Lund University

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EQUAL PRICES FOR EVERYBODY?

AN EMPIRICAL ANALYSIS OF THE EFFECTS OF LIBERALIZATION ON ELECTRICITY PRICES IN EUROPE USING THE LAW OF ONE PRICE

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Master Thesis

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LIST OF ABBREVIATIONS

AT	Austria
BE	Belgium
BG	Bulgaria
CH	Switzerland
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
ES	Spain
FI	Finland
FR	France
GR	Greece
HU	Hungary
IE	Ireland
IT	Italy
LT	Lithuania
LU	Luxemburg
LV	Latvia
PL	Poland
PT	Portugal
NL	Netherlands
NO	Norway
RO	Romania
SE	Sweden
SI	Slovenia
SK	Slovakia
UK	United Kingdom

1 INTRODUCTION

1.1 BACKGROUND AND MOTIVATION

According to the theory of international trade the absence of transport costs and trade restrictions and the possibility for perfect arbitrage lead to homogeneous goods being uniformly priced across countries – a relationship also known as the *law of one price*. Empirical research however shows that "... [in] reality the law of one price is flagrantly and systematically violated"[1]. This includes famous studies on the prices for Big Mac hamburgers[2], the Economist magazine[3] and IKEA furniture[4] that show evidence of price differences for the same products across countries.

The efforts of the European Union aim at the reduction of trade barriers between Member States. In this spirit the Directive 2003/54/EC set the ground for an integrated European electricity market. Its goal is to liberalize and harmonize the Electricity Supply Industry of the Member States. The electricity market however, has some unique characteristics that distinguish it from markets for other goods and services. The physical properties of electricity require its production and consumption to take place at the same time. This involves a broad range of issues concerning coordination and transportation. Additionally there are vast investments required to set up the needed infrastructure of networks and facilities. Traditionally this led to a market structure of vertically integrated companies that took over the entire production and supply chain, forming monopolies that were prone with inefficiencies and prevented potential competitors from entering the market. Therefore the measures of Directive 2003/54/EC include the vertical disintegration of the competitive parts of generation and supply from the natural monopolies of transmission and distribution. Additionally it aims at integrating the electricity markets of the Member States and at aligning

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[1] Isard (1977), p. 942
[2] Cumby (1996)
[3] Ghosh & Wolf (1994)
[4] Haskel & Wolf (2001)

national electricity policies. This should ultimately lead to more competition in the electricity market and price harmonization.

1.2 AIM

The aim of our study is to test whether the *law of one price* is applicable to the electricity market in Europe. We further intend to identify factors that can help explain possible differences in electricity prices across Europe. These include trade factors, cost factors and institutional factors.

1.3 DATA AND METHOD

The data used in this study comes from the Statistical Office of the European Commission *Eurostat*. The data is complemented by the *Report on Progress in Creating the Internal Gas and Electricity Market* conducted by the European Commission. The dataset will be analyzed using descriptive statistics and ordinary least squares regression techniques.

1.4 STRUCTURE OF THE STUDY

Following the *Introduction Chapter*, *Chapter 2* will give an overview of the structure and characteristics of the Electricity Supply Industry. *Chapter 3* then provides a survey of previous research as well as experiences from electricity liberalization both worldwide and in Europe. The theory on the *law of one price* will be presented in *Chapter 4*. The methodology and model specification will be presented in *Chapter 5*. *Chapter* 6 gives a description of the data and variables used in the study and presents the descriptive statistics of the electricity sector in Europe. The results obtained from the linear regressions will be provided in *Chapter 7*, followed by a discussion in *Chapter 8*. *Chapter 9* draws the conclusions of the study.

2 ELECTRICITY SUPPLY INDUSTRY

The Electricity Supply Industry (ESI) can be illustrated as a sequential process consisting of generation, transmission and distribution and finally supply of electricity. There are only limited and very expensive storage possibilities for electric power which requires the generation and consumption of it to take place simultaneously. Moreover, the segments of transmission and distribution are natural monopolies. This has implications on the requirements for the transmission and distribution network as well as the resulting market structure. In order to provide an understanding of the ESI we review its functional segments in *Chapter 2.1* and market structure in *Chapter 2.2* as well as the implications of natural monopolies and their regulation in *Chapter 2.3* and *2.4*, respectively.

2.1 FUNCTIONAL SEGMENTS

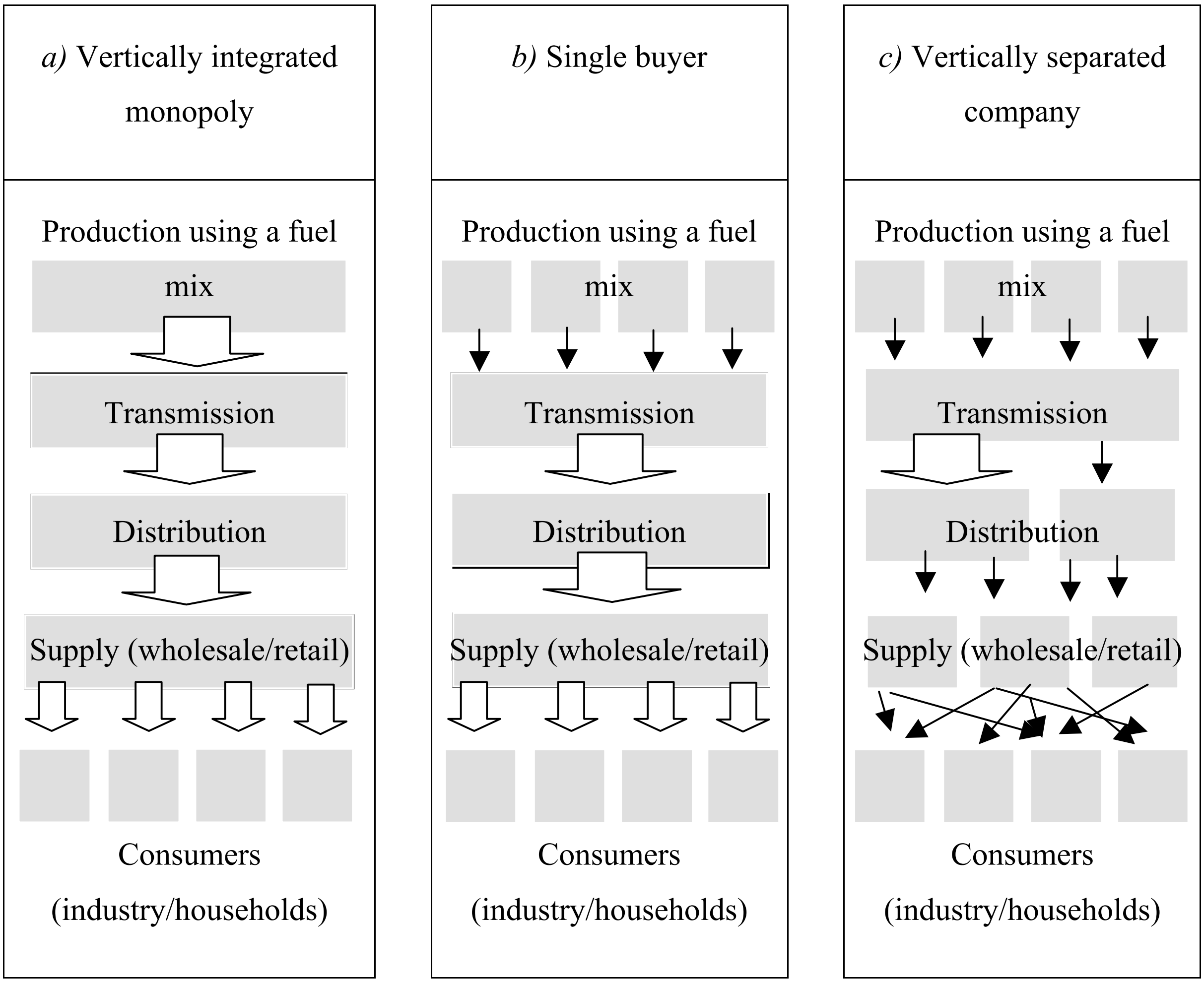
The main areas of business in the ESI consist of generation and sales of electricity on the one hand and transmission and distribution of it on the other hand. An overview of the process of electricity provision is given in *Figure 1.* Accordingly, electricity is first generated from various fuel sources such as oil, natural gas, coal, nuclear power, but also renewable sources like wind turbines, hydro power and photovoltaic technologies. Steiner[5] illustrates the cost structure of the ESI in the United Kingdom where generation is attributed the major part of the cost, about 65% of the final electricity price. Moreover, transmission adds 10%, distribution 20% and finally the supply 5% to the final price.

In the process of electricity generation the major cost factors are fuel prices, capital costs, and operational costs. But also the performance of the underlying generation technology (capacity, thermal efficiency, and operating life) plays a role in the cost structure. There are e.g. high capital costs associated with nuclear technology, resulting from long construction and retiring times as well as costly waste disposal. However, the variable costs for fuel and overall operation are relatively low. The costs of coal, oil, and natural gas fired generation on the other hand show lower capital costs but fuel prices are more volatile and generally higher than

[5] Steiner, Faye (2001)

for nuclear generation. Hydro power has generally low variable costs; the overall costs however, depend for the most part on local geography as well as climate.

Figure 1 Functional Segments of Electricity Production



Source: based on Wild[6]

The generated electricity is transported via the so called "wire" functions, with transmission being the high-voltage and distribution the low-voltage transport of electricity[7]. Additionally, these segments also carry out the coordination of scattered generators in the grid in order to sustain proper voltage and frequency and to prevent blackouts.

Transmission and distribution are considered to be natural monopolies since competition in these areas would result in duplications of high and low voltage networks and thus raise

[6] 2001, pp. 17-23
[7] see *Appendix*

transportation costs. Unlike transmission and distribution, the generation and supply of electricity can be organized in a competitive manner. The suppliers' responsibility is then the wholesale and retail sale of electricity to consumers. This involves also tasks such as marketing, billing, metering, credit control and risk management.

2.2 Market Structure

The physics of electricity require the generation, transport and consumption to take place at the same time. As a result, all these business activities have been traditionally vertically integrated within the same company in order to cut transaction costs and reduce uncertainty since one firm has all the required information and thus can manage the daily operations more smoothly. Kühn and Vives[8] define vertical integration as "...vertical merger or [...] set of vertical restraints that eliminate the externalities between the upstream and downstream firms...". An overview of different degrees of integration is given in *Figure 1*. Thus, a vertically integrated company on the electricity market operates all functional segments from generation to transmission and distribution, and the supply of electricity (*Figure 1a*). Opposite to vertical integration, in vertically separated companies generation and supply are entirely separated from the transmission and distribution (*Figure 1c*). In-between the two extremes is a situation where just the generation of power faces a competitive market while other business areas remain monopolistic (*Figure 1b*). Thus, there are many producers in the market but just one grid company taking care of the distribution, transmission and supply of electricity, a so called single buyer.

