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.

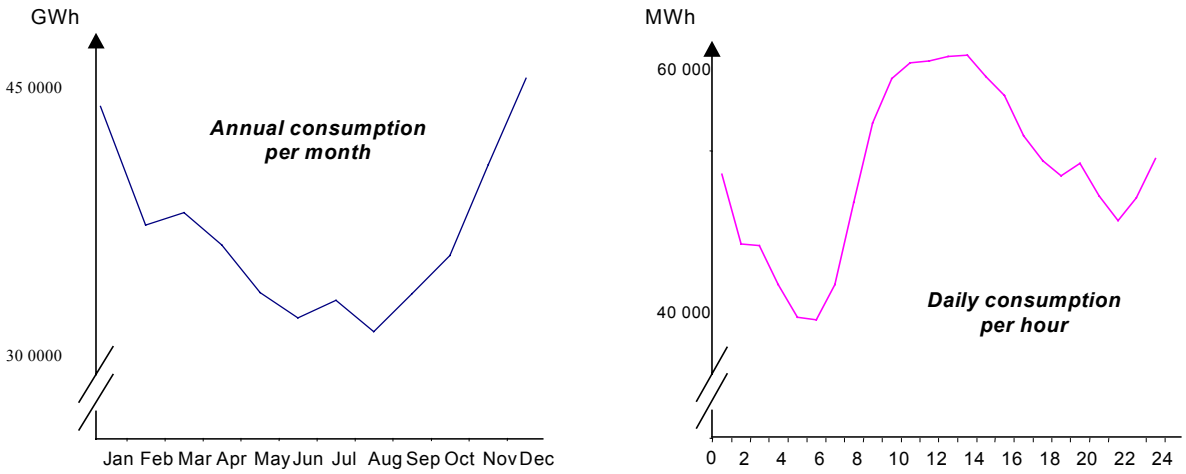
Figure 1-1: The electricity system

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).

[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

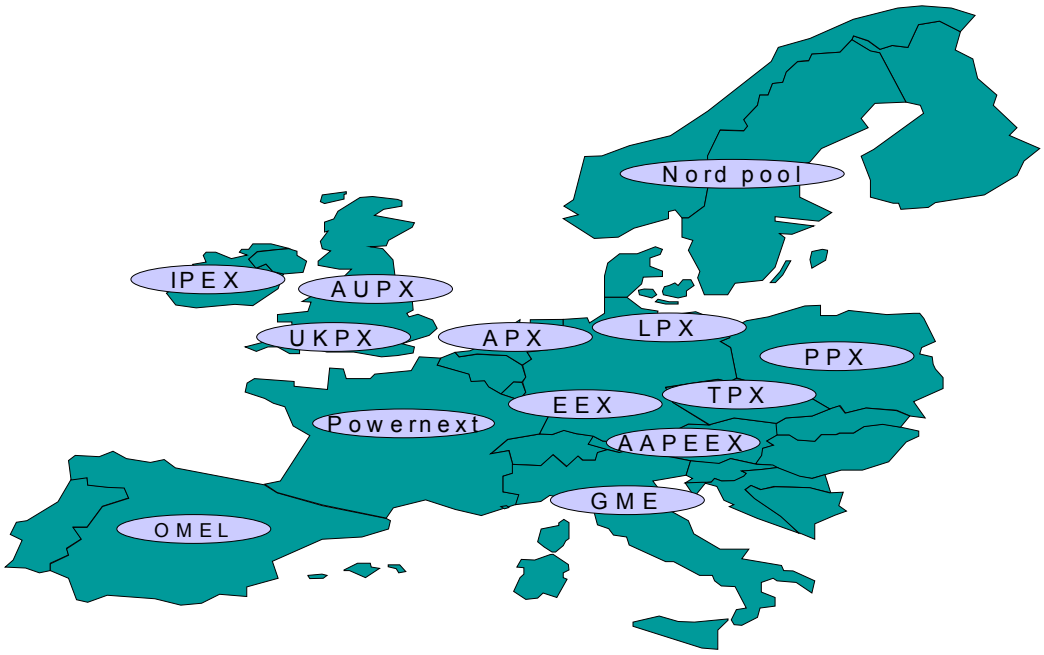
	Power Exchange	**Power Pool**
Participation	Voluntary	Mandatory
Initiative	Private	Public

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.

[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?

