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Contractual incentives

- consumer demand response on the Swedish electricity market

Emanuel Brendarou
Major in Economics
21707@student.hhs.se

Sara Hallberg
Major in Economics
21514@student.hhs.se

Abstract:

Variable electricity rate is endorsed as the most efficient way to evoke consumer demand response, yet actual experience is limited and research within this area is thinly documented. This paper examines consumer demand response on a daily basis based on a unique dataset of hourly consumption data and electricity area prices during one year. This has been done by an OLS – regression where the dependent variable has been defined as a quotient between consumption for households with variable and fixed electricity contracts. Contrary to what the basic theory of supply and demand suggests the results do not support that electricity rate should have a significant explanatory effect on changes in relative daily consumption of electricity.

Keywords: Electricity demand, Electricity pricing models, Consumer demand response

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1. INTRODUCTION

1.1 BACKGROUND

The topic of supply and demand for energy has been reawakened a number of times in the past and is today more prevailing than ever. In Sweden the recent discussion has focused on the problems of peak consumption and high electricity prices during winter periods (Damsgaard & Fritz, 2006). These issues arose as a result of the reorganization of the Swedish electricity market in 1996. Previously the market had been under a public monopoly lead by the state-owned Vattenfall AB (Bergman & Andersson, 1995). This changed with the deregulation of the market which in turn led to more volatile prices partly due to low consumer demand response (Damsgaard & Fritz, 2006).

Consumer response for demand of electricity has been a vital factor when analyzing the impact of the deregulation. The topic is also closely intertwined with the significant question of whether the necessary electricity reserves can be created through normal market mechanisms - which postulate some kind of consumer sensitivity in demand of electricity - or if it should be controlled by the government (Damsgaard & Fritz, 2006).

Large arrays of existing research within this field have focused on estimating a demand equation for electricity and quantifying the sensitivity in demand through elasticity. The results have varied largely depending on the method implemented, available dataset, geography and time. Even so, researchers have come far in understanding the functioning of electricity markets and consumer incentives. Variable electricity rate is endorsed as the most efficient way to evoke consumer demand response, yet actual experience is limited and research within this area is thinly documented (Goldman et al. 2004).

This study continues along the line of these thoughts and further investigates the impact of electricity rates on consumers demand response. A clear understanding of this relationship would yield important implications on how to set up optimal contractual forms for electricity on the market. Contracts with higher consumer response incentives would be beneficial for the whole electricity market and especially so with regard to the issue of electricity reserves. With a higher demand response the volatility of the electricity price could be constrained. Our study brings a contribution to this presently unexplained research-area.

1.2 Overview and Contribution

This paper focuses on residential electricity demand and is intended to investigate demand response by comparing consumption of households on a variable electricity rate to those with fixed contracts and relating the fluctuation in consumption to the current electricity price. This is done by analyzing a unique dataset of hourly metered consumption data, something that researchers for long have given recognition as useful but have not yet done. The hourly consumption data will then be aggregated on a daily basis. In accordance with the theoretical basics of demand and supply as well as researchers' arguments concerning the implementation of hourly metered data, consumers facing higher electricity prices are expected to consume less and vice a versa.

The results from our study show that the electricity price, as given by the spot price of the Nordic electricity commerce, is not a statistically significant factor for explaining the difference in daily consumption between households with different contractual forms. It is beyond the scope of this paper to provide the reasons why, but reasoning is made regarding the incentive structure behind the contractual form based on the variable spot price.

1.3 Contractual forms on the Swedish electricity market

Presently there are three different types of contracts available on the Swedish electricity market: variable, fixed and default contracts. With a variable or fixed contract the consumer have actively made a choice. A default contract is on the other hand automatically assigned to a household without another contract and a consumer can at any time leave this contractual form by choosing either a variable or fixed contract. To avoid confusion of concepts it is necessary to understand that a consumer can per definition choose a default contract. However, the rate offered works the same way as the rate given by the variable contract – both rates are flexible and the contracts are without any binding period – but with an additional charge, therefore offering no reason to stay with the default contract.

The fixed electricity rate is – as implied – fixed per kilowatt hour (kWh). This gives an electricity bill with monthly consumption multiplied by the kWh-price. The variable electricity rate on the other hand varies each month. This rate is based on the average electricity spot price per hour at the Nordic electricity commerce during one month. Therefore, even though this study is based on hourly measured data one must keep in mind that the Nord Pool spot price is represented through an average mean, and not by hourly prices to hourly consumption, on consumers' invoices. The analysis in this paper is made by relating daily spot prices from the Nordic

electricity commerce directly to the difference in consumption between households with variable and fixed contracts.

1.4 Working hypothesis and disposition

A working hypothesis will be employed throughout this paper and the following statement applies:

Since variable contracts should provide stronger incentives for short run consumption alternations, the difference in consumption between households with variable and fixed contracts should be related to the electricity spot price's variation.