In absence of regulation, vertically integrated monopolies raise several concerns. They may impede access to the market for other companies. The grid provider may require a smaller charge for the use of the grid from its own subsidiaries, giving them a cost advantage over new entrants. With scarce network capacities, the grid provider could treat transmission and distribution of electricity preferentially for the own subsidiaries.

Furthermore, vertical integration raises special issues like predatory pricing and cross-subsidisation. Predatory pricing occurs when the monopolistic firm sets its prices below the short run marginal costs in the competitive part of the market, so that competing firms are not

[8] Kühn and Vives 1999, p. 576

able to survive. The monopoly firm is making losses as well, but it is counting on its possibilities to raise the prices later to pay off the losses.

In the case of cross-subsidization the firm is making losses in the competitive area of business activity but it supports the unsuccessful activity with the profits of the monopoly part of its business activities[9]. If the network owner subsidises its own production units, even efficiently run companies are driven out of the market, thus hampering competition and leading to efficiency losses.

2.3 NATURAL MONOPOLY

Natural monopolies typically arise with large networks and utilities for the provision of such goods as gas, electricity, water or telecommunication. In the ESI the transmission and distribution of electricity comprise a natural monopoly. The reason for that is a market situation where a single supplier can supply to the markets more cost efficiently than two or more suppliers. This situation is also known as economies of scope across production systems, represented by the following cost function:

(2.1)

where *C* are the costs of production and *x* is the produced quantity. The implication is that it is more beneficial to let only one firm produce the whole output than to let a higher amount of firms produce smaller parts of the output[10]. In the case of electricity, all companies provide the same product, the infrastructure required is immense, and the cost of adding one more customer is negligible. As long as the average cost of serving customers is decreasing, one firm will more efficiently serve the entire customer base.

Increasing returns to scale are another distinct feature of natural monopolies that also plays an important role in the electricity distribution industry[11]. Here, a proportional increase of input factors results in a more than proportionate increase of the output. According to Perner and

[9] Baumol & Sidak, 1995
[10] Knieps 2001, p. 23
[11] Knieps 2001, pp. 24-25

Riechmann[12] economies of scale lead to cost savings since the shared use of the distribution and transmission grids allows for larger generation facilities. Since there are several generators in the network there is less reserve capacity needed which can be used to provide more customers with electricity, thus reducing both the costs and investment risk.

For the analysis of natural monopolies the concept of contestable markets enables the investigation of a monopoly situation exposed to pressure from possible new entrants. In contestable markets, the natural monopoly might not be sustainable, if its cost structure enables other firms to gain profits by entering the market. Baumol et al.[13] define a contestable market as a market where "...potential entrants can, without restriction serve the same market demands and use the same productive techniques as those available to the incumbent firms". Thus, in the contestable markets a monopoly company can earn zero profits and has to function efficiently because of the possibility of new entrants[14]. However, Baumol et al.[15] reason that if "...entry requires the sinking of substantial costs, it will not be reversible, because the sunk costs are not recoverable." Therefore, entry can be assumed reversible and markets contestable only if operations require no sunk cost. Thus, in the electricity transport business the markets are commonly not contestable.

The concept of market barriers becomes relevant in a situation where there are dependencies between two markets which is the case in the electricity sector, where the competitive production and supply sectors depend on the distribution and transmission monopoly. The concept of market barriers concentrates on the investigation of the comparative advantage and the market power of an incumbent company compared to a potential newcomer. According to Bain[16] the incumbent firms can, due to market barriers, continuously set their prices above the level of minimum average cost without the risk of new entrants. This causes inefficiencies and welfare losses in the markets. The main cause for market barriers is therefore the denied or hampered access to the input factors. In the electricity industry, the distribution of electricity can be seen as an input of the service of providing the customers with electricity. A high entry fee to the distribution network e.g. can be considered a market barrier to a disadvantage of an independent power producer who faces few buyers with market power.

[12] 1998, p. 42
[13] 1982, p. 5
[14] Baumol et al. 1982, pp. 5-6
[15] 1982, p. 7
[16] 1968, p. 253

Another concept for the analysis of natural monopolies is network access, where it can be distinguished between monetary access and other conditions. Monetary access refers to prices that power companies have to pay in order to get the right to use the grid. The general criteria state that access prices should be non-discriminating, transparent and based on the true cost of the maintenance. They may also have a signal or a steering function to increase the efficiency of the grid use. The principle that the firm pays the cost that it has caused is reasonable but sounds simpler than it is because the allocation of costs to the individual customers is difficult[17]. Other access conditions refer e.g. to the physical characteristics of the infused and diverted power, the details of the connection contract, metering services etc. In most countries, there is a set of complicated rules and regulations to manage these conditions[18].

The above described issues of natural monopolies and vertical integration cause inefficiencies and thus make a case for regulation[19]. This is the topic of the next chapter.

2.4 REGULATION

In general, regulation occurs when the government believes that the company, left to its own devices, would behave in a way that is contrary to the social optimum. In Europe, the initial reaction to this problem was government provision of an utility service. However, this approach raised its own problems. Some governments used the state-provided utility services to pursue political agendas, as a source of cash flow for funding other government activities, or as a means of obtaining hard currency. These and other consequences of state provision of services often resulted in inefficiency and poor service quality[20].

Another regulatory approach is to oblige private companies that are natural monopolies to be listed on the stock market. This ensures they are subject to financial transparency requirements, and maintains the threat of a takeover if a company is mismanaged, thus ensuring that companies are run efficiently. However, in practice, the notorious short run nature of the stock market may be adverse to appropriate spending on maintenance and investment in industries with long term planning, where the failure to do so may not have immediate effects but leads to problems in the long run.

[17] Perner and Riechmann 1998, p. 44.
[18] Perner and Riechmann 1998, p. 43.
[19] Baumol & Sidak, 1995
[20] Schleifer, 1998

Common carriage competition involves diverse electricity companies competing to provide services to customers over the same electricity network. For this to work government intervention is required to break up vertically integrated monopolies, so that generation and supply are separated from distribution and transmission. The key element is that there is access to the network for any firm that needs it to provide its service, with the price the infrastructure owner is permitted to charge being regulated. Such a system requires active government creation of a new system of competition rather than simply the removal of existing legal restrictions.

3 LIBERALIZATION OF THE ESI

3.1 PREVIOUS RESEARCH

The number of research papers published on the liberalization of the Energy Supply Industry and the development of electricity prices is quite limited. Most papers published on the topic focus on the effect of liberalization, regulation and privatization on electricity prices for industrial or household customers. Evaluating a large number of countries these studies aim at explaining the development of prices in those countries over time and at identifying the driving factors behind price changes. This chapter gives a brief summary of previous research done in this field.

Steiner (2001) conducted a panel study on the impact of regulatory reforms in the ESI on retail prices for industrial consumers in 19 OECD countries and on the difference between retail prices for industrial and household consumers. The study covers the years 1986 to 1996 and includes countries on all levels of regulatory reform in the ESI sector. He finds that "...a high degree of private ownership and imminence of both privatisation and liberalization tend to increase industrial end-user prices"[21]. The study however also shows that "the ratio of industrial to residential end-user electricity prices is reduced by the unbundling of generation and transmission, expansion of Third Party Access (TPA), and introduction of electricity markets"[22].

Hattori and Tsutsui (2004) conducted a similar study, also using panel data from OECD countries. Covering the years 1987 to 1999 they assess the influence of the unbundling of transmission from generation, third party access (in retail), wholesale spot markets and private ownership on industrial customer prices and on the ratio of industrial to household prices. The study finds "that expanded retail access is likely to lower the industrial price, and at the same time increases the price differential between industrial customers and household customers"[23]. The unbundling of generation and transmission also shows to be negatively correlated with prices. Hattori and Tsutsui use legal unbundling as their measure. Therefore this result cannot be compared to that of Steiner, who uses accounting unbundling. They explain their result with the increased transaction costs in the case of unbundling that are being transferred to the

[21] Steiner (2001), p. 176
[22] Steiner (2001), p. 176
[23] Hattori & Tsutsui (2004), p. 830

customers. For the existence of an electricity wholesale spot market they find a slightly negative correlation with prices, an unexpected result. Hattori and Tsutsui explain this with spot markets making it possible for generators to exercise market power.

Ernst & Young (2006) provide a report of a study undertaken on the "The Case for Liberalization". The study analyzes five questions, mainly whether liberalization lowers prices, whether it increases price volatility and inhibits investment, whether liberalized markets provide a reliable and secure supply and how liberalized markets effectively interact with other public policies. They find that the liberalization of ESIs is negatively correlated with prices, since "the price of electricity falls by 0.035€/kWh for every unit increase in the competition indicator"[25]. Regarding price volatility the report finds that it is positively correlated with liberalization but that volatility has decreased over time. The report also finds that there is "no linkage between spot market volatility and consumer prices"[26] and sees the volatility increase as an essential factor for incentivising investment. For the security of supply the study uses measures of outages in the electricity networks and measures of diversity in generation. The findings indicate that there was a marginal improvement in the reliability and security of supply during the liberalization. This can be attributed to higher plant utilization, increased diversity and more interconnections[27]. Ernst & Young also find that liberalization of the ESI effectively interacts with other public policies. Studying expenditures on energy as a proportion of income, the energy intensity of economies and environmental emissions, the study finds that "liberalized markets can perpetuate other public policies and indeed increase the efficiency of implementation"[28].

What distinguishes the study by Ernst & Young from other studies arriving at quite different results about the effect of liberalization on prices is that it only uses data on industrial customer prices. Since other studies[29] showed a positive correlation between liberalization and household customer prices, the study by Ernst & Young is likely to over-estimate the positive effect of the liberalization of ESIs.

Percebois (2008) studied the benefits and risks of the electricity liberalization in the European Union. The main questions he attempts to answer in his study are whether the increase in electricity prices is a result of the market liberalization, whether increased interconnections

[25] Ernst & Young (2006), p. 2
[26] Ernst & Young (2006), p. 4
[27] Ernst & Young (2006), p. 4
[28] Ernst & Young (2006), p. 5
[29] Hattori & Tsutsui (2004), Steiner (2001)

create surplus transfers and whether the market power of generators is a threat to competition. Percebois does not only study the development of prices in the EU countries but also the convergence of prices in different countries. As an example he uses France and Germany, two countries with a quite different energy mix in generation. Percebois finds that while price increases in most countries that have a high share of thermal power in the generation mix are due to the increase of the price of fossil fuels, this is not true for all countries. Some countries experienced higher prices due to increased interconnection and the existence of spot markets for electricity.