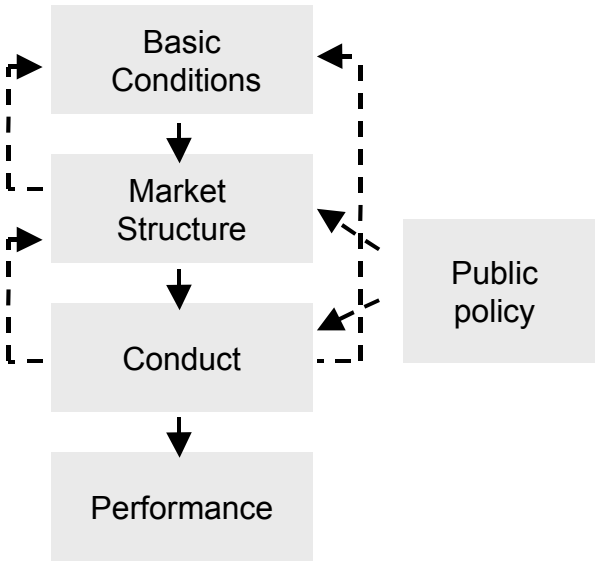
(7) What is the impact of power exchanges on market integration at the European level?
(8) How can power exchanges provide solutions for technical problems?
(9) To what extent can power exchanges facilitate the creation of a European electricity market?

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),

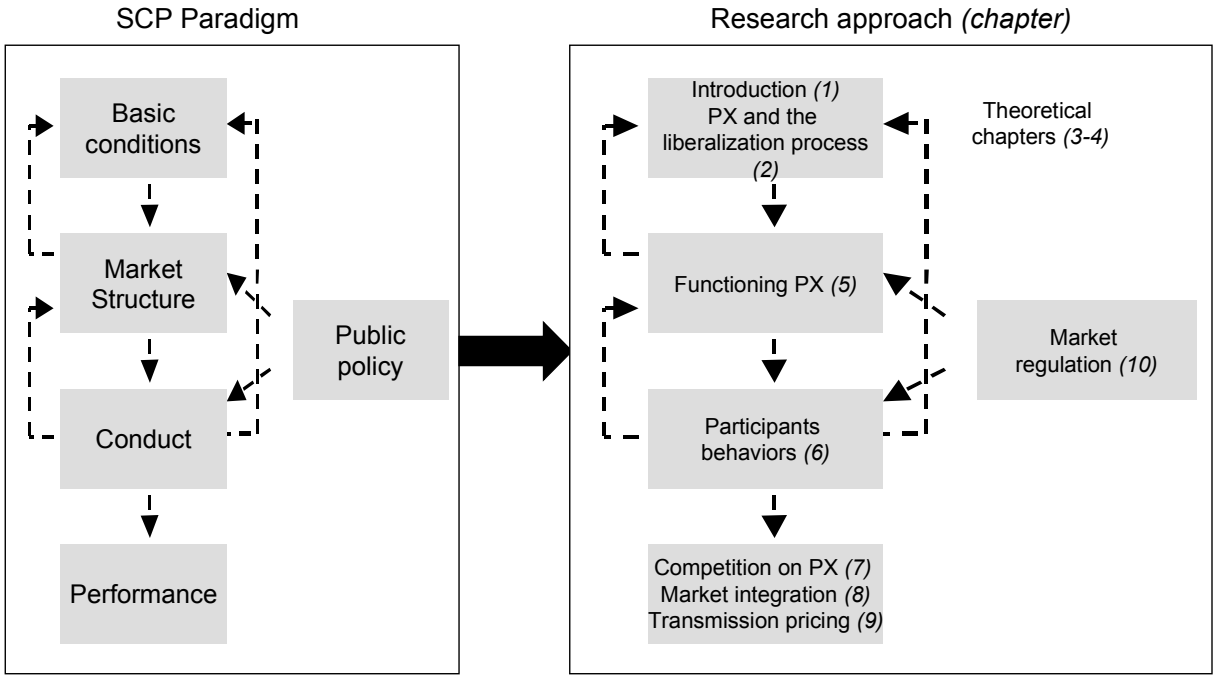
Demsetz (1967; 1968) and Brozen (1971), known as the *Chicago School,* critiqued the SCP paradigm. One important result of these criticisms has been the introduction of basic conditions in the paradigm, which affect the structure of the industry. Based on these studies they developed the SCP paradigm (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

