Deregulation and Regulation of Electricity Markets

Niclas Damsgaard

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Contents

Acknowledgements

For as long as I can remember I have had an interest in social issues in a broad sense This led me early on into politics and in economics I later on found one, although certainly not the only, fruitful approach to analyzing and understanding important social and political questions. From their common source, my interest in politics and economics has always been closely connected. That does not mean that politics determine my economic analysis and conclusions, nor that politics is only a question of economic efficiency. But, they do affect each other. The economic research is perhaps mostly affected through the choice of subjects, rather than as a bias in the conclusions. My basic ideological views have not been that much affected of my studies in economics, but certainly some of the position I take are affected by my training in economics. Overall, I think that these two interests have constituted a fruitful combination. My first thanks therefore go to my friends from the early years in politics. Almost none those have gone into economics but in spite of that they contributed by nurturing and developing my interest in social and economic issues. Among those early friends from politics I would especially like to mention Niklas Claesson, Jessica Polfjärd, Karin Alkstål and Svend Dahl.

With this long interest in social issues - and economics - entering a PhD-program is perhaps a logical step. Sometimes it feels more to have been determined by coincidences (or a wish to postpone going in to a normal job). In fact, I believe the real reason was that my undergraduate studies had learned me a lot - but the primary lesson was that I still did not understand most of the important issues. My PhD-studies has improved that considerably, even though there is still a lot to learn.

When I entered into the PhD-program the electricity market in Sweden had recently been deregulated and I had had some contacts with the industry. Lars Bergman, my supervisor throughout these years, convinced me to also do research related to the electricity market. I have since then benefited especially from Lars broad and deep knowledge about the electricity market. The convincing was perhaps not such a hard task, since I have always found such drastic changes fascinating. During these years there has been a small group at the school working with electricity market issues under the Lars' supervision. Besides me, this group consisted of Jon Thor Sturluson and Chloé Le Coq. I have benefited a lot from the collaboration with them. Thanks.

During my time as a PhD-student I have received financial support from the Nordic Energy Research Program - Energy and Society, the Swedish Energy Agency (AES program) and the Stockholm School of Economics, which is gratefully acknowledged.

The Nordic Energy Research Program did not only offer financial support, but also many fruitful seminars and conferences. Everyone involved in this program has helped in many ways. Through the program I also have had the opportunity to spend periods at SNF in Bergen and at the Institute of Economic Studies (IoES) in Reykjavik. I am very grateful for the hospitality shown to me during may stays there and I especially would like to thank Eirik Amundsen and Germund Nese at SNF and Fridrik Mar Baldursson at IoES.

Writing a dissertation is sometimes a rather lonesome task. You are basically on your own, which also make you value your friends more. The friendship of my fellow PhD-students has made these years so much more enjoyable. Jon Thor Sturluson, who also co-authored one of the papers in the thesis, has been a great friend, discussion partner and colleague throughout these years. We shared office from the first day in the program, until he moved back to Iceland. Petra Lennartsdotter made the first years in the program so much more fun, until she abandoned the place.

The discussions at the lunch table concerning whatever bizarre subjects you could imagine have always been enjoyable, although one often worried that some undergraduate student would pass by and hear only fragments of an arbitrary and rather extreme position taken by someone. I have also been teaching in the undergraduate microeconomics course at the school, which I have enjoyed. The discussions and after-class beers with my fellow teachers have also been an enjoyment.

Among my friends at the SSE some, besides the ones already mentioned, have been particularly important: Erik Grönqvist, with whom I have always been able to discuss important subjects such as climbing and out-door equipment (especially tents). Andreas Madestam, a good friend when needed. Daniel Waldenström, who is always eager to discuss anything and always has firm opinions. Nina Waldenström, who can scare almost anyone but really isn't that dangerous. Therese Lindahl, who has had to put up with discussions about tents and "snören" but also has an efficient counter-attack in capoeira. Björn Lagerwall and John Ekberg, who (together with a few more) managed to break two table hockey games with me. It is probably a good thing that that interest vanished over time.

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My friends outside academia have in their own way – primarily by not knowing economics at all – contributed to the completion of this thesis. Without skiing, kayaking, hiking, climbing and all the other activities that constitute life it would have been so much harder to endure all the hours in the office. Among those the traditional "New Year gang" should be mentioned and especially Patrik Horsell – my prime kayaking and skiing buddy during the last couple of years.

Finally, I would like to thank my family for their support and encouragement throughout the years.

Stockholm, September 2003

Niclas Damsgaard

Introduction and Summary

During the last decades many markets, which previously were subject to intensive industry specific regulation, have been deregulated. The examples are numerous: airlines, financial markets, telecommunications and energy markets are only a few. A common theme for many of these markets is the presence of networks, which can be regarded as essential facilities for operation in the market. One market of this kind is the electricity market.

The electricity market can be described as consisting of several vertically separate parts: generation, transmission (high-voltage transportation), distribution (low-voltage transportation) and supply/retail sales (see Figure 1). The traditional view has been that to ensure a well functioning market these functions are best performed in vertically integrated companies. From the 1970's that traditional view has been more and more questioned, and today experience has shown that this vertical integration is not a prerequisite for a well functioning industry. Today there also exist, more or less, a consensus that the generation and supply parts of the industry potentially can function as competitive markets and be deregulated[1], while the transmission and distribution parts are generally considered to be natural monopolies and best kept regulated. In general, the introduction of competition in generation and/or supply may increase the demands on the regulation of transmission and distribution.

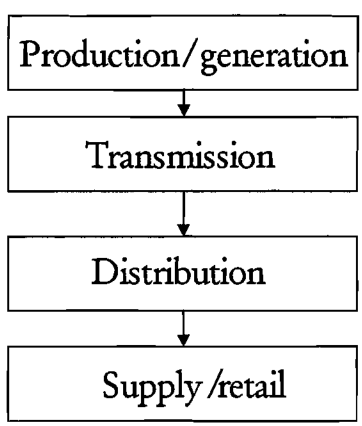

Figure 1. Vertical functional chain for the electricity industry

[1] Although there might not be a consensus that it is beneficial to introduce competition.

Considering that the industry can be vertically separated, deregulation and introduction of competition can mean several different things. The lowest level of deregulation would probably be to abolish entry barriers and price controls in generation and wholesale. An intermediate level of deregulation would be to also open up for competition in parts of the retail market and the highest level to abolish entry and price control both in generation and for the entire retail market. Irrespective of the exact definition of deregulation it is clear that only part of the market is actually deregulated, while other parts are kept regulated.

This thesis consists of four essays, mainly related to the fields of industrial organization and political economy. The focus is on deregulation of electricity retail markets and on the continued regulation of parts of such markets after the introduction of competition. The first essay is an empirical essay on the causes of deregulation. The second (theoretical) and third (empirical) essays deal with the interaction between regulation of the (distribution) networks and the retail market. When the regulated and unregulated operations are conducted within a vertically integrated company the regulation may not only have an effect on the regulated market, but also affect the behavior in the unregulated market. The fourth essay is a study of domestic electricity demand. It is thus somewhat different than the other papers since it is not directly connected to the issue of electricity market deregulation. Since the energy sector is an essential part of any modern economy and energy production has considerable environmental effects the sector has for a long time been subject to political interventions. To some extent the policy instruments available to the legislator are reduced by deregulations. In that context the understanding of the demand for electricity – and other energy goods – may become even more important. The use of taxes to affect prices and thus the demand for electricity may at the same time become an even more important policy instrument and more difficult to implement due to the internationalization of the electricity market.

Essay I:

Why Deregulation? Economics and Politics of Retail Electricity Markets

Within economics there are two main theories of regulation. In the traditional theory, the public interest theory, economic regulation is explained by the presence of market failures. The regulators are, implicitly or explicitly, assumed to be benevolent social welfare maximizers and regulation is introduced to correct for the market failures. During the 1970's and 80's an alternative economic theory of regulation, the private interest theory, was developed (Stigler, 1971; Peltzman, 1976; Becker, 1983). The regulators were now modeled as all other agents within economics, i.e., as rational maximizers of their own personal utility. The existence of regulation is in this framework a response to the political pressure from interest groups. At the same time as this theory gained acceptance, many markets were deregulated, and the obvious question is thus: If regulators are captured by interest groups, why do then deregulations occur? Is the theory wrong or is it a shift in the power balance between interest groups.

Peltzman (1989) studied a number of different deregulated markets and found that the private interest theory was compatible with the deregulation and that "It was one plausible response to forces that called for a regulatory change". Kroszner and Strahan (1999), in a study of the relaxation of bank branching restrictions in the US, employed a similar method to the one used in this essay and found that the private interest theory gave the most compelling overall explanation.

White (1996) and Ando and Palmer (1998) study the deregulation of the US retail electricity market. According to White the main explanatory factor is the presence of a large gap between the existing price and the expected price in a deregulated market and that deregulation occur where this gap is large, which supports to the public interest theory. In the study by Ando and Palmer more variables were added and more sophisticated methods were employed, but their findings are not inconsistent with White's.

This essay expands this rather small literature. With a data set covering all US states, Canadian provinces, EU and EFTA countries, Australian states and New Zealand a duration model is used to analyze the timing of deregulation of retail electricity markets. Besides analyzing the entire data set, separate analysis are also conducted for the US and European sub-samples.

One interesting result is that there exist important qualitative differences between the United States and Europe. The results for the US sub-sample support, to a large extent, the previous findings of White (1996) and Ando and Palmer (1998). For instance is deregulation more likely in high-price states. One conclusion is that retail electricity market deregulations in the US seem to a large extent be based on consumer protection considerations.

For Europe the opposite seems to be the case. Electricity retail deregulation has been more likely in low-price countries and deregulation has to a larger extent been dependent on interest group pressure. A likely explanation is that where the price is low the resistance from the electricity industry is weaker. Furthermore, there is some support that the existence of strong industrial consumers facilitates deregulation.

If the US experience is that where the old regime failed it was replaced, the European experience is that where the old regime failed it was kept. These results indicate that the case for EU deregulatory initiatives is stronger than for federal initiatives in the US.

Essay II:

Power to Cheat? (joint with Jon Thor Sturluson)

In the second essay an important policy issue concerning vertically integrated firms in network industries is studied. An incumbent firm, with an relationship to all consumers, provides regulated local network services and is also active in the deregulated but imperfectly competitive retail market. The total costs of the incumbent are known, both to its competitor and the regulator. The distribution of these costs between the network and retail services is private knowledge of the incumbent.

The firm has a natural incentive to overstate its costs for the network service to receive a higher regulated price. However, since total costs are known , a claim of high network costs signals low retail costs. When firms compete in prices, which are strategic complements, the integrated firm would like its competitor to believe that retail costs are high as well.

The regulator can, through a combination of price incentives and monitoring, utilize this trade-off and induce information-revealing separating equilibrium in which the incumbent claims its true type. The optimal combination of price incentives and monitoring and the conditions under which such a separating equilibrium is preferred to a pooling equilibrium are derived.

Essay III:

Using Price-data do test for Cross-subsidization

The third essay shares a common theme with the second essay – the relationship between the regulation of a regulated market and a related unregulated market. One problem that for a long time has been recognized both in the economic literature on regulation and among regulators is the presence of cross-subsidization. Generally vertically integrated firms operating in one regulated and one unregulated market have incentives to use cross-subsidization tactics, such as misallocation of costs, in order to raise the regulated price.

Averch and Johnson (1962) showed in an early contribution that when a rate-of-return cap was applied to a diversified firm, the firm has incentives to overproduce in the competitive market. Faulhaber (1975) provided a rigorous treatment and explicitly defined subsidy-free pricing and suggested two tests for cross-subsidization. Braeutigam and Panzar (1989) arrived at similar results as Averch and Johnson (1962), although the source of the effect differs between their models.

The theoretical literature shows that cross-subsidization generally implies increased production in the unregulated market. If an assumption of imperfect competition is added it follows from almost any model of cross-subsidization that cross-subsidization results in a lower price in the unregulated market and a higher price in the regulated market.

The retail electricity market consists of two vertically related markets: retail and local networks. In many countries the retail market is now deregulated, while the local network is a regulated monopoly. The retail market is normally characterized by imperfect competition.

When the regulator sets the price for the regulated service it can use different regulatory rules. Cost-based regulation refers to regulatory rules were the regulator sets a maximum allowed rate-of-return and the price is thus dependent on the costs of producing the service. With price-based regulation the regulator instead sets a maximum allowed price for the service independent of the firm's costs.

The incentives for cross-subsidization will be stronger with cost-based regulation compared than with price-based regulation. Furthermore, it is likely that closely integrated firms will have better possibilities to engage in successful cross-subsidization.

In Norway the regulation of the networks was changed in 1997 from cost-based to more price-based regulation. Furthermore, it is likely that more closely integrated firms are more able to engage in successful cross-subsidization.

Employing a panel data set containing almost all Norwegian retail and local distribution companies and covering periods with different regulatory regimes and firms with different organizational structure the effect of regulation on the presence of cross-subsidization is analyzed.

The main finding is that data support our hypotheses. The regulated price is higher in periods with cost-based regulation and there is also some evidence that more closely integrated firms charge a higher price for the regulated service. Furthermore, there exists a negative relationship between the regulated and unregulated prices in this industry, which we expect to find if some firms are cross-subsidizing, while others are not. This effect is reduced when cost-based regulation is replaced with price-based regulation and it is also smaller for less integrated firms.

Essay IV:

Residential Electricity Demand. Effects of Behavior, Attitudes and Interest

For a long time considerable resources have been spent on analyzing the demand for electricity and other energy goods. More and more detailed data set have been used and it is naturally to assume that more detailed data will improve the analysis and prognostication of electricity demand. However, it is also more difficult and costly to collect such data.

For an economist the natural starting point is to use economic variables such as price and income. Much of the analysis done had a technical foundation and data on heating system, size of the house and stock of appliances are regularly used. In addition it has been argued that this is not enough, but that we also need "soft" information regarding preferences and behavior.

Using a rich data set, which partly was collected with the intent of including behavior, attitudes and interests of household, the importance of such additional data is analyzed. The results show that economic variables, especially the price, are important explanatory factors even when other variables are added. The introduction of data such as the stock of electric appliances improves the estimations. Additional information on the use of these appliances leads to a very small, although significant, improvement in the explanatory power. Attitudes towards and interest in energy issues does however not improve the explanatory power. Finally, the analysis suggests that the data requirements, both in terms of size of the data set and included variables, are quite severe for a more thorough analysis of these "soft" variables.

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I

Why Deregulation?
Economics and Politics in Retail Electricity Markets*

Niclas Damsgaard

Abstract

During the last decades a wave of deregulations has swept across the world. One market that has been heavily affected by this is the retail electricity market, where the previous system of regulated monopolies in many cases have been replaced by competition. Exogenous technological and institutional changes are often seen as explanations for this. But different countries have responded in very different ways and especially the timing of deregulation vary widely.

Using a data set covering jurisdictions from the US, Canada, Europe, Australia and New Zealand the deregulation of retail electricity markets is analyzed using a duration model. Separate analyses are also done for the US and Europe subsamples. The results indicate that there are important qualitative differences between the US and Europe. In the US, deregulation is more likely in states where the old regulatory regime had resulted in high prices and the results are fairly consistent with the public interest hypothesis. For Europe almost the opposite is true and deregulation has been more likely where the old system had resulted in low prices. The private/producer interest hypothesis is better at explaining the European example.

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1 Introduction

During the latter part of the last century a wave of deregulations[1] swept the world. Numerous markets, such as financial markets, airlines, telecommunications and energy markets, were deregulated. One market that has undergone a dramatic regulatory change during this period is the electricity market. Important exogenous factors such as technological development and political and institutional changes might have provided the opportunity for this change. The response to these exogenous changes differs dramatically. Not all countries or states have chosen to deregulate and among those who have done so the path of deregulation and the timing differ widely.

Today there exists a huge literature on how deregulation should be implemented. The literature on the fundamental issue on why politicians and regulators chose to give up much of their control over this market is, however, very limited. As David Newbery puts it: "The attempted de-politicisation of energy is an admirable goal for an economist but, perhaps, surprising to a political scientist" (Newbery, 2002, p. 11). This paper attempts to bring some further light on the question of why deregulation takes place.

The why issue can be separated into at least two different questions. Firstly, why did deregulation occur at all after almost a century of regulation. Secondly, why have different countries/states chosen different ways?

The first question is not the main focus here, but, as already hinted, there are a couple of possible explanations. One could be that regulation once was the correct policy, but that primarily technological developments have changed that. Smaller, and economically competitive, power plants have become available. Economies of scale on the plant level, that previously might have been an obstacle to efficient competition, have thus become less important. Furthermore, the development of computer technology and IT has drastically lowered the cost of measuring, billing and settlements facilitating coordination of a decentralized industry. A second explanation might be that regulation has been the wrong policy all along, but that it has not been realized until now[2].

[1] What is here called deregulation is a change of regulatory regime that might in fact increase the volume of regulation. Other terms such as liberalisation, re-regulation or regulatory reform are frequently used. However, the terms re-regulation and regulatory reform say very little about the direction and intentions of the regulatory changes which is focused upon here. Liberalisation or deregulation thus seem more preferable. Deregulation here simply refers to regulatory changes that as common features have unbundling of different parts of an industry, increased reliance on markets as an allocating and controlling device and the use of regulation only in those parts of an industry where markets are not believed to work properly. One important feature is the deregulation of pricing and investment decisions.

[2] In the case of the deregulation of the US airline industry this explanation has been suggested by Levine (1981). In general, the opposite could of course also be true, i.e., that regulation is still the right policy and that deregulation is a mistake.

The focus of this paper is instead on the second question. Given that deregulation occur, why are different countries/states responding in such different ways? Both the details and the timing of deregulations differs a lot between countries. Here the focus is on the timing issue. In the economic literature one can identify two lines of theories that aim at explaining regulation. The traditional theory might be labeled as the public interest theory[3], which explains the existence of regulations with market failures that are corrected by the regulations. An alternative positive theory of regulation is the private interest theory (or economic theory of regulation), which was developed primarily by Stigler (1971), Peltzman (1976) and Becker (1983). The basic feature of the private interest theory is that lawmakers and regulators are assumed to behave as all other agents in economic models, i.e., they are rational utility-maximizing agents.

At the same time as the private interest theory gained a wider acceptance the deregulation wave took off. But if regulators are, as this theory suggest, more or less captured by the regulated companies, why would then deregulation occur? There are two possible answers to this question. Either the private interest theory is wrong and the correct positive theory is the public interest theory. Due to technological changes the market failures that regulations were supposed to solve have disappeared (or become less severe). The regulatory response to this change is deregulation and where the gains from deregulation are largest implementation is faster. One other possible explanation is that the private interest theory is correct, but that the power-balance between different interest groups has shifted causing the regulatory equilibrium to change.

Recently, the causes of deregulation have been studied using US data from the banking sector (Kroszner and Strahan, 1999) and the electricity market (White, 1996; Ando and Palmer, 1998). This paper expands this small literature. The existing literature is solely based on US data, and one might question the validity of the conclusions in other institutional and political settings. Apart from US data, data from Europe, Australia, New Zealand and Canada is also used here. Secondly, in contrast with Ando and Palmer (1998) who use "consideration" and "decision" to deregulate as response variables, the actual implementation of deregulation is used here. Finally, since deregulation is an ongoing process time is essential and since data from later dates are used in this paper the conclusions are less tentative.

The electricity industry is characterized by a vertical structure consisting of generation, transmission, distribution and retail. For a long time the dominant view was that a considerable degree of vertical integration is needed for the market to work efficiently. For

[3]It as also been called "the normative analysis as a positive theory" (Joskow and Noll, 1981).

different reasons this view became questioned and today vertical separation, which is a prerequisite for deregulation, is widespread. Usually it is considered possible to introduce competition in the generation and retail sectors, while the transmission and distribution operations are kept as regulated monopolies. In this paper deregulation of the retail sector is considered. A market is defined as deregulated if the market is opened up for competition for at least some customers, which is labeled as partial opening or partial deregulation. The choice of this definition is discussed in Section 4.1.1.

The remainder of this paper is organized in the following way. Section 2 contains a brief description of the development of electricity market regulations. In section 3 the relevant theoretical and empirical literature is discussed and based on this some hypotheses are set up in section 4, which also contains a description of the data used. Finally, the econometric method and the results are presented in section 5.

2 A Brief History of Electricity Market Deregulations

The electricity industry has existed for more than 100 years. In the beginning the industry was fragmented and to a large extent privately owned. In dense areas the competition was fierce and the suppliers had to provide both the infrastructure and the supply. Between world war I and world war II governments began to view electricity more as a everyday necessity and large, publicly financed and owned, hydro-electric projects were constructed. The geographic coverage was extended to rural areas. After world war II the minimum efficient plant size increased dramatically and increasing economies of scale made many old, small power companies uneconomic. Many governments concluded that the industry was a natural monopoly. To prevent monopolistic behavior many countries placed the industry in public ownership. This was the case for most of Europe[4], Australia and New Zealand. In the United States the dominant model was to regulate private monopolies by independent regulatory commissions.

During the 1970s doubts emerged in the United States whether the chosen model worked efficiently. During the energy crisis it was discovered that independent power producers could operate without destroying the stability of the grid. Furthermore, new technology decreased the minimum efficient scale in generation. Combined this implied that the vertical integrated monopoly was not the only possible industrial structure.

[4]One exception in Europe is Spain.

During the 1980's and 90's the reform process of the electricity industry continued. New information technology also facilitated coordination of decentralized supply, which further weakened the argument for the old structure.

United States

In the United States deregulation of retail markets have been considerable slower than in for instance Europe. On the federal level the focus has mostly been on the wholesale market and not the retail market. In 1978 The Public Utility Regulatory Policies Act (PURPA) was passed by Congress. One smaller section of the Act dealt with incentives for nontraditional generation technologies, e.g., cogeneration. A more or less unintentional effect was that PURPA to a considerable degree opened up wholesale power markets to non-utility producers, which lead to the creation of a new interest group for continued restructuring of the electricity industry[5]. In 1992 Congress passed the Energy Policy Act, which aimed at promoting greater competition in the bulk power market and the intent of the Act was implemented by Federal Regulatory Commission (FERC) orders 888 and 889 in 1996. The stated objective was to "...remove impediments to competition in wholesale trade and to bring more efficient, lower cost power to the Nation's electricity customers" (FERC order 888). As already mentioned retail competition has not been introduced on a national level, but is still a matter for the individual state. In general electricity unbundling has been seen as a route to lower prices in high-priced states. The first state that opened up for some retail competition was Rhode Island in 1997 and to this date 21 states have followed (see Table 1).

The restructuring and deregulation of the US electricity industry seems to a high degree be unintentional effects of other regulatory changes originating primarily from environmental and security of supply concerns during the energy crisis. These regulatory changes showed that unbundling was possible and that cheaper electricity was available, but the consumers were not able to buy this electricity. This created a pressure for introduction of competition.

Canada

The Canadian electricity industry is basically a provincial/territorial responsibility and decisions to open the retail market for competition are taken on that level. The provinces differ in geographical size, population, population density and their endowment of natural

[5]The reader is referred to Hirsh (1999) for a more detailed description of this process.

Jurisdiction	Partial opening	Jurisdiction	Partial opening
Alabama	*	Utah	*
Alaska	*	Vermont	*
Arizona	Jan 1999	Virginia	Jan 2002
Arkansas	*	Washington	*
California	April 1998	West Virginia	*
Colorado	*	Wisconsin	*
Connecticut	Jan 2000	Wyoming	*
Delaware	Oct 1999	Australian Capital Territory	Dec 1997
DC	Jan 2001	New South Wales	Oct 1996
Florida	*	Queensland	April 1998
Georgia	*	Western Australia	July 1997
Hawaii	*	Victoria	Dec 1994
Idaho	*	South Australia	Dec 1998
Illinois	Oct 1999	Tasmania	*
Indiana	*	Northern Territory	April 2000
Iowa	*	New Zealand	April 1993
Kansas	*	Austria	Feb 1999
Kentucky	*	Belgium	May 1999
Louisiana	*	Denmark	Jan 1998
Maine	March 2000	Finland	Nov 1995
Maryland	July 2000	France	Feb 2000
Massachusetts	March 1998	Germany	May 1998
Michigan	Sep 1999	Greece	Feb 2001
Minnesota	*	Ireland	Feb 2000
Mississippi	*	Italy	Jan 2000
Missouri	*	Luxembourg	Aug 2000
Montana	July 1998	Netherlands	Jan 1999
Nebraska	*	Portugal	Aug 1995
Nevada	April 2002	Spain	Jan 1998
New Hampshire	May 2001	Sweden	Jan 1996
New Jersey	Nov 1999	England/Wales	April 1990
New Mexico	*	Iceland	*
New York	May 1998	Norway	Jan 1991
North Carolina	*	Switzerland	*
North Dakota	*	Alberta	Jan 2001
Ohio	Jan 2001	British Columbia	*
Oklahoma	*	Manitoba	*
Oregon	March 2002	New Brunswick	*
Pennsylvania	Jan 1999	Newfoundland and Labrador	April 2003
Rhode Island	July 1997	Nova Scotia	*
South Carolina	*	Ontario	May 2002
South Dakota	*	Quebec	*
Tennessee	*	Saskatchewan	*
Texas	Jan 2002		

Note: * indicate that the state has not implemented partial deregulation.

Table 1: Dates of implementation of partial retail deregulation

resources. Some have large amounts of hydropower, while others fuel their plants with oil, gas and coal. The provinces are mostly interconnected with the neighbors, but the size of the connections differ. There also exist important interconnections with the US and some provinces sell (cheap) hydropower to the south. The ownership of the utilities also varies across provinces, but public ownership is quite common.

Only three provinces, Alberta, Ontario and New Brunswick, have opened up for retail competition. Both Alberta (January 2001) and Ontario (May 2002)[6] opened the market for all customers. In April 2003 New Brunswick opened up competition for the largest industrial customers and municipal distribution companies.

An important factor behind the restructuring and deregulation of the Ontario electricity industry seems to have been the deteriorating performance of the large incumbent, Ontario Hydro, leading to accumulation of debts and large price increases. In other provinces export motives and a concern for future access to the US market has been a stated restructuring motive.

Europe

By the mid 1980's the market structure differed substantially between different European countries. In some there were large state-owned monopolies such as Electricité de France (EdF) in France and the Central Electricity Generating Board (CEGB) in England. In for instance Norway and Sweden there were a mixture of state and municipal ownership combined with some private firms. Others, for instance Belgium, Germany and Spain, had substantial private sector ownership, but with some firms partly privately and partly publicly owned. Irrespective of the ownership structure the firms had monopoly power, which were either supported by legal protection or by government supported contracts between companies. The incumbents faced no threat of entry.

In the United Kingdom the re-election of the Conservative government 1987 pushed further towards restructuring and privatization of the then fully state-owned UK electricity supply industry and by 1990 the industry had been restructured. At about the same time the Norwegian industry was restructured through a break up of the large state-owned

[6]On December 9, 2002 the Ontario government passed a legislation setting the commodity price of electricity to 4.3 cents/kWh for residential customers and most small business customers. The regulation was retroactive and the price set was valid from May 1, 2002. Customers who had signed a contract with a higher price would pay the legislated price and they would also be refunded for the excess amount paid between May 1 and November 30. For customers who sign/signed a new contract after December 9, 2002 the contracted price will paid and not the legislated.(Based on information available at http://www.oeb.gov.on.ca/html/en/consumerinformation/electricityfreeze.htm (Downloaded on January 27, 2003).)

firm Statkraft into one grid company (Statnett) and one generating and supply company (Statkraft), which since then has become a popular restructuring model. In contrast to the UK example the Norwegian reform did not include any transfers of ownership.

In Europe the EU commission has endorsed the deregulation of energy markets and has worked hard for the passing of an Electricity Directive that would set a time-table for deregulation of the EU markets. In 1997 the EU Electricity Market Directive was passed and it gave member states two years to prepare for the partial but progressive opening[7] of their electricity markets by passing legislation. Most member states passed such legislation prior to the official date of 19 February 1999[8], when the first step of the market opening should be implemented. The approach to and speed of liberalization differ substantially between the EU member.

In Europe there seem to have been a number of motives behind the introduction of electricity market competition. In Britain the political goal of privatization of the industry seem to have been an important driving factor. In the Nordic countries the main (stated) objective was to increase efficiency and lower prices through competition. The early liberalizations of England and Scandinavia were quite successful, which increased the support for deregulation. The European Union's work with creating the single market is also an important factor.

Australia

Electricity generation in Australia was previously developed independently by the states, but during the 1990's a national electricity market has been developed in the south-eastern parts of the country. Retail competition has also been introduced, but each state has made different arrangements and adopted different time schedules. The state of Victoria was the first state to start the reforms. In October 1993 the State Electricity Commission of Victoria was vertically separated into three parts: generation, distribution and transmission. A year later the electricity industry was further restructured with the intent of privatization. Presently all but Tasmania have opened their markets to some extend. Tasmania is waiting for the connection of their electricity system to the mainland grid.

The states differ in their approaches, but all have chosen to open their markets grad-

[7]The directive called for an opening of at least 25% of each member state's electricity demand from February 19th 1999, 28% from February 19th 2000 and 33% from February 19th 2003. In November 2002 the European Council reached an agreement for full market opening. By July 1st 2004 all non-household users will be subject to competition and complete opening for all users by July 1st 2007

[8]Ireland and Greece had derogations of one and two years respectively

ually. Victoria, New South Wales and South Australia have already reached full opening. Western Australia has decided on a time-table for full opening. The Australian Capital Territory has not yet reached a decision on full opening, while Queensland has decided not to implement full opening.

New Zealand

Prior to the New Zealand electricity market reforms local distribution and supply were the responsibility of local electricity supply authorities (ESA), which were electorally oriented statutory monopolies. In 1985 there were 61 ESAs. The Ministry of Energy had the responsibility for generation and transmission with extensive political involvement in investment decisions. This structure had, among other things, led to a low level of efficiency. In the 1980s there were also growing concerns in New Zealand about the country's economic performance in general and the reformation of the electricity sector can be seen as part of a bigger reform agenda for the New Zealand economy.

In April 1993 the Electricity Act of 1992 came into effect. This act provided for, among other things, the removal of distributors' statutory monopolies and the obligation to supply (deregulation), information disclosure and some temporary provision for price control for domestic customers. At first franchise restrictions were removed for small customers (less than 0.5 GWh per year). In April 1994 the restrictions were removed also for larger consumers.

New Zealand is also interesting since they originally chose a very light-handed regulation, which consisted primarily of two parts: 1) The ordinary competition legislation with rules on abuse of dominant position and rules about information disclosure and 2) a threat of more regulation, e.g., price regulation and requirement of separation of net operations from competitive operations. In 1998 this threat was to some extent carried out. The Electricity Industry Reform Act of 1998 called for ownership separation of line and energy businesses, and strengthening of the information disclosure regulations.

3 Literature

3.1 Theoretical background

In the literature two competing main explanations of economic regulation can be found. The traditional explanation, implicitly or explicitly, assumes that regulators are benevolent social welfare maximizers and basically takes the existence of different kinds of market failures as its starting point. In the present context factors such as economies of scale, switching costs or imperfect information might lead to an uncompetitive market structure and thus justify economic regulation. This kind of explanation is usually labeled as the public interest theory of regulation. According to this line of theory deregulation could be explained by changes in the economic environment, that remove the motives for regulation. In the case of the electricity market changes such as the development of smaller power plants, which reduce the importance of economies of scale and the introduction of new technology that facilitates the operation of a decentralized market could be examples of such changes. When the economic rationale motivating the regulations disappear, the response from the politicians would be to deregulate the market to the benefit of consumers.

From the 1970's an alternative explanation, which can be called the private interest theory, has been developed. Instead of assuming that legislators and regulators are maximizing some social welfare function, these agents are modeled in the same way as any other agent within economics, i.e., as maximizers of their own personal utility. One common result in these models is that more concentrated interest groups, e.g., the producers, are more likely to be able to influence the regulation, which thus will reflect the interests of that group. Especially in the early versions of the private interest theory of regulation it was often referred to as a capture theory in which the regulators are captured by the industry that it is supposed to regulate.

The private interest theory of regulation was primarily developed from the end of the 1960's to the beginning of the 1980's. One central view is that regulation is essentially a tool to redistribute wealth and raise the welfare of more influential groups. According to Posner (1971) regulation is to a considerable degree a system of taxation. An early contribution to the private interest theory of regulation is Friedland and Stigler (1962). They analyzed the effects of regulation on electricity prices and the basic conclusion was that regulation had not led to lower prices, which could be interpreted as a support for a capture theory. They did however lack a theoretical foundation. The first basis for such a foundation was provided by Stigler (1971), who presented a non-formalized economic theory of regulation. The wealth redistribution aspect of regulation cause a demand for regulation. Many interest groups are bidders for regulation of an industry, but only one will be successful. Stigler (1971) did not solve the problem that most industries consist of more than one firm, which would lead to a potential free-rider problem, although one conjecture was made: More concentrated industries will have more resources to invest in campaign for legislation and will thus be more likely to succeed.

In Stigler's model the regulatory body was, apart from an exogenous inclusion of opposition in industry councils, completely captured by one interest group. Peltzman (1976) developed the private interest theory further, and introduced utility-maximizing politicians who in equilibrium allocates benefits across groups. Other interest groups than producers can give some political benefit to the regulator (such as votes) and the equilibrium outcome is thus not the pure producer protective regulation of Stigler. In Peltzman's model the effect of the size of an interest group is not clear. On the one hand a large group provides a broader base for support, but on the second hand it dilutes the net gain of regulation per group member. Peltzman's model provide a number of other empirical predictions and only a few of them will be mentioned here. Firstly, the political gain of regulating an industry is greater if it is either a natural monopoly or a naturally competitive industry. The regulated price will be in between the monopoly price and the competitive price. For a oligopolistic industry the difference between the regulated price and the unregulated price will be relatively small, which reduces the demand for regulation. Secondly, regulation will tend to be more heavily weighted toward "producer protection" in depression and toward "consumer protection" in expansions.

Becker (1983) followed the path of Peltzman, but introduced the important element of deadweight losses following from the distortions created by taxes, subsidies and regulation. One implication is that if marginal deadweight losses from regulation is increased the winners of the regulation must overcome an increased opposition from the losers. In the presence of market failures, which is the explanation of regulation according to the public interest theory, incentives for regulation are strengthened. If regulation successfully eliminates the market failure it would result in an increase in welfare and according to Becker "Political policies that raise efficiency are more likely to be adopted than policies that lower efficiency" Becker (1983, p. 384).

3.2 Empirical literature

Once the private interest theory of regulation gained increasing acceptance many markets were deregulated. Even if the private interest theory could give a satisfactory explanation of regulation, could it also provide such an explanation of deregulation? In the empirical literature different methods to study regulatory reforms are used. Early studies were mainly case studies. In later studies different econometric methods have been used.

Levine (1981) analyzed the deregulation of the US airline industry and his conclusion was that airline deregulation was better explained by an revised version of the public interest theory, which is a kind of a "mistake theory". When the airline industry was regulated in the 1930's, politicians tried to act according to the public interest but they did not understand the problems related to regulation. When the understanding improved the market was deregulated. An alternative interpretation, more in line with Becker (1983), is that the airline industry originally was successful in acquiring producer protective regulation. Over time the deadweight losses due to regulation increased (or perhaps that some market failure the previously existed became less important) and this led to increased opposition, which changed the political equilibrium and triggered deregulation.

Peltzman (1989) studied a number of different markets that had been deregulated. His conclusion was that the private interest theory of regulation is, although not in all cases, compatible with the wave of deregulation. In Peltzman's own words: "It was one plausible response to forces that called for regulatory change. But it was not, in many instances, the only plausible response." Two commentators to Peltzman claims that he was to generous to the private interest theory (Levine, 1989) and that a number of issues were left unsolved (Noll, 1989). One seems to be able to draw at least one clear conclusion from Levine (1981) and Peltzman (1989): It is not an easy task to evaluate the theories of (de)regulation with case studies and in the end the conclusions are to a high degree dependent of the researchers judgement and interpretation.

Some US market have been deregulated on state level, which provides cross-sections of observations and it then becomes possible to compare deregulatory processes between states and use more formal quantitative methods.

In Kaserman, Mayo and Pacey (1993) deregulation of intrastate long-distance telecommunication pricing is studied using a logit model. In the model variables motivated both by the private and public interest theories are incorporated. Their results support the private interest theory and fail to give any support to the public interest theory.

When logit (or probit) models are used it basically becomes a study of a snap-shot picture of the industry and the timing aspect is lost. One other possibility is to explicitly take time into account and use duration models. Kroszner and Strahan (1999) employed duration models to study the relaxation of bank branching restrictions in the US. They find some support for both theories, but that the private interest theory provides the most compelling overall explanation. One advantage of this study is that most states deregulated prior to the end of the study and there are very few censored observations.

Since this paper is focused on electricity market deregulation, previous studies of electricity markets are of particular interest. White (1996) studies electricity market deregulations in US states without turning to more sophisticated econometric techniques.

The main "explanatory variable" is the gap between prices of incumbent utilities and expected prices in a deregulated market and the conclusion is that states with a large price gap will deregulate. When the gap is small, the regulator is able to adjust prices within the existing regulatory framework to close the gap . If the gap is large enough, the constraints of the institutional setting becomes binding. Regulation usually allows utilities to earn a fair rate-of-return. To close a large gap the regulated price would have to be lowered so much that the rate-of-return constraint would bind. The demand for reforms can then not be met within the existing regulatory structure and the response is deregulation. Thus, deregulation would occur in states where the regulated price is substantially above the competitive price. At the time when the study was made only a handful of states had made substantial progress toward retail competition and White shows that all of these states had a large price gap.

Ando and Palmer (1998) study the progress of regulatory reform as a two-step model. The first step is from "No action" to "Consideration" and the second step from "Consideration" to "Decision". This analysis was made separately for the state legislator and the state regulatory commission. The data is analyzed both with an ordered probit model and a duration model. The findings of Ando and Palmer (1998) are not inconsistent with White's hypothesis and they find that high average prices and high stranded cost burdens have a positive influence on the propensity of state legislatures to consider competition. But, they also find that the availability of nearby profitable export markets have a positive influence on the likelihood that deregulation would be considered, which might explain moves towards deregulation in low-cost states. Their results regarding the move from "Consideration" to "Decision" are only tentative, since at that time only a few states had reached the final decision stage. Their results suggest that in states with high prices, large price differentials with neighboring states, and where the industrial consumers share of the consumption is high it is more likely that retail competition is introduced.

4 Hypotheses and data

We are aiming at explaining the timing of the introduction of retail competition. The theoretical discussion above highlighted the fact that there are two main explanations of regulation (and deregulation). Prior to the 1970's the public interest theory of regulation dominated and regulators were generally assumed to act as benevolent social-welfare maximizers. Later the political-economy literature, in which regulators are perceived as rational self-interested agents, gained influence and interest-group pressure became an important explanatory factor.