Usually the marginal electricity producers are thermal power plants and hence the price for electricity generated from fossil fuels sets the price paid on the spot market. French customers experienced price increases as an effect of increased interconnection and the existence of spot markets. The price for French electricity is now set on international spot markets. This leads to the fact that due to the "interdependence between European electricity markets, some consumers bear a net loss of surplus"[30]. Hence "electricity price convergence between countries is not necessarily profitable for all consumers"[31]. Percebois however also states that these price increases in some countries also have positive effects. They make it possible for generators to benefit from increasing rents that can be invested in new electricity generation plants and to promote energy saving. These are important factors to ensure that the European Union will not experience an "electricity under-capacity in the future, which would involve more and frequent "black-outs" "[32].

Price increases could however also be an effect of increasing market power and strategic behaviour of electricity generators. While suspecting that this is the case, the European Commission and the regulators do not have proof of such practices yet. Ownership unbundling is one of the measures aiming at reducing the power of the generators although it incurs the risk of a weakening of European generators who, due to the liberalization, increasingly have to compete with foreign generators that have a monopolistic position in their domestic countries[33].

Pollitt (2009) analyzes the regulatory reform in the European Union and draws conclusions for a possible reform of the electricity markets in South Eastern Europe (SEE). He also uses evidence from regulatory reforms of the ESI in other OECD countries and developing and

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[30] Percebois (2004), p. 18
[31] Percebois (2004), p. 18
[32] Percebois (2004), p. 18
[33] Percebois (2004), p. 18-19

transition countries. Although the paper aims at analyzing the possibilities and best paths toward liberalization of the SSE electricity markets, there are some conclusions that are of interest for our study. Among the important aspects discussed in Pollitt's study are the institutional framework, regional integration and security of supply issues. Pollitt notes that electricity reform "will not be successful unless there is sufficient institutional reform in the rest of the economy to support developments in the electricity sector"[34]. The EU aims at harmonizing the institutional standards in its member countries and at fostering integration, but with the regulatory reform still being on very different levels in the European countries this has not been achieved yet. When talking about security of supply issues Pollitt finds it very unclear whether this challenge "will eventually derail the competitiveness agenda embodied in the EU electricity directives"[35].

3.2 ESI Liberalization Experiences

While the liberalization of the Energy Supply Industry in the European Union has only started quite recently there are some countries that have taken regulatory reforms of their ESI in the past, among them being Chile, Argentina and California.

Chile was the first country to liberalize its Energy Supply Industry. Liberalization started in 1982 when the electricity industry was privatized and vertically and horizontally unbundled. Electricity in Chile is dominated by hydropower generation and electricity prices are strongly correlated with the water level in the biggest reservoir, "Las Lajas", making the electricity market very vulnerable to external shocks. The market in the Interconnected Central System, the biggest of four independent systems in Chile, is managed by the Economic Dispatch Load-Center, CDEC. Prices are set using a cost-based system where prices and generation volumes are calculated through optimization. Generators are, by law, obliged to deliver electricity whenever their plants are available and the CDEC commands it.

The price they are paid by the CDEC depends on the marginal operating cost of the respective plants. Generators that provide capacity during the peak period between May and September get a fixed capacity payment. The Chilean ESI is very price rigid which makes it extremely vulnerable to external shocks such as special weather conditions. Chile experienced a supply

[34] Pollitt (2009), p. 21
[35] Pollitt (2009), p. 22

crisis in 1998 and 1999 when during a time of governance problems in the industry such an external shock occurred (the weather phenomenon La Nina, causing severe droughts). This caused major black-outs and shortages. The regulatory reform has positively influenced investments, leading to a high capacity increase. While in the first years after the deregulation the market concentration was high, in recent years the market power of the market participants has decreased and the HHI index[36] has fallen from above 3000 to around 1500.

The Argentinean electricity sector was deregulated in 1993 as a reaction to an energy crisis in 1988-89. Prior to the reform the ESI in Argentina was characterized by vertically integrated state and provincially owned utilities with frequently occurring blackouts and high distribution system losses. The regulatory reform was based on experiences that were made in the UK and Chile. Within a few years the government privatized "more than 80% of the generation, all of the transmission and 60% of the distribution sector"[37]. The regulatory reform also gave rise to competition by breaking the former state owned companies into several independent generators and distributors. The Argentinean electricity market is hence characterized by very low market power, a factor that is also reflected in an HHI index of 1500 for generation and of 1400 for distribution[38].

On the wholesale market, that is managed by CAMMESA, a not-for-profit joint stock company, prices are set on a spot market and a bilateral contract market. Spot prices are based on short-term marginal costs and are estimated for three different load periods per day. Twice a year thermal and nuclear generators submit bids for the prices at which they are willing to supply energy at every hour during the following 6 months. These cannot exceed 115% of the fuel costs the generators face. The hydro generators must declare their generation capacities for the same time period. CAMMESA then determines which power plants are the marginal ones at each point in time and sets prices. Those generators having available capacity during the 90h high demand period weekly are being paid a fixed capacity payment.

The regulatory reform in Argentina has created several positive effects. Electricity prices in Argentina are the lowest in South America and extremely low in a global comparison. The price decreases were (partly) caused by sharp efficiency improvements. Unavailability of power plants fell from around 50% to 20% within 5 years and labour productivity went up. Generation capacity increased by roughly 4.5% per year between 1992 and 2002 while in

[36] Herfindahl-Hirschman Index, see Appendix for definition
[37] Pollitt (2008), p. 1539
[38] Arango, Dyner & Larsen (2006)

transmission the increase was 2.7 % per year. The low price level might though cause the risk of too low investments being made in the future.

Electricity restructuring in California began in the mid 1990s and was finalized by 1998. Before the liberalization the Energy Supply Industry in California was dominated by vertically integrated monopolistic suppliers. In 1978 the market was opened for small, private, independent generators who were allowed to produce up to 80 MW and to sell to the utilities (often through fixed price contracts). Developed as a reaction to the 1970s oil crisis and to support alternative electricity generation from wind, solar, biomass etc. these so-called qualifying facilities (QFs) became extremely popular. In 1991 the newly established qualifying facilities in California provided about 25% of the energy need, thereby proving that there was no longer a need for vertically integrated monopolistic suppliers. Additionally, California was exposed to a high risk for future under-capacity (due to low investment rates) and very high electricity prices (that were 30%-50% above the national average). These characteristics of the market lead to the restructuring of the Electricity Supply Industry.

Implementation of the new regulated electricity system came into operation in 1998 with the opening of the California Power Exchange and the establishment of the California Independent System Operator (CAISO). On the California Power Exchange electricity was traded on a day-ahead hourly spot market and market-clearing prices were calculated using supply and demand curves for every hour of the day. This system was replaced in 1999 with a spot market with three auctions per day that were setting prices for certain time periods on the same day. The CAISO was established to balance out supply and demand of electricity at every given point in time and to avoid overloads in the transmission system. Due to the need for selling and buying capacity to avert black-outs it also held auctions and set prices independently of the Power Exchange. From the same year on customers were eligible to freely choose their electricity providers. Despite a multimillion public information campaign the percentage of customers switching providers was very low, which was due to low competition caused by high market entry barriers.

Between April 1998 and March 2000 the new system was in operation and wholesale electricity prices seemed to be stable. The collapse of the electricity market in California began in late spring of 2000 when prices on the Power Exchange started to increase sharply. Although the wholesale price caps were lowered twice the wholesale prices stayed very high during the summer and peaked during December. In January of 2001 the system collapsed completely and there were blackouts on 8 days during the winter and spring. The CISO and several market participants went bankrupt. The market collapse was caused by a combination of several factors including fuel price increases, poor market design, and the impossibility of supply and demand to equilibrate because of price caps and the exercise of market power by generators.

The State had to take over and do spot purchases of electricity and sign long-term contracts. Due to qualifying facilities going offline and low hydroelectricity production (caused by low rainfalls) prices remained high and blackouts occurred. In June 2001 the crisis was over and prices began to fall again. This was due to the decrease in demand by Californian customers, decreasing fuel prices and a new design of market auctions forcing all generators to be price takers. Additionally new generation capacity came into operation.

3.3 European ESI Liberalization

3.3.1 Directive 2003/54/EC of the European Parliament

The foundation for the liberalization and integration of the electricity markets in the European Union was laid in Directive 2003/54/EC of the European Parliament and of the Council in June 2003. This Directive set the common rules for generation, transmission and distribution of electricity. These include "rules relating to the organisation and functioning of the electricity sector, access to the market, the criteria and procedures applicable to calls for tenders and the granting of authorisations and the operation of systems"[39]. The objective is to create a single market for the European Union that is characterized by fair competition. It is the Member States' responsibility to take the measures necessary to achieve this objective and to protect the rights of consumers. This includes:

- the security of supply and environmental protection;
- the supply of customers and small enterprises with electricity at reasonable and transparent prices;
- the protection of end-users;
- third party access to the transmission and distribution system.

[39] Directive 2003/54/EC, p. 4

Since the transmission and distribution sector of the ESI remain natural monopolies, the Member States must designate one or more system operators for the transmission and distribution networks. These cannot be engaged in generation and supply of electricity.

The transmission operators must ensure that the system meets the demands for transmission, that there is enough transmission capacity to ensure security of supply, that there is no discrimination between the users of the system and that the system users receive all information necessary for efficient access to it. Additionally the transmission operators are responsible for managing the electricity flow and the interconnection with other systems. The distribution systems operators have the same responsibilities as the transmission system operators when it comes to security of supply, non-discrimination and information management. They also have "to give priority to generating installations using renewable energy sources or waste or producing combined heat and power"[40]. In order to balance out supply and demand and to cover for energy losses in the system the distribution systems operators buy electricity on the market. Directive 2003/54/EC also rules the timeline for market opening, requiring the market to be open for all non-household customers at the latest from 1 July 2004 and for all customers from 1 July 2007.