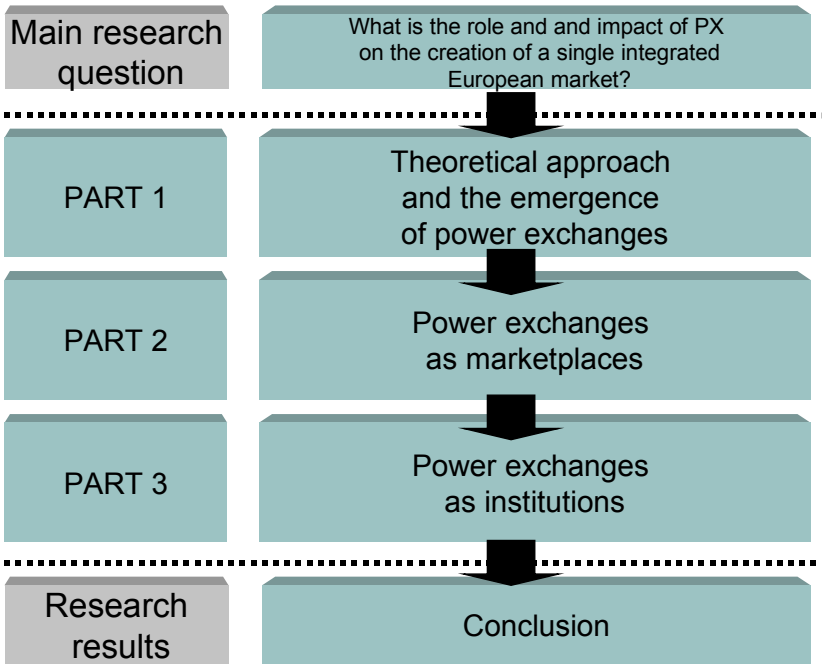
1-4-1 Summary

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.

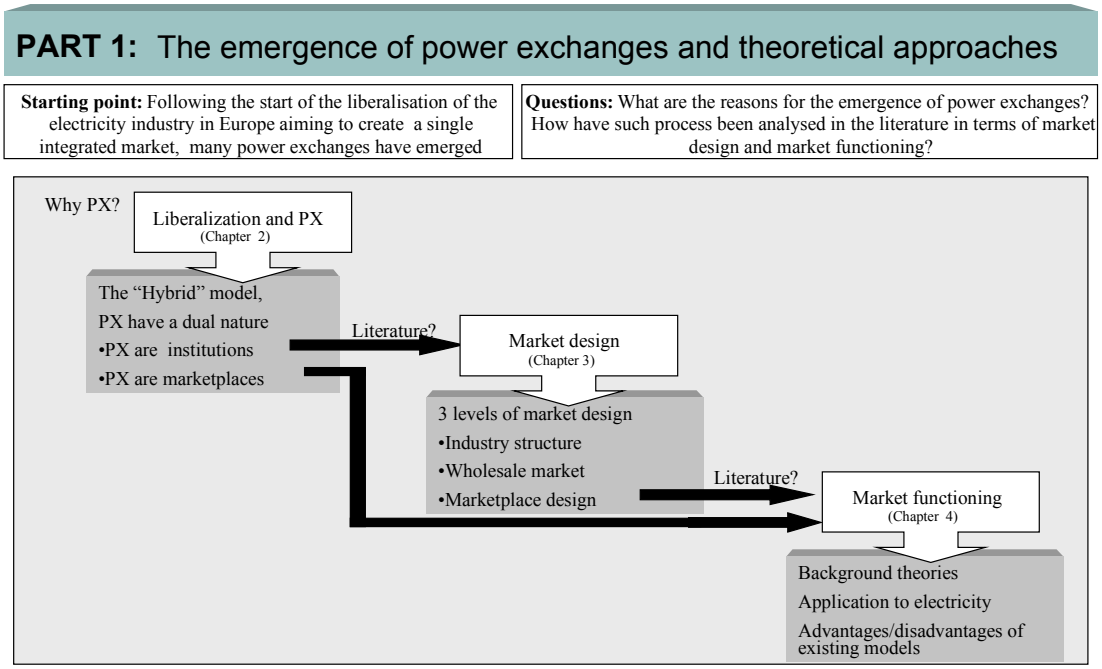
1-4-2 Content of part 1: The emergence of power exchanges and theoretical approaches