Empirically it can often be rather difficult to distinguish between these two lines of theories. If some interest group gains from a particular policy, an other interest group will often loose[9]. If the outcome is an "inefficient" regulation the public interest hypothesis is unlikely to have any explanatory power and it should be possible to distinguish between the theories. But if the regulatory change is believed to be welfare enhancing, both theories can potentially be correct.

From a normative perspective economist often argue that regulators should behave such that the public interest is promoted, e.g., to maximize some total social surplus. In practice this often have a lot of similarities with promoting a particular interest group, namely the consumers. Instead of trying to distinguish between the public and private interest hypotheses, we might try to identify which interest group that is the winner in the regulatory game: Consumers or producers.

4.1 Data

The data-set consists of a total sample of 88 jurisdictions[10]. 40 of these have not implemented partial retail deregulation at the end of the studied period, i.e., are right-censored. The implementation rate differ considerable between regions. In the US 30 of 51 jurisdictions are censored, in Canada 7 of 10 jurisdictions[11] are censored, while there are only two censored observations for Europe and one in Australia. No jurisdiction had implemented partial deregulation prior to the studied period.

Data on the time of deregulation has been collected using a large number of government and industry sources. Prices and production data are obtained from the International Energy Agency (IEA) for European nations and New Zealand, from the Electricity Supply Association of Australia (ESAA) for Australia, from the Energy Information Authority (EIA) for the United States and from Statistics Canada for Canada. A more detailed description of the sources can be found in Appendix A.

[9] If the policy is enough efficiency enhancing this, of course, need not be the case.

[10] Due to missing observations this sample is in some cases reduced.

[11] In the analysis in this paper the northern territories of Canada (Yukon, Northwest Territories and Nunavut) are excluded. Their electricity systems consist of a mixture of isolated small hydro plants, oil-fired turbines and internal combustion plants located at communities and industrial sites. These territories do not have centralized and integrated systems and are very sparsely populated. Presently, they do not seem to be very well suited for the introduction of competitive markets. When the three northern territories have been excluded their remains 10 provinces.

	Mean	Std.Dev.	Minimum	Maximum	# obs
Deregulation period 1	146.011	37.9747	15	178	89
Deregulation period 2	118.688	32.3256	15	172	48
Market size	60169.5	75966.1	752.206	481001	89
Low concentration	0.157303	0.366149	0	1	89
Medium concentration	0.41573	0.49564	0	1	89
High concentration	0.426966	0.49744	0	1	89
Peak demand/capacity	0.754016	0.098306	0.326759	0.933492	85
Share industrial consumers	38.2442	13.129	8.56507	75.2816	89
Price industrial consumers	0.042282	0.018129	0.009773	0.106731	86
Price domestic consumers	0.072572	0.031443	0.029906	0.179241	86
Price difference	0.03029	0.020332	-0.02015	0.120066	86
Import price gap	0.009252	0.011062	0	0.05375	86
Export price gap	0.009577	0.010497	0	0.043062	86
Employment/output	0.317013	0.183213	0.052873	1.02289	88
Right-wing government	0.629214	0.485752	0	1	89
Economic freedom	7.14417	0.984154	4.082	9.25	89
Spill-over	0.674157	0.471344	0	1	89
French civil law	0.11236	0.317598	0	1	89
German civil law	0.033708	0.181499	0	1	89
Scandinavian civil law	0.05618	0.231573	0	1	89
Public ownership	0.386364	0.489706	0	1	88
Mixed ownership	0.306818	0.463816	0	1	88
Private ownership	0.306818	0.463816	0	1	88
Population density	0.306818	0.463816	0	1	88
Independent power producers	7.93542	11.4089	0	67.3	51

Note: Values for deregulation/censoring period used. Deregulation period 1 includes censored observations, for which the deregulation period is 178. Deregulation period 2 includes only non-censored observations.

Table 2: Summary statistics

4.1.1 Response variable: Time until deregulation

The definition of the event that constitute the "failure" time is of course of importance. Some previous studies have for instance used decision by the legislator or regulator as the event. The decision to deregulate is however not always followed up by implementation, and even if it is implementation may come several years after the decision. Because of this, it would be preferable to use the time of implementation of deregulation.

Deregulation is implemented in different ways in different countries or states. Some choose to gradually open the market for different consumer groups. Usually this means that the largest customers are allowed to trade freely in the market, and the threshold for eligibility is then gradually lowered[12]. This process is then completed when all customers are eligible. The opening of the England/Wales market was done in this fashion. Others have chosen to open up the market completely from the beginning and giving all customers the formal opportunity to choose supplier. Norway, one of the other pioneers when it comes to electricity market deregulation, used that approach. In some cases the real possibility of choosing a different supplier has been limited due to high switching cost[13] or limited access to network facilities[14]. There is clearly great differences in the way deregulation is implemented and one obvious question is then what should constitute the event that is defined as deregulation. "Full market opening" might be a natural candidate. When the markets are fully opened we have clearly seen a shift from the old regulation based system to one based on competition. This alternative does have some drawbacks. One is that it is not obvious how this event should be defined consistently across states. Was the German market completely opened at once in spite of the fact

[12]This approach will here be called "Partial retail electricity market deregulation" or "Partial opening" and is defined as opening of competitive supply for a part of final consumers of electricity. "Full deregulation" is defined as opening of competitive supply for all final consumers of electricity.

It is common that the market is opened in steps. First large consumers become eligible for competitive supply. The treshold for eligibility is then reduced with full opening as the final stage. The English market was opened up in this fashion, with partial opening in 1990 and full opening in 1998.

New Zealand is the only exception that the author is aware about that used the inversed approach and first lifted the franchise restrictions for smaller customers and then for larger customers. This was done to avoid that small customers would have to face the cost of cross-subsidization.

Some jurisdictions, for instance Norway (1991) and Sweden (1996), have opened up their markets completly from the beginning. The details of the regulation after opening might differ considerble between jurisdictions.

[13]For instance a requirement to install a new and more advanced metering system to be able to switch supplier.

[14]For instance Germany originally chose to use a system of negotiated third party access to the networks. This means that a supplier has to negotiate the conditions for access to the network. The cost of doing so might prevent real competition from evolving. One alternative is the so called regulated third party access, in which the terms of access are regulated by an independent regulator.

that their choice of system for network access might have prevented small customers from choosing a different supplier? Was the Swedish market opened completely at once in spite of the fact that their requirement for an expensive new meter in practice prevented many small customers from choosing a different supplier? A second problem is that relatively few have yet opened their markets completely. This means that very many observations would be censored.

One alternative is to simply choose the time at which some customers were given the opportunity to choose. The argument for this choice would be that it at least is a clear signal of the state's willingness to deregulate. It is also more easy to find a consistent definition of such an partial opening. This definition however captures events ranging from only giving a handful of very large electricity consumers the opportunity to choose to full market opening giving even the smallest consumers the freedom of choice[15].

Due to the problems of defining full market opening and the fact that choosing that definition would lead to a serious censoring problem, we will here use "partial opening" as the event that constitute the time of deregulation.

The response variable in this study will thus be the implementation month of partial retail electricity market deregulation. The retail electricity market is regulated at different levels in different countries. In the United States, Canada and Australia the regulation is conducted on state/provincial/territorial level. In Europe the regulation is primarily on national level. However, the European Union directive makes market opening mandatory from certain dates.

The data set used here takes this fact into consideration and the data is collected for the relevant jurisdictional level. Thus, it includes all the U.S. states, Canada's provinces, the Australian state and territories, New Zealand, European Union member countries, Norway, Switzerland, and Iceland.

The time until deregulation is measured in months starting from January 1989 (period 0). The final period is October 2003. For jurisdictions that have not deregulated at that time the observations are right-censored[16]. The first partial market opening was the deregulation of the England/Wales market in March 1990. Norway opened up its market

[15]One extreme would be countries such as Norway and Sweden, who (formally) opened the market for all consumers at once. An other extreme would, for instance, be Portugal, who opened the market already in 1995 but only for 19 consumers. Bergman et al. (1999) characterize Portugal as a "Slow progress" country.

[16]Some jurisidictions might have decided to deregulate from a certain date after October 2002. A decision on deregulation might not be followed by an implementation and it is certainly very unsure that the decided date will be the actual implementation data. Furthermore, jurisdictions that not yet have decided on deregulation might decide on and implement deregulation quickly. For these reasons any information on deregulation decisions is disregarded.

completely in January 1991.

4.1.2 Hypotheses and explanatory variables

The public/consumer interest hypothesis

According to the public, or consumer, interest hypothesis a market would be deregulated with a higher probability the more likely it is that consumers gain from the deregulation. In the electricity market the primary gain would come from decreased prices. If deregulation of a particular market results in a competitive market, price decreases and gains for consumers are more likely. Variables that affect the likelihood that deregulation results in a competitive market, i.e., primarily variables that describe market characteristics, and variables that measure the performance of the market prior to deregulation could thus be interpreted in the public/consumer interest framework.

Market characteristics and expected outcome of deregulation. Firstly, given the existence of some fixed costs, a large market has the potential to support a larger number of competitors. This is of special importance if the production technology is characterized by economies of scale. For some small markets economies of scale might prevent efficient competition from evolving[17]. To capture this factor the size of the market, measured as total consumption (MWh) in the beginning of the considered time period, is included. The hypothesis is that it is more likely that a large market is deregulated.

Secondly, the pre-deregulation market structure might influence the outcome of the deregulation. If the market is very concentrated a competitive outcome is less likely[18] and the consumers will gain less, or perhaps even loose, from deregulation. In the public/consumer interest framework it is less likely that a concentrated market is deregulated.

A third variable that might capture the likelihood of a competitive outcome is the production capacity in relation to demand. If capacity is relatively scarce, generation firms will more often be able to exploit market power. A non-integrated retailer is basically performing a financial service to its customers, insuring them from short-term price fluctuations. If producers often are able to increase their price it will be more costly to offer this service. Retail competition will then probably be less intense, which will reduce the benefits of competition for the consumers and the hypothesis is that deregulation will

[17] This might especially be a factor to consider for some small and isolated markets.

[18] The link between pre-deregulation market structure and post-deregulation competition is weakened by the fact that deregulation sometimes have been accompanied by restructuring of the industry (privatization, break-up of dominant firms etc).

be less likely.

Fourthly, deregulation in neighboring states/countries may affect the likelihood of deregulation within the public interest framework. A similar regulatory regime in states that trade a lot of electricity between each other is probably efficiency enhancing since it facilitates trade. Furthermore, integration of neighboring markets might dilute market power and thus result in a more competitive outcome. The existence of deregulated neighboring markets should thus increase the likelihood of deregulation.

Prices and performance prior to deregulation. If the market performs badly and prices are high prior to deregulation, consumers will have more to gain from a quick deregulation. The expected time until deregulation should thus be shorter if prices are high.

The state-average price does, however, not completely capture the potential for price decreases due to deregulation. Underlying cost factors differ and a high price level might depend on unfavorable conditions[19]. It is likely that the potential for price decreases to some degree depend on prices in neighboring states. If prices are lower in neighboring states it might imply large potential customer savings and thus strengthen the incentives to push for deregulation. To capture these effects a measure of import price gap is included. The import price gap is defined as $p_{ind} - \min[p_{neighbor}]$ truncated at 0, where p_{ind} is the price for industrial consumers in the state and $p_{neighbor}$ is the price for industrial consumers in each neighboring states. A large import price gap indicates that consumers can gain a lot through imports of electricity if deregulation is implemented and that deregulation should be more likely according to the public/consumer interest framework.

Furthermore, an export price gap, defined as $\max[p_{neighbor}] - p_{ind}$ truncated at 0, is included. This variable is primarily possible to interpret within the private interest framework. However, if the export price gap is large the electricity price might increase through price equalization caused by exports and the consumers might loose. Although prices may increase and consumers loose this export may be welfare enhancing and the link between consumer interest and the more general public interest will not necessarily exist in this particular case.

Industrial consumers usually pay a lower price for their electricity than domestic consumers. This can to a large extent be explained by differences in costs. However, it might also be a result of the regulatory game. If industrial consumers are able to influence

[19]The cost of producing electricity might differ depending on available production technology and the cost of distributing electricty might depend on factor such as population density. At least some of these factors will be unaffected by retail deregulation.

regulation in a direction that is favorable to them it would result in a larger gap between the price for domestic consumers and the price for industrial consumers. If the gap is large, industrial consumers might have less of an incentive to push for deregulation. Thus the gap between domestic and industrial prices is included as an explanatory variable. This variable is defined as $p_{dom} - p_{ind}$, where p_{dom} and p_{ind} are the average prices for domestic and industrial consumers respectively. Here different consumer groups have opposing interests.

Public interest motivated politicians should also be concerned about the production efficiency in the sector. The employment in the sector could be interpreted as an indicator of efficiency. A very high employment to output ratio is then a sign of an inefficient organization and should thus increase the likelihood of deregulation if politicians are motivated by public/consumer interest.

The private/producer interest hypothesis

According to the private interest theory regulation is demanded by interest group since it essentially is a system to redistribute wealth. Regulation is then a response to this from rational utility-maximizing politicians. In its purest form economic efficiency plays no role, but in more developed versions of the theory efficiency enhancing policies are more likely to be adopted. Here we abstract from efficiency considerations, since those are discussed within the public interest framework.

Within the private/producer interest framework deregulation should thus not be explained by differences in efficiency gains caused by deregulation, but by differences in interest group incentives and strength.

Market characteristics and expected outcome of deregulation. The market characteristics will affect the outcome in a deregulated market and thus the gains and losses for different interest groups. In general we have the same variables as within the public interest framework, but usually with the opposite sign.

As argued above a larger market may result in a more competitive outcome if economies of scale are important, which could decrease profits. The producers may therefore have more to loose in a large market and deregulation would then be less likely in a large market.

The second variable is the pre-deregulation market structure. Within the political economy framework there need not be a monotone relationship between the level of concentration and the likelihood of deregulation. The political gain of regulating an industry is greater if it is naturally either a monopoly or a highly competitive industry. The regulated price will most likely be somewhere between the monopoly price and the competitive price. With an oligopolistic industry structure the difference between the regulated price and the unregulated price will be smaller compared with the two extremes of monopoly and (perfect) competition. Different interest groups will have a strong incentive to push for deregulation if the market is very concentrated (producers) or very fragmented (consumers). The opposing interest group will on the other hand have strong incentives to resist deregulation. With a medium concentration level both the incentives to push for deregulation and oppose deregulation will be weakened. In general it must thus be an empirical question when the likelihood of deregulation is the highest. The degree of concentration may also affect the strength of the producer interest group. A high concentration is likely to mitigate the free-rider problem and a more concentrated industry will have better possibilities to raise resources for lobbying efforts. This should particularly be the case if the industry is dominated by a single firm.

Thirdly, we have the peak demand/capacity ratio. A high ratio indicates that capacity will at times be scarce and at those time only a few producers are able to meat the marginal demand. In a deregulated market the producers can exploit those situation and drive up prices. Incumbent producers should therefore have weaker incentives to resist deregulation if capacity is scarce and deregulation should thus be more likely.

The fourth interest group variable does not affect the producers directly, but is an important consumer group. One prediction from the political economy literature on regulation is that dispersed groups have less potential to influence regulation. One important consumer group that is likely to be able to influence regulation and push for deregulation is thus industrial consumers, for whom the cost of electricity is of great importance. To measure the size of this group the share of electricity consumption for industrial use in relation to total consumption is included and the hypothesis is that a large share of industrial consumption will increase the likelihood of deregulation.

Prices and performance prior to deregulation. High prices may be a reflection of many things. One is of course the available production technology, but interest group strength is also an important factor. A high price may thus be an indication of a strong producer interest group, which also has a strong position to resist deregulation. Furthermore, there is the obvious effect that with a high price level producers have more to loose and thus stronger incentives to resist deregulation. Within the private/producer interest framework deregulation will be less likely if prices are high.

The import and export price gap discussed above also affects the producers. A large import price gap indicates that incumbent producers will face intense import competition from low-cost out-of-state producers. The incumbent producers will thus have strong incentives to resist deregulation if the import price gap is large. The opposite is true for the export price gap. With a large export price gap local utilities might push for deregulation in their own state, hoping that it would encourage deregulation in the high-price neighboring state and deregulation would be more likely.

The existing employees of the utilities is another interest group that might loose from deregulation. Employees are likely to get a share of the producers' profits from regulation, which they will loose if deregulation occur. Measuring the employee gain of regulation is not an easy task. The employee gain could take many forms: Higher wages, more on-the-job leisure or more slack in the organization (higher employment). Probably it would be a combination of all of these. The variable that is most easy to compare between jurisdiction is the level of employment in the sector. The hypothesis within the producer interest framework is that a high level of employment will reduce the likelihood of deregulation.

Following the PURPA-legislation in the US, independent power producers were able to enter the market. This meant that an additional important interest group in favour of retail deregulation was created. For the analysis of the US sub-set of the sample the relative size of non-utility power producers will be included to measure the importance of that interest group and the prediction is that a large share of non-utility producers will increase the likelihood of deregulation.

The incentive of the utilities to defend the status quo might also differ depending on ownership structure. The owners of privately owned utilities are a relevant interest group, which does not exist for publicly owned firms. Deregulation might thus be harder to accomplish if firms are privately owned. The reversed could also be true. If privately owned utilities are more prone to see business opportunities coming from deregulation they might be less likely to oppose deregulation.

4.1.3 Ideology, politics and institutions

Political and ideological factors may also influence the propensity to deregulate[20]. Attitudes towards regulation, economic freedom, taxes, and free-trade may both differ between countries/states and over time in one state, e.g., between different governments. It is highly probable that such differences are of at least some importance. We therefore try to include some variables that could capture this effect.

First the political color of the government is included. The variable is a dummy variable taking the value 1 if the head of government[21] belongs to the more right-wing/market liberal party (or parties) of the state and 0 otherwise. A more detailed description of the variable can be found in Appendix A. The hypothesis is that a market liberal party will be more prone to deregulate or resist deregulation less for ideological reasons and the likelihood of deregulation will then be higher.

A second variable is introduced to capture ideological differences between countries. The Economic Freedom of the World Index (Gwartney, Lawson, Park and Skipton, 2001) is introduced to capture the general attitude towards regulation in one country. Unfortunately it is extremely hard to find a reasonable measurement that is available for all the jurisdictions included in the cross-section and this index only exist at the national level. Consequently the value for all non-independent jurisdictions (US states, Canadian provinces and Australian states/territories) are set to the respective national value.

The third political variable is the spill-over effect, which has been discussed previously. It is however also relevant here. Deregulation in other places affect the political climate and change the perception of what is possible to achieve. Deregulation in places close to the state in question are likely to influence the political climate more and we expect that nearby deregulations increase the likelihood of deregulation.

Fourthly, a variable that is supposed to capture institutional differences between jurisdictions is introduced. Laws differ a lot between countries and these differences may affect regulation and deregulation processes. The differences in laws is partly due to differences in legal origin. Legal scholars typically identify two broad legal traditions: civil law and common law. Within the civil law tradition three families are typically identified:

[20] Some argue that individual politicians and leaders are of great importance when it comes to important reforms (e.g. Yergin and Stanislaw, 1998). That argument seems to have some validity if one considers the example of the market reforms conducted in the UK during the 1980's. On the other hand it is less obvious that it is of general importance and it is impossible to measure such an effect. Any "leader" effect will therefore be disregarded.

[21] The state governor in the United States, provincial Premier in Canada, the national prime minister in Europe and New Zeland and the state/territorial prime minister in Australia.

French, German and Scandinavian[22]. These four categories are used. Since we lack any more detailed analyzes of the legal systems we have no expectations on the effects of the different legal systems.

Regional dummies are used to control for unobserved differences between regions. Four regions are defined: United States, Canada, Australia/New Zealand and Europe.

Finally, the population density is used as a control variable. As long as the country is enough densely populated such that it has an integrated electricity system there are no strong reasons to expect that population density affect the outcome of deregulation. However, there may still exist a belief that competition will be more intense in more densely populated areas, which then could make deregulation more likely in such areas.

Summary of predicted effects

A comparison between the predicted effects under the different hypotheses shows that the sign of the predicted effects often differs or that the variable is only interpretable within one of the frameworks (see Table 3). Since the sign of the expected effect under the private interest hypothesis can go in any direction depending on which interest group is the winner, it is not always possible to discriminate between the private and public interest hypotheses without relying on some assumption on which interest group is the winner in the regulatory game. In the political economy literature on regulation the dominant view is however that regulation primarily is producer protective. Furthermore, as argued earlier there often exists a strong link between public and consumer interest. Therefore the public and private interest hypotheses are interpreted as a furtherance of, respectively, the consumer and producer interests.

[22]The common law tradition has its origin in English common law and is formed by judges who have to resolve specific disputes. Common law spread to the British colonies and thus Ireland, the United States (except Lousiana), Canada (except Quebec), Australia and New Zeland have common law.

The French Commercial Code was written under Napoleon and spread by his armies to many European countries and to French colonies.

The classification into legal families for the independent nations in the sample follows the classification used by La Porta, Lopez-de-Silanes, Shleifer and Vishny (1998). The classification of the US states is based on the Martindale-Hubbell Law Digest and the classification of Australian states/territories and Canadian provinces is based on Reynolds and Flores (1989-).

Variable	Effects on expected time until deregulation Public/consumer interest	Private/producer interest	Politics/Ideology
Market size	-	+	No prediction
Concentration	+	U-shape	No prediction
Capacity/demand	-	+	No prediction
Share industrial consumers	No prediction	-	No prediction
Prices	-	+	No prediction
Import price gap	-	+	No prediction
Export price gap	(+)	-	No prediction
Price difference domestic-industrial	?	?	No prediction
Employment	-	(+)	No prediction
Independent power producers	(-)	-	No prediction
Private ownership	No prediction	?	No prediction
Right wing government	No prediction	No prediction	-
Economic freedom	No prediction	No prediction	-
Spill-over effect	-	?	-
Legal origin	Control variable	Control variable	Control variable
Regional dummies	Control variable	Control variable	Control variable
Population density	Control variable	Control variable	Control variable

Table 3: Predicted effects of explantory variables on expected time until deregulation

5 Methods and results

5.1 Econometric method[23]

Data that measure the length of time until an event occur is often called lifetime, failure time, survival or duration data. This kind of data is often analyzed in technical applications, as well as in medicine and biology. In economics survival data has been used specially within the field of labor economics. More recently it has also been used to study regulatory change (e.g. Kroszner and Strahan, 1999; Ando and Palmer, 1998). This kind of data consists of a response variable that measures the time until the event occur and a number of independent variables, covariates, that are thought to be associated with the failure time. Here the studied variable is the time until deregulation, which would be the failure time of the old regulatory regime, and is measured in month from the beginning of the sample (January 1989) until deregulation. Below, when the term "time until deregulation" is used, it should be interpreted as the failure time. When working with this kind of data entire completed spans are often not available to the researcher. Here, not all jurisdictions have (yet?) deregulated and the data used in this study are consequently sometimes right censored, i.e., we have not observed the end of all the spans.

[23]The presentation in this section are based on Kalbfleisch and Prentice (1980), Kiefer (1988), Greene (1996) and Econometric Software, Inc (1998).

When using duration data it is not the unconditional probability that an event takes place that is of interest, but rather the conditional probability, i.e., what is the probability of failure in the next period given that failure has not yet occurred. The distribution function

$$F(t) = \Pr(T < t)$$

specifies the probability that the random variable T is less than some value t and the corresponding density function is $f(t) = dF(t)/dt$. The survivor function gives the probability that the random variable T is equal or larger than the value t and is defined as

$$\begin{aligned} S(t) &= 1 - F(t) \\ &= \Pr(T \geq t). \end{aligned}$$

As already mentioned we are primarily interested in the conditional probability, which means that an useful function is the hazard function

$$\lambda(t) = \frac{f(t)}{S(t)},$$

which can be interpreted as the rate at which failure occurs at duration t, given that it has lasted until t.

Failure time data can be studied in a number of different ways. There are simple non-parametric methods which puts no structure on the problem. These are best suited for an initial investigation of some qualitative aspects of the hazard functions, such as if it exhibits any duration dependency. The method does, however, not provide very much insight beyond that and to investigate the effect of a set of explanatory variables on the duration other methods must be employed. The method used in this paper is the estimation of a log-linear parametric model with time-varying covariates with a proportional hazard specification. The hazard function then depends on a vector of explanatory variables $\mathbf{x}(t)$ with the unknown coefficients $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$ and λ_0:

$$\lambda(t, \mathbf{x}(t), \boldsymbol{\alpha}, \boldsymbol{\beta}) = \lambda_0(t, \boldsymbol{\alpha})\phi(\mathbf{x}(t), \boldsymbol{\beta})$$

where λ_0 is the "baseline" hazard. The effect of a change in x will then be

$$\frac{\partial \ln \lambda(t, \mathbf{x}(t), \boldsymbol{\alpha}, \boldsymbol{\beta})}{\partial x} = \frac{\partial \ln \phi(\mathbf{x}(t), \boldsymbol{\beta})}{\partial x},$$

and we see that the proportional effect of x on the conditional probability does not depend on the duration. To estimate the parameters the following log-likelihood function is maximized:

$$L(\boldsymbol{\alpha},\boldsymbol{\beta}) = \sum d_i \ln \lambda(t_i, \mathbf{x}(t_i), \boldsymbol{\alpha}, \boldsymbol{\beta}) - \sum \Lambda(t_i, x_i, \boldsymbol{\alpha}, \boldsymbol{\beta}).$$

Often the covariates used are some initial value which is constant over time. In the problem considered in this paper we have several time-varying covariates, which the model should allow for. Following Petersen (1986), time-varying covariates can be handled by dividing the interval from 0 (starting point) to t_i (end of studied period) into k exhaustive and nonoverlapping intervals, $t_0 < t_1 < ... < t_{k-1} < t_k$, where $t_0 = 0$ and $t_k = t_i$. Within each of these intervals the covariates are assumed to stay constant, but they may change between intervals. The hazard function is then modeled as a step function, with different values of the covariates through the intervals between $t = 0$ and $t = T$, which is the terminal value at which either failure or censoring take place.

The use of a parametric model implies that a structure is imposed on the baseline hazard. The main advantage is that it provides an opportunity to translate the estimates into time metric and calculate the change in expected time to failure for a given change in the covariates. The drawback is that the choice of structure is of great importance for the results and a wrong choice may severely affect your estimates.[24]

5.1.1 Choice of Structural Form

For the choice of functional form there are several possibilities. The Kaplan-Meier product-limit estimator[25] is a usual non-parametric estimator of the hazard function that can be used to get an intuitive idea on a suitable structure to impose (estimates are shown in Figure 1[26]). When using the Kaplan-Meier estimator of the hazard rate the estimated conditional probability of failure will exhibit very large variations over time

[24] An alternative would be to use some semi-parametric model such as Cox's proportional hazard model (Cox, 1972), which provides a method of estimating the $\boldsymbol{\beta}$, without estimating the baseline hazard λ_0. It is then not possible to calculate anything but relative hazard rates associated with changes in the covariates.

[25] Kaplan-Meier product-limit estimator is simply the observed relative frequency of failure at time t, i.e., $\widehat{\lambda}(t) = \frac{h_t}{n_t}$,where h_t is the number of failures at time t and n_t is the number of observations neither completed or censored before time t.

[26] To be able to compare the non-parametric estimates of the hazard function with the form of the structure imposed in the regressions plots of the underlying hazard, integrated hazard and survival functions using the estimated values for the shape parameters of the Weibull function are also provided in the figure.

and may be difficult to interpret. One response is some kind of smoothing and thus plots non-parametric estimates of the integrated hazard, $\widehat{\Lambda}(t) = \sum_{s \leq t} \lambda(s)$, and the survival function are also shown.

From the plots we can see that the propensity to deregulate is fairly low in the beginning of the studied period and rises towards the end. One distribution which is fairly flexible and can approximate this shape is the Weibull distribution, which has the base-line hazard

$$\lambda(t) = \lambda p(\lambda t)^{p-1}.$$

If $p = 1$ it results in the exponential distribution. If $p > 1$ or $p < 1$ it exhibits positive and negative duration dependency, respectively. Using the Weibull distribution the hazard rate function takes the form

$$\lambda[t, \mathbf{x}(t), \boldsymbol{\beta}, \lambda, p] = \lambda p(\lambda t)^{p-1} \exp[-\boldsymbol{\beta}' \mathbf{x}_i(t)].$$

Using the Weibull model, it is possible to invert the hazard function and map it into the time domain. Rewriting the model, the log of the time until deregulation is a linear function of the covariates and an error term:

$$\ln(T) = \mathbf{x}'\mathbf{b}^* + e,$$

where $\mathbf{b}^* = \mathbf{b}/p$.

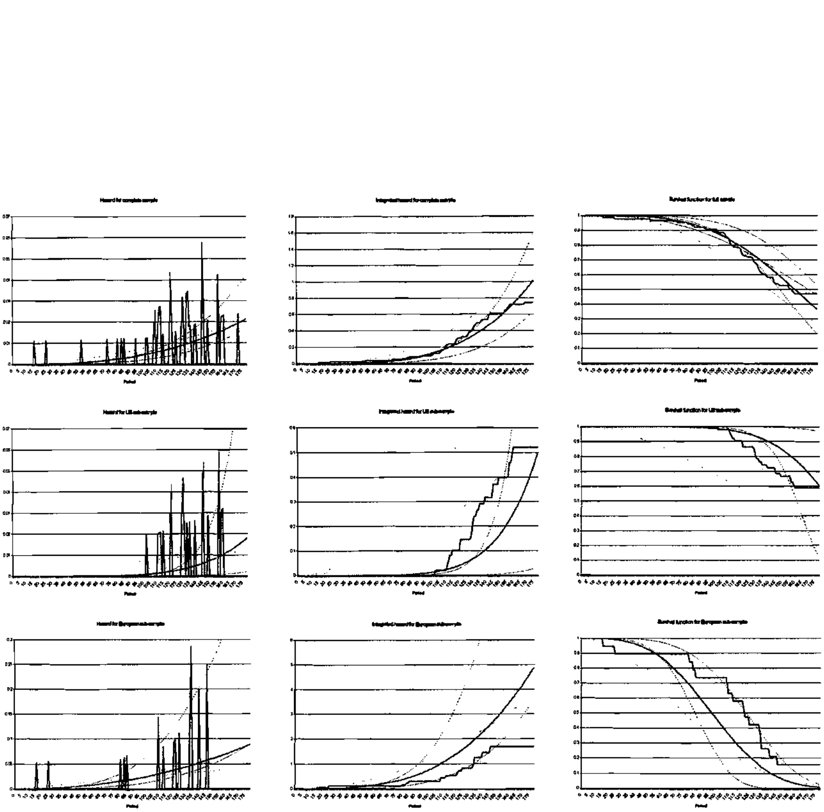
5.2 Estimations and Results

Most previous studies on deregulation focus on the United States and employs differences between US states. The validity of the results outside the US context can therefore naturally be questioned. Here the data set, in addition to US data, also covers a large number of non-US jurisdictions. This provides an opportunity to study whether the US results are also valid for other countries.

In addition to the analysis of the complete sample, separate analyses are also carried out for two sub-sets: The United States and Europe.

5.2.1 Estimations using the complete sample

The public/consumer interest hypothesis predicts that deregulation should be implemented fastest where the benefits to consumers are large. The estimations using the complete sample (see Table 4) give some limited support to that hypothesis. Market



Note: Bold smooth line is theoretical function using Weibull distribution with estimates shape parameters. Dotted lines are theoretical distributions using upper and lower bounds for lambda and p confidence intervals.

Figure 1: Kaplan-Meier estimates of hazard, integrated hazard and survival functions and theoretical functions using Weibull distribution with estimates shape parameters.

size, price and the spill-over effect have significant coefficients with signs that are consistent with that hypothesis. The estimate for the price variable supports previous findings for the United States (White, 1996; Ando and Palmer, 1998). Regarding the spill-over variable the predictions are the same from both the public/consumer interest and the private/producer interest hypotheses. The peak demand/capacity variable has a significant (on the 10% level) coefficient with a negative sign, which contradicts the consumer interest hypothesis[27].

Political and institutional factors seem to be important. In the reported regressions the Economic Freedom index is found insignificant. If the regional dummy variables are excluded the surprising result is that deregulation is less likely in a more free economy. Considering that this variable is only available at the national level so that all US states,

[27]Peak demand/capacity is excluded in the two last regressions (Complete 3 and Complete 4) to reduce the number of missing observations.

Canadian provinces and Australian states/territories have the respective national index value this is probably simply a regional effect driven by the fact that the United States has a high economic freedom ranking and has also been relatively slow when it comes to the introduction of retail competition. This interpretation is supported by the fact that the coefficient is found insignificant when regional dummies are included. We do however not find a support that a general positive attitude towards economic freedom increases the likelihood of deregulation, but such an effect might be present if a better measurement was available.

An ideological or political effect does however seem to exist. Deregulation is more likely if the country/state is led by a right/right-centre government. The most obvious interpretation is that politicians are not only motivated by re-election possibilities or by public welfare concerns, but also by ideological perceptions.

Based on a belief that the legal system might influence the behavior of legislators and regulators the legal origin of the jurisdictions were introduced. Lacking a more detailed analysis of the legal systems it is hard to give any reasonable interpretation of these results, and they should perhaps more be treated as control variables. Deregulation is however less likely in countries/states with French and German civil law system compared with those with common law or Scandinavian civil law.

The regional dummies for Australia/New Zealand and Europe show that deregulation is more likely in these regions compared with North America. For Europe this could be explained by the fact that, as part of the creation of the single market in Europe, the European Union has pushed for deregulation of energy markets and made progressive opening of the electricity market mandatory for member countries. At the same time the pioneers in Europe deregulated well in advance of both any US state and the EU directive. In Australia the creation of the National Electricity Market (NEM) might indirectly have facilitated a common approach also to the regulation of the retail sector.

5.2.2 Estimations using US data

The estimations for the US sub-sample (see Table 5) yield to some extent similar results as the estimations using the complete sample. Deregulation is more likely if the market is large, while the other market structure variables are insignificant. Also in line with the results for the complete sample, and previous results for the United States (White, 1996; Ando and Palmer, 1998), deregulation is more likely if prices are high. In some of the specifications the estimated parameter for the price difference between industrial and domestic consumers is negative and significant, i.e., with a high price difference the

Regression	Complete 1	Complete 2	Complete 3	Complete 4
Log likelihood function	−234.9811	−235.6815	−247.0119	−247.9308
# obs.	908	908	937	937
Variable	**Coefficient (Std. dev)**	**Coefficient (Std. dev)**	**Coefficient (Std. dev)**	**Coefficient (Std. dev)**
Constant	7.80583***	7.93262***	5.98297***	6.11329***
	(1.46758)	(0.995372)	(0.715006)	(0.206972)
Market size	$-1.70E-06$***	$-1.85E-06$***	$-1.66E-06$***	$-1.70E-06$***
	$(7.45E-07)$	$(6.52E-07)$	$(6.09E-07)$	$(5.23E-07)$
Low concentration	−0.024325	−0.024977	−0.115737	
	(0.164664)	(0.150792)	(0.150424)	
High concentration	0.118287	0.09879	0.09432	
	(0.124584)	(0.126564)	(0.128885)	
Peak demand/capacity	−1.65753*	−1.70374*		
	(1.00397)	(0.9464)		
Share industrial cons	−0.002016	−0.001745	0.001114	
	(0.006591)	(0.006137)	(0.005505)	
Price	−8.2643*	−6.30382**	−4.46521	−5.32642*
	(4.99673)	(3.19822)	(2.99598)	(2.79074)
Price difference	1.38572			
	(3.63759)			
Import price gap	0.607346			
	(6.94399)			
Export price gap	−4.5197			
	(5.39456)			
Employment/output	−0.100306	−0.179684	−0.210989	
	(0.44686)	(0.350547)	(0.349956)	
Right-wing government	−0.181396	−0.184845*	−0.214275**	−0.196867*
	(0.116507)	(0.104866)	(0.107164)	(0.103315)
Economic freedom	−0.039863	−0.059404	0.009006	
	(0.109159)	(0.075291)	(0.075326)	
Spill-over	−0.329609**	−0.350773**	−0.371499**	−0.372763***
	(0.156957)	(0.146984)	(0.149406)	(0.119999)
French civil law	0.61014	0.418586*	0.523913***	0.591942***
	(0.373085)	(0.228939)	(0.20159)	(0.168393)
German civil law	0.973593*	0.838054	0.997162***	0.983302***
	(0.538798)	(0.368592)	(0.29946)	(0.262716)
Scandinavian civil law	0.180865			
	(0.475627)			
Mixed ownership	0.050291	0.099784	0.106836	
	(0.195852)	(0.165028)	(0.169877)	
Private ownership	−0.172786	−0.152067	−0.206372	−0.238544*
	(0.208652)	(0.162979)	(0.165541)	(0.125994)
Australia/New Zealand	−0.704486**	−0.7148***	−0.666433***	−0.669981***
	(0.283426)	(0.213144)	(0.214111)	(0.158443)
Europe	−1.07792***	−0.945548***	−0.801586***	−0.847177***
	(0.351943)	(0.197891)	(0.191215)	(0.152094)
Canada	−0.046042			
	(0.30385)			
Population density	−0.000241	−0.000224	−0.000258	−0.000239
	(0.000161)	(0.000164)	(0.000173)	(0.000169)
Ancillary parameters for survival				
Sigma	0.243861	0.257282	0.269113	0.267155
	(0.039462)	(0.038205)	(0.039996)	(0.035497)
Parameters of underlying density at data means				
Lambda	0.00557	0.00557	0.0056	0.00563
	(0.00031)	(0.00031)	(0.00031)	(0.00029)
P	4.1007	3.88679	3.71591	3.74315
	(0.66358)	(0.57716)	(0.55227)	(0.49736)

Note: Weibull hazard model is used, where the dependent variable is log of month of partial deregulation: $\ln(T) = \mathbf{x}'\mathbf{b}^* + e$. January 1989 is period 0.. *, ** and *** indicate that the coefficient is significantly different from zero on respectively the 10%, 5% and 1% level.

Table 4: Results for estimation using the complete data set

expected time until deregulation is reduced. This indicate that the effects on smaller consumers are of some importance.