The sub sequential section will be dedicated to the theories that form the basis behind the above-mentioned statement. The third section contains summaries of relevant research that has been conducted within the area of our study. The fourth section provides an overview over three requirements that must be fulfilled for the hypothesis to hold. The dataset used for testing our hypothesis is presented in section five, while the results from the econometrical application will be accounted for in the sixth section. The last section of this paper contains a concluding analysis of the results and a discussion of their implications as well as potential problems.

2. THEORETICAL FOUNDATION

By reviewing the basic theoretical model of supply and demand, as well as existing empirical work on consumer demand for electricity, it is clear that this field of research is mature to the point that it can provide a general understanding of the market-specific characteristics surrounding electricity as a good. This provides a solid foundation for further investigations of specific consumer behaviour on the Swedish electricity market.

2.1 THE BASICS OF SUPPLY AND DEMAND

As explained by economic theory, ceteris paribus, supply and demand is determined by the prevailing market price. With a higher price producers are willing to supply a greater quantity of a good whereas consumers' demand decreases. In a free market the price is expected to change until the market clears, that is when the quantity supplied equals the quantity demanded, by which economist refer to when using the term *market mechanisms*. Meanwhile it is important to understand that several factors surrounding the supply and demand side have additional implications for the market outcome, for example production costs, income, consumer characteristics, good characteristics, complements and substitutes (Pindyck & Rubinfeld 2009:21-34).

One also needs to distinguish between different time horizons before making a definite statement about the absolute effects of price and income changes on consumer demand and furthermore understand the characteristics of demand for the object of research. Dependent on the chosen time horizon some factors become more relevant than others when analysing the effects on consumer demand.

2.2 SHORT-RUN DEMAND VERSUS LONG-RUN DEMAND

When considering the time horizon a distinction is made between long-run and short-run demand and a clarification is made on how much time that is allowed to pass before an exogenous shock is related to changes in demand and supply. The definition fluctuates depending on the analysed objective - there are however some general guidelines. Often when economists refer to the long run it is assumed that enough time is allowed to pass for consumers and producers to fully adjust to any price changes. As a more concrete reference short run usually means one year or less. The time horizon has implications for the analysis as some variables become more relevant than others; affecting the characteristics of demand and supply behaviour.

Whether the short-run or long-run demand is more sensitive than the other depends on the characteristics of the good. For example, demand for consumer products is more sensitive in the

long run than in the short run because it takes time for people to change their consumption habits. An example is the consumption of gasoline where a higher price only causes a smaller reduction in consumption in the short run, but in the long run the stock of cars changes towards other types of vehicles making the effect greater. The opposite is true for durables such as automobiles, refrigerators, televisions et cetera. In those cases a price change initially leads to a larger drop in consumption, since consumers defer from buying the good. In the long run however there is a need to replace the old stock and the demand thus increases again. For most consumer goods and services the effects are larger in the long run than in the short run, because of the time necessary for individuals to change their behaviour (Pindyck & Rubinfeld 2009:40-42).

2.3 Consumer Demand Response

To quantity the effects on demand and supply, elasticities have served as an accepted measure. An elasticity measures the percentage change occurring in one variable in response to a one percent increase in another variable. Price elasticity and income elasticity are two such measures. When looking at price elasticity of demand it is normally negative since a price increase of a good usually leads to a decrease in consumption of that good. The magnitude of the elasticity of demand depends on the availability of substitutes. In the case of a good that can be substituted, a price increase will cause the consumer to switch consumption towards other goods. Following the same logic, in the case where there are no substitutes, consumer demand is less sensitive to a change in price (Pindyck & Rubinfeld 2009:34).

3. PREVIOUS RESEARCH ON ELECTRICITY DEMAND

> Researchers seeking to analyse the demand for electricity are at once both fortunate and unlucky fortunate in that they are favored with data that are more extensive and probably of higher quality than those available to the typical empirical demand study, but unlucky in that electricity demand contains a number of features that are singularly difficult to model (Taylor 1975:75)

Much of the greatest influence in research concerning electricity demand comes from the work of Taylor (1975). He presents critique of the economic literature of electricity demand, specifies the unique characteristics of electricity and discusses its implications for analyzing demand response. The characteristics identified by Taylor are three: i) electricity, rather than being consumed directly, is an input to other consumption, ii) the importance of making a distinction between short run and long run electricity demand and iii) the special pricing models used for the good. These ideas have imbued later research within this field and have important implications for the analysis in this paper.