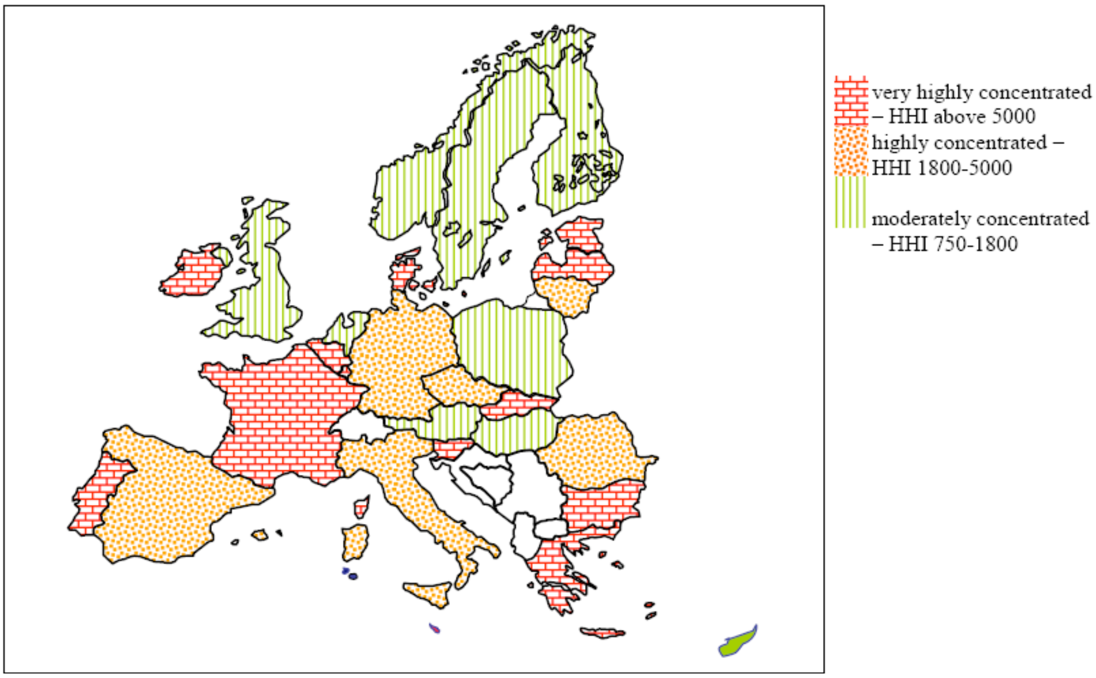
3.3.2 Current State of the Liberalization in Europe

In order to achieve an integrated electricity market in Europe the markets of the Member States need to be interconnected. The cross-border trade that is enabled by these interconnections will lower market power and make the markets more competitive. This should ideally lead to lower prices for the customers.

Evidence from the European Countries however shows that market concentration is still very high in many countries. In 15 Member States more than 70% of the generation capacity is controlled by the three biggest generators, leading to a high concentration on the wholesale market. *Figure 2* shows the market concentration on the wholesale market using the HHI index.

[40] Directive 2003/54/EC, p. 9

Figure 2 Market concentration of the electricity wholesale market



Source: *Communication from the Commission to the Council and the European Parliament, SEC (2009) 287*

More than half of the Member States have a system of liberalized energy markets and regulated electricity prices. These are Bulgaria, Denmark, Estonia, France, Hungary, Ireland, Italy, Latvia, Lithuania, Poland, Portugal, Romania, Slovakia, Spain and Greece. The regulation of electricity prices has a negative effect on the efficient functioning of the electricity markets. Regulated prices distort competition (by e.g. setting entry barriers for new suppliers) and send the wrong signals to the markets. This could lead to a lower level of competition and fewer investments being made. Additionally these price regulations are often not compatible with EU law.

4 LAW OF ONE PRICE

The integration of regional and national markets is often described using the law of one price (LOOP). The theory of the LOOP states that in perfect markets identical goods should be identically priced. For the price equality to hold the market must be characterized by frictionless consumer arbitrage, profit-maximizing firms and the absence of „tariff and non-tariff barriers and other related market frictions“[41] as well as of transport costs.

The term *law of one price* is used when the price of single goods in different locations is studied while the term *purchasing power parity* is used when price aggregates are compared. Formally the equality underlying the law of one price can be written as

$$(4.1) \quad P_{uct} = E_{cc't} * P_{uc't}$$

P_{uct} is the price in country 1 while $P_{uc't}$ is the price of the good in country 2 and $E_{cc't}$ is the exchange rate between the two countries[42]. Equation (4.1) states that once prices are converted to the same currency, identical goods sell at the same price in different countries. It is referred to as the “absolute LOOP“, since it uses the absolute prices of a good. The second formal way of expressing the LOOP is called the „approximate relative LOOP“[44].

$$(4.2) \quad \Delta p_{uct} = \Delta e_{cc't} * \Delta p_{uc't}$$

The approximate relative LOOP states that changes in the relative price of a good traded in two countries are offset by changes in the exchange rate between these two countries. The law of one price is often violated because trade barriers drive a wedge between prices in different countries. Despite market integration international goods markets remain quite segmented due to differences in labour costs, tariffs, transportation costs and information costs. Empirical studies[45] have showed that it holds for very few goods and usually only for goods traded on organized exchanges.

This study aims at analysing reasons for the deviation of electricity prices in Europe from the predictions of the *law of one price*. Electricity that is supplied within one network is of the same quality; however there are increasing possibilities for suppliers to differentiate the

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[41] Mathä (2006), p.564
[42] Broda &Weinstein (2008)
[44] Broda &Weinstein (2008)
[45] Broda &Weinstein (2008)

product in order to charge higher prices. Green energy and branding are some examples.. Nevertheless, the major share of electric power is still marketed conventionally and thus we consider it to be a perfect substitute, a good that fits well into the law of one price. Electricity produced in different countries is homogenous as well and imported electricity is hence also a perfect substitute for domestically produced electricity.

Electricity is a good that has some unique characteristics. Unlike other goods electricity can only be traded and transported using existing connections. Electricity networks are costly to set up on the one hand but have very marginal costs on the other hand, making the transportation of electricity cheap. However, the transmission and distribution of electricity are natural monopolies, which might lead to higher than marginal transportation costs. The dependency on existent interconnections also limits the potential for trade between countries. The convergence of prices across countries is hence likely to be slower than in the case of unlimited import and export possibilities. This trade limitation comprises a violation of the assumptions of the *law of one price*.

Another possible violation of the law of one price derives from the difference between generation costs in different countries. The electricity generation costs depend strongly on the availability and usage of different fuels. While there are countries that have a good availability of the relatively cheap hydro power for electricity generation, other countries need to import fuels and face high generation costs. The costs of electricity generation are significantly different between countries and this might be reflected in electricity prices, thereby further violating the law of one price.

Many countries have liberalized their electricity markets just recently and not all markets are unbundled yet. The unbundling of generation and supply from the natural monopoly of transmission and distribution enables competition on electricity markets. Competitiveness of the market is one of the assumptions of the *law of one price*. However, transmission and distribution will remain natural monopolies, which often are regulated. Unless the regulation rules are identical in all countries, this fact will add to a further diversion from the LOOP.

Additionally, not in all countries customers are able to switch electricity suppliers (yet). Hence there are differences in the market power of customers in different countries, a factor being correlated with prices. All these aspects of electricity violate the assumptions of the law of one price. Therefore it can be expected that electricity prices in different countries are not the same when converted into the same currency.

5 MODEL AND METHODOLOGY

In order to explain price differences across countries we identify possible factors causing these differentials. We construct three model specifications that will be estimated. A fourth model is used to test the robustness of the results. All four models are run for differences in household prices and for differences in industrial customer prices respectively, yielding a total of eight estimations. The specifications are based on equation

$$(5.0) \quad P_{i\text{-}j} = c + \beta X + \delta Z + \varepsilon$$

where $P_{i\text{-}j}$ is the price differential, c is a constant, X is the matrix of independent variables, Z is the matrix of dummy variables and ε an error term. β and δ are the vectors of parameters to be estimated.

5.1 TRADE MODEL

The first model specification is used to estimate the effect of trade on the price differential between countries. The dependent variables are the natural logarithm of the price differentials for household customer prices and for industrial customer prices respectively. The independent variables are the natural logarithm of the difference in the GDP per capita, the natural logarithm of the distance between capitals and the average of the share of imports on total electricity consumption of the country pairs as well as the natural logarithm of the difference in energy intensity, yielding:

$$(5.1) \quad P_{i\text{-}j} = c + \beta_1 * gdp + \beta_2 * distance + \beta_3 * imports + \beta_4 * intensity + \varepsilon$$

5.2 COST MODEL

The second model specification estimates price differentials between two countries as a function of differences in the cost associated with energy generation and transmission. As independent variables the difference in the percentage shares of electricity that is generated from nuclear power, the difference in the percentage shares of electricity that is generated from hydro power and the country-pair differential in tariffs are used. While the variables for nuclear and hydro power are expressed in absolute terms the tariff differentials are expressed as natural logarithms.

$$(5.2) \quad P_{i\text{-}j} = c + \beta_1 * nuclear + \beta_2 * hydro + \beta_3 * tariffs + \varepsilon$$

5.3 INSTITUTIONAL MODEL

This model specification estimates the correlation between price differentials and institutional characteristics. It includes the following variables: a dummy variable for unbundling, an interaction term between distance and unbundling, a dummy for price regulation and the respective interaction term with distance, the market share of the three biggest generators and the respective interaction term with distance and a dummy variable for new Member States. For the regression on household price differentials the difference in the share of customers having switched suppliers and an interaction term between distance and switching are included as additional variables. The model specification for household price differences is:

$$(5.3a) \quad P_{i\text{-}j} = c + \delta_1 * unbundling + \beta_1 *(distance\_unbundling) + \delta_2 * regulation\_hh + \beta_2 *(distance\_regulation\_hh) + \beta_3 * switching + \beta_4 *(distance\_switching) + \beta_5 * three\_biggest + \beta_6 *(distance\_three\_biggest) + \delta_3 * eu\_enlargement + \varepsilon$$

while for the regression with industrial price differences the model is:

$$(5.3b) \quad P_{i\text{-}j} = c + \delta_1 * unbundling + \beta_1 *(distance\_unbundling) + \delta_2 * regulation\_ind + \beta_2 *(distance\_regulation\_ind) + \beta_3 * three\_biggest + \beta_4 *(distance\_three\_biggest) + \delta_3 * eu\_enlargement + \varepsilon$$

5.4 Mixed Model

The fourth model specification is a mixed model including the variables of the three previous models. It is used to test whether the results obtained in the individual models are robust. The variable for distance is excluded from the mixed model since it is highly correlated with the interaction terms, yielding:

$$(5.4) \quad P_{i\text{-}j} = + \beta_1 * gdp + \beta_2 * imports + \beta_3 * intensity + \beta_4 * nuclear + \beta_5 * hydro + \beta_6 * tariffs + \delta_1 * unbundling + \beta_7 * (distance\_unbundling) + \delta_2 * regulation\_hh + \beta_8 * (distance\_regulation\_hh) + \beta_9 * switching + \beta_{10} * (distance\_switching) + \beta_{11} * three\_biggest + \beta_{12} * (distance\_three\_biggest) + \delta_3 * eu\_enlargement + \varepsilon$$

All regressions are run with the software Stata, using OLS regression with robust standard errors to control for heteroskedasticity problems.