Furthermore, the results also show that the export price gap variable is significant and that a large gap increases the propensity to deregulate. This effect was also found by Ando and Palmer (1998). This is best explained from the private/producer interest hypothesis, although the result does not necessarily contradicts the public interest hypothesis. Where retail electricity deregulation opens up for profitable export possibilities the producers resist the regulatory change less and might even support it, which increases the propensity to deregulate. Profitable export possibilities might result in an increase in the price, which the in-state consumers will loose from. However, as already mentioned, it is far from clear that the proposed link between the public and consumer interests hold here. If the electricity is exported at a higher price than the in-state price it might in fact be welfare enhancing even though the consumers loose. The effect of interest group pressure is also supported by the fact that a high share of independent power producer (IPP) in the state seems to increase the likelihood of deregulation. This result is not that strong and the parameter estimate for this variable is only significant in one of the specifications reported, and then on the 10% level, but it do consistently turn up with a negative sign.

Combined, the results indicate the deregulatory process in the United States primarily has been driven by consumer interest concerns. Profitable export possibilities mitigate the resistance from the incumbents and facilitates the introduction of retail competition in spite of the fact that exports can increase the price for the in-state consumers.

In the specifications reported here there is no significant political effect, but the sign for the "Republican governor" variable is always negative. Occasionally, in some regressions that are not reported, the estimated parameter is also significant. There is thus some weak support that a state led by a republican governor is more likely to deregulate.

5.2.3 Estimations using European data

In the estimations using only European data we soon run into problems caused by the limited number of observations and the number of included variables has to be reduced. Some variables, such as the political color of the government, the spill-over effect and the peak demand/capacity ratio are excluded from the reported regression since they were found insignificant in preliminary analysis. In spite of this almost none of the included variables are significant in the two regressions labeled as Europe 1 and Europe 2 in Table 6.

Especially there is a problem with including other price variables beside price itself.

Regression	US 1	US 2	US 3	US 4
Log likelihood	−95.9625	−97.86956	−100.6823	−102.3856
# obs.	603	603	615	615
Variable	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
	(Std.Err.)	**(Std.Err.)**	**(Std.Err.)**	**(Std.Err.)**
Constant	6.42181***	6.79071***	6.81129***	6.61571***
	1.48185	1.57533	0.863802	0.8104
Market size	$-3.22E-06$**	$-2.94E-06$*	$-4.12E-06$**	$-4.25E-06$**
	$(1.51E-06)$	$(1.53E-06)$	$(2.00E-06)$	$(1.89E-06)$
Low concentration	0.200369	0.185489	0.265404	0.163869
	(0.173224)	(0.17527)	(0.200669)	(0.186785)
High concentration	−0.0589245	−0.0401712	0.0098453	0.004465
	(0.105746)	(0.0840554)	(0.11471)	(0.103035)
Peak demand/capacity	0.182698	−0.256119		
	(1.60984)	(1.85508)		
Share industrial cons	−0.0024366	−0.0035982	−0.001716	0.0006029
	(0.0084625)	(0.0059585)	(0.0083089)	(0.0078941)
Price	−12.3668*	−13.9035**	−8.29424*	−10.9575**
	(6.57052)	(5.5631)	(4.83742)	(4.55481)
Price difference	−8.84594**	−9.08235*	−8.15102	
	(3.95778)	(4.91093)	(5.51376)	
Import price gap	5.03753	5.53581		
	(7.10116)	(6.59834)		
Export price gap	−13.9423**	−13.4982**	−18.454**	−22.3876**
	(6.45069)	(6.29945)	(8.87474)	(9.28176)
Employment/output	0.179866	0.247516		
	(0.524211)	(0.552424)		
Republican governor	−0.104885	−0.0765524	−0.162389	−0.141668
	(0.0999441)	(0.101156)	(0.12284)	(0.110159)
IPP	−0.0063411	−0.0073418	−0.0138156*	−0.0125411*
	(0.0060568)	(0.0065052)	(0.008387)	(0.0074252)
Spill-over	−0.197281	−0.265103	−0.473465	−0.432759
	(0.167296)	(0.202688)	(0.305228)	(0.27103)
Mixed ownership	0.0099705			
	(0.235893)			
Private ownership	−0.130351			
	(0.224347)			
Population density	−0.0002084	−0.0002253	−0.0003493	−0.0003592
	(0.0001637)	(0.0002344)	(0.0004511)	(0.0003346)
Ancillary parameters for survival				
Sigma	0.100671	0.111359	0.161349	0.155752
	(0.0408398)	(0.0439916)	(0.0668733)	(0.05641)
Parameters of underlying density at data means				
Lambda	0.00521	0.00532	0.00502	0.00504
	(0.00049)	(0.00043)	(0.00052)	(0.0005)
P	9.93335	8.97998	6.19774	6.42047
	(4.02973)	(3.54748)	(2.56874)	(2.32536)

Note: Weibull hazard model is used, where the dependent variable is log of month of partial deregulation: $\ln(T) = \mathbf{x}'\mathbf{b}^* + e$. January 1989 is period 0.. *, ** and *** indicate that the coefficient is significantly different from zero on respectively the 10%, 5% and 1% level.

Table 5: Results for estimation using US data

Regression	Europe 1	Europe 2	Europe 3	Europe 4
Log likelihood	−71.28138	−71.74779	−71.81855	−71.9302
Variable	**Coefficient (Std.Err.)**	**Coefficient (Std.Err.)**	**Coefficient (Std.Err.)**	**Coefficient (Std.Err.)**
Constant	4.07325	4.81957**	5.00556***	5.83117***
	(2.55216)	(3.16178)	(1.85865)	(0.989899)
Market size	$-1.86E-06$	$-2.13E-06$	$-2.22E-06$**	$-2.34E-06$**
	$(1.30E-06)$	$(1.55E-06)$	$(1.13E-06)$	$(1.15E-06)$
Low concentration	0.368841	0.447763	0.376785	0.551248
	(0.49868)	(0.591213)	(0.48881)	(0.398759)
High concentration	0.369528	0.525693	0.511804	0.620536
	(0.471241)	(0.56005)	(0.50207)	(0.455876)
Share industrial cons	−0.0255855	−0.0326364	−0.0366232	−0.0443099*
	(0.034095)	(0.0399504)	(0.028661)	(0.0239302)
Price	11.9293	16.5379	16.2371*	17.065**
	(20.9733)	(28.4626)	(8.49357)	(7.01462)
Price difference	5.71369			
	(7.00303)			
Import price gap	−0.238953	0.131284		
	(27.9372)	(34.7373)		
Export price gap	−1.15274	4.66806		
	(21.1098)	(20.215)		
Employment/output	−0.917716	−0.786691	−1.07656	−0.962405
	(1.17844)	(1.39359)	(0.735893)	(0.696226)
Economic freedom	0.170577	0.0739722	0.108959	
	(0.359721)	(0.48368)	(0.238501)	
French civil law	0.999578	0.702543	0.86666*	0.677455***
	(0.834016)	(1.12715)	(0.486313)	(0.254545)
German civil law	0.989217	0.904991	1.04022*	0.869889*
	(0.98226)	(1.32346)	(0.606784)	(0.456484)
Population density	−0.0033239*	−0.0024316	−0.0027506**	−0.0024341**
	(0.0018225)	(0.0020803)	(0.0012214)	(0.0010044)
Ancillary parameters for survival				
Sigma	0.294203	0.311833	0.307255	0.311711
	(0.105042)	(0.101152)	(0.063871)	(0.0594298)
Parameters of underlying density at data means				
Lambda	0.00933	0.00923	0.00916	0.0092
	(0.00127)	(0.00154)	(0.0009)	(0.00086)
P	3.39901	3.20684	3.25463	3.2081
	(1.21357)	(1.04023)	(0.67656)	(0.61165)

Note: Weibull hazard model is used, where the dependent variable is log of month of partial deregulation: $\ln(T) = \mathbf{x}'\mathbf{b}^* + e$. January 1989 is period 0.. *, ** and *** indicate that the coefficient is significantly different from zero on respectively the 10%, 5% and 1% level.

Table 6: Results for estimation using European data

Variable	Sample Complete	US	Europe
Market size	−18.89	−34.44	−34.00
Share industrial cons	*N.S.*	*N.S.*	−50.16
Price	−14.10	−25.75	38.01
Export price gap	*N.S.*	−29.37	*N.S.*
Right-wing government	−28.74	*N.S.*	–
Spill-over	−54.43	*N.S.*	–
French civil law	86.43	–	78.19
German civil law	143.57	–	100.40
Australia/New Zealand	−97.82	–	–
Europe	−123.70	–	–
IPP	–	−22.76	–

Note: Effect of a one-standard deviation change in the covariates or for the dummy variables (right-wing govern, spill-over, law and regional dummies) a unit change. Time is measured in month. Calculations are based on mean deregulation month, where deregulation month for censored observation is 178. N.S. denote that the estimated coefficient is not significantly different from zero. A – indicates that the variable is not relevant for the sample or has not been included in the estimations.

Table 7: Effect on expected time until deregulation

When price difference and the import and export price gaps are excluded we find a significant effect from the price indicating that a high price increase the expected time until deregulation, i.e., decrease the likelihood of deregulation. This result contradicts both the results found for the complete sample and the US subsample, as well as previous findings for the US.

There is also some weak support that a high share of industrial consumers increases the likelihood of deregulation. The parameter estimate is only significant (10% level) in one of the reported regressions, but it consistently has a negative sign.

In general the results for the European subsample can not easily be explained by the public/consumer interest hypothesis. The only significant effect that can be explained from that viewpoint is the estimate for the market size, where, as previously, deregulation is more likely in a large market. This indicates that there are some qualitative differences between US and Europe. In Europe a high price increases the expected time until deregulation, which is clearly no consistent with the consumer/public interest hypothesis, but very much in line with the private/producer interest hypothesis.

The are a number of possible explanations. The first one takes the current price as given. The utilities have less interest to defend the existing regulation if prices are low. Where prices are high the utilities have stronger incentives to defend the existing regulation and they are also the winners. One can also take another step back and consider why prices are low. If utilities constitute a weak interest group, relative to other groups, the regulation would probably result in a low price. When deregulation becomes an issue the utilities both lack the strength and strong incentives to resist deregulation.

A third potential explanation is that the price to a considerable degree is exogenously given. Where the electricity price is low, energy intensive industries are established and become a strong interest group, which then can give strong support to deregulation. Each of these potential explanations prabably offer some part of the truth.

6 Conclusion

Although there are two theoretically distinct explanations of regulation, these two lines of theory are often hard to discriminate between empirically. Some variables are more directly related to one or the other theory and for some variables the theoretical prediction differ. For many variables the theoretical prediction may, or may not, be the same - all depending on which interest group one believes is winning the regulatory game. The development of the private interest theory of regulation made by Becker (1983) also narrowed the gap between the private and public interest theories of regulation. Thus it is quite hard to empirically determine that one or the other theory is correct. The interpretation of the result is, to some extent, depending on the researcher's judgement.

The public interest theory of regulation can, however, to some extent be seen as a advocacy of the interest of a particular interest group, namely the consumers. In principle consumer welfare and social welfare are not the same, but for many practical purposes they may be quite similar. Instead of trying to discriminate between the private and public interest theories directly, one can try to identify the importance of different interest groups: is the process driven by consumer or producers concerns?

The perhaps most interesting result from the analysis is that the price level affect the likelihood of deregulation differently in Europe and the US. This indicates that there are qualitative differences between the US and Europe, and that conclusions based on US data might not be valid outside that particular institutional context.

For the US it seems to be a fairly well established fact that deregulation first occurred in high price states. Previous research points in that direction, and that position is also supported here. This indicates that deregulation of electricity retail markets in the US to a large extent is based on consumer protection - where the old regulatory regime had failed it was replaced. In Europe almost the opposite story seems to be true - where the old regulatory regime had failed it was kept.

If the US experience might be explained by the public interest hypothesis, this is not the case for Europe where the strength of interest groups seems to be of greater importance. Where the producers had little to loose, or perhaps even something to win from price increases, the resistance was weaker and deregulation more likely. There is also some support that strong industrial consumers facilitate deregulation. These industrial consumers might already previously have won the regulatory game and succeeded in keeping prices low. When deregulation in became a realistic alternative this interest group also managed to push for deregulation. Electricity prices are however not entirely determined by regulation. The existence of cheap hydro-power in for instance Scandinavia has both resulted in relatively low electricity prices there and the development of a large electricity-intensive industry, which is an interest group that then seems to have played the regulatory game quite successfully. There is thus some support for the private interest hypothesis, but almost none for the public interest hypothesis when it comes to Europe.

In the US there is a long tradition of policies aiming at protecting the interests of consumers, with the century old anti-trust legislation as the prime example. Although it is uncertain to what degree such policies actually manages to reach their goals of consumer protection, the tradition may still be important. In Europe a similar tradition is lacking. For instance the anti-trust legislation has previously been much weaker in Europe and only lately been strengthened. When it comes to utilities the US consumers have been primarily protected by regulatory boards and commission, while in Europe the existence of public monopolies/dominant firms have been seen as enough protection for the consumers.

Furthermore the analysis suggest that it is hard to fight with efficiency. In the US this is indicated by the fact that a high export price gap facilitates deregulation. If the regulator acted only in the interest of the local consumers this would not be observed. The producers might however gain from deregulation if there are profitable export possibilities and the overall welfare might also be improved. For the full sample there is evidence that high employment in the sector increases the likelihood of deregulation. It would be interesting to analyze the influence and power of employees in more detail. One possibility would be to also use some measure of unionization in the sector. For the respective subsamples there is no significant effect from employment, but the sign of the effect is consistent with the result for the complete sample.

Both in Europe and the US there has for a long time existed discussion about EU (Europe) or federal (US) deregulatory initiatives. In Europe this has resulted in EU directives calling for the opening of energy markets, while no such decision has yet been made in the US. The results here indicate that such initiatives might be more motivated in Europe than in the US.

A Variables

Variable	Definition
Market size	Total sales in GWh (1990)
Low concentration	Dummy variable =1 if HHI<0.18 (1990)
Medium concentration	Dummy variable =1 if 0.18<HHI<0.6 (1990)
High concentration	Dummy variable =1 if HHI>0.6 (1990)
Peak demand/capacity	Peak demand/installed capacity (1990)
Share Industrial Consumers	Sales to industrial consumers/total sales (1990)
Price	Average price for industrial consumers. Time-varying. 2 years lag.
Import price gap	Own price minus the price in the lowest priced neighbor truncated at 0. Time-varying. 2 years lag.
Export price gap	Price in the highest priced neighbor minus own price truncated at 0. Time-varying. 2 years lag.
Price difference	Price domestic consumers - price industrial consumers. Time-varying. 2 years lag.
Employment	Number of employees/total sales (1990)
Independent power producers	Production capacity IPP/total production capacity (1990)
Public ownership	Dummy variable =1 if dominant public ownership in generation (1990)
Private ownership	Dummy variable =1 if dominant private ownership in generation (1990)
Mixed ownership	Dummy variable =1 if neither dominant private nor public ownership in generation (1990)
Right wing government	Dummy variable =1 if head of government belongs to right wing/market liberal party. Time-varying.
Economic freedom	The Economic Freedom of the World Index
Legal origin	Dummy variables. Common law, french civil law, german civil law or scandinavian civil law.
Population density	Number of inhabitants/km^2

Table 8: Definition of variables

The definition of the dummy variable for head of government partisanship The head of government partisanship is included to capture ideological biases to deregulation. A more right-wing government is believed to have a bias for deregulation.

For the United States the party of the governor is used, except for Washington D.C. where the party of the mayor is used. The US two-party system makes this fairly easy, but there are some cases were the governor is labeled as independent. Since we are interested in an liberalization, we want to separate out governments that have an ideological bias for liberalization. Based on the assumption that republicans, in general, are more free-market oriented the variable is set equal to one if the governor is republican and equal to zero otherwise. The data regarding US governors have mostly been collected from the on-line version of The Political Reference Almanac, 2001-2002 and in some cases supplemented with information from state government web pages.

For Canada the party of the Premier of the province has been used. Canada has a more complex party system than the United States and it is harder to classify the parties into two distinct groups. Canadian politics is dominated by three parties. The Progressive Conservative Party, the Liberal Party and the New Democratic Party, with the latter being the left-wing party. In addition to these three there are two more parties that have been in power during the time period considered here. In British Columbia the Social Credit party was in power until November 1991 and in Quebec Bloc Québécois was in power between September 1994 and April 2003. Bloc Québécois is an issue-specific party focusing on separation of Quebec from Canada. Social Credit can, according to the author's understanding, to a large degree be seen as a conservative party and it has had alliances with the Conservative and Liberal parties. Based on this Premiers belonging to the Conservative, Liberal and Social Credit parties have been grouped together and the variable is set equal to one if the Premier belong to either of these parties, and zero otherwise. The data on Canadian Premiers have been collected from the web site Canadainfo.

Most of Europe has an even more fragmented party structure and the policies may differ considerable between sister-parties in different countries. Conservative, Christian democratic and liberal prime minsters have been grouped together as more market liberal and the variable has been set equal to one in these cases and zero otherwise (mostly this means a social democratic/labor government). The classification of parties, who's ideological belonging is not easily identified by its party name are based on information in The Political Reference Almanac.

Australia and New Zealand has a simpler party structure. In Australia there are three parties that have been in power on the state/territorial level (Labor, Liberal and National Party), and in New Zealand there is only two parties (Labor and National Party). For Australian states/territories and New Zealand the variable has been set equal to one if the prime minister belong to either the National or the Liberal Party and zero if it belongs to the Labor Party. Data on the prime ministers of the European countries, Australian states/territories and New Zealand have been obtained from government web pages.

List of sources

Variable	Sources: US	Canada	Europe	Australia	New Zealand
Time of deregulation	Various sources: (1) Status of State Electricity Restructuring Activity (EIA) (2) Weekly Utility Restructuring Updage (EIA) (4) Edison Electric Institute (5) ENERGYguide.com (6) www.sel.com	Information from provincial authorities and the National Energy Board	(1) Information from national authorities (2) Energy Liberalisation Indicators in Europe (OXERA, Oct 2000) (3) Individual reports by country on the implementation of the internal market for electricity. Available at http://europe.eu.int/comm/energy/en/elec_single_market/implementation/index_en.html	Information from state authorities	Ministry of Economic Development, Chronology of New Zealand Electricity
Market size	EIA datafile EIA-861 (1990)	EPS vol 1, 1990	IEA	ESAA	EPINZ
Market concentration	EIA datafile EIA-861 (1990)	Various sources	Various sources		EPINZ
Peak demand/capacity	NERC. Only available for NERC regions	EPS vol 1, 1990	Eurelectric	ESAA	EPINZ
Price	EIA datafile EIA-861	EPS vol 2	IEA	ESAA	IEA
Employment	Bureau of Labor Statistics	EPS vol 2	Eurelectric. Data from 1996 except for Norway (1990 data) and England/Wales (1989 data. Source: HESS)	ESAA	EPINZ
Market growth	EIA State Electricity Profiles	EPS vol 2	IEA	ESAA	EPINZ
Independent power producers	EIA State Electricity Profiles	Not available	Not available	Not available	Not available
Ownership	EIA datafile EIA-861	Various sources	Various sources	Various sources	EPINZ
Right wing government	The Political Reference Almanac and state webpages	Canadainfo and provincial webpages	Government webpages	Government webpages and australianpolitics.com	Government webpages
Economic freedom index	<<<<<<<<<<The Economic Freedom of the World Index (Gwartney, Lawson, Park and Skipton (2001)>>>>>>>>>>				
Legal origin	<<<<<<<<<<La Porta et.al. (1998), Martindale-Hubbel Law Digest, Reynolds and Flores (1989-)>>>>>>>>>>				
Population density					

Explanation of abbreviations:

EIA	Energy Information Authority (US)
IEA	International Energy Agency (OECD), Official statistics
ESAA	Electricity Supply Association of Australia, Historical statistics and Electricity Prices in Australia 2002/2003
EPINZ	Annual statsistics in relation to the Electric Power Industry in New Zealand for the year that ended 31 March 1991
EPS	Electric Power Statistics, Statistics Canada
HESS	Handbook of Electricity Supply Statistics 1988/89 (UK)

	Deregulation period	Market size	Low concentration	Medium concentration	High concentration	Share industrial consumers
Deregulation period	1	-0.24817	-0.11039	0.23066	-0.15134	-0.20431
Market size	-0.24817	1	0.35557	-0.10485	-0.15296	0.02795
Low concentration	-0.11039	0.35557	1	-0.3667	-0.35808	0.18315
Medium concentration	0.23066	-0.10485	-0.3667	1	-0.73734	-0.34034
High concentration	-0.15134	-0.15296	-0.35808	-0.73734	1	0.20858
Share industrial consumers	-0.20431	0.02795	0.18315	-0.34034	0.20858	1
Price industrial consumers	-0.51751	0.11227	-0.02301	-0.07863	0.09562	0.08515
Price domestic consumers	-0.49489	0.30955	0.08175	0.0096	-0.06899	0.07625
Price difference	-0.30389	0.37862	0.14694	0.08496	-0.19196	0.04199
Import price gap	-0.16393	0.18688	0.05334	0.12208	-0.16125	-0.18251
Export price gap	-0.04329	0.11112	0.07834	-0.00579	-0.05107	0.03344
Employment/output	-0.35296	-0.10488	-0.14639	-0.20137	0.3084	0.2421
Right-wing government	-0.17357	0.06315	-0.06753	-0.13534	0.18486	-0.15206
Economic freedom	0.37001	-0.28091	-0.03912	0.21394	-0.18631	-0.30802
Spill-over	0.16728	0.08149	0.15466	0.05245	-0.16494	-0.08607
USA	0.43511	-0.13758	0.01921	0.43303	-0.44854	-0.25779
Canada	0.25571	-0.07257	-0.15307	-0.16868	0.28043	-0.24505
Europe	-0.49233	0.39221	0.21533	-0.17404	0.01831	0.21119
Australia/New Zealand	-0.34022	-0.2018	-0.14427	-0.29708	0.40291	0.40187

	Price domestic consumers	Price difference	Import price gap	Export price gap	Employment/ output	Right-wing government
Deregulation period	-0.49489	-0.30389	-0.16393	-0.04329	-0.35296	-0.17357
Market size	0.30955	0.37862	0.18688	0.11112	-0.10488	0.06315
Low concentration	0.08175	0.14694	0.05334	0.07834	-0.14639	-0.06753
Medium concentration	0.0096	0.08496	0.12208	-0.00579	-0.20137	-0.13534
High concentration	-0.06899	-0.19196	-0.16125	-0.05107	0.3084	0.18486
Share industrial consumers	0.07625	0.04199	-0.18251	0.03344	0.2421	-0.15206
Price industrial consumers	0.79288	0.3345	0.52908	-0.23873	0.47618	0.06596
Price domestic consumers	1	0.83949	0.5095	0.02936	0.3462	-0.05976
Price difference	0.83949	1	0.31616	0.25827	0.11079	-0.15124
Import price gap	0.5095	0.31616	1	-0.12592	0.06124	0.02046
Export price gap	0.02936	0.25827	-0.12592	1	-0.22426	-0.11184
Employment/output	0.3462	0.11079	0.06124	-0.22426	1	0.03766
Right-wing government	-0.05976	-0.15124	0.02046	-0.11184	0.03766	1
Economic freedom	-0.49325	-0.47443	-0.03803	-0.26486	-0.30888	0.09814
Spill-over	-0.00414	0.08623	0.17816	0.31945	-0.3143	-0.089
USA	-0.22086	-0.18556	0.14331	-0.15637	-0.42156	-0.06961
Canada	-0.36556	-0.21451	-0.17466	0.21371	-0.25722	0.13704
Europe	0.64671	0.66393	0.12524	0.16951	0.37112	-0.11432
Australia/New Zealand	-0.08487	-0.3216	-0.20631	-0.18833	0.47413	0.11354

	Economic freedom	Spill-over	USA	Canada	Europe	Australia/ New Zealand
Deregulation period	0.37001	0.16728	0.43511	0.25571	-0.49233	-0.34022
Market size	-0.28091	0.08149	-0.13758	-0.07257	0.39221	-0.2018
Low concentration	-0.03912	0.15466	0.01921	-0.15307	0.21533	-0.14427
Medium concentration	0.21394	0.05245	0.43303	-0.16868	-0.17404	-0.29708
High concentration	-0.18631	-0.16494	-0.44854	0.28043	0.01831	0.40291
Share industrial consumers	-0.30802	-0.08607	-0.25779	-0.24505	0.21119	0.40187
Price industrial consumers	-0.32341	-0.10389	-0.17495	-0.39344	0.37704	0.21348
Price domestic consumers	-0.49325	-0.00414	-0.22086	-0.36556	0.64671	-0.08487
Price difference	-0.47443	0.08623	-0.18556	-0.21451	0.66393	-0.3216
Import price gap	-0.03803	0.17816	0.14331	-0.17466	0.12524	-0.20631
Export price gap	-0.26486	0.31945	-0.15637	0.21371	0.16951	-0.18833
Employment/output	-0.30888	-0.3143	-0.42156	-0.25722	0.37112	0.47413
Right-wing government	0.09814	-0.089	-0.06961	0.13704	-0.11432	0.11354
Economic freedom	1	-0.08231	0.73816	-0.11912	-0.73913	-0.12031
Spill-over	-0.08231	1	0.08105	0.0198	0.01335	-0.16779
USA	0.73816	0.08105	1	-0.43787	-0.57711	-0.41269
Canada	-0.11912	0.0198	-0.43787	1	-0.17342	-0.12401
Europe	-0.73913	0.01335	-0.57711	-0.17342	1	-0.16345
Australia/New Zealand	-0.12031	-0.16779	-0.41269	-0.12401	-0.16345	1

Table 9: Correlation matrix

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II

Power to Cheat?*

Niclas Damsgaard Jon Thor Sturluson

Abstract

Consider a vertically integrated electricity company that provides regulated local network services while being active in a deregulated but imperfectly competitive retail market for electricity. Its total costs are known, both to the regulator and its competitor, while the distribution between the two costs is private knowledge of the incumbent. The firm has a natural incentive to overstate its costs for the network services to receive a higher regulated price. However, since total costs of both operations are known, a claim of high network costs signals low retail costs. When firms compete in prices, which are strategic complements, the integrated firm would like its competitor to belief that retail costs are high as well. The regulator, through a combination of price incentives and monitoring, can utilize this trade-off and induce an information-revealing separating equilibrium in which the incumbent claims its true type. The optimal combination of price incentives and monitoring and the conditions under which such a separating equilibrium is preferred to a pooling equilibrium are derived.

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1 Introduction

The waive of deregulation that has swept across the world economies, leaving few industries untouched. Among the most recent developments is the partial deregulation of network industries, through separation of operations. In industries like electricity and gas, for instance, the networks are usually considered to be natural monopolies and therefore kept regulated, while the services provided via the network are deregulated. The electricity supply industry, which we use as the primary example throughout this paper, is commonly separating into four distinct product levels: production or generation, transmission via high-voltage power lines, low-voltage local distribution, and retailing. The electricity grid used for transmission and distribution is, for all practical purposes, a natural monopoly and given a status as essential facilities for the provision of the deregulated services.

In the pre-deregulation era most electricity industries were dominated by large vertically integrated, and usually publicly owned, power companies or utilities. An important feature of any deregulation scheme is a formal and effective separation of transmission from generation, introducing an independent system operator. Restructuring has not been as widespread when it comes to local distribution and retailing, and integrated incumbents are usually allowed to continue to provide both services. Formal requirements for separation, in one form or another, are common but rather imperfect in practice. In Norway, and initially in England and Wales, a separation of accounts was considered sufficient. In the United Kingdom the requirements were strengthened by the Utilities Act of 2000, prohibiting a single company to hold both distribution (local network) and supply (retail) licenses. Also in Sweden, a formal separation of the operations in different legal entities is required, but these entities can still have the same owner and be part of the same group of companies, and occasionally also share CEO's and personnel. The EU-directive for the electricity market, specifies a separation of production, transmission and distribution, where distribution is defined as "the transport of electricity on medium-voltage and low-voltage distribution systems with a view to its delivery to customers" (Directive 96/92/EC). This illustrates how the directive does not clearly distinguish between retailing and local network services.

The existence of vertically integrated firms operating as regulated monopolies in distribution while competing with other retailers, is a cause for concern by regulators and competition authorities alike. Cross-subsidization is one problem that has been recognized for a long time both in the academic literature and among practitioners. Two early contributions are Averch and Johnson (1962) and Wellisz (1963), who showed that rate-of-return regulation incites firms to overproduce the competitive service in order to expand their capital base. A substantial literature on cross-subsidization has been developed since then. Faulhaber (1975) explicitly defined subsidy-free pricing and presented two tests for cross-subsidization. The incremental cost test is satisfied if the revenue from any service is greater than or equal to the incremental cost of providing the service, and guarantees that the service does not receive a cross-subsidy. The stand-alone cost test is satisfied if the revenue from a service is less than or equal to the cost of providing that service independently and guarantees that the service does not provide a cross-subsidy. The stand-alone test was later modified by Sharkey and Telser (1978). Brock (1983) explicitly accounts for fixed and common costs faced by a rate-of-return regulated firm and showed that regulated firms are not more likely to engage in predatory cross-subsidization than unregulated firms. Braeutigam and Panzar (1989) arrived at results similar to Averch and Johnson (1962), but without relying on the assumptions that the regulated rate-of-return exceeds the cost of capital. Palmer ((1989*a*; 1989*b*; 1991; 1992)) further developed the tests for cross-subsidization. Brennan (1990) used the incremental and stand-alone cost as two polar cases of a more general set of regulatory regimes and studies different cross-subsidization tactics. He finds that these tactics lead to higher prices in the regulated market and inefficient production in the unregulated market. To some extent he also discusses the effects of strategic interactions between firms.

One aspect that is almost entirely neglected, in this rather extensive literature, is the effect of imperfect competition and strategic interaction in the unregulated market on incentives to cross-subsidize. At the same time, retail electricity markets bear little resemblance to perfectly competitive markets as discussed at length in chapter 1. On the contrary, it seems reasonable to assume that unregulated retail electricity markets are characterized by imperfect competition. In particular we assume that the firms compete in prices, when consumers face switching costs, as analyzed in more detail in chapter 2.

Here we develop a model where an incumbent diversified firm operates in two vertically related markets: a regulated network market and an unregulated retail market. The incumbent's cost structure, i.e., the distribution of costs between operations is private information of the firm, while its aggregate costs are known to all. Cost reporting to a regulatory authority can be interpreted as a signal of the true cost of operating the network. But implicit in the signal is also a claim regarding its costs of providing the unregulated service. For an established (partially) deregulated market this form of signalling can take place repeatedly, as a diversified incumbent is constantly under regulatory scrutiny. A more pertinent example, though, is the once-and-for-all event when new regulatory rules are implemented, that call for a separation of accounts or even a more formal legal and managerial separation. It is reasonable to expect an incumbent to have superior information about its true cost structure, while the process of cost analysis only reveals an imperfect picture.

A firm might want to report high costs for the regulated service in order to increase the regulated network price. But that amounts to claiming to have relatively low costs for the unregulated service. But, as prices are strategic complements, this goes against its interests as the competition lowers its price, if the signal is credible. It is precisely this trade-off facing the incumbent firm, that the regulator can take advantage off. We show that a regulator can induce a separating equilibrium in which the incumbent firm reports its true costs, by a combination of pricing incentives and monitoring. Thereby the expected network price is reduced at the same time as the information problem in the deregulated market is eliminated. The alternative is a pooling equilibrium, in which the incumbent claims to have high costs for the regulated service irrespective of its cost structure.

The practice of manipulating accounts or shifting costs is closely related to cross-subsidization, even though it may not fulfill the formal definitions of the latter (as defined by Faulhaber, 1975). Imperfect competition in the unregulated market makes it possible that both services meet the incremental cost test and receive revenues greater than the incremental cost of producing the service.

We do not address the question whether an incumbent firm should be allowed to remain vertically integrated or diversity into other markets. We assume that the diversification has taken place, or rather that a previously integrated and regulated market is only partially deregulated. Different aspects of diversification policies are analyzed by Brennan (1990), Brennan and Palmer (1994), Braeutigam and Panzar (1989), Braeutigam (1993) and Sappington (2003) among others.

The remainder of this paper is organized as follows. In section 2 the full-information benchmark model is developed. In section 3 we introduce asymmetric information and derive pooling and a separating equilibrium. The optimal regulation, given that the separating equilibrium is preferable, is derived in section 4 and the choice between the two types of equilibria is also discussed. Section 5 concludes the paper.

2 Benchmark model

Consider the following model of a partially regulated electricity industry, which has just been reformed, so that competition is allowed in retailing, the downstream market, while network services continue to be the incumbent utility's responsibility. To keep things simple we assume that a single entrant, firm 2, is committed to participate in retailing.[1] The incumbent, firm 1, continues to run its retail operation as well as the network service. It is required to separate its accounts for the two operations, for the sake of transparency. To simplify we assume that all fixed costs and variable costs that can be verified to belong to either operation are zero. What remains is the part of the incumbent's variable costs that can not easily be allocated to either operation, using publicly available information. We call these *disputable costs.*

Marginal (disputable) costs are assumed to be constant. Firm 1's marginal cost of providing retail services is c_1 and c_n for network services. Firm 2's marginal cost is c_2. Due to the normalization of costs, c_2 should be interpreted as firm 2's variable costs in excess of firm 1's undisputed costs.

Infinitesimal consumers are uniformly distributed along the unit interval. Each consumer has a unit demand up to the reservation price s, which is sufficiently high so the market is always covered. By this simple construction, aggregate demand is constant and equal to unity. All consumers have a relationship with the incumbent and incur a switching cost σ if they choose firm 2 as their supplier. When purchasing from the incumbent a consumer pays the incumbent's price for electricity p_1 plus the network charge p_n. When purchasing from an entrant, a consumer pays the entrant's price p_2, the network charge p_n and incurs a switching cost of σ. Consumers have different values of σ, according to their location on the unit interval. More specifically, σ is linearly increasing from 0 on one end to σ_h on the other. Firms are unable to detect individual values of σ, and thereby target consumer, but know the distribution of σ.

Assumption 1 $\sigma \sim U[0, \sigma_h]$.

Consumers are utility maximizers. Let u_1 be the net value of purchasing the service from the incumbent and u_2 when purchasing from the entrant. More specifically

$$u_1(p_1, p_n) = s - p_1 - p_n \text{ and} \tag{1}$$

$$u_2(p_2, p_n, \sigma) = s - p_2 - p_n - \sigma. \tag{2}$$

[1] Adding more firms would complicate the analysis, while naturally reduce the scope for market power. We briefly discuss the case when market power is negligiable later on.

The marginal consumer, or the consumer that is indifferent between purchasing from firm 1 and 2 must have $u_1 = u_2$. This implies that his switching cost, $\widetilde{\sigma}$, is equal to the difference in the retail prices, $\widetilde{\sigma} = p_1 - p_2$. The incumbent's demand is equal to the share of consumers with $\sigma \geq \widetilde{\sigma} = p_1 - p_2$, namely

$$q_1(p_1, p_2) = \frac{\sigma_h - (p_1 - p_2)}{\sigma_h}. \tag{3}$$

All consumers with $\sigma < \widetilde{\sigma}$ purchase from firm 2, which has the demand function

$$q_2(p_1, p_2) = \frac{p_1 - p_2}{\sigma_h}. \tag{4}$$

Both firm face a demand function, which is downwards sloping in own price and increasing in the rivals price, even though aggregate demand is constant.

Firm 1's profit is

$$\begin{aligned} \pi^1(p_1, p_2, p_n) &= (p_n - c_n) + (p_1 - c_1)\, q_1(p_1, p_2) \text{ or} \\ &= (p_n - c_n) + (p_1 - c_1) \frac{\sigma_h - (p_1 - p_2)}{\sigma_h}. \end{aligned} \tag{5}$$

The first term on the right represents net revenue from the network service while the second term is the net income from the retail service. Note that the total quantity of network services is one, due to the simple demand assumptions. Firm 2 is only active in the retail market and has a simpler expression for its profit:

$$\begin{aligned} \pi^2(p_1, p_2) &= (p_2 - c_2)\, q_2(p_1, p_2) \text{ or} \\ &= (p_2 - c_2) \frac{p_1 - p_2}{\sigma_h}. \end{aligned} \tag{6}$$

Assume, for now, that all cost parameters are fully disclosed and that p_n is exogenously determined by regulation authorities (the regulator). The firms choose p_1 and p_2 simultaneously from $\mathbb{R}_+$. From first order conditions we can derive each firm's best

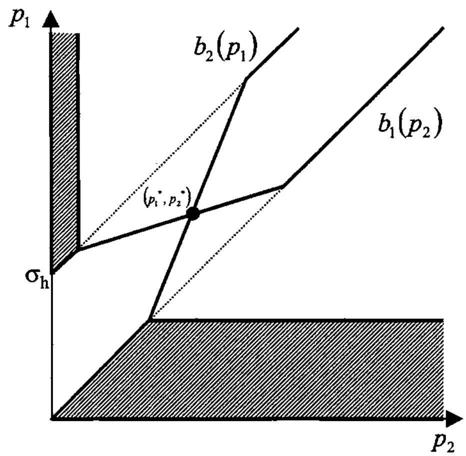

Figure 1: Best-response correspondences and equilibrium prices in the benchmark case

response correspondence,

$$b_1(p_2) = \begin{cases} [p_2 + \sigma_h, \infty] & \text{if} \quad p_2 \leq c_1 - \sigma_h \\ \frac{p_2 + c_1 + \sigma_h}{2} & \text{if} \quad c_1 - \sigma_h < p_2 \leq c_1 + \sigma_h \\ p_2 & \text{if} \quad p_2 > c_1 + \sigma_h \end{cases}, \tag{7}$$

$$b_2(p_1) = \begin{cases} [p_1, \infty] & \text{if} \quad p_1 \leq c_2 \\ \frac{p_1 + c_2}{2} & \text{if} \quad c_2 < p_1 \leq c_2 + 2\sigma_h \\ p_1 - \sigma_h & \text{if} \quad p_1 > c_2 + 2\sigma_h \end{cases}. \tag{8}$$

The first row of (7) describes the case when p_2 is so low, that firm 1 can not attain positive market share without charging a price below marginal cost and is indifferent between any feasible choice of prices for which it will not sell anything and receive zero profit. The second line refers to the interior case, where neither price is sufficiently low to price the other firm out of the market. The third line refers to the situation when firm 2 sets a price so high that it prices itself out of the market. The best response correspondence for firm 2 is analogous and needs not to be explained in detail.

Figure 1 provides an example of both firm's best response functions with an interior intersection. The area between the two diagonal lines represents price pairs that facilitate positive market shares for both firms. When a rival charges a sufficiently high price, the best response is to slightly undercut his price. This means, to stay ε below the respective dotted line. If the competitor charges sufficiently low price, a firm is unable to earn positive profits and any price larger than cost is a best response. This is represented by the grey areas in the figure. For moderate prices however, the best response correspondences are identical to those of a simple linear Bertrand model with product differentiation.

