriculum Vitae

François Boisseleau studied Industrial organization at the University of Paris Dauphine (France), in 1999 after receiving his Diplôme d'Etudes Approfondies (further studies diploma, first year of Ph.D. in France) he joined the Design and Management of Infrastructures research program at Delft University of Technology. His Ph.D thesis entitled "*The role of power exchanges for the creation of a single European electricity market: market design and market regulation*" consists of an analysis of the economic aspects of the electricity industry liberalization process with particular attention given to the development of organised markets in Europe and their role in the creation of a single European electricity market.

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