6 DATA AND DESCRIPTIVE STATISTICS

This chapter provides an account of the sources and composition of the data used in this study. *Chapter 6.1* gives an account of the data sources and describes the variables that are used in the regression analysis. *Chapter 6.2* evaluates the characteristics of the data.

6.1 DATA AND VARIABLES

The data used in our study comes primarily from the Statistical Office of the European Commission (*Eurostat*)[46] and the *Report on Progress in Creating the Internal Gas and Electricity Market*[47] conducted by the European Commission. In the case of Switzerland where data is missing we use national sources[48]. Moreover data on distances between country capitals stems from the *Centre d'Etudes Prospectives et d'Informations Internationales*[49].

We use household and industrial prices for electricity as our dependent variables. In order to be able to explain the deviations from the LOOP we calculate the difference between the electricity prices of all country pairs in the European Union[50], thus yielding 350 observations. The geography of the island states of Malta and Cyprus makes trade with electricity practically impossible so that those two countries are excluded from the 27 Member States of the European Union. Instead, Norway and Switzerland are included in the data, since trade data is available there.

Eurostat publishes data on average electricity prices over a period of 6 months. Semester 1 prices are average prices between January and June of each year, semester 2 prices are average prices between July and December of each year. We use prices for semester 1 of 2009. Exchange rates to convert non-euro prices to euro-prices are taken as the average exchange rate in the reference period. The end-users are characterized by predefined annual consumption bands: we use data on households with an annual consumption lower than 1000 kWh/a and data on industrial users with an annual consumption lower than 20 MWh/a. The

[46] Used for data on: *prices, GDP, fuel mix, imports and energy intensity*
[47] COM (2009) 115, used for data on: *unbundling, regulation, market shares, and propensity to switch providers*
[48] Verband Schweizerischer Elektrizitätsunternehmen
[49] http://www.cepii.fr
[50] 27 EU Member States excluding Malta and Cyprus, adding Norway and Switzerland

prices include the electricity basic price, transmission, distribution and other services, excluding taxes and levies.

The independent variables are chosen with the intention to explain the causes for possible deviations from the LOOP. Data on the independent variables stems from 2007. Thus, we take into consideration the fact that markets need some time to adjust to the given circumstances in order to be able to draw conclusions from the market set up. With data that features absolute or percentage values, differences are always calculated between country pairs, in order to be able to explain price differences. In the case of imports, averages between country pairs are computed and a binary code is applied for dummy variables. A summary all variables used in our study in provided in *Table 1*.

The energy intensity of the economy is given as the ratio between the gross inland consumption of energy and the gross domestic product (GDP) for a given year. It measures the energy consumption of an economy and its overall energy efficiency. The gross inland consumption of energy is calculated as the sum of the gross inland consumption of five energy types: coal, electricity, oil, natural gas and renewable energy sources. The energy intensity ratio is determined by dividing the gross inland consumption by the GDP. Since inland consumption is measured in kilogram of oil equivalent (KgOE) and GDP in 1000 €, this ratio is measured in KgOE per 1000 €.

Data on GDP and network tariffs is nominal and converted to a common currency (€). Data on distance is measured as distance between capitals in kilometres. Imports measure the percentage share of imported electricity that is being consumed during a year. Similarly, data on nuclear and hydro is measured as the percentage share of electricity that is generated with nuclear and hydro power respectively.

The dummy variable *unbundling* accounts for cases where the natural monopolies of transmission and distribution networks have been separated from the generation and supply segments through ownership unbundling. The interaction term *distance_unbundling* is computed by multiplying the variable *distance* with the dummy *unbundling*. It measures the effect of distance on the price differences for those country pairs where the ESI of both countries has been unbundled. The dummy variables *regulation_hh* and *regulation_ind* stand for the existence of regulated prices in the transmission segment, for household and industrial consumers respectively. The variable *switching* quantifies the share of household customers that switched their provider during a year; it is a proxy for potential market power of the suppliers of electricity. The interaction term *distance_switching* is computed by multiplying *distance* with *switching;* it assesses the relation between the distance between two countries and their propensity to switch suppliers. The variable *three_biggest* measures the difference in the percentage shares of the electricity market for the three biggest generators in the country-pairs, serving as a proxy for market power of the generation companies.

Table 1 Dependent and independent variables used in the regression

Dependent variables	**Description**	
hh_price	logged absolute price differences between country pairs (household consumers)	
ind_price	logged absolute price differences between country pairs (industrial consumers)	
Independent variables		**Expected effect**
gdp	logged absolute output per capita differences between country pairs (GDP in absolute prices, converted to €)	Positive - the more similar the GDP the smaller the price gap
distance	logged absolute distance differences between country pairs	Positive – proximity reduces the price gap
imports	average of the share of imports in the final consumption between country pairs	Negative – mutual trade reduces the gap
intensity	logged absolute energy intensity differences between country pairs (measured in KgOE per 1000 €),	Positive - the larger the difference the larger the gap

nuclear	absolute differences in the shares of electricity generated with nuclear power	Positive - similar cost structure
hydro	absolute differences in the shares of electricity generated with hydro power	Positive - similar costs structure
tariffs	logged absolute differences in network tariffs (measured in €)	Positive - similar cost structure
unbundling	dummy variable if the transmission networks are unbundled from generation/supply; dummy=1 if both countries unbundled, else dummy=0	Positive - similar institutional set up
distance_unbundling	*distance* times *unbundling*; measures the effect of distance on price differentials for country pairs in which both have unbundled ESI	Positive - as for distance
regulation_hh	dummy variable for the existence of price controls for access to the transmission networks (for household consumers); dummy=1 if one or both countries have price controls, else dummy=0	Unclear - there are no consistent regulation rules across countries
regulation_ind	same as above, for industrial consumers	Unclear
distance_regulation_hh	*distance* times *regulation_hh*	Positive – see distance
distance_regulation_ind	*distance* times *regulation_ind*	Positive – see distance

switching	absolute differences in the share of household customers that switched their provider during a year	Positive - similar market situation
distance_switching	*distance* times *switching*	Positive – see distance
three_biggest	absolute differences in the market shares of the three biggest generators	Positive - similar market situation
distance_three_biggest	*distance* times *three_biggest*	Positive - see distance
eu_enlargement	dummy variable for the Members of the fifth EU enlargement[51]; dummy=1 if both countries are new, dummy=0 else;	Positive - new members may have more different prices

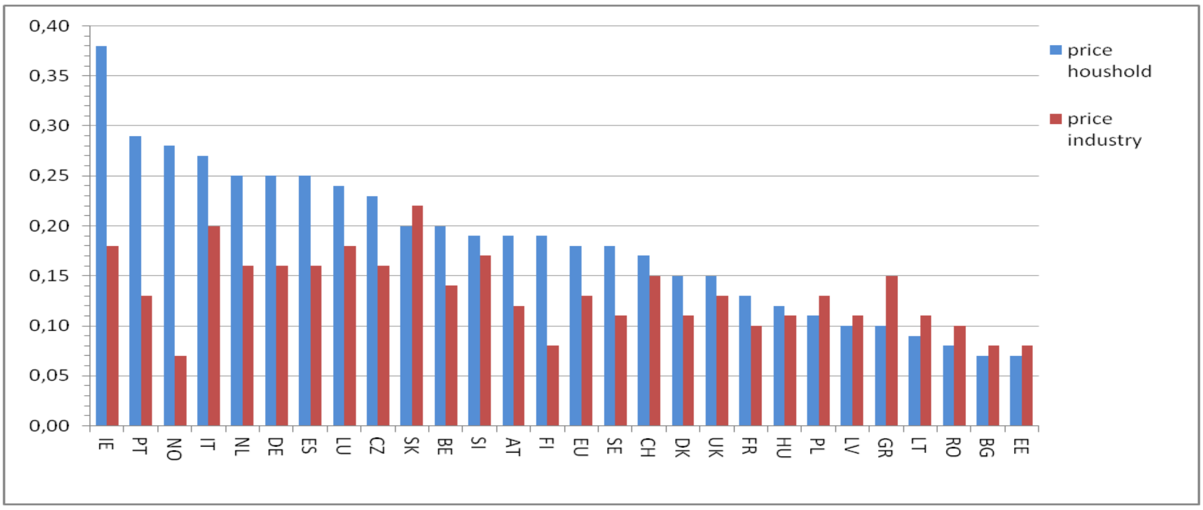
6.2 DESCRIPTIVE STATISTICS

The electricity prices vary considerably across the member states in the European Union. *Figure 3* shows that the prices for household consumers range from around 0.07 € in Estonia and Bulgaria to 0.32 € in Ireland, which is more than a fourfold divergence. Generally it can be said that the average household prices are higher than the industrial prices. The average price in the EU is 0.18 € for households and 0.13 € for industrial users. Thus, variation within the industrial prices is less pronounced, with 0.07 € in Norway and 0.22 € in Slovakia. This can be due to different degrees of market power that the household and industrial consumers exhibit. The industry e.g. has the option to negotiate long term contracts and additionally to buy electricity on the spot markets. Moreover, accordingly to the EU Directive[52], they were able to switch providers as early as 2004, giving them an advantage over the household customers, where switching didn't become mandatory as early as 2007. This is a first

[51] Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia, Romania
[52] Directive 2003/54/EC

indication that the LOOP might be more applicable for industrial prices than for household prices.

Figure 3 Household vs. Industry Prices for Electricity 2009 (€)



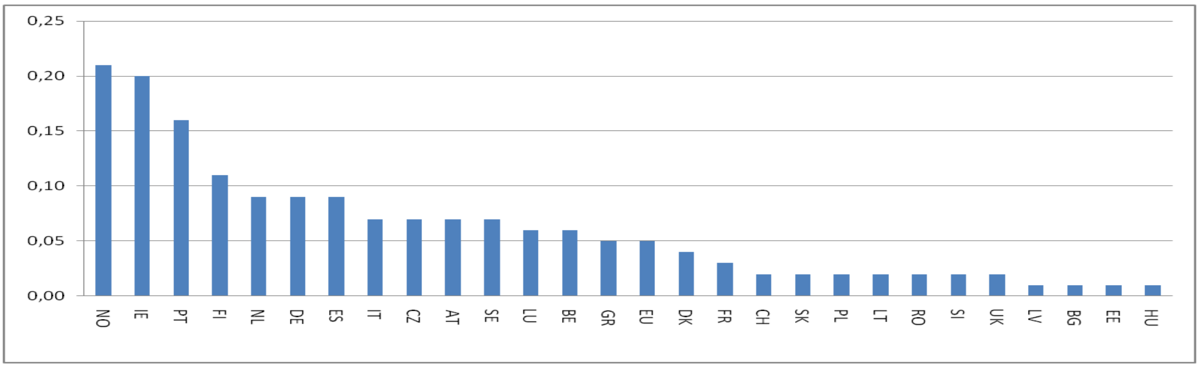
Source: Eurostat

Only in few cases does the industrial price lie slightly above the household price, namely in Estonia, Bulgaria, Rumania, Lithuania and Slovakia. With 0.05 €, Greece has the highest difference household and industry prices. Greece has been liberalizing its electricity market since 1999, although the degree of real competition is low due to the dominance of one state owned electricity utility, responsible for close to 96 % of electricity[53]. Greek electricity prices for households have been stable over the last 10 years. The average household price is about 55% of the European average and the fifth lowest among all Member States. For industrial users on the other hand, prices have been increasing steadily since 2001 and were about 15% above the European average in 2007.