Throughout the paper we will focus on the case when there exists an interior solution, i.e., when both firms have positive market shares in equilibrium. This implies the following parameter restriction.

Assumption 2 $c_1 - 2\sigma_h < c_2 < c_1 + \sigma_h$

Under assumption 2 we can limit our search for a Nash equilibria to the interior segments of the best-response correspondences. We will, occasionally, refer to these interior segments as the best-response functions, despite our stated concern above. A fixed point of these best-response functions defines the equilibrium strategies

$$p_1^* = \frac{2c_1 + c_2 + 2\sigma_h}{3}, \tag{9}$$

$$p_2^* = \frac{c_1 + 2c_2 + \sigma_h}{3}, \tag{10}$$

which translate into the corresponding quantities

$$q_1^* = \frac{c_2 - c_1 + 2\sigma_h}{3\sigma_h}, \tag{11}$$

$$q_2^* = \frac{c_1 - c_2 + \sigma_h}{3\sigma_h}, \tag{12}$$

and equilibrium profits

$$\pi^{1*} = p_n - c_n + \frac{1}{9\sigma_h}\left(c_1 - c_2 - 2\sigma_h\right)^2, \tag{13}$$

$$\pi^{2*} = \frac{1}{9\sigma_h}\left(c_2 - c_1 - \sigma_h\right)^2. \tag{14}$$

Existence and uniqueness follows straight from assumption 2 and the slope of the linear response functions.[2]

This equilibrium outcome has several interesting characteristics that fit well to retail markets for electricity, e.g., asymmetric market shares, price dispersion and limited scope of consumer switching. See chapters 1 and 2 for more details and extensions. Here we

[2] Uniqueness is far from assured if we drop assumption 2. If the parameter values are such that either firm has zero market share, there is a continuum of equilibria.

would like to extend this simple model to allow for an important information problem, which can give rise to cross-subsidization and unnecessarily high network prices. Namely, when the incumbent firm has exclusive information about how its costs are divided between its two operations.

In the standard switching cost literature (see for instance Klemperer (1987*a*; 1987*b*; 1995)) there is an initial period in which the firms compete for market shares and a second period in which the locked-in consumers are exploited. The initial effect with bargains for the consumers is not present in our one-period model, since all consumers are assumed to be committed to the incumbent from the beginning.

3 Shifting costs

It is common, in the regulation literature, to assume that firms that are being regulated have better information about their technology than does the regulator (see Laffont and Tirole (1993)).Typically, a regulator is able to observe total costs while the effort put on reducing costs is only known to the firm. In a similar spirit, we assume that total disputable costs C are observed and verifiable by all, while only firm 1 knows the true cost parameters c_1 and c_n. Firm 2 and the regulator know, however, the sum of the two costs. Since aggregate demand is 1 and the incumbent has previously enjoyed a monopoly in both markets, the cost parameters sum to up to $C = c_n + c_1$. Firm 2's variable retail cost, c_2, is still known to both players.

Firm 1 can be of two types, with respect to its cost structure. With probability ρ it has high network costs and low retail costs and with probability $(1-\rho)$ its network costs are low and retail costs high. We will call the first a high-type, h, and the second a low-type, l, referring to the network cost. The network and retail costs of type θ are denoted as c_n^θ and c_1^θ respectively. Note, that since the retail cost is lower for type h than for type l, we have $c_1^h < c_1^\ell$. Below we will frequently refer to firm 1's unconditional expected retail cost as $E(c_1) = \rho c_1^h + (1-\rho) c_1^l$

Since the total cost C is the same no matter what type firm 1 really is, we must have that $c_n^h + c_1^h = c_n^l + c_1^l$. Further more, this implies that the difference between the network costs of type h and l is equal to the difference between the two types' retail costs. To simplify notation we refer to this difference as Δ, i.e., $\Delta = c_1^h - c_1^h = c_n^l - c_n^l$.[3]

We concentrate on the case where an interior solution can generally be expected, that

[3]In an earlier version of the paper we used an arbitrary market share for firm1 as a benchmark, without altering the results in any way.

is to say, when both firms have positive market shares in equilibrium. If we want that to hold for both types of firm 1, we need to refine assumption 2. The intuition behind the following assumption will be given later on, when we have defined market equilibria.

Assumption 3

$$\frac{3c_1^{\ell} - E(c_1)}{2} - 2\sigma_h < c_2 < \frac{3c_1^h - E(c_1)}{2} + \sigma_h.$$

The common practice in regulating of a firm, which also operates in a non-regulated market, is a two step process (see for instance Braeutigam (1980)). First, those costs that unambiguously can be attributed to either service are assigned to that service. Second, those costs that remain and are disputed, are allocated to each service according to some arbitrary allocation formula. The result of such cost analysis depends, to a large extent, on the regulated firms accounting procedures and its ability to shift costs between different operations. In the following we refer to the cost distribution, as presented in the incumbent's accounts as a signal sent to the regulator. The signal is then revealed to the entrant firm through disclosure of the cost analysis.

In anticipation of the firms signal, the regulator specifies a pricing scheme, which depends on the signal sent. The incumbent firm can choose between two contracts $\left(h, p_n^h\right)$ or $\left(\ell, p_n^l\right)$. If it claims to be of type h it gets to charge p_n^h for its network services and if it says it is of type l the network price is restricted to p_n^l. We choose to represent the pricing scheme by an affine function,

$$p_n\left(\widehat{\theta}\right) = \alpha - \beta(c_n^h - c_n^{\widehat{\theta}}), \tag{15}$$

where $c_n^{\widehat{\theta}}$ is the network cost of a type $\widehat{\theta}$ firm, $\widehat{\theta}$ being the claimed type. Hence, a firm claiming to have high retail costs will get a network price equal to α and a firm claiming to have low network costs will be able to charge $\alpha - \beta\Delta$.

The regulator is also able to monitor claims made by the incumbent firm through an audit. The regulator sets the monitoring intensity, which translates into the probability of discovering the true type of the incumbent so that it can be verified in court. It also determines a fine that the incumbent will have to pay if it is proven to be untruthful in its claim, i.e., its signal is revealed to be different from its type. For now, we let intensity of monitoring, m, and the size of the penalty, f, be exogenous and independent of the signal sent.

Endogenous determination of the network price scheme, the monitoring intensity and the amount of the fine is postponed until section 4. In the remainder of this section we consider the firms' interaction for a given set of regulatory and monitoring parameters. To simplify the exposition we use the expected monetary loss when exposed giving a false signal, ε, to summarize the monitoring procedure. The expected loss equals the probability of detection $\gamma(m, \Delta)$, a function of monitoring intensity and the difference between the types' costs, times the fine, f.

3.1 The game

Now let the model derived in the previous section be the last stage in a three stage game with two players: firm 1 and firm 2. Even though the game is essentially a game of incomplete information we follow the Harsanyi tradition of transforming the game into a game of complete, but imperfect, information. In the first stage (stage 0) nature selects a realization of θ and with probability ρ firm 1 is of type h and with probability $1-\rho$ it is of type l, $\rho \in (0,1)$. The realization is only revealed to firm 1 and not firm 2 (nor the regulator). In stage 1, firm 1 makes a claim, $\widehat{\theta}$, about its type, θ. In stage 2 both firms, having observed $\widehat{\theta}$ and the associated claimed cost structure, $\widehat{c} = (\widehat{c}_1, \widehat{c}_n)$, choose their retail prices, p_1 and p_2, simultaneously.

Firm 1 has two behavioral strategies. The first is a mapping from the type space to the signal space, which are identical by construction, $\phi : \Theta \rightarrow \Theta$, where $\widehat{\theta} = \phi(\theta)$. The second strategy is a mapping from the space of the current history of play, consisting of the correct and the claimed types, to a space of feasible prices, $\varphi_1 : \Theta^2 \rightarrow \mathbb{R}_+$, where $p_1 = \varphi_1\left(\theta, \widehat{\theta}\right)$. Firm 2's strategy is a mapping from the signal space (type space) to the price space, $\varphi_2 : \Theta \rightarrow \mathbb{R}_+$, where $p_2 = \varphi_1\left(\widehat{\theta}\right)$.

Firm 1's payoff is a function of its own strategies (and the competitors strategy which is outside his control) and conditional on its type.

$$\pi_1\left(p_1, \widehat{\theta}|\theta\right) = \alpha - \beta(c_n^h - \widehat{c}_n^\theta) - c_n - \varepsilon \times I_{\widehat{\theta}\neq\theta} + (p_1 - c_1)\frac{\sigma_h + p_2 - p_1}{\sigma_h}, \tag{16}$$

where $I_{\widehat{\theta}\neq\theta}$ is a binary variable, taking the value 1 if $\widehat{\theta} \neq \theta$ and 0 otherwise.

The first three terms on the right hand side of (16) represent the net income firm 1 has from the network service, as specified in (15). The forth is the expected loss of shifting costs (only applies if the signal is untruthful), and the fifth shows net income from the retail service, as specified in (5).

Firm 2's payoff originates solely from its sales in the retail market. Firm 2 is unaware of the correct cost structure of firm 1. Being risk neutral, it maximizes its expected profits conditional on the signal sent by firm 1. Firm 2's belief is characterized by $\omega(\widehat{\theta})$, the probability that firm 1 is of type h conditional on firm 1's signal $\widehat{\theta}$. Expected profit is then given by

$$E(\pi_2) = \omega(\widehat{\theta})\,(p_2 - c_2)\,\frac{p_1^h - p_2}{\sigma_h} + \left(1 - \omega(\widehat{\theta})\right)(p_2 - c_2)\,\frac{p_1^l - p_2}{\sigma_h} \tag{17}$$

where p_1^h and p_1^l constitute particular price strategies for a high and low type firm 1 respectively.

We use perfect Bayesian equilibrium to find pure strategy equilibria in this game. Its simple structure allows for a simplified version of the general definition.

Definition 1 *For the defined game, a strategy profile $\{\phi(\cdot), \varphi_1(\cdot), \varphi_2(\cdot)\}$ and a belief $\omega(\cdot)$, jointly referred to as an assessment, constitute a perfect Bayesian equilibrium (PBE) if the following conditions are fulfilled.*

1. *For any given belief, $\omega(\cdot)$, (16) and (17) are simultaneously maximized with respect to ϕ and φ_1 in the first case and φ_2 in the second.*

2. *Firm 2's beliefs are derived from the prior probability distribution using Bayes rule*

$$\omega(\widehat{\theta}) = \frac{\rho}{\rho I_l + (1-\rho)\, I_h}$$

where I_i are index function taking the value 1 whenever the type i is in the set of types that find the signal $\widehat{\theta}$ optimal (choose $\widehat{\theta}$ according to condition 1).

The first conditions states that for any arbitrary belief, both firms maximize their payoffs with respect to the other firms profit maximization. The second condition limits the set of beliefs to those that are reasonable for the strategy profile in question. Another way to put this is to say that the beliefs have to be consistent with the strategy profile if the assessment is to be an equilibrium.[4]

[4] In a more general setting the definition of a PBE requires three additional requirements: 1) that types of different players are uncorrelated, 2) that players cannot make informative signals about other players types, if they do not have more information than the receiver of the signal, and 3) that all players update their posterior beliefs from a common prior in the same way.

These additional requirements are redundent in our game as only one player has private information about his type. For a general definition of PBE in multi-stage games with observed actions and incomplete information we refer to Fudenberg and Tirole (1991, 331-333).

3.2 Pooling equilibrium

As usually in signalling games, we can expect to find both pooling and separating equilibria. Let us start with the first type. The main feature of pooling equilibria is that signals have no real meaning. In other words, the belief function is totally independent from the signals, $\omega(\widehat{\theta}) = \rho$ for any $\widehat{\theta} \in \Theta$. In which case, the conditional expected retail cost of firm 1 is identical to unconditional expected retail cost

$$\begin{aligned} E(c_1|\widehat{\theta}) &= E(c_1) \text{ or} \\ \omega(\widehat{\theta})c_1^h + \left(1 - \omega(\widehat{\theta})\right) c_1^l &= \rho c_1^h + (1-\rho)\, c_1^l. \end{aligned}$$

Another important feature of pooling equilibria in pure strategies is that only when all types send the same signal can the simple prior belief be consistent. With that in mind it is easy to show that a strategy profile where both firms claim to be of type ℓ (low network costs) is not a pooling equilibrium. A firm which has h (high network costs) as its true type, strictly prefers to claim h rather than ℓ if the belief $\omega(\widehat{\theta}) = \rho$ holds. Such a claim has no impact on the payoff from the retail market and only a negative effect on the payoff from the network service for any $\beta > 0$. It would have to accept a lower network tariff while simultaneously running the risk of being punished for a false claim. As the following proposition states there can exist a pooling equilibrium where both types claim to have high network costs, however.

Proposition 1 *Given assumption 3, if the gain in network price when claiming to have high, rather than low, network costs is greater or equal to the expected loss due to detection of a false claim,*

$$\beta\Delta \geq \varepsilon, \tag{18}$$

there exists a unique pooling perfect Bayesian equilibrium in pure strategies, consisting of the strategy profile $s^p = \left(\phi^p(\theta), \varphi_1^p\left(\theta, \widehat{\theta}\right), \varphi_2^p\left(\widehat{\theta}\right)\right)$, *where*

$$\begin{aligned} \phi^p(\theta) &= h \quad \text{for } \theta \in \{h, l\}, && (19) \\ \varphi_1^p\left(\theta, \widehat{\theta}\right) &= \frac{3c_1^\theta + E(c_1) + 2c_2 + 4\sigma_h}{6} \quad \text{for } \theta \text{ and } \widehat{\theta} \in \{h, l\} \text{ and} && (20) \\ \varphi_2^p\left(\widehat{\theta}\right) &= \frac{E(c_1) + 2c_2 + \sigma_h}{3} \quad \text{for } \widehat{\theta} \in \{h, l\}. && (21) \end{aligned}$$

and the belief $\omega^p\left(\widehat{\theta}\right) = \rho$ *for* $\widehat{\theta} \in \{h, l\}$.

The proof of this and following propositions is given in the appendix. The result illustrates a common concern, that firms may have incentives to overstate their true costs associated with the regulated operation, if they have the opportunity to shift costs from the unregulated operation to the regulated one, with the purpose of receiving a higher compensation for the regulated activity.[5] In the pooling equilibrium the low cost firm gets away with claiming to have high costs in the network operation while neither the regulator nor the entrant can detect its true cost structure. An intuitive criteria for the existence of such an equilibrium is that the gains to a low cost firm claiming to have high costs, $\beta\Delta$, are larger or equal to the expected loss due to successful monitoring of the regulator.

3.3 Separating equilibrium

The incumbent firm has an incentive to overstate its true network costs, as long as the regulated price is responsive to cost claims, i.e., $\beta > 0$. The only counterweight, explicitly mentioned so far, is the expected cost associated with being detected having submitted false cost reports to the regulator. If, however, the rival firm has more sophisticated beliefs a third effect can be added.

As price strategies, in the retail market are complements, firm 1, who possesses private information, can increase his profit if he convinces firm 2 of that c_1 is high. Such a belief, compared with the prior belief, triggers an increase in p_2, according to the best response function (8), which is met by a smaller increase in p_1. The net effect is a higher price and a larger market share for firm 1. The downside of this, from firm 1's perspective, is that by claiming a high c_1 it simultaneously signals a low c_n, which reduces the revenue from the regulated market.

The following proposition states that, taking these three effects together: a) the network pricing scheme, b) the level of monitoring, and c) the signalling of c_1 to firm 2, there exists a separating equilibrium as long as two incentive compatibility constraints are fulfilled.

Proposition 2 *Given assumption 3, if the incentive compatibility constraints IC_h and IC_l are satisfied, there exists a (information-revealing) separating perfect Bayesian equilibrium in pure strategies consisting of the strategy profile* $s^s = \left(\phi^s(\theta), \varphi_1^s\left(\theta, \widehat{\theta}\right), \varphi^s\left(\widehat{\theta}\right)\right)$,

[5] Additional motives for shifting costs, beyond the scope of this paper, were mentioned in the introduction.

where

$$\phi^s(\theta) = \theta \quad \textit{for}\, \theta \in \{h, l\}, \tag{22}$$

$$\varphi_1^s\left(\theta, \widehat{\theta}\right) = \frac{2c_1^\theta + c_2 + 2\sigma_h}{3} \quad \textit{for}\ \theta\ \textit{and}\, \widehat{\theta} \in \{h, l\}\ \textit{and} \tag{23}$$

$$\varphi_2^s\left(\widehat{\theta}\right) = \frac{c_1^{\widehat{\theta}} + 2c_2 + \sigma_h}{3} \quad \textit{for}\, \widehat{\theta} \in \{h, l\}. \tag{24}$$

and the belief $\omega^s(h) = 1$ *and* $\omega^s(l) = 0$.

This result implies that with appropriate selection of parameters controlling incentives through the regulated network price, on the one hand, and monitoring and penalty intensities, on the other, it is possible to resolve the information problem while reducing the average network price, as incumbent firms of type ℓ prefer to reveal their true cost structure.

Two constraints must hold to ensure the existence of a separating equilibrium (see the proof in the appendix for details). The first, is an incentive compatibility constraint on type h,

$$\beta\Delta \geq \frac{2\sigma_h - c_1^h + c_2 + \frac{1}{4}\Delta}{9\sigma_h}\Delta - \varepsilon. \tag{IC$_h$}$$

It states that for type h to prefer to claim its true type rather than pretend to be of type ℓ the difference between the network price each type is permitted to charge (the left hand side) must exceed the increase in profits caused by claiming $\theta = \ell$ net of the expected loss due to successful monitoring.

The second, is an incentive compatibility constraint on type l, for it to prefer claiming to be of type l rather than h,

$$\beta\Delta \leq \frac{2\sigma_h - c_1^\ell + c_2 - \frac{1}{4}\Delta}{9\sigma_h}\Delta + \varepsilon. \tag{IC$_l$}$$

For that to hold, the increase in network price when claiming h, rather than l, must be smaller than the lost profit due to the rivals response to the signal in addition to the expected cost from monitoring.

The naive belief, to interpret the signals as the truth, is self-fulfilling as long as these conditions hold. If the regulatory parameters are consistent with them, the incumbent has no incentive to send false signals. If, however, either of these conditions is violated, the respective type has incentives to cheat rendering the naive-belief inconsistent.

The constraints (IC$_h$) and (IC$_l$) together with (18) define four qualitatively different

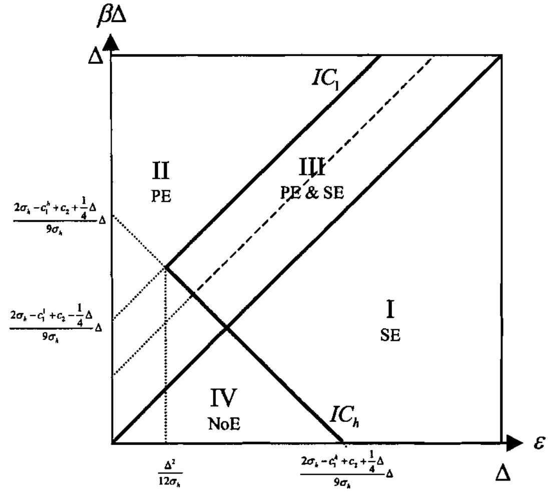

Figure 2: Types of equilibria in the parameterspace $(\beta\Delta, \varepsilon)$

regions in the parameter space $(\beta\Delta, \varepsilon)$ where each type of equilibria can exist or even coexist as shown in Figure 2. The first region, denoted I in the figure, refers to the case when both (IC_h) and (IC_l) are satisfied while (18) is not. Then a separating equilibrium exists but a pooling equilibrium does not. When either (IC_h) or (IC_l) are not satisfied while (18) still is, only a pooling equilibrium is possible. This is referred to as region II in the figure. Region III shows the case when all three constrains are satisfied at once. Then both separating and pooling equilibria exist. The dotted line that divides region III will be discussed below in section 4.2. Finally, in region IV where conditions (IC_h) and (18) are violated, no equilibria exist in pure strategies.

The figure also indicates two important properties of the separating equilibrium, more formally put as follows.

Corollary 1 *For a separating equilibrium to exist:*

1. *The expected penalty due to monitoring, ε, must be larger or equal to $\frac{\Delta^2}{12\sigma_h}$.*
2. *As long as $\frac{\Delta^2}{12\sigma_h} \leq \varepsilon < \overline{\varepsilon}$, where*

$$\overline{\varepsilon} = \min\left(\frac{2\sigma_h - c_1^h + c_2 + \frac{1}{4}\Delta}{9\sigma_h}\Delta, \left(1 - \frac{2\sigma_h - c_1^l + c_2 - \frac{1}{4}\Delta}{9\sigma_h}\right)\Delta\right),$$

the power of the pricing scheme, β must be restricted from below and above.

The first restriction, the lower bound on monitoring, is needed for the Spence-Mirrlees condition to hold. If it does not hold while firm 2 has a naive belief, there are three possible outcomes depending on the level of β. For low-powered incentives (small β) , both types would like to claim they have low network costs. For high-powered incentives (large β), both types would like to claim they have high network costs. For intermediate incentives (intermediate β) each type imitates the other types. Only when $\varepsilon \geq \frac{\Delta^2}{12\sigma_h}$ and β is within the bounds indicated in figure 2, can there exist a separating equilibrium where firms make truthful claims about their cost structure and the naive belief is consistent with the firms optimal strategies.

4 Optimal regulation

The obtained results can be summarized as saying that a combination of price incentives and monitoring can incite incumbents to signal their true cost structure. While truth-telling can be obtained with sufficiently intensive monitoring and large fines, irrespective of the network price scheme, a powerful incentive mechanism can partially replace monitoring, while at the same time reduce the informational rent, $\beta\Delta$, diverted to an incumbent with low network costs. A revelation of the incumbents true cost structure reduces the expected regulated network price while at the same time resolves the information asymmetry in the retail duopoly.

4.1 Choosing the "best" separating equilibrium

Assuming that a truth-revealing separating equilibrium is desirable, we would like to say something about the optimal choice of incentive and monitoring parameters. In order to do that we need to specify a reasonable objective function for the regulator. As demand is completely inelastic, changes in prices are pure transfers between firms and consumers, and should not concern the regulator if he has balanced preferences for the welfare of consumers and firms. Still, relatively higher emphasis on consumer surplus is justifiable for two reasons. First, the model is too simple in this respect and in a more realistic model a price increase would impede total welfare. Second, a certain price level can be viewed by consumers as focal, so that a deviation from that price level calls for compensation - be that through taxes cuts, increased subsidies or in some other latent form. Any such compensating transfers would require alternative financing. Hence, it is reasonable to consider the cost of public funds required for such transfers. We assume, for simplicity, that the expected price level enters regulator's objective function weighted against the cost of monitoring. The weight used can then be interpreted in a number of ways, e.g., a function of the ratio of the deadweight loss to a price change or the cost of public funds. The retail price level is independent of the regulatory parameters, in a separating equilibrium. The expected network price, on the other hand, is directly controlled by the variables α and β :

$$E(p_n) = \alpha - (1-\rho)\beta\Delta.$$

Recall that ρ is the probability of the incumbent firm being of type h. The expected network price is increasing in α but decreasing in β.

The regulator is also concerned with the costs associated with monitoring. To save on notation we use the expected loss of detection, ε, from the incumbents perspective, as the choice variable rather than the monitoring intensity, m, and the fine, f. The regulator always prefers to set the level of the fine to its maximum, as in Baron and Besanko (1984). This is fairly natural since the fine can be considered a pure transfer, while monitoring is a real cost. The expected cost equals the probability of detection $\gamma(m, \Delta)$, a function of monitoring intensity and the difference between the types' costs, times the fine, f. Monitoring pressure is produced with a decreasing returns to scale technology. Let $d(\varepsilon)$ be a twice differentiable cost function with $d' > 0$ and $d'' > 0$.

The regulators objective is to minimize the weighted sum of the expected network price and the cost of monitoring, O_R,

$$O_R = \alpha - (1-\rho)\beta\Delta + \mu d(\varepsilon), \tag{25}$$

μ being a scale parameter, the inverse of the weight put on prices. The regulator has three parameters to set α, β and ε. We have already discussed the incentive compatibility constraints but in addition we must consider the respective individual rationality (IR) constraints. We choose to assume that each type of incumbent firm is assured a nonnegative profit from the network operation. This is by no means the only plausible reference point. A somewhat less restrictive constraint would be to require combined profits of the incumbent to positive (see e.g. Sappington (2003)). Given the significant market power an incumbent has in the retail market, this can result in a pure loss from the network operation for high cost firm. It could prove difficult to require a firm to fulfill a service at a loss, even if it is regarded as an essential facility. The loss of political reputation resulting in disruption of electric services, for example, gives an incumbent firm a serious

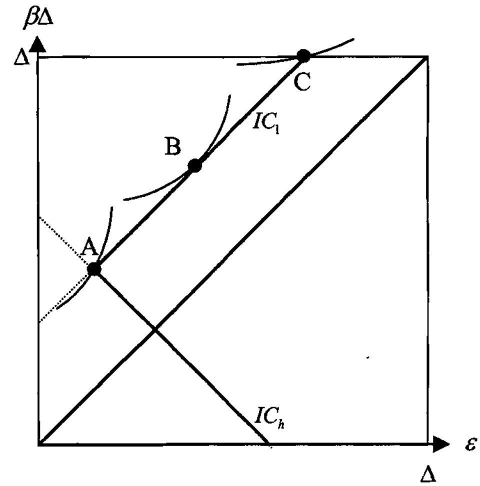

Figure 3: Three types of optimal regulation

potential threat in a such a situation. Hence, the IR constraints used here are

$$\alpha - c_n^h \geq 0 \tag{IR$_h$}$$

$$\alpha - \beta\Delta - c_n^l \geq 0. \tag{IR$_l$}$$

Proposition 3 *Assuming that a separating equilibrium is preferred to pooling equilibrium, the regulator's optimal policy, minimizing (25) with respect to (IC_h), (IC_l),(IR_h) and (IR_l), is to set α, β and ε such that*

$$\alpha = c_n^h, \tag{26}$$

$$\varepsilon = \min\left(\Delta, \max\left(\frac{\Delta^2}{12\sigma_h}, \varepsilon^*\right)\right) \quad \textit{and} \tag{27}$$

$$\beta\Delta = \frac{2\sigma_h - c_1^\ell + c_2 - \frac{1}{4}\Delta}{9\sigma_h}\Delta + \varepsilon. \tag{28}$$

where $\varepsilon^*$is a potential interior solution of ε defined by $d'(\varepsilon^*) = \frac{1-\rho}{\mu}$.

The intuition is best explained with the aid of figure 3. The unconstrained minimization of O_R would yield the solution $\beta = 1$, $\varepsilon = 0$, where neither type of incumbent were left with any informational rent and costly monitoring could be avoided. In general a move in the depicted parameter space to the northwest is an improvement for the regulator's objective. The slope of the indifference curves depends on the monitoring cost function d. In any case the incentive compatibility constraint for the low network cost firm (IC_l) is binding, as it defines an upper bound on β which is increasing in ε. Depending on the slope of the indifference curves, three qualitatively different solutions may emerge.

If the marginal cost of monitoring increases very fast with monitoring intensity the slope of the indifference curve is so steep, that the incentive compatibility constraint for the high cost firm also kicks in (IC_h) and we have a corner solution at point A. The high level of monitoring cost (at the margin at least) makes it attractive to reduce monitoring at the expense of more informational rents to a firm claiming to have low network costs. But lowering the monitoring intensity below the critical level, $\frac{\Delta^2}{12\sigma_h}$, makes it attractive for the high cost firms, to falsely claim to have low costs. Even though such a claim would result in lower network price, it would be more then compensated by the increase in retail price if the rival firm would believe the incumbent really had low network costs implying high retail costs.

For an intermediary increase in the marginal costs when the intensity of monitoring increases, a solution like the one indicated by point B in the figure is made possible, where the balance is struck between monitoring and the incentive scheme. Assume for instance that the cost of monitoring is given by $d(\varepsilon) = \frac{\delta}{2}\varepsilon^2$. Then the marginal cost of monitoring is $d'(\varepsilon) = \delta\varepsilon$. Since the interior solution ε^* is defined by $d'(\varepsilon^*) = \frac{1-\rho}{\mu}$ we would have $\varepsilon^* = \frac{1-\rho}{\mu\delta}$.

If the marginal cost of monitoring increases very slowly with monitoring intensity the indifference curve is relatively flat and is not tangent to (IC_l) within the feasible parameter space. In that case the regulator does not leave any informational rent to the high cost firm and relies on extensive monitoring to make it worthwhile for the high cost firm to give a truthful signal about its cost structure. This situation is indicated by point C in the figure.

4.2 Multiple equilibria

An obvious problem with the result stated in proposition 3 is that in region III of figure 2 there exist both separating and pooling equilibria. Hence, a regulator attempting to choose an optimal mix of regulation and monitoring cannot be sure which equilibria the firms will be playing. The problem can be mitigated or even eliminated, however, by applying a well known refinement to the perfect Bayesian equilibrium - the intuitive criterion (Cho and Kreps, 1987). This refinement puts restriction on beliefs in an out-of-equilibrium information set. If the signal in question is equilibrium-dominated[6] for a particular type, the belief should be updated accordingly. The criterion only applies to the pooling equilibrium, since there are no out-of-equilibrium information sets in the separating equilibrium. Recall that in the pooling equilibrium both types claim to be of type h. It is shown in the proof to proposition 4 that sending the signal $\widehat{\theta} = \ell$ is equilibrium-dominated if the firm is of type h. As a result, the belief in the event of such a signal should be $\omega(\ell) = 0$ according to the intuitive criterion. That is, firm 2 would interpret a deviation from the pooling equilibrium such that firm 1 is of type ℓ. Given this refined belief we can show that for some parameter combination in region III the pooling equilibrium ceases to exist. For most reasonable parameter values the frontier of region III along the IC_ℓ constraint continues to foster both types of equilibria. This leads to the following result:

Proposition 4 *A regulator who wants to implement a separating equilibrium with certainty maximizes his objective function with respect to*

$$\beta\Delta < \frac{2\sigma_h - c_1^\ell + c_2 - \frac{1}{4}\rho\Delta}{9\sigma_h}\rho\Delta + \varepsilon \qquad (InC)$$

instead of IC_ℓ. Proposition 3 holds in other respects.

The restriction presented in proposition 4 is represented by the dotted line that divides region III in figure 2. How large a part of region III can be redeemed from a pooling equilibrium depends on the distribution of types (increasing in ρ).

4.3 Choice of equilibrium and welfare implications

So far we have seen that it is possible for the regulator to induce a truth-telling separating equilibrium. We have also characterized the optimal choice of β and ε given that the separating equilibrium is preferable to the pooling equilibrium. It is, however, not clear if the regulator should choose to implement separating equilibrium instead of pooling equilibrium. If the regulator seeks to maximize the expected consumer surplus net of switching costs and monitoring cost, the choice of equilibrium depends on a combination factors.

[6] A (out-of-equilibrium) signal is equilibrium-dominated if the equilibrium payoff is greater than the highest possible payoff from sending it.

In a pooling equilibrium, the choice of β is irrelevant, as both types claim to be of type h. Hence, consumers pay a lower expected network price in the separating equilibrium when a positive β reduces the network price in case the incumbent is of type ℓ. The expected difference been the network price in the two cases is

$$E(p_n^p) - E(p_n^s) = (1-\rho)\beta\Delta > 0. \tag{29}$$

Moving from one type of equilibrium to another has more profound effects in the retail market. If firm 1 has low production costs in the retail market, i.e., is of type h, firm 2 would decrease its price in the separating equilibrium compared with the pooling equilibrium. Firm 1 would respond with a smaller price reduction, and as a consequence firm 2's market share would be larger in the separating equilibrium compared with the pooling equilibrium. On the other hand, if firm 1 is of type ℓ and has high production costs in the retail market, firm 2 would increase its price in the separating equilibrium and firm 1 would respond with a smaller increase. Hence, firm 2's market share would be smaller in a separating equilibrium than in a pooling equilibrium.

The equilibrium retail price in the pooling equilibrium and the separating equilibrium are given by propositions 1 and 2 respectively, and the equilibrium quantities in are derived from (11) and (12). It is easy to verify that the expected price and expected quantities are identical in each type of equilibria. Expected total expenditure (excluding the network price) is not, however.

Let $e_r(p_1, p_2, q_1, q_2)$ denote the aggregate expenditure electricity, excluding the network price. The expected expenditure in each type of equilibria is then,

$$\begin{aligned} E\left(e_r^p\right) &= \rho\left(p_1^p(h)\, q_1^p(h) + p_2^p q_2^p(h)\right) + (1-\rho)\left(p_1^p(\ell)\, q_1^p(\ell) + p_2^p q_2^p(\ell)\right) \\ E\left(e_r^s\right) &= \rho\left(p_1^s(h)\, q_1^s(h) + p_2^s(h)\, q_2^s(h)\right) + (1-\rho)\left(p_1^s(\ell)\, q_1^s(\ell) + p_2^s(\ell)\, q_2^s(\ell)\right). \end{aligned}$$

The convention used in super- and subscripts is the same as used before. Equilibrium prices and quantities are functions of the incumbent's type, except the price of the entrant in pooling equilibria, p_2^p, when the signal is uninformative. Using the equilibrium prices and quantities derived above, we find the difference in expected aggregate expenditure between the pooling and separating equilibria to be

$$E(e_r^p) - E\left(e_r^s\right) = -\frac{5}{36}\frac{\rho\,(1-\rho)\,\Delta^2}{\sigma_h} < 0. \tag{30}$$

The expected total consumer expenditure is higher in the separating equilibrium compared with the pooling equilibrium.

As market shares can be different between different types of equilibria, switching costs incurred by consumers can also vary. Recall that marginal consumer's switching cost is given by

$$\tilde{\sigma} = p_1 - p_2$$

and all consumers with $\sigma \leq \tilde{\sigma}$ will switch. Firm 2's market share as a function of prices is $q_2 = \frac{p_1 - p_2}{\sigma_h}$ and, due to the simple uniform distribution of switching cost, the total switching cost incurred by the consumers is

$$\Sigma = \int_0^{p_1 - p_2} \sigma \frac{1}{\sigma_h} d\sigma = \frac{(p_1 - p_2)^2}{2\sigma_h}.$$

The difference in expected total switching costs between the pooling and separating equilibria is then given by

$$E(\Sigma^p - E(\Sigma^s) = \frac{5}{72} \frac{\rho (1 - \rho) \Delta^2}{\sigma_h} > 0, \tag{31}$$

where Σ^p and Σ^s are aggregate switching costs evaluated at pooling equilibrium and separating equilibrium prices respectively. Evidently, the total expected switching cost incurred by consumers is larger in the pooling equilibrium.

With reference to (1) and (2), we can express aggregate consumer surplus as the intrinsic value of the service, s, subtracted by the p_n, e_r and Σ:

$$U = s - p_n - e_r - \Sigma.$$

The change in expected consumer surplus going from a pooling to the separating equilibrium is then

$$E(U^s) - E(U^p) = (1 - \rho)\Delta \left(\beta - \frac{5}{72} \frac{\rho \Delta}{\sigma_h} \right). \tag{32}$$

We can now state the following result.

Proposition 5 *Given assumption 3, expected consumer surplus is larger in a separating equilibrium than in a pooling equilibrium.*

While consumers, on the whole, are always better off in a separating equilibrium than a pooling equilibrium, as long as both firms are active in the market (assumption 3) the regulator should weigh consumer gains against the cost of monitoring, which is required to uphold a separating equilibrium. A regulator might also be concerned with firms' profits, at least to the extent they reflect market efficiency. Firm 2's market share is smaller when the retail cost of firm 1 is relatively high (and larger when c_1 is low) in a separating equilibrium relative to a pooling equilibrium. This means that production will be less efficient in a separating equilibrium than in a pooling equilibrium. But due to the simple modelling framework we prefer leave the formal analysis of this issue for future work.

5 Conclusion

An incumbent firm is not only interested in convincing the regulator that it has high costs in its network business. It would also like its rival to believe that retail costs are high. This constitutes a trade-off if firms compete by setting prices, which are strategic complements. If an incumbent manages to convince its competitor that its retail costs are high, it can expect the rival firm to set a higher price than otherwise. If firms compete in quantities, à la Cournot, where strategies are substitutes, trade-off would not exist and an incumbent firm would always prefer to look as if it had high network costs and low retail cost. Consequently, the incumbent's true cost structure could not be identified through a signalling process as described above. The same is true if the rival is non-strategic, e.g., represents a competitive fringe. Then the incumbent has no interest in trying to affect its rival's belief, since its price setting behavior would be unaffected by any attempts to signal high retail costs.

There is little doubt in our minds, that retail competition in electricity market is better characterized with prices than with quantities as the primary strategic variable. Individual retailers are seldom capacity constrained, as they can always buy additional power on the wholesale market. The two firm model is admittedly a simplification of real-world markets. Similar results, though perhaps not as strong, are likely to emerge in a model with a more realistic market structure, as in (Green, 2000).

In this paper we have shown that a regulator can induce a truth-revealing separating equilibrium by a combination of pricing incentives and monitoring. Strategic interaction in the retail market allows the regulator to achieve this at a lower monitoring cost than otherwise would be possible. Consumers gain from such a policy through a lower network price, but the benefit is partially offset by a increased retail expenditures. The separating equilibrium can also lead to a loss in efficiency as an entrant increases its market share if the incumbent has relatively low retail costs and decreases its market share when the incumbent has relatively high retail costs in a separating equilibrium compared with a pooling equilibrium. More importantly though, the problem of cost-shifting by a regulated firm can be reduced or alleviated, if the firm in question is a strategic player in an (imperfectly competitive) unregulated market.

Appendix

Proof of proposition 1.

Consider the belief $\omega^p\left(\widehat{\theta}\right) = \rho$ for $\widehat{\theta} \in \{h, l\}$. Strategy profiles where $\phi(h) \neq \phi(l)$ can be excluded as they are inconsistent with the belief and by condition 2 (definition 1) can not be a part of a PBE. Any strategy profile in which $\phi(h) = l$, given $\omega^p\left(\widehat{\theta}\right)$, can not belong to an equilibrium either. Clearly by (16) $\phi(h) = l$ is strictly dominated by $\phi(h) = h$.

What we are left with are strategy profiles where $\phi(\theta) = h$ for $\theta \in \{h, l\}$. Price enters the objective function of firm 1, (16) only in the last term, which is independent of $\widehat{\theta}$. Hence, the choice of ϕ and φ are independent decisions. Under assumption 3 there are unique best response functions for the firm's price strategies

$$\begin{aligned} b_1(p_2|\theta) &= \frac{c_1^\theta + p_2 + \sigma_h}{2}, \\ b_2(p_1) &= \frac{c_2 + E(p_1)}{2}. \end{aligned}$$

Solving these together returns (20) and (21).