A large array of papers studying the electricity demand has focused on estimating a demand equation for electricity and quantifying the sensitivity in demand response by using elasticities as a measure. The results have varied largely depending on the method implemented, characteristics of the dataset, geography and time – a selection of the results are presented below. Despite the variance in results, researchers have come far in understanding the functioning of electricity markets and consumer incentives. The general consensus is that a price model directly related to the prevailing market prices would provide greater incentives to adapt consumption, but actual experience is limited and thinly documented (Goldman et al. 2004).

The usage of diverse pricing models in different countries complicates the analysis of consumer demand. The current pricing model in the Swedish electricity market is quite different from the ones appearing in current papers. Existing research has largely been focusing on two categories, a static and a dynamic model. The static model, referred to as time-of-use (TOU), has predefined electricity prices, a higher price during daytime and a lower price during night time while the dynamic model, referred to as real-time-pricing (RTP), have prices that are revisited continuously (Börgesson et al. 2004). Existing empirics will therefore be used to provide more general guidelines concerning electricity demand as the more detailed aspects differ from the study in this paper.

3.1 ELECTRICITY DEMAND

Electricity does not yield any utility in itself but is rather used as an input to other activities. In the case of a household these activities are represented by different electrical appliances[1], where electricity provides the energy input (Reiss & White 2004). Thereby the demand for electricity can be derived from the stock of a household's devices. When trying to estimate a model of demand it is therefore necessary to take this into consideration. In this case it is also important to understand the implications that different time horizons might have on the results (see the chapter on short-run versus long-run demand below).

Further, there are other special characteristics of electricity as a good, for example the fact that consumers of electricity do not face a single price but there are different ways of pricing the good. This has important econometric implications. In the case of the Swedish electricity market a consumer with a variable contract faces different rates each month. This complicates the character of the demand curve, which in its most basic form is linear. This discussion is frequently recurring in earlier research and was first brought up by Taylor (1995) who criticized earlier papers for using the wrong price variable in the demand function.

3.2 SHORT-RUN DEMAND VERSUS LONG-RUN DEMAND

An important distinction made by researchers concerns the treatment of households' stock of devices. In the short run researchers take this stock as a given. In this case, when the electricity rate increase a household might lower the heat inside the house or reduce the total number of hours a pool filter is operating (Taylor 1975). In contrast, when long-run demand is the subject of investigation researches have to consider changes concerning consumer behaviour and adjustments in the stock of devices (Reiss & White 2004). In other words there is greater room for consumer demand response in the long run when looking at electricity – a more thorough reasoning concerning these aspects of electricity will be given later on.

3.3 SENSITIVITY IN DEMAND

The research on demand response for electricity is extensive. Earlier studies have focused on quantifying the demand response through the price-elasticity of demand. This has been done both internationally and in the Nordic countries - some results from this research have been summarized by Börgesson et al. (2004) as given in *Table 1*.

[1] Electrical appliance, or **device**, which will be used throughout the rest of the paper

Table 1. Summary of price-elasticities

References	Year	Time-Horizon	Price-elasticity
Parti and Parti, USA	1980	short	-0,58
Morss and Small, USA	1989	long	-0,38
Baker, Blundell and Micklewright, UK	1989	short	-0,23
Dennerlein, Germany	1987	long	-0,76
Bernard, Bolduc and Bélanger, Canada	1996	short	-0,38
Branch, USA	1993	short	-0,67
Andersson and Damsgaard	1999	long	-0,2
- multi-storey dwelling			-0,71
- single family, non-electrical heating			-1,02
- single family, combined heating			-1,96
- single family, electrical heating			-0,45
Aasness og Holtsmark, Norway	1993	long	-0,2
Strømsheim Wold, Norway	1998	long	-0,24
Skjerpen, Norway	2001	long	-0,31
		short	-0,33

It is obvious from this data collection that elasticities vary depending on the time horizon, geographical context, characteristics of data and method of analysis. It is therefore difficult to draw a general conclusion concerning sensitivity in demand. Recently the criticism of price-elasticity as a measure for demand sensitivity has therefore grown. The relationship between electricity consumption and price variations seems to be too complicated to be described with a number, as seen by the great spread in the results given in *Table 1* (Börgesson et al. 2004).