Generally only in some cases the industrial price is similar to the price that private households are paying (*Figure 4*). Primarily the new member countries like Estonia, Bulgaria, Hungary, Slovakia and Romania, where the liberalization is only a recent phenomenon, show a small gap between the two prices. Older members like Portugal, Finland and Netherland however have considerably higher variation, and Norway and Ireland lead the ranks with respectively 0.21 € and 0.20 € price difference between the household and industrial price.

[53] Eurostat

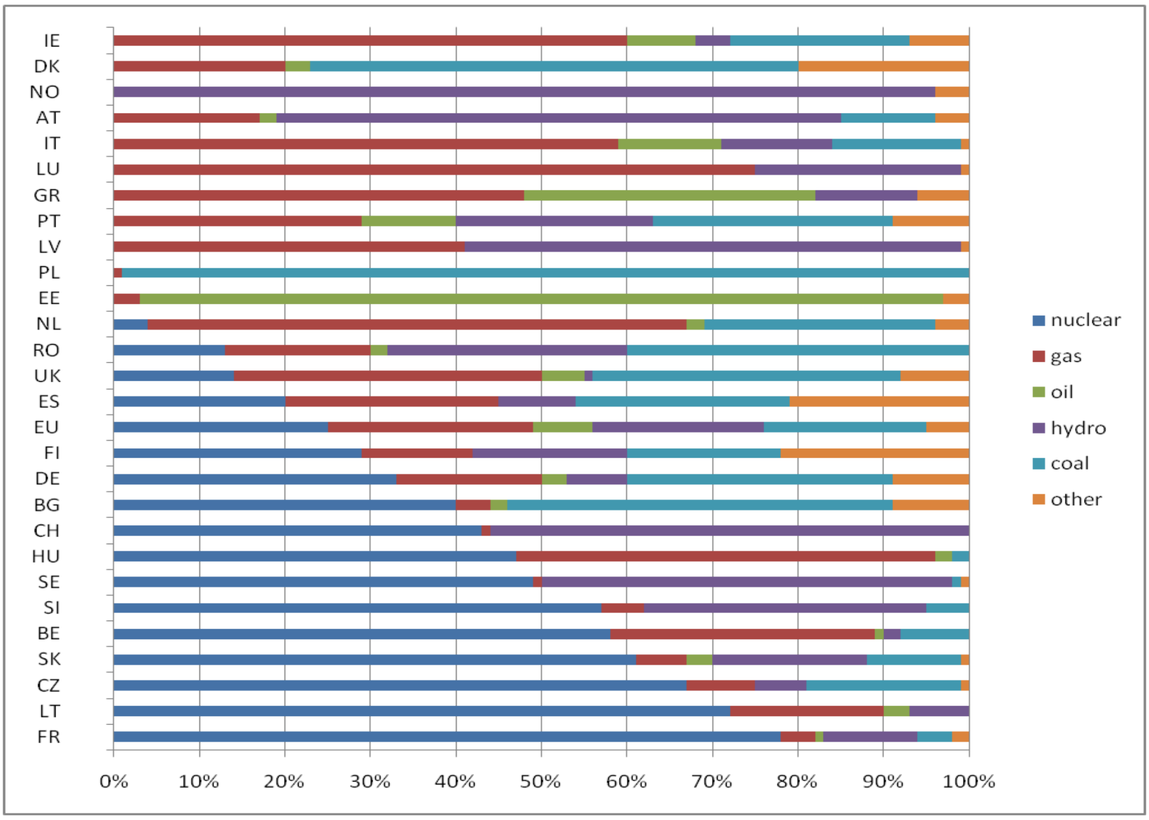
Figure 4 Price differences between household and industrial prices 2009 (€)



Source: Eurostat

There are considerable differences concerning the use of fuel in the generation process. As *Figure 5* shows, over 75% of electricity in France is generated with nuclear power, whereas 2/3 of Irelands electricity is dependent on gas as input fuel while nuclear power is completely absent from the fuel mix. Other countries are mostly dependent on hydro power (Norway, Austria), oil (Estonia) or coal (Poland). Since the cost structure may vary due to inputs costs, the differences in the fuel mix are one possible indicator for differences of final prices.

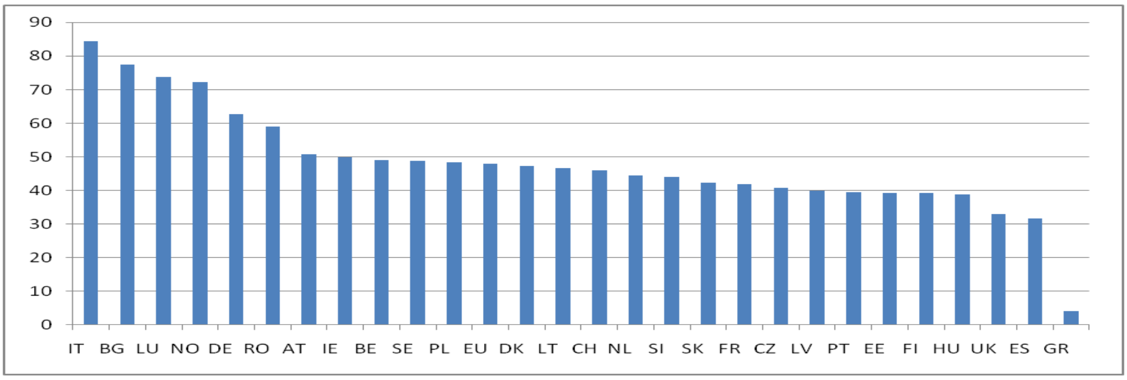
Figure 5 Fuel mix that was used in the process of generation in 2007 (%)



Source: Eurostat

Network tariffs are paid for the access to the transmission grid; they can be regarded as entry prices for the usage of the network. Thus, their height is another possible determinant for the variation of final prices. There seems to be a quiet similar cost structure across Europe, with the exception of Greece where the tariff is very low compared to the average and a group of six countries (Romania, Germany, Norway, Luxemburg, Bulgaria and Italy) that seem to lie above average.

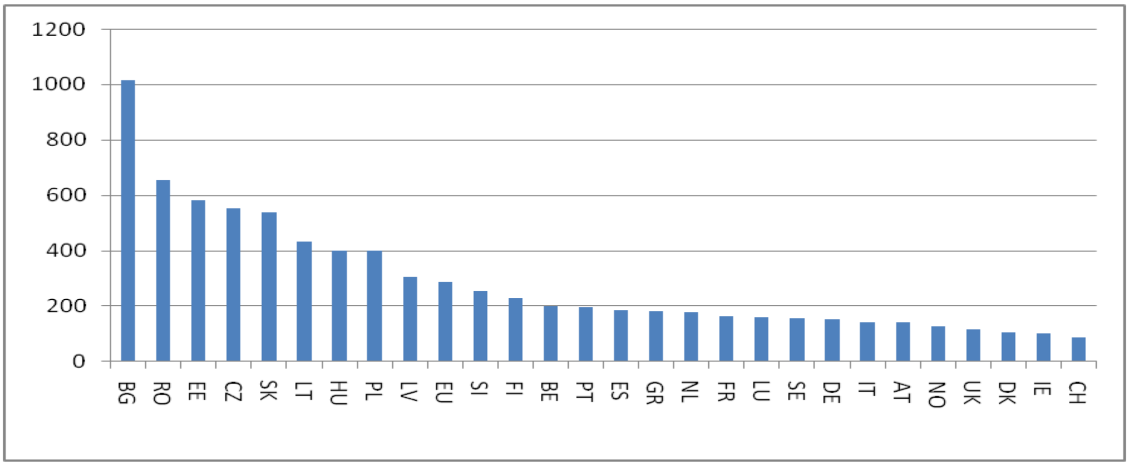
Figure 6 Network Tariffs in 2007 (€)



Source: Eurostat

The energy intensity gives the level of dependency of the economy on various energy sources, thus being a proxy for the overall demand for electricity. It also is an indicator for the possible market power of the ESI where usually a leeway exists when it comes to electricity pricing. *Figure 7* gives an overview of the levels of dependency of the European economies on energy. New Member States seem to have much higher energy input per produced output. This is plausible, since their economies still are in a transition process from previously heavy and energy hungry industry production towards more light industry and services. Knowledge driven Western economies like Denmark, Sweden and Germany are as expected far less dependent on energy in their output. With this variable we hope to identify possible differences in prices due to the dependency on energy.