The assessment (s^p, ω^p) can only be a pooling equilibrium if both types have incentives to claim to be of type h. That is, if $\pi_1(\varphi_1^p(\theta, h), h|\theta) \geq \pi_1(\varphi_1^p(\theta, l), l|\theta)$ for $\theta \in \{h, l\}$. We have already seen that $\varphi_1^p(\theta, h) = \varphi_1^p(\theta, l)$ and hence from (16) we have

$$\begin{aligned} \pi_1(\varphi_1^p(h, h), h|h) - \pi_1(\varphi_1^p(h, l), l|h) &= \beta\Delta + \varepsilon \text{ and} \\ \pi_1(\varphi_1^p(l, h), h|\ell) - \pi_1(\varphi_1^p(l, l), l|l) &= \beta\Delta - \varepsilon. \end{aligned}$$

Thus, a firm of type h will always find it optimal to claim h for any values of the parameters β, Δ and ε, while a firm of type ℓ only finds sending the signal h optimal if $\beta\Delta \geq \varepsilon$. If $\beta\Delta < \varepsilon$ firm of type l could increase its payoff by claiming l while a firm of type h chooses to claim h. But then the belief $\omega\left(\widehat{\theta}\right) = \rho$ is not consistent. ■

Proof of proposition 2.

Take the belief where $\omega^s(h) = 1$ and $\omega^s(l) = 0$ as given. Then, firm 2 perceives firm 1's best response function to be $b_1(p_2) = \frac{p_2 + c_1^{\widehat{\theta}} + \sigma_h}{2}$. Maximizing (17) with respect to p_2 yields a unique optimal strategy for firm 2 as a function of the signal sent by firm 1: $\varphi_2^s\left(\widehat{\theta}\right) = \frac{c_1^{\widehat{\theta}} + 2c_2 + \sigma_h}{3}$. In order order to fulfill condition (2) of definition 1 (consistency of strategies and beliefs) two incentive compatibility constraints must hold, one for each type.

Type h. Firm 1's objective function, given firm 2's optimal strategy is

$$\pi_1\left(p_1,\widehat{\theta}|\theta\right)=\alpha-\beta(c_n^h-c_n^{\widehat{\theta}})-c_n^\theta+\left(p_1-c_1^\theta\right)\frac{\sigma_h+\frac{2c_2+c_1^{\widehat{\theta}}+\sigma_h}{3}-p_1}{\sigma_h}. \tag{33}$$

Consider a firm 1 of type h. If it claims $\widehat{\theta}=h$, (33) is maximized by selecting

$$p_1=\varphi_1^*(h,h)=\frac{2\sigma_h+2c_1^h+c_2}{3} \tag{34}$$

yielding the profit

$$\pi_1^*(h,h)=\alpha-c_n^h+\frac{\left(2\sigma_h-c_1^h+c_2\right)^2}{9\sigma_h},$$

where $\pi_1^*\left(\theta,\widehat{\theta}\right)=\pi_1\left(\varphi_1^*\left(\theta,\widehat{\theta}\right),\widehat{\theta}|\theta\right)$ is the reduced form profit function of type θ that claims $\widehat{\theta}$. A firm of type h who sends the signal ℓ, maximizes (33) by selecting $p_1=\varphi_1^*(h,\ell)=\frac{2\sigma_h+\frac{3}{2}c_1^h+\frac{1}{2}c_1^\ell+c_2}{3}$ yielding the profit

$$\pi_1^*(h,\ell)=\alpha-\beta\Delta-c_n^h-\varepsilon+\frac{\left(2\sigma_h-c_1^h+c_2+\frac{1}{2}\Delta\right)^2}{9\sigma_h}.$$

A firm of type h prefers to send the true signal h and select the retail price, $\varphi_1^*(h,h)$ only if $\pi_1^*(h,h)\geq\pi_1^*(h,l)$. This gives the following incentive compatibility constraint for type h

$$\beta\Delta\geq\frac{2\sigma_h-c_1^h+c_2+\frac{1}{4}\Delta}{9\sigma_h}\Delta-\varepsilon. \tag{35}$$

If (35) does not hold an incumbent of type h will prefer to claim $\widehat{\theta}=l$ rendering the belief inconsistent.

Type l. Then consider an incumbent firm of type l. If it claims $\widehat{\theta}=l$, (33) is maximized by selecting

$$p_1=\varphi_1^*(\ell,\ell)=\frac{2\sigma_h+2c_1^l+c_2}{3} \tag{36}$$

yielding the profit

$$\pi_1^*(\ell,\ell)=\alpha-\beta\Delta-c_n^\ell+\frac{\left(2\sigma_h-c_1^l+c_2\right)^2}{9\sigma_h}.$$

A firm of type l who sends the signal h, maximizes profit by selecting $p_1=\varphi_1^*(l,h)=$

$\frac{2\sigma_h+\frac{1}{2}c_1^h+\frac{3}{2}c_1^\ell+c_2}{3}$ yielding the profit

$$\pi_1^*(\ell,h) = \alpha - c_n^\ell - \varepsilon + \frac{\left(2\sigma_h - c_1^l + c_2 - \frac{1}{2}\Delta\right)^2}{9\sigma_h}.$$

A firm of type l prefers to send the true signal l and select the appropriate price, $\varphi_1^*(,l)$ only if $\pi_1^*(l,l) \geq \pi_1^*(\ell,h)$. This gives the following incentive compatibility constraint for type l

$$\beta\Delta \leq \frac{2\sigma_h - c_1^l + c_2 - \frac{1}{4}\Delta}{9\sigma_h}\Delta + \varepsilon. \tag{37}$$

If $\pi_1^*(l,l) < \pi_1^*(l,h)$ a firm of type l will prefer to claim $\widehat{\theta} = h$ and the belief is inconsistent.

When both (35) and (37) hold, the price strategies (34) and (36), which fulfill condition (1), make it optimal for either type to signal its true cost structure. If either (35) or (37) fails to hold the respective type will prefer to make a false claim about its true type. ■

Proof of corollary 1.

Part 1. The two constraints (IC_h) and (IC_l) put together give

$$\frac{2\sigma_h - c_1^l + c_2 - \frac{1}{4}\Delta}{9\sigma_h}\Delta + \varepsilon \geq \beta\Delta \geq \frac{2\sigma_h - c_1^h + c_2 + \frac{1}{4}\Delta}{9\sigma_h}\Delta - \varepsilon.$$

Using $c_1^\ell - c_1^h = \Delta$, the two inequalities turn into equalities if $\varepsilon = \frac{\Delta^2}{12\sigma_h}$. Clearly when $\varepsilon < \frac{\Delta^2}{12\sigma_h}$ the inequalities are violated, while for any $\varepsilon \geq \frac{\Delta^2}{12\sigma_h}$ they hold, due to the positive sign on ε on the left of the first inequality and negative sign after the second inequality.

Part 2. For a fixed Δ and ε condition (IC_h) defines a lower bound on β that are consistent with a separating equilibrium. It is strictly larger than zero when $\varepsilon < \frac{2\sigma_h - c_1^h + c_2 + \frac{1}{4}\Delta}{9\sigma_h}\Delta$ (as shown in figure 2). Condition (IC_l) defines an upper bound on β that are consistent with a separating equilibrium. The upper bound is strictly smaller then 1 when $\varepsilon < \left(1 - \frac{2\sigma_h - c_1^\ell + c_2 - \frac{1}{4}\Delta}{9\sigma_h}\right)\Delta$. ■

Proof of proposition 3.

1. To minimize (25) with respect to α, either (IR_h) or (IR_l) will be binding. If $\beta \geq 1$, then the optimal α is $\alpha > c_n^h$, as required for (IR_l) to hold. But since $\rho > 0$, the objective can be improved by decreasing α and $\beta\Delta$ by the same amount. When $\beta < 1$ (IR_l) is never binding, since $\alpha - \beta\Delta - c_n^\ell = \alpha - \beta\left(c_n^h - c_n^l\right) - c_n^l > \alpha - c_n^h$. Hence, ($\text{IR}_h$) is binding and $\alpha = c_n^h$.

2. Given $\alpha = c_n^h$ it is convenient to proceed with reference to figure 3. The objective function (that is minimized) is strictly decreasing in β (a larger β is an improvement). As (IC$_h$) only defined a lower bound on β it is never a binding constraint, unless (IC$_l$) is also binding, as is the case indicated by point A in figure 3. Also, because the objective is strictly decreasing in β, the (IC$_l$), which defines an upper bound to β is always binding.

3. Hence, the optimal β and ε are found on a line determined by the binding (IC$_l$) constraint. The β and ε are further constrained from below by (IC$_h$), implying

$$\beta \geq \frac{2\sigma_h - \frac{1}{2}\left(c_1^l + c_1^h\right) + c_2}{9\sigma_h} \quad \text{and} \quad \varepsilon \geq \frac{\Delta^2}{12\sigma_h}$$

when both (IC$_h$) and (IC$_l$) hold simultaneously (see point A in figure 3, and above by the result from step 1 that $\beta \leq 1$, implying $\varepsilon \leq \Delta\left(1 - \frac{2\sigma_h - \frac{1}{2}\left(c_1^l + c_1^h\right) + c_2 - \frac{3}{4}\Delta}{9\sigma_h}\right)$ (point B in figure 3). These bounds are indicated in figure 3 by A and B respectively as well as examples of indifference curves that could facilitate corner solutions. Point C is an example of a solution which is only constrained by (IC$_l$).

4. The potential interior solution ε^* is found by taking the first order condition *w.r.t.* β

$$(1 - \rho) = \lambda$$

and the first order condition *w.r.t.* ε

$$\mu d'(\varepsilon) = \lambda$$

and we see that

$$d'(\varepsilon) = \frac{(1 - \rho)}{\mu}.$$

■

Proof of proposition 4. Consider a pooling equilibrium for any arbitrary parameter values of $\beta\Delta$ and ε in region III. To establish the result we i) show that $\widehat{\theta} = \ell$ is equilibrium-dominated for type h, ii) that when $\omega(\ell) = 0$, as dictated by the intuitive criterion, condition (InC) give the parameter combination for which the pooling equilibrium fails, due to a deviation from type ℓ. It then follows directly that for any combination of $\beta\Delta$ and ε in region III, only when (InC) holds can the pooling equilibrium be discarded. i)

i) In the pooling equilibrium firm 1 of type h gets the payoff

$$\pi_1^p = \alpha - c_n^h + \frac{1}{36\sigma_h}\left(E(c_1) - 3c_1^h + 2c_2 + 4\sigma_h\right)^2,$$

while the payoff if deviating ($\hat{\theta} = \ell$), given the belief $\omega(\ell) = 0$, is

$$\pi_1^d = \alpha - c_n^h - \beta\Delta - \varepsilon + \frac{1}{9\sigma_h}\left(c_2 - c_1^h + 2\sigma_h\right)\left(c_1^\ell - 2c_1^h + c_2 + 2\sigma_h\right).$$

The net effect of deviation is

$$\Delta\pi = -\varepsilon - \beta\Delta + \frac{1}{36\sigma_h}\left(\rho\left(-2\Delta + 4c_1^h - 4c_2 - 8\sigma_h\right) + (1+\rho^2)\Delta\right)\Delta.$$

From corollary 1 we know that $\varepsilon \geq \frac{\Delta^2}{12\sigma_h}$ for a separating equilibrium to exist. $\Delta\pi$ is decreasing in ε and if $\Delta\pi < 0$ for the minimum $\varepsilon = \frac{\Delta^2}{12\sigma_h}$ it will always be negative. Inserting $\varepsilon = \frac{\Delta^2}{12\sigma_h}$ yields

$$\Delta\pi = \left[-\frac{\Delta}{12\sigma_h} - \beta + \frac{1}{36\sigma_h}\left(\rho\left(-2\Delta + 4c_1^h - 4c_2 - 8\sigma_h\right) + (1+\rho^2)\Delta\right)\right]\Delta.$$

For $\rho = 0$ we have

$$\Delta\pi = \left[-\beta - \frac{\Delta}{18\sigma_h}\right]\Delta < 0.$$

Furthermore the derivative of $\Delta\pi$ w.r.t. ρ is

$$\frac{\partial\Delta\pi}{\partial\rho} = \frac{\Delta}{36\sigma_h}\left(4c_1^h - 2(1-\rho)\Delta - 4c_2 - 8\sigma_h\right) < 0$$

for any parameter combination that satisfies assumption 3 and the loss of deviation is increasing in ρ. We can thus conclude that $\hat{\theta} = \ell$ is equilibrium-dominated for type h.

ii) Given that $\widehat{\theta} = \ell$ is equilibrium-dominated for type h, $\widehat{\theta} = \ell$ can only be interpreted as coming from type l. We now proceed to check under which condition a type ℓ firm 1 would like to deviate from the pooling equilibrium. His payoff in the pooling equilibrium is

$$\pi_1^p = \alpha - c_n - \varepsilon + \frac{1}{36\sigma_h}\left(E\left(c_1\right) - 3c_1^\ell + 2c_2 + 4\sigma_h\right)^2$$

while his payoff when deviating $(\widehat{\theta} = \ell)$ is

$$\pi_1^d = \alpha - c_n - \beta\Delta + \frac{1}{9\sigma_h}\left(-c_1^\ell + c_2 + 2\sigma_h\right)^2.$$

The net gain from this deviation is

$$\Delta\pi = \varepsilon - \beta\Delta + \frac{1}{9\sigma_h}\rho\Delta\left(-c_\ell + c_2 + 2\sigma_h - \rho\Delta\right).$$

The parameter space for which the pooling equilibrium does not survive the intuitive criterion can be presented in terms of figure 2 with the inequality

$$\beta\Delta < \varepsilon + \frac{1}{9\sigma_h}\rho\Delta\left(-c_\ell + c_2 + 2\sigma_h - \rho\Delta\right)$$

which separates the parameter space with a line parallel to type ℓ's incentive compatibility constraint for type IC_ℓ. For regulation parameter combinations $(\beta\Delta, \varepsilon)$ lying on or above the line survive the intuitive criterion while those below do not. The proposition follows directly from this.

■

Proof of proposition 5.
Inserting the optimal β given by proposition 3 in equation (32) yields

$$\frac{(1-\rho)\Delta}{72\sigma_h}\left(8c_2 - 2\Delta + 16\sigma_h - 8c_1^l - 5\rho\Delta + \frac{72\sigma_h\varepsilon}{\Delta}\right). \quad (38)$$

If the consumers are to gain from a separating equilibrium compared with a pooling equilibrium this expression must be strictly positive. Since the factor outside the parenthesis is clearly positive this translates into a condition requiring that the part within the parenthesis is positive. This expression is increasing in c_2 as well as ε. The lower bound on c_2 is given by assumption 3 and according to proposition 2 the monitoring intensity must exceed a lower bound, $\varepsilon \geq \frac{\Delta^2}{12\sigma_h}$, for a separating equilibrium to exist. Inserting these into equation (38) and simplifying somewhat the expression within the parenthesis is reduced to $\Delta(4-\rho) > 0$ since $\rho < 1$. Equation (38) is positive for the lowest possible c_2 and the lowest possible ε and it must then also be positive for any higher c_2 and ε. ■

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III

Using Price-data to test for Cross-Subsidization*

Niclas Damsgaard

Abstract

Integrated firms operating in one regulated and one unregulated market may have incentives to use cross-subsidization tactics in order to raise the regulated price. Cross-subsidization generally implies increased production in the unregulated market, which with imperfect competition results in a lower price in the unregulated market and a higher price in the regulated market. This follows quite directly from almost any model of cross-subsidization if one adds the assumption of imperfect competition, but has not been suggested in the literature previously.

Based on this patterns of cross-subsidization within an industry can be detected. The incentives for cross-subsidization will be stronger during periods with cost-based regulation, compared with price-based regulation. More closely integrated firms will have better possibilities to engage in successful cross-subsidization. This is tested using a panel data set the from the Norwegian electricity retail industry that covers periods with different regulatory regimes and firms with different organizational structure.

Our main finding is that data support our hypothesis. The regulated price is higher in periods with cost-based regulation and there is also some evidence that more closely integrated firms charge a higher price for the regulated service. Furthermore, there exists a negative relationship between the regulated and unregulated prices in this industry, which we expect to find if some firms are cross-subsidizing while others are not. This effect is reduced when cost-based regulation is replaced with price-based regulation and it is also smaller for less integrated firms.

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1 Introduction

Consider a firm selling two products or services in two markets. One of these markets is subject to some kind of price regulation, while the other is unregulated. For the firm it would be beneficial if it could make the regulator allow a higher price in the regulated market. If costs are not perfectly known to the regulator the firm has a possibility to affect the regulated price by using different kinds of cross-subsidization tactics. A firm may for instance use the same customer service personnel for the two services. Then, the regulator must not only determine that this personnel was necessary for producing the regulated service, but also that the time claimed to be used for servicing the customers of the regulated service were in fact not devoted to the unregulated service. Similar problems might of course be present for common equipment and financial capital and for the allocation of all other over-head costs. The problem of cross-subsidization has been recognized both in the theoretical literature and among regulators for a long time.

Specifically we will consider an industry consisting of two parts of which one is provided on an unregulated but imperfectly competitive market, while the market for the other service - for some reason - is regulated. One possible rationale for the regulation is that the regulated service has the characteristics of a natural monopoly. The problem of cross-subsidization might be present if the two services are provided by vertically integrated firms to, at least, some part of the market.

A common feature in the models of cross-subsidization, starting with Averch and Johnson (1962), is overproduction in the unregulated market. This overproduction allows the firm to increase its price in the regulated market. If the unregulated sector is characterized by perfect competition, the production of the unregulated good will be expanded so that marginal cost will exceed the price resulting in a production inefficiency. The price will, naturally, remain unaffected. If one instead assumes that the market for the unregulated service is characterized by some kind of imperfect competition the price of the good will generally be affected by this overproduction. With imperfect competition the firm faces a downward sloping demand curve and an increase in production will lead to a lower price. One would then expect that the price of the unregulated service would be lower and the price of the regulated service higher if a firm cross-subsidizes compared with the case of no cross-subsidization. This observation follows rather directly from the models of cross-subsidization if one adds the assumption of imperfect competition, but has not been suggested in the literature previously. It might be used as a basis for a test to detect patterns of cross-subsidization. The purpose of this paper is to develop and use such a price-based test. The test is used on data from the Norwegian electricity retail industry.

This data is particularly well suited for this. The electricity retail industry is exactly the kind of industry considered here. It basically consists of two parts: the supply/sales of electricity and the distribution/transportation of the electricity through the electricity grid to final customers. We will refer to the former as retail operations and the latter as network operations. The network operations are usually considered to be a natural monopoly and therefore regulated. The retail market can be unregulated, but it is reasonable to believe that due to, among other things, switching and search costs it will not be characterized by perfect competition. When the Norwegian electricity industry was deregulated in 1991 the retail market was opened up for competition, while network operations continued to be regulated. In 1997 the regulatory regime for the networks was changed, which is important since the incentives for cross-subsidization differ depending on the type of regulation. Prior to 1997 the regulation was in practice cost-based and in 1997 it was changed to a system that is more price-based.

The theoretical literature on cross-subsidization is quite large. Averch and Johnson (1962) showed in an early contribution that when a rate-of-return cap is applied to the entire diversified firm, the firm has incentives to overproduce the competitive service since this expands the capital base. Their result hinges on that the allowed rate-of-return in their model is larger than the actual cost-of-capital. Later authors have found this feature unappealing.

Some authors (Kahn (1970*a*; 1970*b*) and Posner (1971))discussed cross-subsidization without relying on any formal model. A more rigorous treatment was provided by Faulhaber (1975), who explicitly defined subsidy-free pricing and suggested two tests for cross-subsidization, that since then have become more or less standard in the literature. The first test is the incremental cost test which is satisfied if the revenue from any service is greater than or equal to the incremental cost of providing the service. This guarantees that the service does not receive a cross-subsidy. The second test is the stand-alone cost test, which is satisfied if the revenue from a service is less than or equal to the cost of providing that service independently. When this condition is satisfied the service does not provide a cross-subsidy. In the absence of any economies of scope these tests are equivalent.

In Braeutigam and Panzar (1989) there is a regulated firm operating in two markets. In one of the markets the firm is a monopolist and the other market is highly competitive. In the production of the services for the two markets the firm have some common costs that cannot unambiguously be allocated to any of the two services. They consider a rate-of-return regulation where the allowed rate-of-return equals the cost of capital. With such a rate-of-return restriction applied to the entire diversified firm they arrive at results similar to Averch and Johnson (1962), but the source of the effect is different. If the rate-of-return regulation is replaced with price-cap regulation the incentives for the distortion disappear

The incremental and stand-alone rules have later been used by Brennan (1990) as the two extremes of a more general set of regulatory regimes. Brennan's (1990) model will be discussed in more detail below.

Palmer (1992) used rules similar to the ones suggested by Faulhaber (1975) to test for cross-subsidization between business and residential service provision in the local telecommunication market. A set of sufficient conditions for cross-subsidization with an upper bound on stand-alone cost and a lower bound of the incremental cost were used. Bradley, Colvin and Panzar (1999) study the issue of setting prices and testing for cross-subsidization by using accounting data. Their methodology is applied to the U.S. postal service.

For further references to the literature, both theoretical and empirical, on cross-subsidization we refer to Parsons (1998), which includes a recent survey to the literature of the field.

The empirical studies mentioned above are only a few examples. Common for such studies is the requirement of detailed cost data. Using actual cost data from firms is one possible way of identifying cross-subsidization and is probably necessary for one to be able to find concrete evidence of cross-subsidization in an individual case. It can however be quite difficult to get access to actual cost data, especially if one wish to look at a large number of firms, e.g., an entire industry. It would thus be interesting if cross-subsidization could be detected without detailed cost data. In industries where the unregulated service is characterized by imperfect competition one should be able to detect some pattern in the prices of the services. This is the approach used here.

Our definition of cross-subsidization is somewhat more vague compared with for instance the definition used in Palmer (1992) and it is not required that the revenues from any of the service fall below the incremental cost of providing that service. The firm might still earn positive profits from both products. The unregulated service is sold in an imperfectly competitive market and we would usually expect that the price for such a service exceeds marginal cost. The use of cross-subsidization tactics would then imply that the price of the unregulated service decreases, but the price might still be above marginal cost.

2 Theoretical background and hypotheses

2.1 Cost-based regulation

Our point of departure is the model by Brennan (1990). We will here make the simplifying assumption that there are no economies of scope. The case with economies of scope will be discussed briefly below and in more detail in Appendix A.

Consider a firm producing two products for two markets, one regulated and one unregulated. Let r and u be the product produced for the regulated market and the unregulated market respectively. p_r and p_u are the prices for the two products. The cost of production is $c(r,u) = c(r,0) + c(0,u)$ in the absence of economies of scope. The regulator uses a regulatory rule that allows the firm to recover its costs for producing the regulated service:

$$P_r(r) \cdot r = c(r,0). \tag{1}$$

However, cost information is not necessarily known to the regulator and by producing the unregulated product, the firm might be able to mislead the regulator about its costs of producing r. If the firm can misallocate costs without limit it will in practice be unregulated (Brennan, 1987). That is however not very likely and we will assume that the level of successful cross-subsidization is exogenously given by $s(u)$, with $\frac{\partial s}{\partial u} \geq 0$. Instead of getting a regulated price according to equation 1 the firm can obtain $s(u)$ in addition, which results in the rule

$$P_r(r) \cdot r = s(u) + c(r,0) \tag{2}$$

and the profit maximization problem of the firm will thus be

$$\max_{r,u} P_r(r) \cdot r + P_u(u) \cdot u - c(r,u) - \lambda[P_r(r) \cdot r - s(u) - c(r,u)]. \tag{3}$$

If the firm lacks the ability to engage in cross-subsidization the corresponding expression would be

$$\max_{r,u} P_r(r) \cdot r + P_u(u) \cdot u - c(r,u) - \lambda[P_r(r) \cdot r - c(r,u)]. \tag{4}$$

From these two profit maximization expressions we obtain the first-order conditions with respect to r with cross-subsidization

$$(1-\lambda)\left[\frac{\partial P_r(r^{xsub})}{\partial r}\cdot r^{xsub}+P_r(r^{xsub})-\frac{\partial c(r^{xsub},u^{xsub})}{\partial r}\right]=0 \tag{5}$$

and without cross-subsidization:

$$(1-\lambda)\left[\frac{\partial P_r(r^{no\_xsub})}{\partial r}\cdot r^{no\_xsub}+P_r(r^{no\_xsub})-\frac{\partial c(r^{no\_xsub},u^{no\_xsub})}{\partial r}\right]=0. \tag{6}$$

It is clear that cross-subsidization has no direct effect on the firms first-order-condition with respect to r. The regulatory rules in equations 1 (without cross-subsidization) and 2 (with cross-subsidization) show that the firm will be able to increase its price of the regulated service with $\frac{s(u)}{r}$ per unit. This price increase might have an second order effect, since it might cause a reduction in quantity (from r^{xsub} to r^{no_xsub}). This second order effect will however clearly be dominated by the direct effect from the cross-subsidization. We can conclude that cross-subsidization will increase the price for the regulated service.

We will now continue with the effect on the price of the unregulated service. From equations 3 and 4 we obtain the first-order conditions with respect to u with and without cross-subsidization, which after some rearranging are:

$$\frac{\partial P_u(u^{xsub})}{\partial u}\cdot u^{xsub}+P_u(u^{xsub})+\lambda\left[\frac{\partial s(u^{xsub})}{\partial u}\right]=\frac{\partial c(r^{xsub},u^{xsub})}{\partial u} \tag{7}$$

and

$$\frac{\partial P_u(u^{no\_xsub})}{\partial u}\cdot u^{no\_xsub}+P_u(u^{no\_xsub})=\frac{\partial c(r^{no\_xsub},u^{no\_xsub})}{\partial u} \tag{8}$$

respectively. The left-hand side in each of these two expressions are the marginal revenues. With cross-subsidization (equation 7) the effect from the marginal cross-subsidy is added to the ordinary marginal revenue - an effect which of course is absent when no cross-subsidization take place. The right-hand side in these expressions are the marginal cost. It is obvious that due to the extra marginal revenue from the cross-subsidization the firm will increase its production of u, and the price, p_u, will decrease. This is illustrated in Figure 1.

We can conclude the following. With cost-based regulation, a profit maximizing firm has incentives to engage in cross-subsidization tactics and increase its production in the unregulated market, which will lower the price. This will allow the firm to charge a higher price for the regulated service, which might result in a lower equilibrium quantity. We should be able to observe that cross-subsidizing firms charge a higher price in the

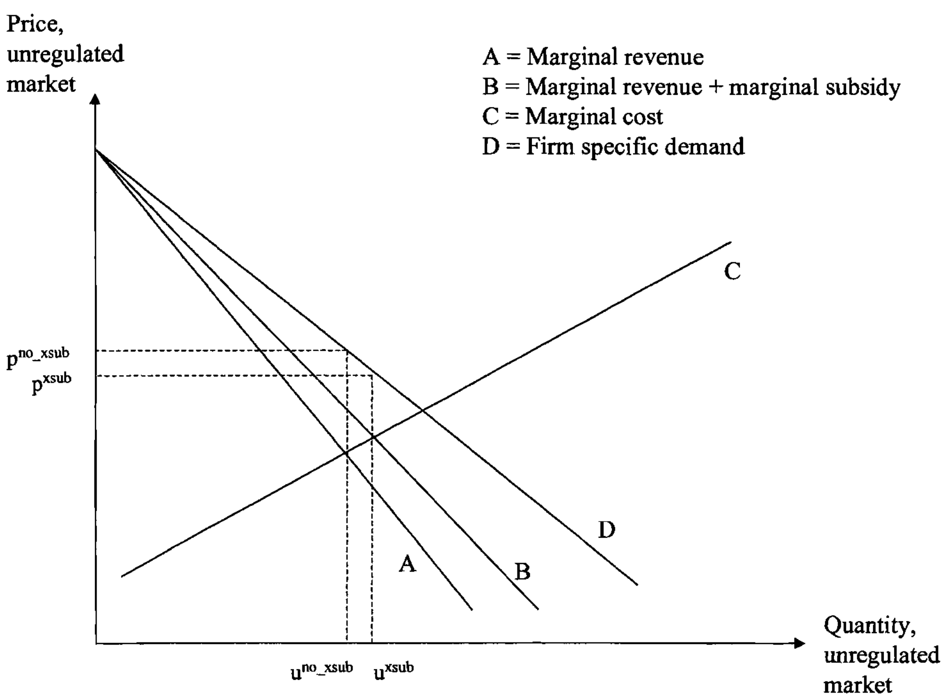

Figure 1: Effect of cross-subsidization on the unregulated market

regulated market and a lower price in the unregulated market.

2.1.1 Economies of scope

Economies of scope are treated in more detail in Appendix A and here we will only discuss the implications informally. We would expect that more closely integrated firms[1] have better possibilities to take advantage of any economies of scope. When studying a market with different types of firms, i.e., firms that are more or less integrated, this could be an important factor.

In the regulated market economies of scope will lower the costs. If the regulator let the consumers reap some of the benefits the price of the regulated service will be lower for firms with economies of scope (e.g. more closely integrated firms). When comparing integrated and non-integrated firms there will be two opposing effects. The integrated firm has better possibilities to engage in cross-subsidization, which will increase the price of the regulated service. But, at the same time, it might benefit from economies of scope, which work in the opposite direction. The total effect is an empirical question.

If there are marginal economies of scope this will also affect the firm's profit maximizing decision in the unregulated market and result in a lower equilibrium price and a higher quantity. The effect from economies of scope thus works in the same direction as cross-subsidization. It is thus likely that integrated firms charge a lower price for the unregulated service.

2.2 Hypotheses

If the cost-based regulation discussed above is replaced with a pure price-based regulation the incentives for cross-subsidization will disappear, since the regulated price then is set independent of reported costs. In reality there hardly exist any pure price-based regulation and the firm's costs might still affect the regulated price. Some incentives for cross-subsidization will therefore be left. These incentives should be much weaker compared with cost-based regulation.

We can then identify two different regulatory regimes, cost-based or price-based regulation, and two different types of firms, integrated or non-integrated firms. This gives us four combinations:

1. Cost-based regulation and an integrated firm

[1] An exact definition of integrated and non-integrated firms is presented below in section 4.2.3.

2. Cost-based regulation and a non-integrated firm

3. Price-based regulation and an integrated firm

4. Price-based regulation and a non-integrated firm.

We can start with comparing cases 1 and 2 with cases 3 and 4, i.e., periods with cost-based regulation and periods with price-based regulation. From the discussion above we know that when a firm cross-subsidizes it will increase its price in the regulated market and decrease its price in the unregulated market (or rather, increase its quantity). The incentives for cross-subsidization are stronger with cost-based regulation. We expect to find a higher price in the regulated market during periods with cost-based regulation, compared with periods with price-based regulation. Furthermore, if some firms are cross-subsidizing, while other firms are not, we expect to find a negative relationship between the unregulated and regulated prices. This negative relationship should be weaker, or non-existent, in periods with price-based regulation. Since there are a number of factors, which we cannot identify, that might affect whether a firm engages in cross-subsidization we believe that it is reasonable to assume that only some firms are cross-subsidizing or at least that the degree of cross-subsidization.

We can then continue comparing cases 1 and 3 with cases 2 and 4, i.e., integrated firms and non-integrated firms. The possibilities for a firm to engage in successful cross-subsidization depend in part on its organizational structure. In reality, it is not a question whether a firm is fully integrated or not integrated at all. Rather it is a question of how integrated a firm is and it is more correct to speak about fully integrated and less integrated firms. A less integrated firm has less possibilities to engage in successful cross-subsidization and we expect a weaker effect from cross-subsidization (or possibly no effect at all) for the less integrated firms. A less integrated firm should thus charge a lower price in the regulated market and the negative relationship between the regulated and unregulated prices should be smaller. For the regulated price, the existence of economies of scope would work in the opposite direction, since less integrated firms cannot take advantage of economies of scope to the same extent. If the effect from cross-subsidization, or the effect from economies of scope dominates is an empirical question. Our hypothesis will however be that the effect from cross-subsidization dominates.

Hypothesis 1a: The regulated price will be higher during periods of cost-based regulation compared with price-based regulation.

Hypothesis 1b: The regulated price will be higher for a fully integrated firm compared with a less integrated firm.

Hypothesis 2a: There will be a negative relationship between the unregulated and regulated prices.

Hypothesis 2b: The negative relationship between the unregulated and regulated prices will be smaller during periods with price-based regulation, compared with periods with cost-based regulation.

Hypothesis 2c: The negative relationship between the unregulated and regulated prices will be smaller for less integrated firms compared with fully integrated firms.

2.3 Some welfare implications of cross-subsidization

Cross-subsidization might affect the welfare in a number of ways. Sometimes cross-subsidization is used openly to support a particular consumer groups, but at other times it is used as a strategy for a regulated firm to increase its profits. It is primarily the latter which we consider here. It is then clear that cross-subsidization reduces output and raises prices in the regulated market which clearly has a negative effect on welfare. In the unregulated market output will increase. If this market is characterized by perfect competition this will lead to over-production and a price below true marginal production cost. Efficient production by competing firms may thus be displaced, which also has a negative welfare effect. If, as the case is here, the unregulated is characterized by imperfect competition the increase in output will reduce the price of the unregulated service. Since the price originally was above marginal cost some level of cross-subsidization might be beneficial, at least if one only considers the unregulated market. On the other hand, a regulated firm has an incentive to cross-subsidize only when cross-subsidization will only when it increases the firms total profit. The potential for a total welfare gain from cross-subsidization seems small.

With economies of scope an increase in the production of the unregulated firm may lower the cost of producing the regulated good. An increase in the regulated firm's market share in the unregulated market through cross-subsidization might thus increase welfare.

Finally the possibility to cross-subsidize might work as a credible predatory threat and help the regulated firm to maintain a monopoly price in the unregulated market. Potential entrants may expect that the post-entry price will fall below the level that would cover then entrants long run cost.

3 The Norwegian Electricity Retail Industry

In Norway the industry was deregulated in the beginning of the 1990's. The supply of electricity was opened up for competition, while the network operations was regarded as a natural monopoly and kept under regulation. The consumers can buy the electricity from any supplier in the market, while they for the actual delivery of the electricity must use the local monopoly network company. These two services are also priced separately and the consumer's electricity bill (or bills if they do not buy their electricity from their local incumbent) consists of two variable parts. One part is the network price paid to the local monopoly network company and the other part is the electricity retail price paid to the supplier chosen by the consumer. In addition to these variable parts there are in some cases a fixed fee.

Generally the incentives for cross-subsidization would be stronger with cost-based regulation than with price-based regulation since the firm's stated costs more directly affects the revenue of the firm with cost-based regulation. From 1993-1996 the Norwegian Water Resource and Energy Directorate (NVE) set a maximum allowable rate of return, which in principle only efficient firms should be able to achieve. In practice all firms were able to achieve this maximum allowable return. This regime was in 1997 replaced with a system in which NVE sets a maximum allowable level for the total revenue of each firm (Bergman et al., 1999; NVE, 1999) . This change of regulatory regime from cost-based system to a price-based system[2] was clearly an exogenous policy change, which we expect affected the incentives for cross-subsidization.

Prior to the deregulation of the Norwegian electricity market about 75 per cent of total consumption of electricity was supplied by vertically integrated companies. After the reform distribution companies were obliged to keep separate budgets and accounts for production/trade and transmission operations. They are however not obliged to split these operations into separate legal entities. Distribution companies could choose to keep their operations completely integrated, separate them in different legal entities within the same group or sell of some of its operations.

[2]What is here called cost-based regulation is frequently referred to as rate-of-return regulation, which means that there is a regulated maximum allowed rate-of-return. With price-based (or price cap) regulation the regulator instead sets a maximum allowed price for the service independent of the firm's costs.

4 Data and explanatory variables

The data consists of an unbalanced panel of yearly data for almost all Norwegian electricity retail companies (about 200 companies) covering the period 1994-1999. These companies operates in a regulated network market and an unregulated electricity retail market, i.e., we consider the part of the electricity industry which sell and deliver electricity to end consumers. The data set covers prices (retail and network), ownership/relationships between retail and network companies, regulatory structure and cost related data. The network price is the dependent variable.

4.1 Dependent variable

The dependent variable is the network price for household consumers. The prices have been collected for the first week in January of each year[3]. The network price used are net of VAT and inflation adjusted to the price level of 1999 by using the Norwegian consumer price index. Prices are in Norwegian öre/kWh. It is common that the network tariff in addition to a variable part also includes a fixed part. Since the fixed part varies between companies an average price for a customer using 20000 kWh/year[4] has been calculated and used.

4.2 Explanatory variables

As the main explanatory variables the retail electricity price-cost ratio, the organizational structure for each individual firm and the regulatory regime are used. In addition there are some control variables mainly of technical character.

4.2.1 The electricity retail price

The electricity retail prices for household consumers have also been collected for the first week in January of each year [5]. In the original data set the retail electricity price include electricity consumption tax and VAT, but in the regressions a price/cost ratio, as defined below, has been used. As with the network price the retail price has also been adjusted to the price level of 1999. Some retail companies also have a fixed part in their electricity tariff and the average retail price for a consumer using 20000 kWh/year has been used.

[3]The network prices have been collected by NVE.

[4]This corresponds approximately to the consumption of a single-family house with electric heating.

[5]For the period 1994-1997 the retail prices have been collected by the NVE and for 1998-1999 by the Norwegian Competition Authority.

For some firms (in some years) there is not a one-to-one relationship between a specific network company and retail company. In some cases several network companies can have a common retail company. In these cases the retail price of that retail company have been used for all the involved network companies. Another possibility is that a network/retail company sells electricity in several different areas at different prices, while charging the same network price to all its consumers. In such cases the average price has been used.

As seen in figure 2 the average retail price is highly correlated with the spot price. Furthermore, in some regions the companies are exempted from paying electricity tax. These two factors are important, and probably quite dominating, determinates of the opportunity cost of supplying electricity. To eliminate variation in these factors a price/cost ratio defined as

$$\text{P/C-ratio} = \frac{\text{P}_\text{u}}{\text{Spot} + \text{Tax}},$$

where P_u is the retail price net of VAT, will be used as the retail price variable.

4.2.2 The regulatory regime

In the period 1994-1996 the regulatory regime was to a large extent cost-based, while it from 1997 became more of a price/revenue based system. As mentioned above the incentives to cross-subsidize will be larger in periods with cost-based regulation. A dummy variable (cap) is used to distinguish between these two regulatory regimes. This variable is set equal to one for years with price-based regulation (1997 and later) and 0 for years with cost-based regulation (pre-1997). An interaction variable between the regulatory dummy and the price variables will be included to control for changes in the slope parameter.