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

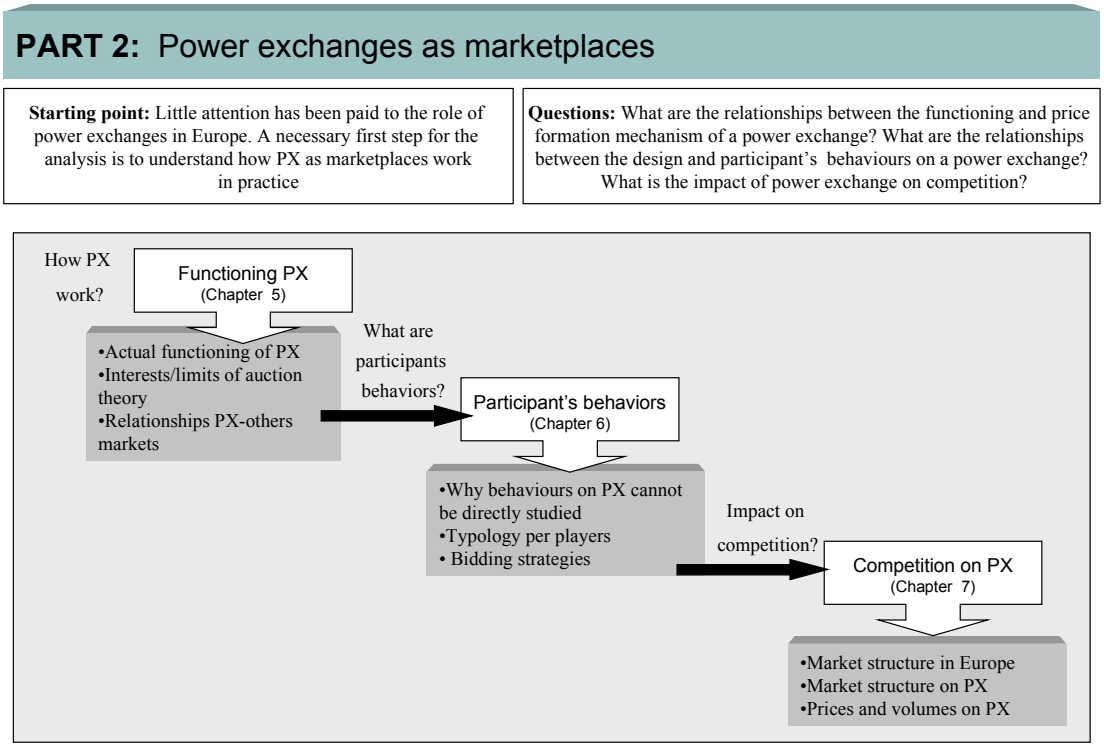
markets and that existing theoretical literature provides guidance for the analysis but that literature applied to the European situation is rather limited.

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.

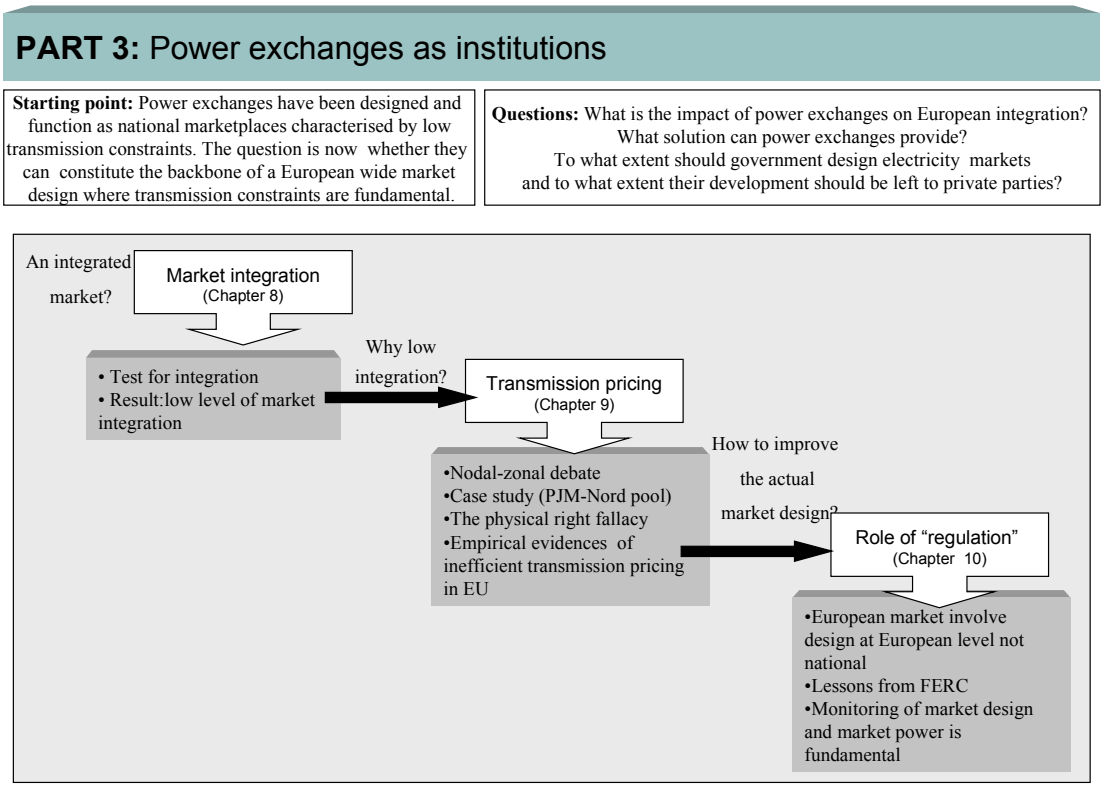
1-4-4 Content of Part 3: Power exchanges as institutions

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



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