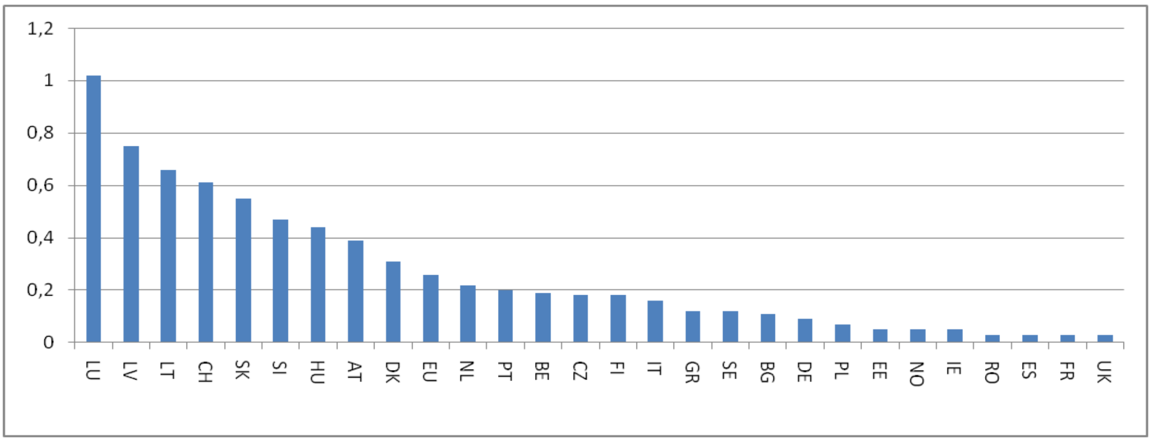
Figure 7 Energy intensity of the economy in 2007 (KgOE per 1000 € of GDP)



Source: Eurostat

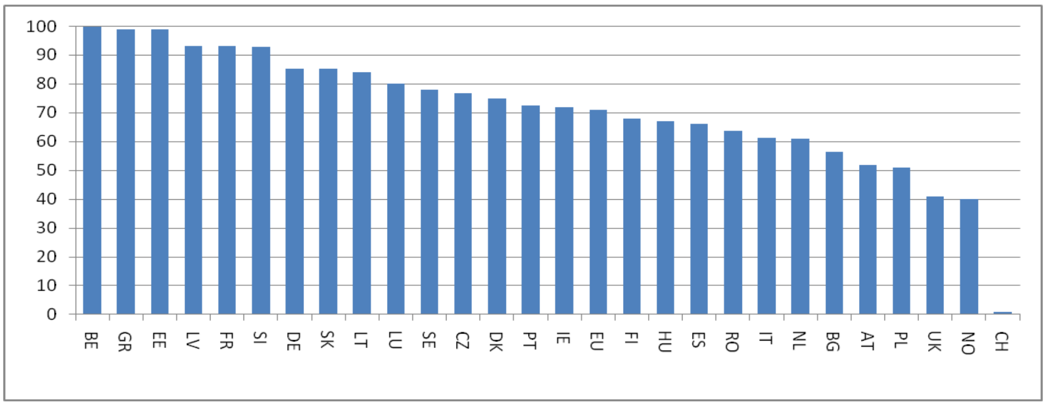
The share of imports in total consumption of electricity is reported in *Figure 8*. Here the countries can be classified roughly in three groups: those with low dependence on imports with import shares of up to 10 % in their final consumption (UK, France, Spain, Romania, Ireland, Norway, Estonia, Poland, Germany), those with moderate levels of 10% to up to 40% (Bulgaria, Sweden, Greece, Italy, Finland, Czech Republic, Belgium, Portugal, Netherlands, Denmark, Austria), and those with high levels of imports of over 40% (Hungary, Slovenia, Slovakia, Switzerland, Lithuania, Latvia, Luxemburg).

Figure 8 Import share in electricity consumption in 2007 (%).



Source: Eurostat

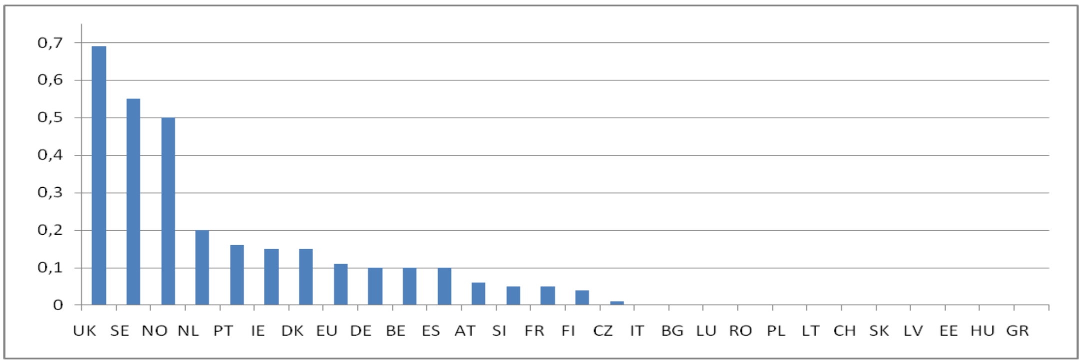
Figure 9 Market share of the three biggest generators in 2007(%)



Source: Eurostat

The market share of the three biggest generators is an indicator for potential market power of energy generators. It is thus indicating to which degree the producers of energy can impose their prices on the consumers. The share of customers that switch their providers on the other hand indicates degree of market power of the customers. Those who are not satisfied with the services or high prices are able to switch to another provider, thus imposing some degree of pressure on the providers to offer satisfactory services and prices and putting them closer to a position where they may act as under the conditions of perfect competition.

Figure 10 Share of customers that switched their provider in 2007 (%)



Source: Eurostat

7 RESULTS

This chapter presents the results obtained from the regression specifications from *Chapter 5* and data from *Chapter 6*. Section *7.1* presents the regression results for all four models run on household customer price differentials. The regression results for industrial customer price differentials are presented in section *7.2*.

7.1 HOUSEHOLD PRICE DIFFERENTIALS

Table 2 shows the regression results for the trade model, the cost model, the institutional model as well as the mixed model that contains all variables. In all four models the dependent variable is the natural logarithm of the household customer price differentials.

The trade model explains around 10% of the variation in price differentials. The coefficient for GDP per capita differences is positive and significant on the 95% level. Hence country-pairs with a higher difference in GDP per capita have higher household customer price differences than countries with lower GDP per capita differences.

The coefficient for distance is also positive and significant on the 95% level. In the sample used in this study the difference between the capitals of country-pairs is positively correlated with the price differential, confirming the assumption that geographical proximity of countries is positively influencing the price harmonization. The difference in the share of imports on final consumption is negatively influencing price differentials, showing that countries with a similar level of trade have similar prices. This result should however be regarded more cautiously since the coefficient for this variable is only statistically significant on the 90% level.

The coefficient for the natural logarithm of the difference in energy intensity is positive, but again, this only holds for 90% of the cases. With this limitation, country-pairs with a higher difference in energy intensity have higher price differences than country-pairs with lower energy intensity differences.

Table 2 Regression results for household price differentials as the dependent variable

	Trade model	**Cost model**	**Institutional model**	**Mixed model**
constant	-6.378 ** (2.91)	-2.863 ** (-19.12)	-2.740 ** (-14.01)	-4.340 ** (-7.35)
gdp	0.161 ** (2.91)			0.161 ** (2.39)
distance	0.265 ** (2.77)			
imports	-0.589 * (-1.94)			-0.705 ** (-2.13)
intensity	0.083 * (1.77)			0.086 * (1.68)
nuclear		0.065 (0.27)		0.253 (1.10)
hydro		0.023 (0.10)		0.108 (0.44)
tariffs		0.028 (0.66)		-0.037 (-0.85)
unbundling			0.381 (0.25)	0.499 (0.34)
distance_unbundling			-0.077 (-0.35)	-0.092 (-0.44)
regulation_hh			-2.877 ** (-2.70)	-2.825** (-2.53)
distance_regulation_hh			0.417 ** (2.76)	0.390** (2.46)
switching			-0.552 (-0.20)	0.370 (0.14)
distance_switching			0.101 (0.25)	-0.075 (-0.20)
three_biggest			0.009 (0.38)	0.005 (0.22)
distance_three_biggest			-0.002 (-0.47)	-0.001 (-0.34)
eu_enlargement			-0.181 (-0.71)	-0.082 (-0.29)
R^2	0.1020	0.0012	0.0562	0.1181
*** significant at 95%; * significant at 90%*				

The R^2 value for the cost model is very low and has virtually no explanatory power. We will discuss this result in *Chapter 8*.

The R^2 value for the institutional regression model indicates that it explains around 5.6% of the variation. The dummy variable for price regulation and its interaction term with distance are the only two significant variables, both on a 95% level. Price regulation is negatively correlated with the price differentials, indicating that country-pairs with at least one country having regulated prices have more unequal prices than country-pairs in which both countries have no price regulation. The interaction term between distance and price regulation has a positive coefficient. In country pairs where at least one country has regulated prices distance is positively correlated with the price difference.

The mixed model, combining all variables of the other models, has an explanatory power of about 12%. The variables *gdp, imports, intensity*, as well as *regulation_hh* and *distance_regulation_hh* are significant. The coefficients of these variables have the same signs as in the previous models and hence confirm the findings.

7.2 INDUSTRIAL PRICE DIFFERENTIALS

The results for the industrial price differentials regression are reported in *Table 3*. The explanatory power of the trade model is approximately 1.6%. As in the regression with household prices the coefficient for *distance* shows a positive effect of distance on price differentials, however, it is only significant at the 90% level. The logarithms of differences of GDP per capita and energy intensity as well as the share of imports are not significant.

The cost model has again very low explanatory power (around 1%). The only variable that is significant is *tariffs* with a t-value of 1.77, indicating that it is significant only at 90%. The difference in tariffs is positively influencing industrial customer price differentials. The coefficients for *nuclear* and *hydro* are insignificant.

The institutional model regression has an explanatory power of roughly 2.5%. The only significant variables are *distance_unbundling* and *unbundling* as well as the dummy variable *eu_enlargement*. The coefficient for *unbundling* is significant on the 95% level and indicates a negative effect on industrial price differences. The dummy variable *unbundling* has a value of 1 when both countries have unbundled transmission and distribution networks and a value of 0 otherwise. This means that country-pairs consisting of two countries with unbundled ESIs have more similar prices than other country-pairs. *Distance_unbundling* is also positive and significant on the 95% level. This means that for country-pairs in which both countries have unbundled their networks, distance has a positive effect on the price differential. The dummy variable *eu_enlargement* controls for Member States that only recently joined the European Union. It is significant at 90% and it affects price differences positively. This means that country-pairs consisting of two new Member States have higher price differences than country-pairs with at least one "old" Member State. All other coefficients are not significant.

Table 3 Regression results for industrial price differentials as the dependent variable

	Trade model	**Cost model**	**Institutional model**	**Mixed model**
constant	-4.890 ** (-6.42)	-3.627 ** (-24.01)	-3.445 ** (1.91)	-3.844 ** (-7.28)
gdp	-0.009 (-1.05)			-0.0130 (0.20)
distance	0.190 * (1.82)			
imports	-0.075 (-0.21)			-0.153 (-0.39)
intensity	0.037 (0.89)			0.036 (0.84)
nuclear		-0.131 (-0.58)		-0.127 (-0.55)
hydro		0.035 (0.16)		0.158 (0.65)
tariffs		0.077 * (1.77)		0.072 (1.60)
unbundling			-3.671 ** (-2.21)	-3.959 ** (-2.32)
distance_unbundling			0.581 ** (2.28)	0.562 ** (2.39)
regulation_ind			-0.561 (-0.52)	0.075 (0.07)
distance_regulation_ind			0.074 (0.50)	-0.018 (-0.12)
three_biggest			-0.011 (-0.51)	-0.004 (-0.18)
distance_three_biggest			0.001 (0.40)	-0.000 (0.07)
eu_enlargement			0.416 * (1.91)	0.418 * (1.67)
R^2	0.0158	0.0092	0.0253	0.0358
*** significant at 95%; * significant at 90%*				

The mixed model combines the variables of the trade model, the cost model and the institutions model. It has an explanatory power of approximately 3.6%. The significant variables in this model are *unbundling*, the interaction term *distance_unbundling* and the dummy variable *eu_enlargement*. The coefficients for *unbundling* and *distance_unbundling* are both significant on the 95% level. They are similar to the coefficients obtained in the institutional model, confirming the previous findings. The dummy variable for new EU Member States is significant only at the 90% level and its coefficient is similar to that obtained in the institutions model.