4.2.3 The organizational structure

The company specific data also include two different categories of organizational structure:

1. fully integrated firm, i.e., the network and retail operations are conducted within the same company (legal person),

2. less integrated firm, which consist of three sub-groups:

    (a) partially integrated firm, i.e., the network and retail operations are conducted within separate legal entities (companies) but within the same group of companies,

(b) ownership connection, i.e., the network and retail operations are conducted within separate legal entities that are connected through some weaker form of owner relationship (for instance a number of network companies that own a joint retail company), and

(c) completely separated firms.

The three sub-groups within the category "less integrated firms" have been merged to a common category due to limitations in data. From Figure 3 below we can see that the organizational forms 2b and 2c, were very uncommon before 1997 and there is a strong correlation between the price cap dummy and these organizational structures.

The firm's choice of organizational form is here treated as an exogenous variable. This treatment can of course be questioned. It is possible that firms choose their organizational structure in order to be able to cross-subsidize. When the regulatory regime creates large incentives for cross-subsidization, firms choose an organizational structure that will increase the opportunity for cross-subsidization, i.e., they choose vertical integration. With a change towards a regulation with less incentives for cross-subsidization the choice of organizational structure might also change. When looking at the data[6] we can see a steady decline in the share of the firms which are fully vertically integrated and increases in the shares of firms which are less integrated. This is clearly a trend that has developed throughout the years following the deregulation of the market and not closely connected to the change in regulatory regime in 1997. We will therefore treat the organizational structure as an exogenous variable.

4.2.4 Additional control variables

In addition to these variables a number of technical and other firm specific data, such as grid size and number of customers, are included. Finally, it is possible that the regulation generally has become tougher - apart from the change in regulatory regime in 1997 - during the sample period. The Norwegian electricity market was deregulated in 1991 and it is quite likely that at least during part of the sample period the regulator was involved in learning how to act in the new market. To try to incorporate such effects time and squared time will be included in the appropriate regressions.

[6] See graph in figure 3

4.3 Descriptive statistics

In the analysis we use yearly data from almost all retail and local distribution companies in Norway for the years 1994-1999. In Figures 2 and 3 the development of prices and organizational structure are presented. From Figure 2 we see that the average real network price has been fairly constant during the period. It decreased somewhat between 1994 and 1997, but increased again during the last two years of the sample resulting in about the same price in 1999 as in 1994. The average real retail electricity price is approximately at the same level in 1999 as in 1994. In the years between it increased slightly and peeked in 1997 and then decreased again. The average retail price net of taxes can to a large extent be explained by the spot price. In this chart the average electricity price-to-cost ratio looks almost like a straight line. This is partly due to the scale and the increase in the price/cost ratio in 1996, which can be explained by the low spot price, is in fact rather substantial. The average price/cost ratio for the entire sample period is 1.02 and for 1996 1.18. The price/cost ratio is below 1 in the early years of the sample period (1994 and 1995) and above 1 in the later years (1998 and 1999). The spot price is not an exact measure of the opportunity cost for supplying electricity, primarily because the retail price and the spot price are not necessarily set for the same period of time. One should thus not over-interpret this observation, but it is consistent with cross-subsidization. A more appropriate measure could be the future price for the coming years. Data over future prices are however only available from mid 1995, meaning that the first full year with future prices is 1996. For the years 1996-1999 the future price and the average spot price of December in the previous year follow each other closely and using the spot price seems to be a fairly good approximation of the opportunity cost.

Regarding the organizational structure we can see from figure 3 that in the beginning of the sample period almost all companies were organized as integrated firms with the network and retail operations within the same company (Orgf1). The other possible organizational forms gain shares throughout the years. In 1999 nearly 60% of the firms still have the operations within the same company. About 17% conducts the operations in separate companies but within the same group (Orgf2a). The share that conducts one of the operations in a separate company, but with some ownership connection (Orgf2b) is also about 17% and finally 6% of the companies have divested and are only involved in one of the two operations (Orgf2c). Orgf2 shows the sum of Orgf2a, Orgf2b and Orgf2c.

In Table 2 a correlation matrix for the most important variables is displayed covering the entire sample period. We can see that we have a negative correlation between the real network price and the real retail electricity price. We have a positive correlation

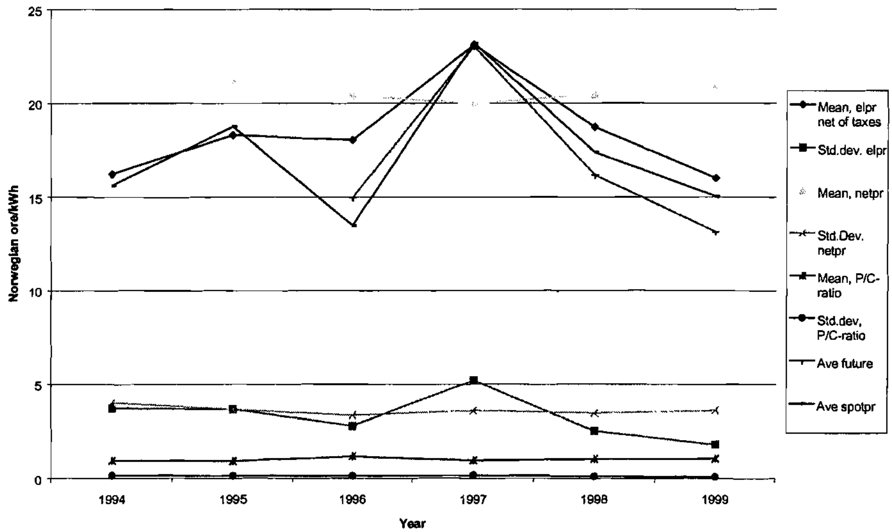

Figure 2: Prices 1994-1999

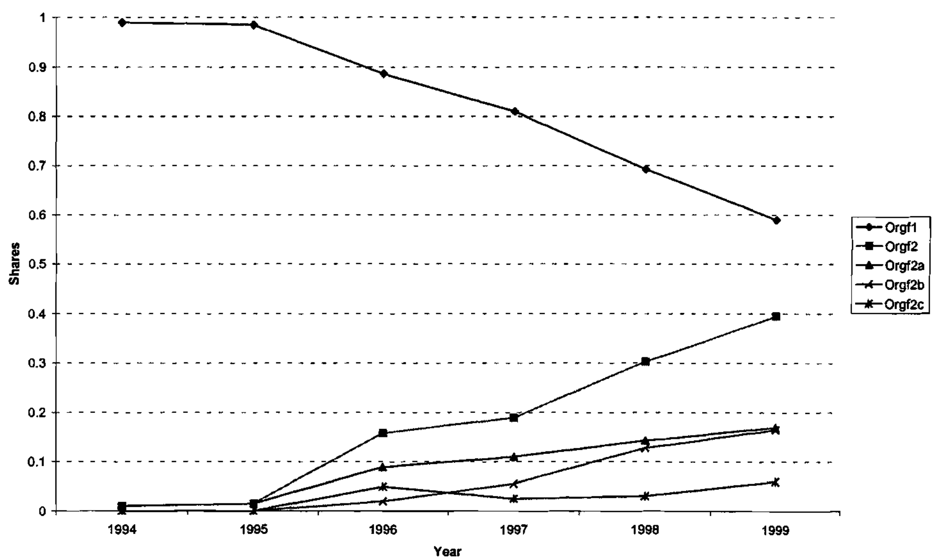

Figure 3: Development of organizational structure 1994-1999

Variable	Mean	Std.dev	Minimum	Maximum	# obs
Real network price	20.904	3.711	10.6186	38.327	1157
Real electricity price	23.975	4.316	7.45435	38.4712	1113
P/C-ratio	1.023	0.168	0.289671	1.74654	1113
Price cap dummy	0.497	0.500	0	1	1196
orgf2 dummy	0.170569	0.376289	0	1	1196
Grid density	7.95793	3.93655	0	29.629	1133
Grid size	1438.18	2448.24	0	53579.3	1140
Quantity distributed electricity	177.278	344.737	0	3700	1157

Table 1: Descriptive statistics for some variables

	P/C-ratio	Real network price	Real el price	Price cap dummy	orgf2 dummy
P/C-ratio	1.000	-0.034	0.463	-0.475	0.13759
Real network price	-0.034	1.000	-0.112	0.014	-0.18141
Real electricity price	0.463	-0.112	1.000	0.174	0.12336
Price cap dummy	-0.475	0.014	0.174	1.000	0.12862
orgf2 dummy	0.13759	-0.18141	0.12336	0.12862	1

Table 2: Correlation matrix

between the dummy variable cap and the electricity retail price as well as between cap and the network price although the latter correlation coefficient is very small. The dummy variable describing the organizational form and the network price are negatively correlated while the organizational form variable and the electricity price are positively correlated., meaning that less integrated firms have a lower network price and a higher electricity price. All these correlations, except the positive correlation between the cap variable and the network price are in line we the cross-subsidization hypothesis.

In addition to using the P/C-ratio and the interaction variables P/C-ratio×cap and P/C-ratio×orgf2 it would also be interesting to include an interaction variable between P/C-ratio, the regulatory regime and organizational structure. In Table 3 a correlation matrix for the interaction variables between price, regulatory regime and the firms organizational structure is displayed. From this we can see that the cross-variables involving the retail electricity price are all positively correlated. It does not seem unlikely that we will encounter problems with multi-collinearity if the last interaction term is included in the regression equations.

	P/C-ratio	P/C-ratio×cap	P/C-ratio×orgf2	P/C-ratio×cap×orgf2
P/C-ratio	1	0.10566	0.20362	0.12966
P/C-ratio×cap	0.10566	1	0.31254	0.41337
P/C-ratio×orgf2	0.20362	0.31254	1	0.88372
P/C-ratio×cap×orgf2	0.12966	0.41337	0.88372	1

Table 3: Correlation matrix, interaction terms involving the electricity price

5 Econometric analysis

In Section 2.2 we stated five hypothesis about (1) the regulated price level and (2) the relationship between the regulated price and the unregulated price. Potentially there are at least two ways to identify cross-subsidization in this data set. Firstly the regulatory regimes affect the incentives for cross-subsidization and we would expect different degrees of cross-subsidization under different regimes. Secondly, it is likely that firms with different organizational structures have different scope for cross-subsidization and we would expect to observe more cross-subsidization for more closely integrated firms. Furthermore, we believe that it is reasonable to assume that some firms will be more prone to cross-subsidize than other firms depending on factors that we cannot observe. If this is the case this will (1) be captured in the firm specific intercepts of a fixed effects model and (2) show a negative relationship between the network and retail prices.

We have first estimated a panel data model, using the entire data set with variations in both the regulatory regime and organizational structure. It might, however, be difficult to isolate these effects in a joint model and to get a clearer picture we have tried to isolate these two factors and study only one at a time, while keeping the other constant. Keeping the organizational structure unchanged also allows us to control for endogeneity in the choice of organizational structure. The latter analysis is presented in Section 5.1.

In the baseline regression (Regression 1) we have estimated the real network price as a function of the retail price/cost ratio, the regulatory regime, the organizational structure and some additional control variables. The results are displayed in Table 4. When discussing the results we will focus on the fixed effects model, since

- according to the test statistic displayed in the table it is the preferred model, and
- it is likely that there exist important unobservable firm specific characteristics, which will influence the pricing behavior of the firms including the incentives and possibilities for a firm to cross-subsidize.

The first hypothesis stated above (Hypothesis 1a), which claimed that the regulated price would be higher during periods of cost-based regulation compared with periods with price-based regulation, is supported by the results from Regression 1. To study the effect from the regulatory regime a dummy variable, Cap, has been used. The value of this dummy variable is set equal to 0 for the cost-based regulatory period and equal to 1 for the price-based regulatory period. In all the models the coefficient for the Cap-variable

Dependent variable = Log(Real net price)						
	Pooling Model		Fixed Effects		Random Effects	
R2/Adj R2	0.2534	0.2470	0.8411	0.7994		
	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.
Constant	3.4963***	0.0425			3.4759***	0.0445
Time	−0.0622***	0.0122	−0.0426***	0.0070	−0.0475***	0.0068
Timesq	0.0101***	0.0021	0.0092***	0.0011	0.0095***	0.0011
Cap	−0.2664***	0.0727	−0.1769***	0.0409	−0.1688***	0.0404
Orgf2	−0.2344*	0.1366	−0.2372***	0.0860	−0.2225***	0.0844
Log(dens)	−0.1164***	0.0128	−0.0061	0.0162	−0.0396***	0.0140
Log(quant)	−0.0343***	0.0049	−0.0490***	0.0187	−0.0411***	0.0079
P/C-ratio	−0.0247	0.0412	−0.1758***	0.0292	−0.1414***	0.0279
P/C-ratio×cap	0.2630***	0.0667	0.1364***	0.0380	0.1368***	0.0376
P/C-ratio×orgf2	0.1806	0.1219	0.1952***	0.0759	0.1821**	0.0745

Sign of group effects:	X and group effects vs only X-variables			X and group effects vs only group effects	
F-test	Test stat	Prob value		Test stat	Prob value
	14.703	0		27.251	0

FE vs. RE:	Test stat	Prob value
Hausman test	35.78	0.0000

***, ** and * indicate point estimate significantly different from zero on the respectively 1, 5 and 10 per cent levels

Table 4: Regression 1. Analysis of the full panel.

show a significant negative effect on the real network price from changing the regulatory regime from a cost-based to a more price-based regulation.

In Hypothesis 1b it was claimed that the regulated price would be higher for a fully integrated firm compared with at less integrated firm. We have here used a dummy for the organizational structure (orgf2), which is set equal to 0 if the firm is "fully integrated" and equal to 1 if the firm is "less integrated". The results from Regression 1 also supports this hypothesis, showing a significant negative coefficient for the less integrated firms. This is particularly interesting since the existence of economies of scope would work in the opposite direction and reduce the regulated price. The cross-subsidization effect seems to dominate any effect from economies of scope.

Both the regulation and organizational structure dummies thus have negative and significant coefficients in the regression. These results are consistent with the cross-subsidization hypothesis, even though the regulatory regime dummy-variable also might capture effects on incentives for efficiency that the change in regulatory regime has had.

Hypothesis 2a claimed that there would be a negative relationship between the unregulated and regulated prices. This will only be true if there are some firms that cross-subsidizes while others are not, or that the degree of cross-subsidization differ, even though the firms have similar observable incentives and possibilities to engage in cross-subsidization. Since we wanted to control for any exogenous changes in the opportunity cost of providing electricity we used a price-cost ratio, instead of directly using the retail price. Changes in retail prices due to changes in taxes and the price of bulk-power do not effect the price-cost ratio. Regression 1 show a significant negative relationship between the price-cost ratio and the network price and thus supports the hypothesis.

Continuing with Hypothesis 2b, which claims that the negative relationship between the two prices would be smaller during periods with price-based regulation, compared with periods with cost-based regulation. The change in regulatory regime to a more price-based regulation decreased the incentives for firms to engage in cross-subsidization and we expect a less strong - if any - relationship between the two prices. Using a interaction variable between the price-cost ratio and the regulatory regime dummy we can investigate whether there is any significant difference in the relationship between the prices. The result from Regression 1 show a significant positive coefficient for the interaction term, which supports the hypothesis. Here we should however mention that at the same time as the regulatory regime changed the fee for switching electricity supplier was abolished. This decrease in switching cost should imply a more intense competition in the retail market. The positive coefficient for this interaction variable could possibly also be explained by the change in competition, since the hypothesis of a negative relationship depends on the assumption of imperfect competition. However, from figure 2 we can see that neither the average retail price nor the average retail price margin have decreased for the years 1997-1999 compared with the pre-1997 period. We can also see that the standard deviation has decreased somewhat in the later years, but that there still existed a large variation in retail prices between firms even in 1999. With perfect competition we would expect that all firms charged the same price, which is not the case here. We take this observation as an indication that even after the abolishment of the fee for changing supplier the electricity retail market was characterized by imperfect competition and conclude that the positive coefficient for the interaction term between the retail price and regulatory regime dummy depend on less cross-subsidization.

The last hypothesis (Hypothesis 2c) claimed that the negative relationship between the unregulated and regulated prices would be smaller for less integrated firms compared with fully integrated firms. Here we have used an interaction variable between the electricity retail price-cost ratio and the organizational structure dummy variable. If the hypothesis is true we would observe a positive coefficient for this interaction variable, which is also the case in Regression 1. Hypothesis 2c is thus also supported by the econometric analysis.

The total effect from the electricity price-cost ratio on the network price for differ-

Type of firm and regulatory period	Total effect on network price	Std.err.
Completely integrated firms 1994 – 1996	−0.1758	0.02915
Partly or non-integrated firms 1994 – 1996	−0.1758 + 0.1952 = 0.0194	0.07706
Completely integrated firms 1997 – 1999	−0.1758 + 0.1364 = −0.0394	0.03848
Partly or non-integrated firms 1997 – 1999	−0.1758 + 0.1952 + 0.1364 = 0.1558	0.07921

Table 5: Effect of retail price margin on network price

ent firms under different regulatory regimes are displayed in Table 5. The total effect for a completely integrated firm is negative under cost-based regulation (1994-1996), but not significantly different from zero after the change in regulatory regime. For "less integrated" firms the total effect is not significantly different from zero under cost-based regulation, but we observe a positive significant relationship under price-based regulation. The positive relationship can possibly be explained by correlation in efficiency, management skills etc. between the two operations. This effect should also be present, and probably larger, for completely integrated firms. However, it seems like the cross-subsidization effect dominates for integrated firms.

The remaining explanatory variables are not very interesting and only serves as control variables. However, they all show the expected signs. The dens variable is the network density measured as the number of customers divided by the length of the distribution network (in kilometers). A high number indicate a densely populated area, which reasonably should be cheaper to serve. In the fixed effects model the coefficient is not significantly different from zero, but it is so in the pooling and random effects models. The quantity variable measures the quantity of electricity delivered to consumers in the grid. The negative sign could be explained by economies of scale.

5.1 Isolating the effects from the regulatory regimes and the organizational structure

As mentioned above there are basically two different ways of identifying cross-subsidization in our data; changes in regulation and changes in organizational structure. One might get a clearer picture if the changes in regulatory regimes and organizational structures are isolated and studied one at a time. We have used two different approaches to study the effects from changes in the regulatory regime and two different approaches to study the effects of the organizational structure.

5.1.1 Effects from the regulatory regime

First, the effect from the regulatory regime can by studied by comparing firms that are most likely to be able to cross-subsidize, i.e., completely integrated firms that do not change their organizational structure, before and after the regulatory reform. This is done in Regression 2. Exploiting only the within-groups[7] variation means that we avoid the problem of potential endogeneity in the choice of organizational structure since the organizational structure is left unchanged. We will focus only on the effect from the change in regulatory regime, which is clearly exogenous. We will thus only use firms that are completely integrated throughout the period 1994-1999. The results from this exercise are presented in Table 6. We see that the change in regulatory regime has a negative effect on the network price level, that the relationship between the electricity retail price-cost ratio and the network price is negative, while the coefficient for the interaction term between the price-cost ratio and the regulatory regime dummy is positive. The change in regulatory regime reduce the negative relationship between the price-cost ratio and the network price, although it does not completely vanish in this sample. The results from Regression 2 thus render support to the cross-subsidization hypothesis.

Dependent variable = Log(Real net price)						
	Pooling Model		Fixed Effects		Random Effects	
R2/Adj R2	0.152966	0.14376	0.840072	0.80244		
	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.
Constant	3.4362***	0.0530			3.4416***	0.0566
Time	−0.0591***	0.0161	−0.03458***	0.00835	−0.0431***	0.0082
Timesq	0.0096***	0.0027	0.00842***	0.00133	0.0092***	0.0013
Cap	−0.2208***	0.0854	−0.15060***	0.04391	−0.1305***	0.0435
Log(dens)	−0.1103***	0.0161	−0.01711	0.01653	−0.0342***	0.0152
Log(quant)	−0.0232***	0.0067	−0.11025***	0.02321	−0.0366***	0.0115
P/C-ratio	−0.0204	0.0507	−0.17724***	0.03376	−0.1350***	0.0325
P/C-ratio×cap	0.2225***	0.0803	0.09938***	0.04172	0.0910**	0.0414

Sign of group effects:	X and group effects vs only X-variables			X and group effects vs only group effects	
F-test	Test stat	Prob value		Test stat	Prob value
	19.352	0		23.183	0

FE vs. RE:	Test stat	Prob value
Hausman test	38.64	0.0000

***, ** and * indicate point estimate significantly different from zero on the respectively 1, 5 and 10 per cent levels

Table 6: Regression 2. Effect of regulatory change. Only completely integrated firms 1994-99.

Secondly, we can also use the between-group variation and study only the firms that have the same organizational structure (integrated or not integrated) before and after the

[7] Here a group is intepreted as companies with the same organizational structure.

Dependent variable = Log(Real net price)						
	Pooling Model		Fixed Effects		Random Effects	
R2/Adj R2	0.2216	0.2024	0.9160	0.8158		
	Coeff.	**Std.Err.**	**Coeff.**	**Std.Err.**	**Coeff.**	**Std.Err.**
Constant	3.2205***	0.0944			3.2245***	0.0810
Cap	−0.3188**	0.1608	−0.1477	0.0983	−0.2082**	0.0906
Log(dens)	−0.0974***	0.0259	−0.0009	0.0411	−0.0553**	0.0267
Log(quant)	−0.0427***	0.0106	0.0334	0.0943	−0.0385***	0.0129
P/C-ratio	0.2132**	0.0987	−0.0618	0.1071	0.1014	0.0787
P/C-ratio×cap	0.2680*	0.1609	0.1327	0.0948	0.1702*	0.0887
P/C-ratio×orgf2	−0.1656**	0.0658	−0.4150	0.3899	−0.1957**	0.0817

Sign of group effects:	**X and group effects vs only X-variables**		**X and group effects vs only group effects**	
F-test	Test stat	Prob value	Test stat	Prob value
	7.249	0	1.326	0.2513

FE vs. RE:	Test stat	Prob value
Hausman test	13.89	0.0309

***, ** and * indicate point estimate significantly different from zero on the respectively 1, 5 and 10 per cent levels

Table 7: Regression 3. Effect of regulatory change. Only firm with unchanged organizational structure before and after change in regulation.

change in regulation. To be able to include companies that are not completely integrated we must then only use a sub-set of the cross-sections since almost every company has been completely integrated in some period, which force us to limit ourselves to only use data from one year before and one year after the change in regulation respectively. To minimize the problem that firms might either adopt the behavior before the regulatory reform comes into effect or that the adoption takes some time due to slow adjustment we will use data from 1995 and 1998. These results are displayed in Table 7. In the fixed effect model, which is preferred to the pooling model and the random effect model, none of the coefficient are significant. In fact, the explanatory variables are not jointly significant compared with using only the group effects. This is in fact not very surprising considering that we only use observation from two periods, but the results are anyhow inconclusive.

5.1.2 Effects from the organizational structure

The effect from the organizational structure can firstly be studied by exploiting between-groups variation and comparing firms with different organizational structure within the same period, i.e., looking at single cross-sections. In Regression 4 one cross-section has been analyzed at time trying to utilize between-group variation while keeping the regulatory regime constant. We will then isolate the effect coming from differences in organizational structure within the same year. These results are displayed in Table 8 and the

Dependent variable = Log(Real net price)						
	1994		1995		1996	
R2/Adj R2	0.2532	0.2334	0.2387	0.2185	0.2371	0.2162
	Coeff.	**Std.Err.**	**Coeff.**	**Std.Err.**	**Coeff.**	**Std.Err.**
Constant	3.6390***	0.0806	3.2514***	0.0870	3.3798***	0.0993
Orgf234	0.1870	1.0951	0.5675	0.5369	−0.0285	0.2893
Log(dens)	−0.1528***	0.0335	−0.1137***	0.0309	−0.0842***	0.0244
Log(quant)	−0.0206*	0.0121	−0.0355***	0.0120	−0.0443***	0.0107
P/C-ratio	−0.1595**	0.0737	0.1816**	0.0878	−0.0151	0.0857
P/C-ratio×orgf2	−0.2095	1.3099	−0.6979	0.4873	0.0442	0.2263
	1997		1998		1999	
R2/Adj R2	0.1792	0.1543	0.2802	0.2572	0.2650	0.2384
	Coeff.	**Std.Err.**	**Coeff.**	**Std.Err.**	**Coeff.**	**Std.Err.**
Constant	3.2334***	0.0922	2.9248***	0.1345	3.1351*	0.1829
Orgf234	−0.7942**	0.3843	−0.3002	0.5270	0.1804	0.4790
Log(dens)	−0.1300***	0.0431	−0.1041***	0.0300	−0.1323***	0.0346
Log(quant)	−0.0306**	0.0142	−0.0491***	0.0122	−0.0259*	0.0137
P/C-ratio	0.1450*	0.0865	0.4906***	0.1355	0.2690	0.1721
P/C-ratio×orgf2	0.6829*	0.3488	0.2455	0.4808	−0.2268	0.4471

***, ** and * indicate point estimate significantly different from zero on the respectively 1, 5 and 10 per cent levels

Table 8: Regression 4. Effect of organizational structure. Analysis of each separate cross-section.

estimated parameters are to a large extent insignificant. The organizational structure dummy is insignificant for all years except 1997 for which it is negative. The coefficient for the price-cost ratio is negative for 1994, positive for 1995 and 1998 and insignificant for the remaining years. The interaction term between the price-cost ratio and the organizational structure is positive for 1997 and insignificant for all other years. The results do no give much support for the cross-subsidization hypothesis, but comparing with the results from Regressions 1, 2 and 3 we see that we usually cannot detect the cross-subsidization pattern without utilizing the panel data structure, which is not possible when analyzing one cross-section at time. Controlling for unobserved firm specific characteristics thus seems important.

Finally one can use within-groups variation and study only those firm that change organizational structure keeping the regulatory regime unchanged. In Regression 5a and 5b we try to isolate the effect from changes in organizational structure and we only include those firms which change their organizational structure within one regulatory regime period, i.e., between 1994 and 1996 or between 1997 and 1999. We would expect to see the largest effects in the period 1994-1996 and these results are displayed in Table 9. The results show a significant negative coefficient for the price-cost ratio variable and the organizational structure dummy. The interaction variable between the price-cost ratio and the organizational structure turns up with a positive sign, but is insignificant. In the pooling and random effects models for the period 1997 to 1999 the estimated coefficient

Dependent variable = Log(Real net price)						
	Pooling Model		**Fixed Effects**		**Random Effects**	
R2/Adj R2	0.540413	0.45792	0.958733	0.92091		
	Coeff.	**Std.Err.**	**Coeff.**	**Std.Err.**	**Coeff.**	**Std.Err.**
Constant	3.9106***	0.1810			3.6089***	0.9247
Time	−0.1508	0.0909	−0.2511***	0.0440	−0.2509***	0.0440
Timesq	0.0906	0.0596	0.1652***	0.0331	0.1651**	0.0331
Orgf2	−0.2966	0.2555	−0.2535*	0.1281	−0.2526	0.1278
Log(dens)	−0.1745***	0.0559	−0.0994	0.2545	−0.1026	0.2517
Log(quant)	−0.0273	0.0258	0.0376	0.0673	0.0372	0.0671
P/C-ratio	−0.2955**	0.1319	−0.4707***	0.1269	−0.4709***	0.1268
P/C-ratio×orgf2	0.1593	0.2155	0.0718	0.0894	0.0714	0.0892

Sign of group effects:	**X and group effects vs only X-variables**			**X and group effects vs only group effects**	
F-test	Test stat	Prob value		Test stat	Prob value
	16.219	0		8.561	0.00003

FE vs RE:	Test stat	Prob value
Hausman test	*No result - could not invert matrix*	

***, ** and * indicate point estimate significantly different from zero on the respectively 1, 5 and 10 per cent levels

Table 9: Regression 5a. Effect of organizational structure. Only firms that change organizational structure within the period 1994-96.

Dependent variable = Log(Real net price)						
	Pooling Model		**Fixed Effects**		**Random Effects**	
R2/Adj R2	0.188616	0.1262	0.914121	0.83498		
	Coeff.	**Std.Err.**	**Coeff.**	**Std.Err.**	**Coeff.**	**Std.Err.**
Constant	2.9531***	0.5492			3.0782***	0.2917
Time	−0.1754	0.2837	−0.0231	0.1277	−0.0467	0.1269
Timesq	0.0195	0.0354	0.0067	0.0159	0.0091	0.0158
Orgf2	−0.1163	0.6115	−0.3095	0.3446	−0.2839	0.3338
Log(dens)	−0.0820	0.0525	−0.1956	0.3079	−0.0846	0.0690
Log(quant)	−0.0338**	0.0164	−0.0770	0.2524	−0.0439*	0.0239
P/C-ratio	0.6569***	0.2428	0.2388	0.1585	0.3066**	0.1476
P/C-ratio×orgf2	0.1194	0.5521	0.2627	0.3131	0.2385	0.3029

Sign of group effects:	**X and group effects vs only X-variables**			**X and group effects vs only group effects**	
F-test	Test stat	Prob value		Test stat	Prob value
	10.771	0		1.766	0.1148

FE vs RE:	Test stat	Prob value
Hausman test	6.96	0.4325330

***, ** and * indicate point estimate significantly different from zero on the respectively 1, 5 and 10 per cent levels

Table 10: Regression 5b. Effect of organizational structure. Only firms that change organizational structure within the period 1997-99.

for the price-cost ratio is actually positive and significant, which is an indication that in the absence of cross-subsidization there actually exists a positive relationship between the two prices. This could be explained both by the firm specific pricing behavior and/or correlation in efficiency between the network and retail operations of a particular firm.

6 Conclusion

Integrated firms operating in one regulated and one unregulated market generally have incentives to use cross-subsidization tactics to increase the price in the regulated market. From a theoretical point of view we expect to find that cross-subsidizing firms reduce their price in the unregulated imperfectly competitive market in order to increase its market share beyond what would otherwise be profitable. Cross-subsidization would cause an increase in the price in the regulated market and cause an overproduction in the unregulated market. If the unregulated market is characterized by imperfect competition an increase in production would lead to a decrease in the price of the unregulated service. The incentives for cross-subsidization are stronger in periods with more cost-based regulation and we thus expect that a change in regulation towards more price-based regulation would have a downward effect on the regulated price. Furthermore, more closely integrated firms are likely to have better possibilities to engage in successful cross-subsidization, and we except that less integrated firms would charge a lower price in the regulated market. This give us two predictions regarding the price level in the regulated market.

If some firms engage in cross-subsidization, while other do not we would find a negative relationship between the prices in the unregulated and the regulated markets. The incentives for cross-subsidization will be stronger during periods with cost-based regulation, compared with periods with price-based regulation. More closely integrated firms will also have better possibilities to engage in successful cross-subsidization.

Using panel data from the Norwegian electricity retail industry these hypotheses are tested and we can conclude that they are supported by data. The regulated price is significantly higher in periods with cost-based regulation and there is a significant negative relationship between the prices. This negative relationship is smaller for less integrated firms. Furthermore, less integrated firms have a lower price level. The organizational structure seems to matter. From the cross-subsidization point of view it seems to be better to require a complete separation of the two operations into separate legal entities and not only require a separation of accounts.

The fact that the price level decreased when regulation became more price-based indicates that the problem is more severe with cost-based regulation. This observation could however both depend on less cross-subsidization, but also reflect the fact that the regulatory change for instance increased the incentives for cost efficiency and that the regulation generally became tougher. However, combined with the fact that the negative relationship between the unregulated and regulated prices is reduced when price-based regulation was introduced this suggest that a cross-subsidization effect is present as expected.

The results are consistent with the hypothesis that firms in the electricity retail industry cross-subsidizes if there are incentives to do so. This is particularly true for integrated firms under cost-based regulation. This result has important policy implications. A regulator/legislator, presently using cost-based regulation, wishing to reduce the amount of cross-subsidization should therefore strongly consider introducing price-based regulation and require vertical separation. The test can however not be used by a regulator as a proof of cross-subsidization in the individual case, but a high regulated price combined with a low unregulated price might be an indication of cross-subsidization that calls for further investigations. The EU electricity directive (Directive 96/92/EC) requires vertical functional separation and this position is supported by the results here.

Finally, from a welfare point-of-view one might question to what extent it is reasonable to devote resources to prevent cross-subsidization. Rate-of-return regulation creates incentives for cross-subsidization and "over-production" in the unregulated market. We have here assumed that the unregulated market is characterized by imperfect competition which means that the producer will choose to under-produce. As already pointed out by Kahn (1970*a*) these are opposing effects. However, the possibility to cross-subsidize might also work as a credible predatory threat and help the regulated firm to maintain a monopoly price in the unregulated market. Potential entrants may expect that the post-entry price will fall below the level that would cover the entrants long run cost. Such as strategy could be compared with using capacity as an entry deterrent. This would strengthen the case against allowing cross-subsidization.

A Cost-based regulation with economies of scope

Let r and u be the product produced for the regulated market and the unregulated market respectively. p_r and p_u are the prices for the two products. The cost of producing the regulated product alone is $c(r,0)$, and the incremental cost of producing the regulated product when simultaneously producing the unregulated product is $c(r,u)-c(0,u)$. If there are economies of scope the stand-alone cost, $c(r,0)$, will be higher than the incremental cost, $c(r,u)-c(0,u)$. Without economies of scope $c(r,0)=c(r,u)-c(0,u)$.

If the regulator uses some cost-based regulation it could adopt two different extreme cost-recovery rules. Either p_r could be set equal to the average stand-alone cost, i.e., $p_r(r)=c(r,0)$, or equal to the average incremental cost, i.e., $p_r(r)=c(r,u)-c(0,u)$. In reality it is likely that the cost-recovery rule will be somewhere in between these two extremes,

$$\begin{aligned} P_r(r)\cdot r &= (1-k)\cdot c(r,0)+k\cdot[c(r,u)-c(0,u)] \\ &= c(r,0)+k\cdot[c(r,u)-c(r,0)-c(0,u)], \end{aligned} \tag{9}$$

where $k\in[0,1]$. If $k=0$ customers share none of the gains from economies of scope and if $k=1$ customers gains fully from economies of scope. Without economies of scope k has no effect.

However, cost information is not necessarily known to the regulator and by producing the unregulated product, the firm might be able to mislead the regulator about its costs of producing r. If it can misallocate costs without limit it the firm will in practice be unregulated [Brennan (1987)]. That is however not very likely and we will assume that the level of successful cross-subsidization is exogenously given by $s(u)$, with $\frac{\partial s}{\partial u}\geq 0$. Instead of getting a regulated price according to equation 9 the firm can obtain $s(u)$ in addition, which results in the rule

$$P_r(r)\cdot r=s(u)+c(r,0)+k\,[c(r,u)-c(r,0)-c(0,u)] \tag{10}$$

and the profit maximization problem of the firm will thus be

$$\max_{r,u} P_r(r)\cdot r+P_u(u)\cdot u-c(r,u)-\lambda[P_r(r)\cdot r-s(u)-(c(r,0)+k\cdot[c(r,u)-c(r,0)-c(0,u)])]. \tag{11}$$

If the firm lack the ability to engage in cross-subsidization the corresponding expression would be

$$\max_{r,u} P_r(r)\cdot r+P_u(u)\cdot u-c(r,u)-\lambda[P_r(r)\cdot r-(c(r,0)+k\cdot[c(r,u)-c(r,0)-c(0,u)])]. \quad (12)$$

From these two profit maximization expressions we obtain the first-order conditions with respect to r with cross-subsidization

$$(1-\lambda)\left[\frac{\partial P_r(r^{xsub})}{\partial r}\cdot r^{xsub}+P_r(r^{xsub})-\frac{\partial c(r^{xsub},u^{xsub})}{\partial r}\right] \\ -\lambda(1-k)\left[\frac{\partial c(r^{xsub},u^{xsub})}{\partial r}-\frac{\partial c(r^{xsub},0)}{\partial r}\right]=0 \quad (13)$$

and without cross-subsidization:

$$(1-\lambda)\left[\frac{\partial P_r(r^{no\_xsub})}{\partial r}\cdot r^{no\_xsub}+P_r(r^{no\_xsub})-\frac{\partial c(r^{no\_xsub},u^{no\_xsub})}{\partial r}\right] \\ -\lambda(1-k)\left[\frac{\partial c(r^{no\_xsub},u^{no\_xsub})}{\partial r}-\frac{\partial c(r^{no\_xsub},0)}{\partial r}\right]=0. \quad (14)$$

It is clear that cross-subsidization has no direct effect on the firms first-order-condition with respect to r. From the regulatory rules in equations 9 (without cross-subsidization) and 10 (with cross-subsidization) show that the firm will be able to increase its price of the regulated service with $\frac{s(u)}{r}$ per unit. This price increase might have an second order effect, since it might cause a reduction in quantity (from r^{xsub} to r^{no_xsub}). This second order effect will however clearly be dominated by the direct effect from the cross-subsidization. We can thus conclude that cross-subsidization will increase the price for the regulated service.

Using equation 13 we find that

$$\begin{aligned}\lambda &= \frac{\Delta\Pi}{\Delta\Pi+\Delta E}, \text{ where} \\ \Delta\Pi &= \frac{\partial P_r(r^{no\_xsub})}{\partial r}\cdot r^{no\_xsub}+P_r(r^{no\_xsub})-\frac{\partial c(r^{no\_xsub},u^{no\_xsub})}{\partial r}, \text{ and} \\ \Delta E &= (1-k)\left[\frac{\partial c(r^{no\_xsub},u^{no\_xsub})}{\partial r}-\frac{\partial c(r^{no\_xsub},0)}{\partial r}\right].\end{aligned}$$

ΔE is the marginal change in the regulatory rule due to economies of scope. With economies of scope $\Delta E < 0$, otherwise $\Delta E = 0$. $\Delta\Pi$ is the marginal profit from producing one more unit of r. Here we can distinguish two cases. First, if the regulation is causing

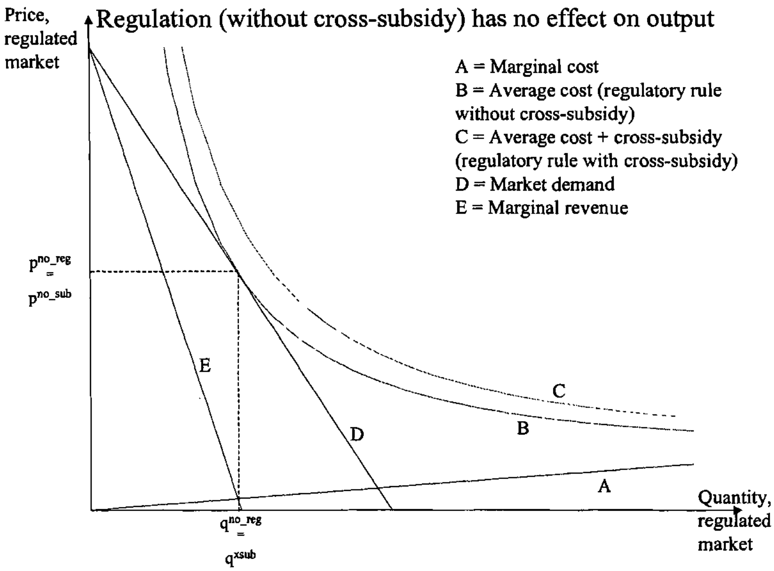

Figure 4:

the firm to increase its production of r $\Delta\Pi < 0$, which implies that $\lambda \leq 1$. Second, if the regulation has no effect on the quantity r and the firm is producing at the unregulated level $\Delta\Pi = 0$, implying that $\lambda \geq 0$. The case that regulation will reduce output so that $\Delta\Pi > 0$, i.e., that $MR > MC$, will not happen since there is nothing that prevents the firm from increasing its output and reducing its price beyond the regulatory requirements. Thus, we know that $0 \leq \lambda \leq 1$.

Figure 4 illustrates the situation when the regulation (without cross-subsidy) has no effect on the output of the regulated product. If the market was deregulated the profit maximizing firm would set r so that $MR = MC$, resulting in the price p^{no_reg}, which is also the average cost. The regulator sets the price equal to average cost, which in this case is equal to the unregulated price and we have no effect on output.

The slope of the average cost curve is

$$\begin{aligned}\frac{\partial}{\partial r}AC &= \frac{\partial}{\partial r}\left[AFC + AVC\right] = \frac{\partial}{\partial r}\left[\frac{FC}{r} + \frac{VC}{r}\right] \\ &= -\frac{FC}{r^2} + \frac{MC}{r} - \frac{VC}{r^2} = \left[MC - AC\right]/r\end{aligned}$$

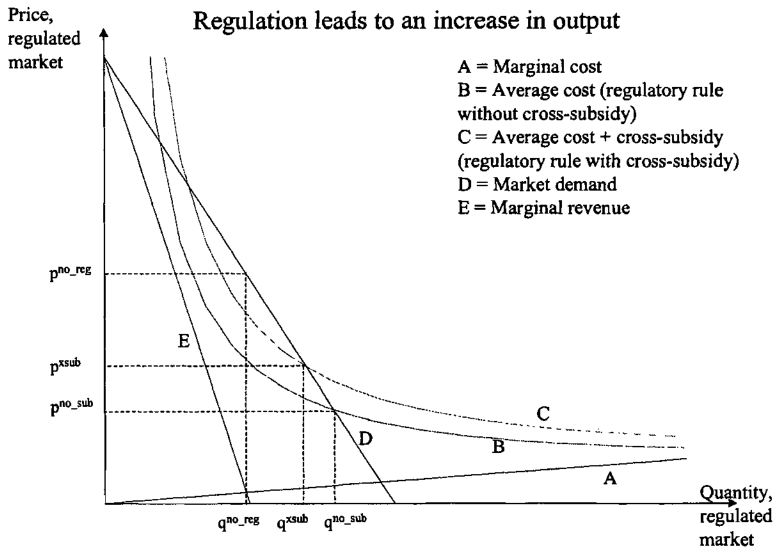

Figure 5:

which for the profit maximizing quantity (i.e., when $MR = MC$) is equivalent with

$$\left[\frac{\partial p_r}{\partial r} r + p_r - AC\right] / r.$$

When the price set by the regulator equals the price that the firm would set if unregulated $p_r = AC$ and we see that the slope of the $AC-$ curve is $\frac{\partial p_r}{\partial r}$, which is also the slope of the demand curve. When average costs are lower than the profit maximizing price that the firm would set we see that the slope of the average cost curve is flatter than the slope of the demand curve, which is illustrated in Figure 5. Since the average cost curve is flatter it will intersect the demand curve at some point to the right of the unregulated profit maximizing quantity. Regulation will thus cause an increase in quantity.

We will now continue with the effect on the price of the unregulated service. From equations 11 and 12 we obtain the first-order conditions with respect to u with and without cross-subsidization, which after some rearranging are:

$$\begin{aligned} &\frac{\partial P_u(u^{xsub})}{\partial u}\cdot u^{xsub} + P_u(u^{xsub}) + \lambda\left[\frac{\partial s(u^{xsub})}{\partial u}\right] \\ = &\frac{\partial c(r^{xsub}, u^{xsub})}{\partial u} + \lambda k\left[\frac{\partial c(0, u^{xsub})}{\partial u} - \frac{\partial c(r^{xsub}, u^{xsub})}{\partial u}\right] \end{aligned} \tag{15}$$

and

$$\begin{aligned} &\frac{\partial P_u(u^{no\_xsub})}{\partial u}\cdot u^{no\_xsub} + P_u(u^{no\_xsub}) \\ = &\frac{\partial c(r^{no\_xsub}, u^{no\_xsub})}{\partial u} + \lambda k\left[\frac{\partial c(0, u^{no\_xsub})}{\partial u} - \frac{\partial c(r^{no\_xsub}, u^{no\_xsub})}{\partial u}\right] \end{aligned} \tag{16}$$

respectively. The left-hand side in each of these two expressions are the marginal revenues. With cross-subsidization (equation 15) the effect from the marginal cross-subsidy is added to the ordinary marginal revenue - an effect which of course is absent when no cross-subsidization take place. The right-hand side in these expressions are the marginal cost. Since the regulatory rule only allows the firm to capture some fraction of the gains from economies of scope a term representing the part of the marginal economies of scope that the consumers reap is added to the costs in both expressions. The effect from the economies of scope is similar in both expressions - the only difference is that the equilibrium quantities might differ. The obvious total effect is that the extra marginal revenue due to cross-subsidization will increase the output of the unregulated service and as an effect the price of the unregulated service, p_u, will decrease. Which is illustrated in Figure 1.

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IV

Residential Electricity Demand*

Effects of Behavior, Attitudes and Interest

Niclas Damsgaard

Abstract

Households electricity consumption constitute a considerable part of total electricity consumption and knowledge about what determines their electricity demand is of interest to many parties. Previously there exist a number of studies using both aggregated data and detailed household micro data where the demand for electricity are estimated.

The purpose of this study is to investigate whether information about the household's stated behavior, attitudes and interest in energy issues can improve our understanding of household's demand for electricity. The main conclusion is that information about the stock of appliances, in addition to economic and demographic information, is important, but that the information about behavior, attitudes and interest are less important.

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1 Introduction

The electricity demand of household constitutes a considerable part of total electricity demand. In Sweden domestic consumption is approximately about 1/3 of total consumption. Thus, estimation and prognostication of domestic electricity consumption are of interest for many parties. Governments may, for environmental or other reasons, want to induce energy conservation through taxation. The introduction of competitive markets may bring about reductions in prices, which then would have an opposite effect. Energy companies can of course also benefit from a further understanding of electricity demand. Considerable resources have thus for a long time been spent on analyzing electricity consumption.

Early studies often used aggregated time-series data to analyze the demand for electricity, but today there also exist numerous studies using micro-data (see Madlener (1996) for a survey). There exist several approaches when modeling energy demand. For an economist variables such as prices and income are the natural starting point for the analysis and additional explanatory variables may then be added. Much of the analysis done have a technical foundation use more of a bottom-up approach where data on, for instance, heating technology, size of the dwelling and the stock of durables in the household are the starting point. The appliances do by themselves, of course, not cause consumption of electricity. Instead it is the use of these appliances that cause the consumption. The use is affected by many factors, but the attitudes and behavior of the household members is of importance. Some authors (e.g. Schipper et al., 1992) have thus argued that neither the economic nor the technical data is enough, but that information regarding the preferences and activities of the households is also needed, i.e., "...how people and technology interact to provide the services that are desired" (Schipper et al., 1992, p. 56). The primary purpose of this paper is to test the relative value of these three approaches, or level of data requirements, when it comes to understanding household electricity consumption and analyze whether additional information on preferences and behavior improves our understanding of the electricity demand.

Even though it is natural to assume that a more detailed data set facilitates a more thorough analysis of electricity demand, the collection of such data set is also associated with increases in costs. It is not only more difficult to collect a more detailed data set of a given size, but to be able to exploit it one would also need more observations. If such detailed data does not substantially improve our understanding of the electricity demand, one may question whether it is worthwhile to collect it.

The data set used in this study is very detailed and contains information not only about economic, demographic and technical characteristics of the households, but also about their behavior, attitudes and interest in energy issues. In fact, the collection of the data set was to a large extent done with the need for the latter type of information in mind. The data set is particularly well suited to investigate whether the inclusion of more detailed data on household preferences and activities improves the estimation of electricity demand.

The modelling approach used here follows an extensive literature of energy demand studies. The demand for electricity is estimated by a single equation using survey data combined with register data. The demand is conditioned on the stock of durables in the household, such as dwelling size, insulation, heating standard and the stock of electric appliances. Furthermore, the respondents have been asked how they use different appliances and about their attitudes towards, knowledge about and interest in energy issues.

Strictly speaking the model used is a short-run model since the demand for electricity is conditioned on goods of a durable nature. On the other hand, the price variations in the data set are regional price variation, which have been present for a long period of time. The households have thus adjusted their electricity consumption, and stock of appliances, to these price differences. Assuming that people to not adjust their behavior immediately if prices change, the model could be seen as a partial long-run model in which the household have been given time to adjust their behavior, but the stock of appliances is kept constant. We should probably not expect that households react to extremely short-run fluctuations in the electricity price in the same way as the estimations here show.

2 Literature

Early studies of energy demand often used log-linear demand functions applied to aggregated data. This may be problematic for many reasons. One problem is that the use of aggregated data usually implies that the number of observations are restricted, which affects the precision of the estimates negatively. Secondly, and perhaps more important, consumption choice is intrinsically a micro phenomenon and thus better analyzed at the micro level. The use of micro data to analyze residential demand for energy is today widespread. The studies usually simplifies the consumers decision making problem by assuming separability between the demand for energy and other goods and estimate a single demand equation. Compared with analyzing a complete demand system, the advantage is that it opens up for the possibility to introduce a detailed vector of explanatory variables that are of specific importance for energy demand, e.g., the stock of durable appliances. Most of these studies can be categorized based on the exogeneity assumptions made.

In the first group all included variables are assumed exogenous. Some examples of demand studies assuming exogeneity of all included explanatory variables are Parti and Parti (1980), Gillingham and Hagemann (1984), Garbacz (1982; 1985*b*; 1985*a*), Hartman and Doane (1986), Green (1987), Reilly and Shankle (1988), Morss and Small (1989*a*), Baker, Blundell and Micklewright (1989), Baker and Blundell (1991), Schwarz and Taylor (1995), Bartels, Fiebig and Plumb (1996), Haas, Biermayr, Zoechling and Auer (1998), Leth-Petersen and Togeby (2001) and Leth-Petersen (2002).

Many have considered this exogeneity assumption as to restrictive. The choice of appliances and the use of these may be related decisions by the households. For instance may, especially for the most energy consuming durables, energy efficiency may be traded off with the purchase price of the durable. If the demand for durables and their use are related decisions by the consumer it should also be modelled as such. Hausman (1979) modelled demand for electricity and the acquisition of air conditioners simultaneously and Dubin and McFadden (1984) modelled the demand for electricity simultaneously with the holding of heating equipment. According to Dubin and McFadden (1984) estimations where the choice of durables are not explicitly analyzed are likely to underestimate the true long-run price sensitivity since portfolio shifts are the primary contributor to price sensitivity. The estimated income elasticity might at the same time be too large. Following these two studies, a number of studies have been conducted. This approach is attractive since, especially for the more energy consuming durables, the exogeneity assumption is most likely not correct. Some problems do however arise with this approach. First the data requirements are quite severe and very rich data sets, with information on operating and capital costs for durables, are needed. Secondly, restrictive assumptions about housing markets and price expectations have to be made.

There also exists a third group of studies, in which the demand for energy for households facing block rates are modelled. Block rates implies that the marginal price facing the consumer is a function on the level of consumption. This implies that price and consumption are determined simultaneously. This is not of part of the problem that we face here and this literature will therefore not be discussed further.

Variable	Short description	Source
Consumption	Standardized consumption of electricity measured in kWh: $(E/NDays) \cdot 365$	Company register data
Price	Variable price for electricity	Company register data
Income	Sum of income in the household	Public register data
# persons	Number of persons in the household	Questionnaire
Heatarea	Heated dwelling area	Questionnaire
Building year	Year of construction	Questionnaire
Age	Age of oldest person in the household	Questionnaire
Educ2	Highest degree in household is high school (Sw. gymnasieskola)	Questionnaire
Educ3	Highest degree in household is college/university	Questionnaire
Appliances	Dummy variables = 1 if the appliance is present in the household	Questionnaire
Appliance use	Level of use with 3 to 5 categories for each appliance. Dummy variables.	Questionnaire
Appliance index	Index variable capturing level of use for each variable	Calculated from info in questionnaire
Energy conservation measures	Dummy variables = 1 if the technology is present.	Questionnaire
Energy conservation index	Index capturing the total level of energy conservation technologies present	Calculated from info in questionnaire
Advice	Dummy variable = 1 if the household has been in contact with an energy advisor	Questionnaire
Eloff	Dummy variable = 1 if the respondent is familiar with the "Eloff" energy label	Questionnaire
Interest	Level of interest in energy issues. From 0 = "not at all" to 3 = "much"	Questionnaire

Table 1: Description and sources for selected variables

3 Data

The data consists of household survey data which is combined with public and company register data on income, prices, consumption and local weather conditions. The survey data covers household characteristics (e.g. size of family, age, education), size of dwelling, heating system, insulation and other energy conservation measures taken, the stock and use of appliances and awareness about and interest in energy conservation issues. In this section the included variables will be described and discussed. A short description of selected variables can be found in Table 1 and some summary statistics and correlations can be found in Tables 2 and 3.

The data was collected by Statistics Sweden during 1997. The original data set covered about 1600 households. After exclusion of a few outliers the data set includes 1559 households. The data set can be divided into four categories depending on heating system and dwelling type:

1. Single family houses with only electric heating (381 obs)

	All single family houses			Houses with electric heating		
Variable	**Mean**	**Std Dev**	**N**	**Mean**	**Std Dev**	**N**
Consumption, kWh	15836.44	9875.55	1225	22208.04	8368.65	381
Price	69.34636	11.256325	1205	66.949078	13.19363	375
Income	20255.9	10300.04	1072	20895.81	10837.04	334
# persons	2.7307061	1.2971341	1218	2.6931217	1.268264	378
Heatarea	124.55382	40.813407	1217	124.64474	39.330044	380
Stove	0.9950577	0.0701567	1214	0.9973262	0.0517088	374
Microwave	0.7559184	0.4297168	1225	0.7585302	0.4285372	381
Dishwasher	0.6579592	0.4745869	1225	0.6666667	0.4720244	381
Laundry	0.9673469	0.1777995	1225	0.9632546	0.1883835	381
Tumbler	0.3755102	0.4844521	1225	0.3805774	0.4861673	381
Drying cabinet	0.1853061	0.3887044	1225	0.2755906	0.4473989	381
TV	0.9802794	0.1390957	1217	0.9761905	0.1526574	378
Computer	0.4726531	0.4994555	1225	0.4986877	0.5006557	381
Fridge	0.7640816	0.4247448	1225	0.7979003	0.4020943	381
Fridge/freezer	0.284898	0.4515502	1225	0.2572178	0.4376752	381
Freezer	0.5820408	0.4934248	1225	0.6509186	0.4773065	381
Freezerbox	0.475102	0.4995837	1225	0.3490814	0.4773065	381
Sauna	0.1714286	0.377037	1225	0.1496063	0.3571541	381
Car engine heater	0.4416327	0.4967844	1225	0.3937008	0.4892123	381
Car heater	0.3306122	0.4706257	1225	0.2965879	0.4573538	381
Infra	0.1804082	0.3846841	1225	0.1811024	0.3856094	381
Extra electric heating	0.1314286	0.3380065	1225	0.0734908	0.2612836	381
Advice	0.1284176	0.3346928	1207	0.128000	0.3345362	375
Eloff	0.087348	0.2740745	1199	0.0673854	0.2510269	371
Interest	1.6806370	0.7789829	1193	1.6883469	0.7681851	369
	Houses with mixed heating			**Houses without electric heating**		
Variable	**Mean**	**Std Dev**	**N**	**Mean**	**Std Dev**	**N**
Consumption, kWh	18377.8	8763.03	435	7198.13	5105.63	409
Price	69.518389	12.086102	423	71.376366	7.3547943	407
Income	21382.26	11168.64	375	18503.51	8496.95	363
# persons	2.7465438	1.2967536	434	2.7487685	1.3262538	406
Heatarea	127.05774	43.02044	433	121.78465	39.661479	404
Stove	0.9907621	0.0957796	433	0.997543	0.0495682	407
Microwave	0.7770115	0.41673	435	0.7310513	0.4439563	409
Dishwasher	0.7195402	0.4497411	435	0.5843521	0.493437	409
Laundry	0.9724138	0.1639726	435	0.9657702	0.1820417	409
Tumbler	0.4229885	0.4946025	435	0.3202934	0.4671607	409
Drying cabinet	0.183908	0.3878553	435	0.1026895	0.3039247	409
TV	0.9815668	0.1346669	434	0.982716	0.1304885	405
Computer	0.5126437	0.5004156	435	0.405868	0.4916606	409
Fridge	0.7724138	0.4197568	435	0.7237164	0.4477064	409
Fridge/freezer	0.2781609	0.448609	435	0.3178484	0.4662105	409
Freezer	0.6068966	0.4890019	435	0.4914425	0.500539	409
Freezerbox	0.5011494	0.5005744	435	0.5647922	0.4963914	409
Sauna	0.2206897	0.4151891	435	0.1393643	0.3467504	409
Car engine heater	0.5103448	0.5004686	435	0.4132029	0.4930117	409
Car heater	0.3885057	0.4879717	435	0.3007335	0.4591386	409
Infra	0.2114943	0.4088382	435	0.1466993	0.3542392	409
Extra electric heating	0.1655172	0.3720746	435	0.1491443	0.3566669	409
Advice	0.1561772	0.3634471	429	0.0992556	0.2993765	403
Eloff	0.0762125	0.2656447	433	0.1012658	0.3020630	395
Interest	1.7652582	0.7554131	426	1.5829146	0.8042141	398

Table 2: Summary statistics

	Cons	Price	Income	#Persons	Heatarea	Building year	Degree days	City	Town	Rural
Cons	1	−0.243***	0.301***	0.174***	0.322***	0.080***	0.050*	0.119***	−0.001	−0.091***
Price	−0.243***	1	−0.234***	−0.031	−0.045	0.049*	−0.357***	−0.586***	−0.052*	0.489***
Income	0.301***	−0.240***	1	0.361***	0.424***	0.105***	0.014	0.234***	−0.0318	−0.154***
#Persons	0.174***	−0.031	0.361***	1	0.331***	0.091***	0.059**	0.029	0.094***	−0.097***
Heatarea	0.322***	−0.045	0.424***	0.331***	1	0.143***	−0.041	0.062**	−0.056**	−0.003
Building year	0.080***	0.049*	0.105***	0.091***	0.143***	1	−0.041	−0.116***	−0.008	0.095***
Degree days	0.050*	−0.357***	0.014	0.059**	−0.041	−0.041	1	0.093***	0.305***	−0.315***
City	0.119***	−0.586***	0.234***	0.029	0.062**	−0.116***	0.093***	1	−0.183***	−0.618***
Town	−0.001	−0.052*	−0.032	0.094***	−0.056**	−0.008	0.305***	−0.183***	1	−0.660***
Rural	−0.091***	0.489***	−0.154***	−0.097***	−0.003	0.095***	−0.315***	−0.618***	−0.660***	1

***, ** and * indicate correlation coefficient significantly different from zero on the respectively 1, 5 and 10 % levels

Table 3: Pearson correlation coefficients for selected variables

2. Single family houses with mixed heating[1] (435 obs)

3. Single family houses without electric heating (409 obs)

4. Apartments (334 obs).

The division into heating categorizes for the single family houses is based on the information given by the respondents in the questionnaire regarding used heating system[2]. Apartments and single family houses differ in many important aspects and in the estimations only single family houses are included, which means that the data set is reduced to 1225 observations. In the analysis some additional observations are also lost due to missing observations caused by incomplete answers from the respondents.

The consumption variable is the measured consumption obtained from company register. If the measurement period is shorter or longer than one year the consumption is re-calculated to yearly consumption. The observation is excluded if the measurement period is shorter than 90 days. If measured consumption is not available estimated consumption is used[3].

[1]Electric heating combined with some other heating (oil, wood stove, etc).

[2]The respondents answered questions on both used and exisisting heating system. The choice between these two categorizations is for practical purposes rather arbitrary. Furthermore, register information from the power companies contained information on heating system, but only with two categories: with and without electric heating. That information is both less detailed compared with the survey information, but in some cases it also seems to be incorrect.

[3]The register data contains measured and/or estimated consumption of electricity. Measured consumption is the actual consumption during the measurement period, while estimated consumption is an estimate primarily based on earlier consumption. In practice the estimated consumption is thus lagged measured consumption. The difference between these is usually rather small.

The price is obtained from company register data and is the constant variable (marginal) price for electricity. For customers with time dependent price[4] a weighted average price is calculated using the consumed quantities in each period as weights. As shown in Table 2 the price exhibits considerable variation. The primary source of this variation are regional differences, i.e., differences between companies. At the time the data was collected the deregulation of the Swedish electricity market had not yet had any significant effect on prices for household consumers and these regional price differences had been rather stable over time. Table 3 displays correlation coefficients for selected variables. From there we can see that, as expected, there is a significant negative correlation between price and consumption of electricity.

The household income is obtained from public register data and is the sum of the monthly income for all adults in the household. In the survey the respondents were asked about the number of persons in the household and the personal numbers[5] of the adults. This information was later used to obtain register data on income. In general we would expect a positive income effect and the correlation coefficient is also positive. Primarily this effect should go via a larger home and the stock of appliances, but there may also be a direct effect if persons with higher income are less concerned with the cost of electricity. On the other hand, people with higher income are less likely to be credit constrained and may thus be more likely to invest in energy saving technologies (better insulation, heating equipment). These effects should however be captured by the introduction of such variables directly.

In the questionnaire the respondents have reported the existence (dummy variables) and use of each appliance in three to five categories for each appliance. For each use level there is a dummy variable, which is set equal to one if it is the stated level of use for the appliance and zero otherwise. If the appliance is not present in the household all use level dummies for that appliance are set equal to zero. In some specifications these use levels are included as dummy variables.

The reported appliance stock and use are also the basis for appliance indexes that are constructed for each appliance. These indexes are intended to capture both the effect of appliance holdings and the use of the appliance in one variable for each appliance. The index is set to 0 if the appliance is not present in the household. The index is then constructed using the reported use levels from the questionnaire, where the relative difference between the index values corresponds to the relative difference in use, e.g., if

[4]Some customers (mostly with electric heating) have two meters used in high respectively low load periods (day and night prices).

[5]Comparable to social security number.

the appliance is used once a day the index values value is seven times higher compared with if the appliance is used once a week.

Many households have not filled out the questionnaire completely. Many respondents have only filled out which appliances they have and left out answers for appliances which they do not have. Exclusion of observations due to incomplete answers of this kind would lead to a dramatic loss of observations if all (or many) appliances are to be included in the regression. To reduce this problem it is assumed that missing observation for appliance holdings implies that the appliance is not present in the household.

Installed energy conservation technologies are included in two ways. The first alternative is to introduce them as dummy variables, which are set equal to one if a particular conservation measure has been taken. To save on the degree of freedoms a index variable for heating conservation is constructed in the following way. The before mentioned dummy variables are multiplied with a relative impact factor for each of these conservation measures, which are then summed to an index. The relative impact factors are based on information on energy conservation contained in the brochure *"Minska energikostnaderna i ditt hus"*[6] published by the Swedish Energy Agency (Statens Energimyndighet, 2001).

The data set also includes two variables intended to capture regional variations. Since the price variation primarily comes from regional price differences it is of particular importance the control for other regional factors. The first variable is degree days, which captures local weather conditions. If for instance the price is lower in colder areas, we could get significant price effect in the estimation, even if it is in reality is driven by the weather characteristics. From the correlation matrix in Table 3 we do in fact see a negative correlation between price and degree days, which implies a lower price in colder areas. The other are dummy variables capturing type of location, i.e., if the household is in a city, town or rural area. It is not unreasonable that habits differ between different locations, e.g., people living in cities might spend more time out of their homes which would reduce electricity consumption, and controlling for type of location may thus be important.

The level of education may have an effect on electricity consumption if for instance higher educated persons have better access to information regarding energy conservation. Education is measured in three levels: elementary school (Sw. grundskola), high school (Sw. gymnasieskola) and college/university, where the respective dummy variable is set equal to one if the level is completed and zero otherwise. The educational level for the highest educated person in the household is used and included as dummy variables.

[6]Translation of title: "Reduce the energy costs in your house"

In the questionnaire the respondents were also asked questions regarding their knowledge about and interest in energy issues. They were asked whether they are interested in energy issues, if they are familiar with a particular energy labeling system[7] and if they at any time had been in contact with a energy advisor. Of the respondents a little less than 13 per cent had been in contact with an energy advisor. The share is somewhat higher for households with mixed heating and lowest for households without electric heating. The average interest in energy issues is 1.68[8]. Households with mixed heating have the strongest interest, while households without electric heating have the weakest interest. Almost 9 per cent is familiar with the Eloff energy label, with the highest rate of familiarity among households without electric heating.

4 Econometric model and estimations

The econometric model to be estimated is a single demand equation for consumption of electricity in a household. The demand is conditioned on the stock of durables. A full long-run model of electricity demand could be described by the following two equations

$$E = E(P_e, K, I, Z) \quad (1)$$

$$K = K(P_k, P_e, I, W), \quad (2)$$

where$E$ is household consumption of electricity, P_e is a vector of energy prices, P_k is a vector of prices for durables, K is a vector of durables, I is household income and Z and W are two vectors of other explantory varibles. Due primarily to the problems with endogenizing the stock of durables the choice of heati. ͜ ,stem and the stock of appliances are not analyzed here, but treated as exogenous variables. Equation 2 is thus fixed and equation 1 is replaced with

$$E = E(P_e, \bar{K}, I, Z),$$

where $\bar{K}$ is the fixed stock of durables. The model is short-run in the sense that the demand is conditioned on the stock of durables, which of course can be adjusted in the long-run. However, the price variations displayed in the material are primarily due to regional variations in the price. These variations have been present for a considerable

[7]The labeling system Eloff was at that time used in Sweden to label household appliances with a low energy consumption. In the questionnaire the symbol used for labeling was printed next to the question.
[8]0 = "not at all", 1 = "little", 2 = "fairly much", 3 = "much".

time and the households have thus been able to adjust their behavior to these prices. Furthermore, the purpose of this paper is not to perfectly model the stock of durables, but to investigate whether additional information on consumer behavior and attitudes can improve our understanding of household electricity consumption. Since the stock of appliances is not explicitly modelled it is possible that the importance of these variables, in addition primarily to economic variables such as prices and income, in explaining the electricity demand is overstated. If the full long-run model was estimated some of the effect that we expect to see from the stock of durables would most likely be price and/or income effects since price and income possibly could explain the stock of durables.

It is thus simply assumed that the conditional demand for electricity by a household can be described by

$$\begin{aligned} E &= \alpha + \boldsymbol{\beta}_1 \mathbf{heat} + \boldsymbol{\beta}_2 \mathbf{location} + \boldsymbol{\beta}_3 (\mathbf{price} \times \mathbf{heat}) + \boldsymbol{\beta}_4 (\mathbf{income} \times \mathbf{heat}) \\ & + \boldsymbol{\beta}_5 (\mathbf{building\_charc} \times \mathbf{heat}) + \boldsymbol{\beta}_6 (\mathbf{appliance}) + \boldsymbol{\beta}_7 \mathbf{household\_charc} \\ & + \boldsymbol{\beta}_8 (\mathbf{degree\_days} \times \mathbf{heat}) + \boldsymbol{\beta}_8 (\mathbf{energy\_cons} \times \mathbf{heat}) + \boldsymbol{\beta}_9 (\mathbf{soft} \times \mathbf{heat}), \end{aligned}$$

where E is household consumption, **heat** are dummy variables for heating system, **location** are dummy variables for city/town/rural location, **appliance** are either dummy variables for electric appliances or measurement of use of these appliances, **household_charc** are demographic factors such as size of the household and age, **degree_days** are the number of degree days (capturing local weather conditions), **energy_cons** are either indexes covering a broad range of installed energy conservation technologies or dummies for each specific technology and **soft** are variables capturing the interest, knowledge and attitude towards energy issues as stated by the household. The remaining variables are self-explanatory.

Preliminary analysis suggest that the logarithmic specification is preferred to a linear specification[9]. With a logarithmic specification the variables enters multiplicatively, which is somewhat contra-intuitive especially when one considers the effect of electric appliances on consumption. A more reasonable approximation would be the appliances affect the consumption additively, which would be an argument for a linear specification. The logarithmic specification is particularly problematic since the levels of consumption,

[9]Preliminary estimations with a limited number of the explanatory variables using the Box-Cox transformation indicates that a logarithmic specification is reasonably good at least regarding the relationship between consumption and price and income. Furthermore, Leth-Petersen (2002) analyze the choice of functional form specifically and finds the log(total expenditure) affects the log(consumption) linearly. Total expenditure is expected to be endogenous and therefore gross income is used as an instrument.

primarily due to different heating technologies, differ widely. Since the preliminary analysis suggest a logarithmic functional form, while the logic behind electricity consumption to some extent suggest a linear specification the model is estimated with two different functional form specification: One where all variables (except for dummy variables) are in natural logarithms and one completely linear specification.

4.1 Results

In Tables 4 and 5 the results of the estimations using a logarithmic specification are presented and Tables 6 and 7 contain the results for the linear specification. Preliminary analysis suggested that the logarithmic functional form was preferable and the explanatory power for these regressions are also higher than for the ones with the linear specification. This is also the case when the appliance dummies are introduces, although the logic behind electricity consumption would imply a linear specification for the appliances. The primary focus of the discussion in this section will be on the results from the logarithmic specification.

Price effect

With the logarithmic specification the price elasticity is highest (in absolute terms) for houses without electric heating and the point estimate varies between −0.92 and −1.35. As expected the highest price elasticity is estimated in regressions with relatively few included variables, and drop when appliance dummies and other explanatory variables are included. It thus seems clear that a considerable part of the price sensitivity goes via the choice of appliances, but that there also exist a direct price effect. Separate estimations for each of the heating categories have also been made (point estimates for selected variables from these separate regressions are reported in Table 14 in Appendix A). The results are consistent although the point estimates in these regressions generally indicate a larger price sensitivity for houses without electric heating (estimated coefficients between −1.11 and −1.69).

The estimated price elasticity for houses with electric heating and mixed heating are relatively similar. The estimated coefficients varies between −0.54 and −0.72 for electric heated houses and −0.37 and −0.79 for houses with mixed heating. In contrast with the estimates for houses without electric heating the point estimates of the price sensitivity are lower in the regressions with few included variables and increases when other variables, such as appliance dummies, are included. In the separate analyzes of each heating category this pattern is still present for houses with mixed heating. The point

Regression	Log 1	Log 2	Log 3	Log 4	Log 5
R-Square	0.5902	0.6528	0.7034	0.7065	0.7148
Adj R-Sq	0.5863	0.646	0.6922	0.6944	0.6979
# obs	1056	942	933	933	933
Variable	Estimate (Std. Err)	Estimate (Std. Err)	Estimate (Std. Err)	Estimate (Std. Err)	Estimate (Std. Err)
Intercept	11.06586***	12.00689***	6.53461	5.93768	5.60699
	(1.846237)	(1.911163)	(3.990467)	(3.948713)	(3.944692)
Electric heating	0.64206	−1.02422	4.54594	4.63787	4.18312
	(1.925611)	(1.886024)	(4.648327)	(4.590516)	(4.577041)
Mixed heating	−3.71381*	−3.67097*	11.36564**	11.95818**	11.69915**
	(2.091966)	(2.075974)	(5.096482)	(5.091692)	(5.127936)
City	−0.22606***	−0.22925***	−0.18796***	−0.18402***	−0.18133***
	(0.064439)	(0.063628)	(0.059516)	(0.059359)	(0.058764)
Town	0.02197	0.01226	0.03526	0.0331	0.03327
	(0.041134)	(0.041811)	(0.040249)	(0.040055)	(0.040041)
Log(Price)	−1.31289***	−1.35406***	−1.13562***	−1.07286***	−1.05137***
	(0.358659)	(0.37361)	(0.343427)	(0.344571)	(0.345686)
Log(Price×electric heating)	0.64665*	0.66577*	0.51257	0.50016	0.5145
	(0.352374)	(0.3595469)	(0.340455)	(0.340054)	(0.339381)
Log(Price×mixed heating)	0.94281**	0.82443**	0.49721	0.43956	0.40351
	(0.37338)	(0.381795)	(0.358944)	(0.358682)	(0.360991)
Log(Income)	0.33518***	0.16348**	0.0996	0.11387*	0.10876
	(0.068656)	(0.076928)	(0.069616)	(0.062933)	(0.060495)
Log(Income×electric heating)	−0.22662***	−0.24656***	−0.18766**	−0.19589***	−0.18613***
	(0.084671)	(0.083789)	(0.076956)	(0.070544)	(0.069078)
Log(Income×mixed heating)	0.06341	−0.04769	−0.05495	−0.07055	−0.06568
	(0.096111)	(0.104637)	(0.095741)	(0.091826)	(0.092389)
Log(Building year)		−0.05267**	−0.06629***	−0.06579***	−0.07613***
		(0.021146)	(0.019478)	(0.019609)	(0.02077)
Log(Area)		0.11828	0.1539*	0.11528	0.14997*
		(0.105952)	(0.086404)	(0.086389)	(0.089918)
Log(Area×electric heating)		0.38406***	0.1994*	0.24312**	0.21374*
		(0.13115)	(0.113227)	(0.112303)	(0.115795)
Log(Area×mixed heating)		0.33064**	0.21908*	0.25435**	0.2092*
		(0.146593)	(0.126499)	(0.126418)	(0.123612)
Log(Age)		0.08608	0.0646	0.08154	0.09517
		(0.06783)	(0.067268)	(0.066128)	(0.066372)
Educ2		0.03956	−0.00673	−0.00437	−0.00961
		(0.041286)	(0.039975)	(0.039922)	(0.039868)
Educ3		0.06523	0.01477	0.01385	0.00757
		(0.042352)	(0.041896)	(0.041748)	(0.041781)
Log(#Persons)		0.17484***	0.12575***	0.13442***	0.15153***
		(0.043482)	(0.042426)	(0.04213)	(0.042864)
Electric waterheater			0.17425***	0.17105***	0.17004***
			(0.023201)	(0.023369)	(0.023357)
Log(Degree days)			0.51155	0.5442	0.55593
			(0.396199)	(0.395586)	(0.395614)
Log(Degree days×el heat)			−0.59564	−0.60436	−0.55357
			(0.475279)	(0.472291)	(0.472607)
Log(Degree days×mix heat)			−1.61833***	−1.65627***	−1.58535***
			(0.530132)	(0.533589)	(0.535636)
Energy conservation index				0.03795**	
				(0.016039)	
Energy cons index×el heat				−0.0582***	
				(0.018147)	
Energy cons index×mix heat				−0.03789**	
				(0.018764)	
Appliances dummies	NO	NO	YES	YES	YES
Appliance use	NO	NO	NO	NO	NO
Appliance indexes	NO	NO	NO	NO	NO
Energy conservation dummies	NO	NO	NO	NO	YES
Attitude and interest	NO	NO	NO	NO	NO

Dependent variable is log(consumption). Robust standard errors within parenthesis. ***, ** and * indicate point estimate significantly different from zero on the respectively 1, 5 and 10 % levels.

Table 4: Estimation results single-family houses. Logarithmic specification.