8 DISCUSSION

Our results show that there are significant differences both in prices for electric energy in Europe as well as the factors influencing them. Since the causes for price differentials vary for household and industrial prices we discuss the results separately. *Chapter 8.1* discusses the regression results for household customer price differentials and *Chapter 8.2* analyses the results for industrial customer price differentials.

8.1 HOUSEHOLD PRICES

Chapter 6 showed that there is substantial variation in household customer prices within Europe. The aim of *Chapter 7* was to analyze possible causes behind these price differentials.

Firstly, the trade regression confirms our expectation that income differences help explain price differences, as the data shows evidence that electricity prices reflect the general price levels of countries. Despite liberalization the electricity markets seems not to be an exception from economy wide price trends. Secondly, similar levels of dependency of an economy on electric power produce similar prices. Such dependencies are difficult to change since it requires a restructuring of the economy, typically a very slow process. Hence, price differences caused by intensity differences are likely to persist. A further factor that is strongly affecting price differences is distance. As trade theory predicts[54], countries that are far apart tend to trade less as distance functions as a trade barrier. This seems reasonable since longer distances make arbitrage more difficult and countries that lie far apart thus have a bigger price gap. One key to decrease this trade barrier is to increase import capacities. Our results confirm this assumption as the trade regression shows that the average level of imports has a strongly negative effect on price differences. Countries that trade more have more similar prices. Thus, price differences between countries with limited import shares in their consumption are likely to persist, unless a common grid with low capacity and transmission restrictions can be created. One extreme example of how imports can influence the electricity price is Luxemburg. 100% of its electricity consumption is imported resulting in an electricity

[54] Anderson and van Wincoop (2003)

price (0.24 €) that is nearly identical with the prices of the supplying countries Netherlands and Germany (0.25 € each).

The cost model yielded less significant results. However, what we can say is that price differences do not seem to be cost driven, since differences in the generation fuel mix do not explain the price differentials in the data. This could be due to the fact that the ESI has marginal price setting, meaning that the price is set equal to the cost of the marginal power plant (in many cases this is a gas fired power plant). Since most countries use an energy mix consisting of three to six fuels and there are only few countries that are almost entirely dominated by one fuel source (Norway with hydro, Estonia with oil and Poland with coal power), the price differences are not likely to reflect the fuel composition of the electricity generation. The model does not detect any effect of differences in tariffs on price differentials either. A reason for lack of correlation could be that household customers pay these prices only indirectly.

The institutional model shows a significant negative correlation between the existence of price controls in the transmission sector and price differences. The fact that the natural monopolies of transmission are not regulated apparently drives a wedge between the prices of two countries. In the case of no regulation the monopolists has the option to set prices arbitrarily and due to different conditions for network access and maintenance cost on the one side and local contract details and rules on the other side they might vary considerably. However, there is no correlation between unbundling and price differences. A correlation test between the dummy variables for regulation and unbundling showed that there is no relationship between regulation and unbundling, meaning that even in the case vertically integrated companies are not unbundled their transmission and distribution networks still can be regulated and vice versa. According to the regression results regulation seems to be a more powerful tool for household prices than unbundling.

The share of customers that switched their providers does not seem to affect price variation. As *Figure 10* shows over 50 % of the countries in the sample have a switching rate below 5%. This is due to the fact that in most countries household customers did not have the possibility to switch their electricity supplier until June 2007. The UK is the country with the longest and most successful ESI liberalization history[55] in Europe and it has a switching rate of close to 70 %. The fact that the UK has relatively low electricity prices (13 % below EU average) might

[55] Pollit (2007)

be an indicator of that supplier switching increases the customers bargaining power and helps bring the prices down. The market share of the three largest generators shows to be insignificant in the sample. This can be explained with the fact that they possess considerable market power of over 50 % in all but three countries[56], hence leaving little room for variation.

The dummy for new EU Member States shows to be insignificant. Thus, countries with a longer history of integration do not have more similar prices than countries that just joined the integration process. Accordingly, we can confirm our hypothesis that the LOOP does not hold for household electricity prices across Europe.

8.2 INDUSTRIAL PRICES

As *Figure 3* shows, prices for industrial customers show less variation across Europe than household customer prices. Unlike the case for the household consumers, our analysis from the trade regression shows that both GDP and energy intensity differences do not result in price differences for the industrial consumers. This is a first indicator of that the price setting mechanism follows international markets more for industrial prices than for household prices. Moreover, imports do not seem to influence industrial price differences either. This might be due to the fact that the wholesale prices follow more closely the international spot market prices and thus are less influenced by imports. However, as for the household price differentials, the distance between two countries appears to be a significant trade barrier increasing the price differentials for industrial customers.

As in the regression for household customer prices the fuel mix seems to have no influence on international price differentials for industrial customers either. The reasoning behind the insignificance of the fuel variables applies similarly as in the previous chapter. Furthermore, the regression results show that tariff differences are positively related with price differences. We suggest that this is caused by the fact that tariffs often are paid by industrial customers directly. In many cases there is no middleman between the industrial consumers and the industrial transmission system operators which gives industrial wholesale consumers a more direct insight into the market. Consequently, the transmission system operators have fewer options to charge a mark-up after the tariffs thus making sure that countries with similar tariff

[56] exceptions are Norway, Switzerland and the UK; *Figure 9*

levels also have similar prices. This relative transparency in price setting also renders the existence of regulation more unimportant.

Unbundling has a negative influence on price differences. That means that country pairs in which both countries have unbundled their transmission networks from the rest of the ESI have more similar prices. This is due to the fact that these country pairs have more similar market structures and that the unbundling reduces the market power of the individual companies leading to more competition and price convergence. What is more, the share of the three biggest generators appears to be insignificant as in the regression with household prices.

The dummy variable for EU enlargement is positively correlated with price differences. This means that the new Member States that only recently joined the common European electricity market have bigger price differences than old Member States, which might be due to the fact that the new Member States developed their ESI independently and were not subject to the harmonization process. The old Members have more similar prices since they have been exposed to liberalization process for a longer time, which indicates that the LOOP apparently does work better for the industrial prices than for the household prices.

9 CONCLUSIONS

The aim of this study was to test whether the *law of one price* holds for the European Electricity Supply Industry. Additionally it aimed at identifying factors behind possible price differences. The descriptive statistics showed that the variation of prices is greater for household consumers when compared to industrial buyers of electricity, which served as a first indication for the LOOP being more applicable to the industrial rather than the household market. Drawing on this finding we construct a model for explaining price differentials with the differences in trade, cost and institutional factors in the European countries that were included in our analysis.

The regression analysis that was run separately for household and industrial price differentials showed that there is a number of factors that significantly influence the differences in prices for electric power across European countries. One factor that showed big influence on both types of prices was distance between the trading countries, thus confirming conventional trade theory - countries that lie closer simply trade more. Another finding that is similar to both the household and the industrial prices is that price differences are not driven by the respective fuel costs. While at first glance a surprising result it can easily be rationalized by the existing practice of price setting for electricity, where the prices are set according to marginal fuel costs.

For household customers a number of variables showed significant influence on price differentials. Imports and the existence of price controls for the transmission networks tend to close price gaps across countries. However, differences in GDP and energy intensity have the opposite effect. Additionally we do not find any signs of convergence for countries that have been exposed to liberalization for longer time, thus giving further evidence of the LOOP being violated for household prices.

For industrial customers similar levels of network tariffs as well as network unbundling decrease price differences. Moreover, we find a strong positive effect of liberalization and regional integration on price divergence. The data showed that new Member States had significantly higher levels of price differentials than the old Member States. This is a strong conformation that the LOOP is more applicable to electricity prices for industrial customers of the Electricity Supply Industry.

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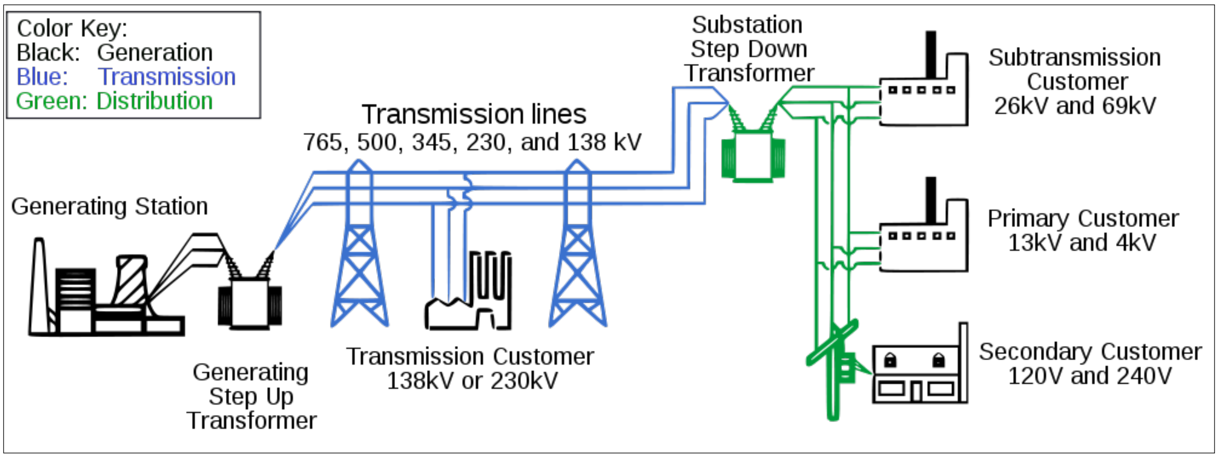
11 APPENDIX

Figure 11 Power Transport from Generation to Customers



Source: US Department of Energy

Herfindahl-Hirschman Index[57]

The HHI measures the size of firms relative to the industry and can be seen as a measure of competition in industries. It can be calculated with the following formula:

$$H = \sum_{i=1}^{N} s_i^2$$

S denotes the market share of firm i and N the number of firms in the market.

For the interpretation of the HHI the following scale is used:

Below 100: indicates a highly competitive market

Between 101 and 1000: unconcentrated market

Between 1001 and 1800: moderate market concentration

Above 1800: high market concentration

[57] Miller (1982)