Regression	Log 6	Log 7	Log 8	Log 9	Log 10
R-Square	0.7138	0.7174	0.7196	0.7334	0.7374
Adj R-Sq	0.6983	0.7024	0.7003	0.7093	0.709
# obs	897	755	730	741	780
Variable	**Estimate (Std.Err)**	**Estimate (Std.Err)**	**Estimate (Std.Err)**	**Estimate (Std.Err)**	**Estimate (Std.Err)**
Intercept	6.59326	5.84618	6.91742	5.29881	6.14719
	(4.112411)	(4.690875)	(4.907446)	(4.460554)	(4.75199)
Electric heating	3.9016	3.84102	2.28843	6.64078	4.80748
	(4.679471)	(5.298641)	(5.374729)	(5.115704)	(5.244375)
Mixed heating	11.21245**	14.27538**	13.23357**	14.56114***	13.72594**
	(5.202382)	(5.715959)	(5.8991699	(5.378774)	(5.605323)
City	−0.18612***	−0.23494***	−0.23027***	−0.23535***	−0.23741***
	(0.059928)	(0.06698)	(0.069292)	(0.064238)	(0.066162)
Town	0.01706	0.00324	−0.00679	0.03962	0.02284
	(0.040508)	(0.045361)	(0.04574)	(0.045031)	(0.045185)
Log(Price)	−1.14417***	−0.92126**	−1.00567**	−1.12633***	−1.2409***
	(0.350736)	(0.42393)	(0.425807)	(0.387794)	(0.403821)
Log(Price×electric heating)	0.55381	0.22142	0.33545	0.4069	0.54755
	(0.343451)	(0.405357)	(0.40442)	(0.370178)	(0.38225)
Log(Price×mixed heating)	0.49371	0.13623	0.21671	0.37881	0.47979
	(0.365735)	(0.422161)	(0.425249)	(0.388251)	(0.40421)
Log(Income)	0.08903	0.20748***	0.19695***	0.13386**	0.11304*
	(0.058234)	(0.062163)	(0.061699)	(0.062123)	(0.063621)
Log(Income×electric heating)	−0.17364*	−0.27452***	−0.24965***	−0.22879***	−0.1952***
	(0.065823)	(0.071292)	(0.069827)	(0.070528)	(0.071313)
Log(Income×mixed heating)	−0.05591	−0.10188	−0.10073	−0.07299	−0.0585
	(0.089)	(0.090676)	(0.09086)	(0.07985)	(0.081745)
Log(Building year)	−0.06004***	−0.05105**	−0.0485**	−0.05128**	−0.04952**
	(0.019347)	(0.021084)	(0.020815)	(0.02081)	(0.020525)
Log(Area)	0.08748	0.03211	0.00156	0.09311*	0.06099
	(0.088924)	(0.107408)	(0.108296)	(0.056381)	(0.057964)
Log(Area×electric heating)	0.25097**	0.43224***	0.4437***	0.26859***	0.27049***
	(0.114706)	(0.131976)	(0.132156)	(0.021605)	(0.021986)
Log(Area×mixed heating)	0.27405**	0.39009***	0.43165***	0.33116***	0.3523***
	(0.126567)	(0.14877)	(0.149932)	(0.014489)	(0.01481)
Log(Age)	0.05996	0.12652*	0.0924	0.10836	0.06548
	(0.066469)	(0.068992)	(0.070461)	(0.068619)	(0.069895)
Educ2	−0.00524	0.03286	0.02821	0.0073	$6.12E-05$
	(0.041317)	(0.039912)	(0.040866)	(0.041033)	(0.042334)
Educ3	0.01933	0.05533	0.06193	0.01706	0.02807
	(0.043315)	(0.04307)	(0.044449)	(0.045398)	(0.046802)
Log(#Persons)	0.14396***	0.08449	0.08076	0.06295	0.0638
	(0.042783)	(0.053997)	(0.054855)	(0.051952)	(0.052901)
Electric waterheater	0.17313***	0.15914***	0.152***	0.15964***	0.15868***
	(0.023553)	(0.02617)	(0.026028)	(0.025619)	(0.0256)
Log(Degree days)	0.50863	0.4787	0.41721	0.62207	0.6042
	(0.414888)	(0.457527)	(0.486779)	(0.453453)	(0.487873)
Log(Degree days×el heat)	−0.5475	−0.37753	−0.25724	−0.77747	−0.64388
	(0.484724)	(0.54206)	(0.556254)	(0.536635)	(0.554731)
Log(Degree days×mix heat)	−1.60283***	−1.82027***	−1.7377***	−1.98298***	−1.94289***
	(0.544097)	(0.586762)	(0.609044)	(0.569761)	(0.593189)
Energy conservation index	0.03622**	0.02545	0.02824	0.02675	0.02743
	(0.016323)	(0.017973)	(0.018671)	(0.017221)	(0.017913)
Energy cons index×el heat	−0.05377***	−0.0475**	−0.04725**	−0.04614**	−0.04433**
	(0.018365)	(0.020226)	(0.02083)	(0.019757)	(0.020277)
Energy cons index×mix heat	−0.03365*	−0.02789	−0.02938	−0.03275*	−0.03003
	(0.019007)	(0.020379)	(0.020979)	(0.019615)	(0.020254)
Appliances dummies	YES	NO	NO	YES	YES
Appliance use	NO	NO	NO	YES	YES
Appliance indexes	NO	YES	YES	NO	NO
Energy conservation dummies	NO	NO	NO	NO	NO
Attitude and interest	YES	NO	YES	NO	YES

Dependent variable is log(consumption). Robust standard errors within parenthesis. ***, ** and * indicate point estimate significantly different from zero on the respectively 1, 5 and 10 % levels.

Table 5: Estimation results single-family houses. Logarithmic specification.

Regression	Linear 1	Linear 2	Linear 3	Linear 4	Linear 5
R-Square	0.4902	0.5761	0.615	0.6175	0.6265
Adj R-Sq	0.4853	0.5684	0.6015	0.6028	0.606
# obs	1056	1011	1001	1001	1001
Variable	Estimate (Std. Err)	Estimate (Std. Err)	Estimate (Std. Err)	Estimate (Std. Err)	Estimate (Std. Err)
Intercept	18365***	18424***	3209.873	2349.674	2027.848
	(4146.711)	(4401.222)	(6380.14)	(6493.78)	(6430.567)
Electric heating	10187**	−1062.2	−7699.07	−7603.12	−9649.15
	(4601.469)	(4451.814)	(9484.399)	(9500.659)	(9477.29)
Mixed heating	−1011.31	−7350.9	7821.472	8613.755	6937.462
	(5287.813)	(5256.828)	(9436.852)	(9521.642)	(9667.298)
City	−1795.3**	−2090.95**	−1294.38	−1308.79	−1368.77
	(908.6705)	(863.5716)	(849.7607)	(849.5856)	(835.7104)
Town	594.2238	363.5457	493.0813	440.4635	440.5412
	(571.9069)	(562.6618)	(575.4419)	(571.307)	(570.8325)
Price	−201.106***	−223.979***	−204.145***	−198.579***	−194.715***
	(57.78974)	(58.22345)	(54.28928)	(55.5279)	(54.81346)
Price×electric heating	61.4905	78.2344	97.32443	102.3406	106.2288*
	(62.51871)	(61.38549)	(62.35094)	(63.3894)	(62.49018)
Price×mixed heating	138.8642**	131.8689**	98.88014*	92.31168	90.26669
	(67.84639)	(67.23093)	(64.88227)	(65.7107)	(64.70597)
Income	0.17421***	0.12354***	0.07186	0.07492*	0.07123*
	(0.042307)	(0.047008)	(0.043319)	(0.042565)	(0.042176)
Income×electric heating	−0.00634	−0.12903**	−0.08099	−0.07457	−0.06359
	(0.064617)	(0.062621)	(0.060959)	(0.060846)	(0.060598)
Income×mixed heating	0.08173	−0.02186	0.00461	−0.00046	0.00346
	(0.079275)	(0.083168)	(0.078265)	(0.078606)	(0.081041)
Building year		−30.7839***	−38.4532***	−37.6047***	−44.5901***
		(7.892134)	(7.784141)	(7.801508)	(8.586713)
Area		−1.17435	2.55659	0.86099	2.47611
		(6.928303)	(6.337722)	(6.414572)	(6.606444)
Area×electric heating		106.3005***	90.25998***	92.55781***	92.22477***
		(13.93079)	(13.85102)	(13.55509)	(13.84053)
Area×mixed heating		73.04958***	59.86644***	60.79568***	56.11006***
		(14.31417)	(13.88366)	(13.9984)	(13.81651)
Age		34.94838**	34.16846**	36.42958**	39.71848**
		(17.51131)	(17.33397)	(17.15234)	(17.27623)
Educ2		725.5109	453.9316	486.9604	435.4859
		(563.9086)	(552.691)	(551.2904)	(558.101)
Educ3		882.9184	748.0967	706.1899	595.9185
		(612.445)	(617.1104)	(614.887)	(620.579)
#Persons		666.7857***	518.7859***	564.8464***	658.0492***
		(216.6534)	(217.9571)	(217.7025)	(220.0637)
Electric waterheater			1934.739***	1912.234***	1882.307***
			(332.0342)	(333.9375)	(333.2442)
Degree days			1.01481	1.08329	0.93273
			(0.971754)	(0.971069)	(0.989237)
Degree days×el heat			1.01692	1.06923	1.44587
			(1.928847)	(1.911741)	(1.925995)
Degree days×mix heat			−3.88511**	−3.92764**	−3.23978*
			(1.877645)	(1.891521)	(1.924746)
Energy conservation index				216.8693	
				(154.7951)	
Energy cons index×el heat				−595.406***	
				(218.2871)	
Energy cons index×mix heat				−157.478	
				(236.904)	
Appliances dummies	NO	NO	YES	YES	YES
Appliance use	NO	NO	NO	NO	NO
Appliance indexes	NO	NO	NO	NO	NO
Energy conservation dummies	NO	NO	NO	NO	YES
Attitude and interest	NO	NO	NO	NO	NO

Dependent variable is consumption. Robust standard errors within parenthesis. ***, ** and * indicate point estimate significantly different from zero on the respectively 1, 5 and 10 % levels.

Table 6: Estimation results single-family houses. Linear specification.

Regression	Linear 6	Linear 7	Linear 8	Linear 9	Linear 10
R-square	0.6243	0.634	0.6367	0.6554	0.6602
Adj R-Sq	0.6055	0.616	0.6136	0.6222	0.6217
# obs	965	810	785	854	826
Variable	Estimate (Std.Err)	Estimate (Std.Err)	Estimate (Std.Err)	Estimate (Std.Err)	Estimate (Std.Err)
Intercept	1130.14	11819*	12283*	4603.763	4408.723
	(6998.511)	(6599.884)	(6597.624)	(7323.764)	(7717.561)
Electric heating	−5959.99	−11388	−10282	−8602.21	−8777.98
	(9798.981)	(10527.93)	(10446.17)	(10233.41)	(10199.16)
Mixed heating	7710.801	8698.95	7070.827	8406.354	7571.984
	(9658.131)	(10844.48)	(10972.839	(10315.88)	(10510.29)
City	−1338.63	−2075.73**	−1987.7**	−2180.93**	−2146.84**
	(854.8174)	(948.2892)	(961.6788)	(923.4078)	(932.1616)
Town	259.7959	−15.4178	−110.785	342.8169	99.86453
	(573.8872)	(623.27)	(628.9957)	(629.6455)	(620.4481)
Price	−206.56***	−192.859***	−204.315***	−222.899***	−242.69***
	(56.86517)	(68.44264)	(68.76881)	(64.35227)	(66.8847)
Price×electric heating	107.5271*	75.78559	89.91273	110.712	136.496*
	(64.79974)	(72.89216)	(72.96735)	(68.45164)	(70.4298)
Price×mixed heating	104.5689	69.73974	87.3818	105.6599	128.8836
	(67.62017)	(77.12212)	(78.30255)	(71.89383)	(75.00189)
Income	0.06425	0.10856*	0.10785*	0.07522	0.07461
	(0.041327)	(0.053332)	(0.051706)	(0.051052)	(0.050262)
Income×electric heating	−0.06005	−0.10893	−0.09879	−0.10659	−0.09638
	(0.060292)	(0.070391)	(0.068485)	(0.068263)	(0.067141)
Income×mixed heating	0.00641	0.03123	0.02634	0.04539	0.04778
	(0.078002)	(0.074948)	(0.074898)	(0.06902)	(0.069106)
Building year	−36.4336***	−34.4649***	−34.078***	−33.0194***	−32.6167***
	(7.81351)	(8.318896)	(8.293457)	(8.325071)	(8.263094)
Area	−0.80766	−2.02403	−4.22878	1.17637	−0.40377
	(6.325694)	(7.495349)	(7.295088)	(7.103568)	(7.277444)
Area×electric heating	93.24274***	107.8939***	108.4589***	95.89315***	95.88175***
	(14.07385)	(14.4889)	(14.65963)	(14.33565)	(14.59847)
Area×mixed heating	60.81887***	65.98822***	68.15385***	61.82693***	61.6811***
	(13.95323)	(15.60718)	(15.63988)	(14.49182)	(14.44534)
Age	28.54077	37.82038**	27.6881	38.59273**	25.98616
	(17.38499)	(18.29149)	(18.80547)	(18.23052)	(18.50381)
Educ2	503.4037	1114.32	1061.57	830.9562	782.9171
	(578.9404)	(561.9094)	(588.8611)	(562.8708)	(582.2635)
Educ3	685.4273	1344.358**	1336.611**	909.7513	1014.415
	(644.9007)	(633.556)	(663.5084)	(652.9393)	(676.134)
#Persons	558.8008***	201.6366	127.221	163.0912	119.9072
	(221.6192)	(268.9367)	(274.0877)	(270.6507)	(276.1233)
Electric waterheater	1901.896***	1636.124***	1538.96***	1744.459***	1727.467***
	(338.0619)	(372.5121)	(372.8056)	(340.9002)	(342.8616)
Degree days	1.04121	0.65877	0.56233	1.32597	1.36797
	(0.998927)	(1.095228)	(1.14149)	(1.122555)	(1.17066)
Degree days×el heat	1.1813	2.31423	2.48031	1.15648	1.38957
	(1.954354)	(2.093353)	(2.081767)	(2.030668)	(2.018698)
Degree days×mix heat	−3.52651*	−3.84351*	−3.3549	−4.39744**	−4.16367**
	(1.912834)	(2.067375)	(2.10689)	(2.017112)	(2.035248)
Energy conservation index	182.2883	113.1793	121.1132	53.29342	60.45532
	(155.1121)	(172.6026)	(180.2789)	(182.738)	(192.2321)
Energy cons index×el heat	−536.357**	−528.32**	−484.955**	−421.855*	−395.819
	(219.0125)	(235.9518)	(242.0439)	(238.6745)	(246.2483)
Energy cons index×mix heat	−80.9464	−52.5939	−33.1549	−61.1187	−22.7475
	(236.0598)	(244.1864)	(250.6921)	(247.769)	(257.2681)
Appliance dummies	YES	NO	NO	YES	YES
Appliance use	NO	NO	NO	YES	YES
Appliance indexes	NO	YES	YES	NO	NO
Energy conservation dummies	NO	NO	NO	NO	NO
Attitude and interest	YES	NO	YES	NO	YES

Dependent variable is consumption. Robust standard errors within parenthesis. ***, ** and * indicate point estimate significantly different from zero on the respectively 1, 5 and 10 % levels.

Table 7: Estimation results single-family houses. Linear specification.

	Logarithmic	Linear
Regr 2 vs Regr 1	20.80206***	25.12762***
Regr 3 vs Regr 1	14.2804***	13.04727***
Regr 3 vs Regr 2	9.574933***	6.100227***
Regr 4 vs Regr 3	3.151051**	2.098039*
Regr 5 vs Regr 4	1.70734*	1.522892*
Regr 6 vs Regr 4	2.40896**	1.846154*
Regr 7 vs Regr 4	27.61642***	34.7582***
Regr 8 vs Regr 7	0.594547	0.608588
Regr 9 vs Regr 4	1.765754***	2.251749***
Regr 10 vs Regr 9	1.176271	1.163037

***, ** and * indicate significant F-statistic at the 1, 5 and 10% levels respectively.

Table 8: F-statistics for improvment in explanatory power of regressions.

estimate is not significantly different from zero when only price and income are included and the highest estimate is -0.67. For houses with electric heating the pattern is reversed with the the highest estimate when only price and income are included (-0.75) and the lowest point estimate (-0.5) is obtained in the regression corresponding to regression 6.

The fact that households without electric heating exhibits the highest price elasticity might be rather counter intuitive. Since these households consume relatively small amounts of electricity the effect on the consumed quantity is not as high. With the linear specification the estimated quantity effect is however still highest for households without electric heating, although for most of the regressions the differences in price sensitivity between heating categories are then not significant. A one unit change in the price (1 öre)[10] decreases yearly consumption with approximately 200 kWh[11]. The standard deviation of the price is 11.3 öre and a one standard deviation change in the price would thus change the yearly consumed quantity by more than 2000 kWh. Table 9 contains a comparison between the price elasticities and quantity effects for the logarithmic and linear specifications.

There is thus a significant and quantitatively rather important price effect. Furthermore, it is likely that these estimations under estimate the true long run price sensitivity since heating technologies and other durables are fixed here. In the long run these can be adjusted. The most important long run adjustment would probably be heating technologies and energy conservation investments (such as insulation).

The estimates are approximately within the range of estimations from previous studies. Since Swedish data is used here it might be of special interest to compare with Andersson (1997) where the estimated price elasticities were -1.37 for single family houses

[10]This is a change in price with about 1.4% compared with the sample average.

[11]This is a change with about 1.3% change based on sample average, 0.9% for households with electric heating, 1.1% for households with mixed heating and 2.8% for households without electric heating.

	Logarithmic specification		Linear specification	
	Est elasticity	Calc quantity effect	Calc elasticity	Est quantity effect
Electric heating	−0.666	−221.0	−0.421	−139.6
Mixed heating	−0.370	−97.8	−0.235	−62.2
No electric heating	−1.313	−132.4	−1.994	−201.1

Based on estimates from regression 1 specification (log and linear) and mean consumption and price for each heating category. Quantity effect is change in consumed quantity (in kWh) caused by a one unit change (1 öre) in the price.

Table 9: Comparison of price elasticities and quantity effect evaluated at mean for each heating category

with electric heating, −0.64 for single family houses without electric heating and −1.38 for apartments. The estimates for single family houses without electric heating and apartments were not significant. Baker and Blundell (1991) estimated the price elasticity to between −0.673 to −1.044 depending on type of housing and time of year. In Morss and Small (1989*b*) and Parti and Parti (1980) found elasticities of −0.38 and −0.58 respectively.

Income effect

The estimated income elasticity using the logarithmic specification for the households without electric heating is positive and significant in most of the specifications. The point estimate is highest when few variables are included and reduced considerably when additional variables are included. The estimated coefficient for the interaction term between income and mixed heating is insignificant in all the regressions, while the coefficient for the interaction term between income and electric heating is negative and significant and in many of the specifications larger than the income coefficient. The income elasticity for houses with electric heating thus seems to be zero or perhaps even negative, when one controls for the stock of appliances. A negative income elasticity would be hard to explain given that we control for installed energy conservation technologies.

In the separate regressions for each heating category the estimated income elasticity is positive for all three categories in the simplest specification (corresponding to regression 1) with the highest estimated income elasticity for houses with mixed heating and the lowest for houses with electric heating. When additional variables are included the estimates are insignificant for all three categories in almost all specifications.

With the linear specification the income effect is only significant in the regressions with the fewest included variables (regressions 1 and 2). When appliance dummies are introduced there is no longer any direct income effect. This would indicate that the income does not affect the behavior of the household members directly, but that the effect is only indirect. The interaction terms between income and electric respectively mixed heating are never significant.

Both the logarithmic and the linear specifications thus show that a considerable part of the income effect, if not all of it, is indirect and goes through, among other things, the dwelling area and stock of appliances.

Dwelling size

While the size of the dwelling has no effect on electricity consumption for houses without electric heating in most of the specification, this variable is, quite naturally, important for houses with electric or mixed heating is. In the logarithmic specification the estimated coefficient for houses with electric heating is 0.38 when no appliance dummies are included. When one includes appliance dummies the estimate drops to between 0.2 and 0.27 depending on specification. A 1% increase in the area of the house would thus increase electricity demand with 500 – 600 kWh. The pattern is similar for houses with mixed heating.

With the linear specifications the estimated coefficient for households with electric heating is consistently around 100 and for households with mixed heating between 60 and 70. This is a considerable lower effect compared with the logarithmic specification.

Stock and use of appliances

The introduction of appliance dummies to measure the stock of electricity consuming appliances results in an considerable improvement in the explanatory power of the regressions. This becomes particularly obvious when separate estimations are made for each heating category. In the separate analysis by heating category with regression specification 2 (with price, income and area included) the adjusted R^2 is around 0.2 for houses with mixed heating and without electric heating and about 0.3 for houses with electric heating. When appliance dummies are introduced (regression 3) the adjusted R^2 increases to 0.4 for houses without electric heating, 0.33 for houses with mixed heating and to 0.39 for houses with electric heating. In the estimations using all houses the adjusted R^2 increases from 0.65 to 0.69. From this we can also draw the (obvious) conclusion that the high explanatory power in the regressions using all houses to a considerable degree depends on the differences between the heating categories.

Also with the linear specification the introduction of appliance dummies increases the explanatory power somewhat. The large increase does however come when the size of the dwelling is introduced (regression 2 compared with regression 1). The linear specification was introduced since it presumably would better capture the effect of appliances than the logarithmic specification, especially when the levels of total consumption differ. The interpretation of the multiplicative effect that is the result of a logarithmic specification

	Logarithmic specification				Linear specification			
Regression Variable	Log 3 Estimate (Std. Err.)	Log 4 Estimate (Std. Err.)	Log 5 Estimate (Std. Err.)	Log 6 Estimate (Std. Err.)	Linear 3 Estimate (Std. Err.)	Linear 4 Estimate (Std. Err.)	Linear 5 Estimate (Std. Err.)	Linear 6 Estimate (Std. Err.)
Stove	0.3103	0.3195	0.3455	0.442	3731.1	3767.1	4232.1	4149.6
	(0.360)	(0.362)	(0.359)	(0.456)	(3379.5)	(3437.0)	(3362.7)	(4379.8)
Dishwasher	0.0506	0.0473	0.0385	0.0458	348.9	315.2	170.9	308.3
	(0.035)	(0.035)	(0.035)	(0.036)	(465.4)	(465.2)	(463.6)	(469.7)
Laundry	0.216**	0.218**	0.212**	0.267***	2161.8**	2244.1**	2252.1**	2610.3***
	(0.093)	(0.091)	(0.086)	(0.090)	(1004.0)	(991.4)	(953.3)	(988.0)
Dryer	0.0444*	0.0489**	0.051**	0.044*	530	577.2	699.7**	496.4
	(0.023)	(0.023)	(0.023)	(0.023)	(359.4)	(357.8)	(354.2)	(370.7)
TV	0.218***	0.1916**	0.1931**	0.222***	2931.8***	2679.4***	2750***	3097.8***
	(0.079)	(0.077)	(0.076)	(0.071)	(861.2)	(816.2)	(856.6)	(850.9)
Computer	0.0633**	0.0635**	0.064**	0.059*	324.1	315.3	308.5	225.5
	(0.032)	(0.032)	(0.032)	(0.032)	(461.4)	(461.7)	(467.8)	(466.1)
Fridge	0.048**	0.0453**	0.044*	0.053**	579.3*	534.9	519.7	601.9
	(0.023)	(0.023)	(0.023)	(0.023)	(340.2)	(339.7)	(345.6)	(344.8)
Sauna	0.129***	0.133***	0.133***	0.125***	1229.7**	1306.4**	1370.3**	1207.9**
	(0.037)	(0.037)	(0.037)	(0.037)	(602.5)	(602.6)	(590.2)	(607.5)
Infra	0.081**	0.0744**	0.073**	0.0681**	1467.1**	1400.1**	1362.9**	1293.9**
	(0.034)	(0.034)	(0.034)	(0.035)	(591.7)	(594.6)	(588.3)	(598.7)
Engine heater	−0.0139	−0.0138	−0.0129	−0.0016	9.77	17.6	54.3	220.6
	(0.041)	(0.040)	(0.040)	(0.040)	(563.5)	(559.2)	(558.9)	(574.5)
Car heater	0.0013	0.01	0.012	−0.011	−540	−460	−400.7	−706.8
	(0.041)	(0.040)	(0.040)	(0.040)	(601.4)	(599.3)	(595.2)	(608.2)
Extra heater	0.0509	0.0585	0.0574	0.0405	229.8	350.3	253.8	66.4
	(0.044)	(0.044)	(0.043)	(0.045)	(692.2)	(695.4)	(672.7)	(702.3)

Dependent variable is log(consumption) and consumption. Robust standard errors within parenthesis. ***, ** and * indicate point estimate significantly different from zero on the respectively 1, 5 and 10 % levels.

Table 10: Estimated coefficient for appliance dummies

is rather unclear. As we can see in Table 10 the same appliances do seem to be important for explaining the electricity consumption independent of the choice of functional form.

The introduction of the appliance indexes and appliance use dummies has a rather small effect on the explanatory power in both the logarithmic and linear specifications. The appliances indexes are used in regressions 7 and 8 and use dummies in regressions 9 and 10. Comparing these with regression 4, where only the appliance stock is included, do however show that these small increases in explanatory power is highly significant (see Table 8).

In regressions 7 and 8 the before mentioned appliance indexes are introduced. Most of the estimated coefficients have the expected positive sign, i.e., a more intense use increases electricity consumption, but only a few of these are significant. The explanatory power hardly increases at all. Almost the same result can be observed in regressions 9 and 10, when the appliance use dummies are introduced. Almost none of the estimated coefficients are significant, but here the signs also varies. The explanatory power is also not improved by the inclusion of the use level dummies.

Heating conservation technologies

In regression specifications 4 and $6 - 10$ the heating conservation index variable is included and in regression specification 5 individual dummies for each installed heating conservation technology are included. From a comparison of regressions 4 and 5 we see that the introduction of the individual dummies, independent of the functional form, implies no improvement in the explanatory power compared with the use of the index variable, which therefore is used in later regressions to save on the degree of freedoms. Throughout the estimated coefficient for the index variable is positive or non-significant (this should be interpreted as the effect for houses without electric heating). The interaction term between the index and electric heating is always significant and negative with the logarithmic specification. In the linear specification the sign is still negative, while only significant in some of the regressions. The corresponding coefficient for mixed heating is negative or non-significant for both functional forms. This is in line with what should be expected. Houses without electric heating should not save on their electricity consumption by taking measures to reduce the energy consumption for heating purposes (since it is provided by some other energy carrier). The results are similar in the separate estimations made for each heating category with a usually significantly negative coefficient for houses with electric heating, usually non-significant coefficient for houses with mixed heating and usually significantly positive coefficient for houses without electric heating. The sometimes positive coefficient for houses without electric heating could be an indication of the endogeneity issue raised earlier. Households with an unusual high energy consumption are more likely to invest in energy conservation, which could lead to a positive coefficient in this case[12]. The negative coefficients for electric heating and mixed heating indicates that these measures indeed lead to a lower energy consumption.

Interest and knowledge

In Table 11 the estimated coefficient for the variables measuring the household's interest in energy issues are reported. Energy conservation advice seems to have little effect on the household's electricity consumption. The estimated coefficients for the interaction terms between advice and electric respectively mixed heating are sometimes positive and significant. It is highly unlikely that such advice would actually increase consumption and the estimated coefficient is probably a sign of a reversed causality - households with high electricity consumption seek advice to reduce the consumption. The results do raise

[12]This would here require a positive correlation between electricity consumption for non-heating purposes and the energy consumption for heating purposes.

Regression Variable	Logarithmic specification Log 6 Estimate (Std. Err.)	 Log 8 Estimate (Std. Err.)	 Log 10 Estimate (Std. Err.)	Linear specification Linear 6 Estimate (Std. Err.)	 Linear 8 Estimate (Std. Err.)	 Linear 10 Estimate (Std. Err.)
Advice	−0.00045	−0.12932	−0.03843	13.64349	−1198.36	−1045.36
	(0.088729)	(0.096587)	(0.087997)	(1036.977)	(1134.149)	(966.7355)
Advice×el heat	0.12751	0.28067**	0.17272	1771.369	3465.961**	3315.203**
	(0.103864)	(0.114065)	(0.106431)	(1543.058)	(1668.214)	(1523.167)
Advice×mix heat	0.11933	0.22213*	0.11344	2476.624*	2865.232*	2318.122
	(0.107331)	(0.115695)	(0.108688)	(1491.298)	(1567.849)	(1420.097)
ELOFF	0.03312	0.03391	0.09194	446.0065	421.4635	731.6185
	(0.089748)	(0.117545)	(0.100648)	(800.7234)	(1053.387)	(940.001)
ELOFF×el heat	−0.20387*	−0.17157	−0.25645**	−3859.81***	−3374.9*	−3927.35**
	(0.108396)	(0.138998)	(0.123596)	(1387.009)	(1758.292)	(1691.471)
ELOFF×mix heat	0.04599	−0.01456	−0.02254	71.37541	−284.941	19.35409
	(0.134984)	(0.160864)	(0.14492)	(1801.385)	(2084.392)	(1980.462)
Interest	0.1025***	0.09273**	0.08128**	1036.191***	945.2555**	796.4036**
	(0.030221)	(0.037886)	(0.034469)	(293.4329)	(376.4402)	(357.3827)
Interest×el heat	−0.13849***	−0.13865***	−0.1185***	−1692.38***	−1866.25***	−1672.9***
	(0.037722)	(0.045462)	(0.043169)	(559.1606)	(634.0996)	(620.9866)
Interest×mix heat	−0.12099**	−0.1267**	−0.11195**	−1319.02**	−1193.84*	−1260.62**
	(0.047634)	(0.053955)	(0.049575)	(595.1958)	(676.1775)	(633.1865)

Dependent variable is log(consumption) and consumption. Robust standard errors within parenthesis. ***, ** and * indicate point estimate significantly different from zero on the respectively 1, 5 and 10 % levels.

Table 11: Estimated coefficient for attitude and interest variables

the question of the usefulness of the energy advisors. For a more definite conclusion on that matter a more thorough analysis is needed.

The second interests variable is if the respondent is familiar with a particular energy conservation symbol (ELOFF) used to mark household appliances with low energy consumption. In two of the specifications (for each functional form) the estimated coefficient for the interaction term between ELOFF and electric heating is significant and negative[13]. This variable could be interpreted as a proxy for the household's general attitude and interest in energy conservation. The negative coefficient for this interaction term could thus be a sign that households with an interest in this issues actually reduce consumption.

This is to some extent supported by the estimated coefficient for the direct question on whether the respondent is interested in energy conservation. The estimated coefficient for the interest variable is in all three relevant regressions with the logarithmic specification significant and positive. The same is true for two of the regressions with the linear specification, although in one of these only at the 10% level. This is probably also a sign of a reversed causality. The interaction terms between the interest variable and electric and mixed heating both have negative, and mostly significant, coefficients indicating that

[13]Since this labeling system were used for household appliances there is no reason to expect different effects on the level of consumption depending on the heating categories. The interaction terms are included since the electricity consumption is in log-form in the regressions.

an interest in energy issues does indeed decrease the consumption level for households with the largest potential.

Overall the introduction of the attitude and interest variables has a small, if any effect, on the explanatory power of the regressions. When attitude and interest variables are included in addition to the stock of appliances (regression 6 compared with regression 4) the change in R_2 is significant for the logarithmic specification at the 5% level, but only at the 10% level for the linear specification. When the behavior variables also are included the addition of attitude and interest variables does not cause an significant improvement.

5 Conclusion

Considerable resources have for a long time been spent on analyzing electricity consumption. Economic variables such as price and income are important explanatory factors, although they explain only a small part of the variation by themselves. This is especially clear if each heating category is analyzed separately. This raises the question of which additional variables that it is worthwhile to include in the analysis. Variables of a more technical character are often used and it is quite clear that these variables contribute a lot to the estimation of the residential electricity demand. Still, when such variables are introduced, through which one could expect that the price and income effect would go through, price remain a significant explanatory variable while the presence of a direct income effect is more questionable. If one would also endogenize the choice of the stock of appliances, heating system and other nondurables the price effect would probably be larger, but it would also increase the demands on the data set, both in terms of size and included variables. For instance we would also need price information for alternative heating sources. Ideally one might want to endogenize all durables, as well as the behavior, attitude and interest variables.

It has been argued that specific information on the behavior and preferences of the households are needed. Part of the intent behind the collection of the data set used in this study was to incorporate such information with the purpose of better explaining residential electricity consumption. The information on the use of appliances leads to a small , but statistically significant, increase in the explanatory power. One conclusion is that information on the stock of appliances is important, but that additional information on the use of these appliances are of less importance.

The inclusion of the interest and knowledge variables did not increase the explanatory power of the regressions, but many of the estimated coefficients are significant. For houses with electric heating, i.e. those with a high level of consumption, an interest in energy conservation seems to reduce electricity consumption. There are however also signs of a causality from high electricity consumption to an interest in these issues. Interest in energy conservation thus seem to reduce electricity consumption, even when controlling for the stock of appliances in the household. Some attempts have been made to further analyze the determination and effect of these interest, attitude and knowledge variables, and although the data set used here is rather rich these attempts had limited success. This indicates that the requirements on the data set for a more thorough analysis are quite severe.

A Supplementary results

Regression Variable	Logarithmic specification Log 7 Estimate (Std. Err.)	Log 8 Estimate (Std. Err.)	Linear specification Linear 7 Estimate (Std. Err.)	Linear 8 Estimate (Std. Err.)
Stoveind	−0.0034	−0.0022	−11.1294	1.72065
	(0.002516)	(0.002539)	(35.24344)	(36.0842)
Microind	0.000422	−0.00032	−10.374	−18.7157
	(0.002311)	(0.002349)	(35.7314)	(36.99681)
Dishind	0.01288**	0.01362**	106.7908	113.6163
	(0.005773)	(0.005636)	(82.27081)	(81.97125)
Washind	0.01056*	0.01085*	110.7679	126.9463
	(0.00618)	(0.006196)	(100.93729	(102.1143)
Tumbind	0.01477**	0.01308*	273.4265**	264.643**
	(0.006663)	(0.006894)	(108.6405)	(112.8434)
Dryind	−0.0005	−0.00427	−90.9853	−161.927
	(0.012257)	(0.012233)	(204.6392)	(206.1048)
TVind	0.000438	0.00326	135.8307	181.2093
	(0.010008)	(0.010194)	(144.0818)	(147.4148)
Refrig	0.05634**	0.06285**	585.4979	623.6552
	(0.026573)	(0.02702)	(378.8674)	(388.9897)
Saunaind	0.22647***	0.19869***	1733.558	1161.326
	(0.065493)	(0.068384)	(1342.62)	(1297.617)
Infraind	0.28974	0.30321	7158.827**	7389.247**
	(0.210903)	(0.201372)	(3182.264)	(3168.264)
Engind	−0.03349	−0.03061	−835.776	−696.672
	(0.085165)	(0.081636)	(1133.508)	(1102.276)
Carhind	0.06816	0.06347	1269.159	1213.532
	(0.095208)	(0.092895)	(1378.779)	(1363.858)
Extraind	0.08895	0.06945	1955.944	1330.48
	(0.099415)	(0.107671)	(1826.64)	(1939.583)

Dependent variable is log(consumption) and consumption. Robust standard errors within parenthesis. ***, ** and * indicate point estimate significantly different from zero on the respectively 1, 5 and 10 % levels.

Table 12: Estimated coefficient for appliance use indexes

Regression Variable	Log 5 Estimate (Std. Err.)	Linear 5 Estimate (Std. Err.)
Walls	0.10532	561.6873
	(0.066047)	(620.0795)
Walls×el heat	−0.0775	−880.282
	(0.089472)	(1352.575)
Walls×mix heat	−0.25558***	−3248.57***
	(0.095709)	(1144.807)
Roof	−0.00972	−152.03
	(0.060503)	(549.446)
Roof×el heat	0.01899	1167.64
	(0.085036)	(1398.104)
Roof×mix heat	0.05242	1051.039
	(0.089711)	(1093.009)
Windows	−0.12507**	−1309.49**
	(0.062682)	(565.5241)
Windows×el heat	0.11508	688.5949
	(0.077134)	(1097.08)
Windows×mix heat	0.15073*	1844.77*
	(0.088317)	(1090.672)
Air heat pump	0.46071***	2918.46
	(0.164471)	(1824.953)
Air heat pump×el heat	−0.61022***	−5627.04***
	(0.177113)	(2156.755)
Air heat pump×mix heat	−0.49249***	−2814.57
	(0.177561)	(2158.945)
Vent heat pump	0.33652***	3194.583***
	(0.110698)	(1021.579)
Vent heat pump×el heat	−0.44913***	−5023.28***
	(0.122398)	(1459.902)
Vent heat pump×mix heat	−0.21595	−1780.96
	(0.136943)	(1662.017)
Control system	0.03933	545.961
	(0.056018)	(544.6127)
Cont syst×el heat	−0.04578	−379.262
	(0.070717)	(1021.517)
Cont syst×mix heat	−0.04411	56.49211
	(0.080388)	(1062.813)

Dependent variable is log(consumption) and consumption. Robust standard errors within parenthesis. ***, ** and * indicate point estimate significantly different from zero on the respectively 1, 5 and 10 % levels.

Table 13: Estimated coefficient for energy conservation measures

Variable	Elheat	Mixheat	Noelheat	Elheat	Mixheat	Noelheat
		Regression 1			*Regression 2*	
R^2	0.1115	0.1363	0.1976	0.3214	0.2342	0.2428
Adj R^2	0.1006	0.1266	0.1886	0.2981	0.2097	0.2181
Log(Price)	−0.75338***	−0.15854	−1.58874***	−0.67981***	−0.3428*	−1.69268***
Log(Income)	0.11341***	0.38016***	0.32994***	−0.05764	0.0712	0.12661*
Log(Area)				0.57593***	0.39699***	0.13723
		Regression 3			*Regression 4*	
R^2	0.4363	0.3844	0.4425	0.4435	0.3849	0.4513
Adj R^2	0.3867	0.3347	0.3962	0.3923	0.3329	0.4036
Log(Price)	−0.58626***	−0.47581**	−1.19189***	−0.56303***	−0.47522**	−1.10831***
Log(Income	−0.06046	0.01893	0.0246	−0.0558	0.01514	0.03831
Log(Area)	0.49741***	0.38586***	0.1651	0.49659	0.36543***	0.12855
				−0.0156*	0.00579	0.03544**
Other variables		Appliance dummies			Appliance dummies	
		Regression 5			*Regression 6*	
R^2	0.449	0.3968	0.468	0.4816	0.4047	0.4656
Adj R^2	0.3871	0.3347	0.4116	0.425	0.3458	0.4106
Log(Price)	−0.55229***	−0.48102**	−1.11875***	−0.49881***	−0.47139**	−1.16954***
Log(Income)	−0.05651	0.01753	0.03261	−0.06699*	0.00324	0.02807
Log(Area)	0.49483***	0.36504***	0.16609*	0.51101***	0.33703***	0.10639
Cons index				−0.01505*	0.00811	0.03364**
Advice				0.05583	0.11078	0.03729
ELOFF				−0.1473**	0.12508	0.00948
Interest				−0.03022	−0.03444	0.07572**
Other variables		Appliance and conservation dummies			Appliance dummies	
		Regression 7			*Regression 8*	
R^2	0.4387	0.4076	0.4171	0.466	0.4061	0.4309
Adj R^2	0.3717	0.344	0.3466	0.3912	0.3322	0.3488
Log(Price)	−0.75808 * **	−0.65768 * **	−1.27982 * **	−0.69028 * **	−0.67478 * **	−1.29648 * **
Log(Income)	−0.04351	0.05832	0.12249	−0.0344	0.05166	0.11942
Log(Area)	0.53709 * **	0.34441 * **	0.02846	0.52372 * **	0.3466 * **	0.01165
Cons index	−0.01676*	0.00451	0.01948	−0.0152	0.00651	0.0215
Advice				0.10515*	0.06838	−0.12044
ELOFF				−0.14481*	0.04868	0.02543
Interest				−0.02669	−0.03347	0.06441
Other variables		Appliance indexes			Appliance indexes	
		Regression 9			*Regression 10*	
R^2	0.4551	0.4231	0.4552	0.481	0.4287	0.4717
Adj R^2	0.3384	0.3149	0.3443	0.3558	0.3089	0.3486
Log(Price)	−0.88438***	−0.56423***	−1.33067***	−0.81122***	−0.61479***	−1.36721***
Log(Income)	−0.08537	0.07696	0.06175	−0.07191	0.06372	0.06062
Log(Area)	0.5685***	0.36811***	0.11938	0.54105***	0.35557***	0.07754
Cons index	−0.00552	−0.00234	0.02017	−0.0056	−0.000351	0.02328
Advice				0.09851	0.0561	0.06635
ELOFF				−0.12749	0.08567	0.10276
Interest				−0.03825	−0.02988	0.06914*
Other variables		Appliance and use dummies			Appliance and use dummies	

Dependent variable is log(consumption). ***, ** and * indicate point estimate significantly different from zero on the respectively 1, 5 and 10 % levels.

Table 14: Point estimates from separate regressions by heating category. Selected variables

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