4. REQUIREMENTS FOR THE HYPOTHESIS

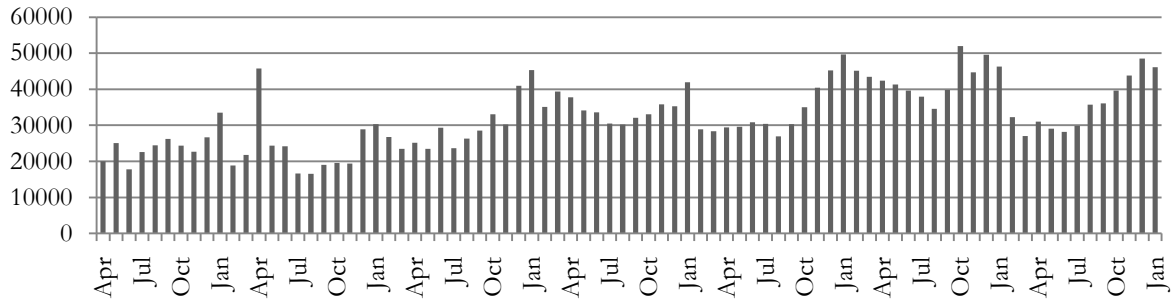
4.1 RATIONAL CHOOSERS

The notion that electricity consumption should vary between households with fixed contracts and households with variable contracts is based on the idea of consumers as rational choosers. Aldridge (2003) describes these rational choosers as individuals who, in the usual case, know their own interest and act thereby. There are however contesting views on the subject or as Slater (1997:51) chooses to describe the academia's literature on consumer behaviour as divided between "the study of formally rational behaviour (economics) and the study of its irrational, cultural content (the rest)". This paper will admittedly employ the economic perspective on consumers but still recognizes the importance of transactional costs.

Transactional costs can be divided into two categories which both contain specific implications for the electricity market. The first category involves switching costs which Weizsäcker (1984) defined as costs occurring for a consumer when switching between suppliers or brands. These are therefore the costs a consumer needs to take into account when faced with the decision of whether or not to change electricity supplier. The other category concerns costs related to the actual information search. These so called search costs are thought of as the costs weighing in when a consumer is making a decision whether to be active on the market or not. This latter category is of greater importance for the hypothesis of this paper since too high search costs will lead to passive consumers. In his study about switching and search costs for consumers on the electricity market Sturleson (2003:7) "[…] find(s) that active consumer participation is a prerequisite for active response to price competition." Therefore, in order to study a response for price fluctuation on the electricity market, consumers must first be defined as active.

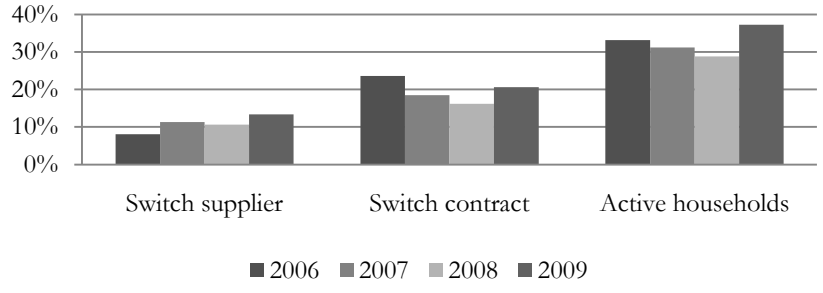
Since the deregulation of the market several studies have been undertaken with the purpose of determining if consumers are taking advantage of the opportunity to switch between electricity suppliers. Statistics Sweden (SCB) has together with the Swedish Energy Agency published quarterly reports since 2004 regarding the number of households switching electricity suppliers.

Figure 1. Number of switches by households/month: Apr 2004 - Jan 2011



As seen in *Figure 1* the total annual volume of switches has not varied greatly during the years, although the seasonal effect is quite apparent – since 2005 most households alter their electricity supplier during the fourth quarter of the year. From this paper's perspective however, the main flaw with these numbers is that they do not included consumers that alter their contracts without switching suppliers. Sturleson (2003) argues that "…most Swedish electricity suppliers offer a similar range of contracts…" which would imply that factors causing a switch in supplier are not the same that determines the choice of contract. For the past four years this issue has been recognized and as an attempt to present figures that more thoroughly show Swedish households' activities on the electricity market, SCB and the Swedish Energy Agency have produces statistics over the number of households that not just only switch suppliers but also alter their contracts, these can be seen in *Figure 2*.

Figure 2.Household activities (percent of total population)



From *Figure 2* it is clear that a substantial share of households' activities of on the electricity market is in fact an alteration of contract with their incumbent supplier. Given that the definition of an active consumer alters between studies, it is therefore important to return to what the hypothesis of this paper requires of concept "active". Since it is only vital for the search costs to

have been sufficiently low in order to make the decision of being active, this does not mean that those consumers necessarily have made a switch of electricity supplier. Therefore, the definition of an active consumer in this paper will correspond to a consumer who has made a decision concerning the contract, whether or not it being with the incumbent supplier or a change to another. This classification excludes households on default contracts according to the motivation given earlier in section 1.3.

As for a further inquiry into the rational aspect, we must given an account of the factors relevant when making a decision concerning electricity contract. A study by Thelander (2008) presents information on the reasoning made by household before the decision of electricity supplier and contract is made. In the survey included in the study over 90 percent of the respondents stated that the main motive behind their choice of contract was financial. This is in line with what SCB (2009) presents a main answer when consumers were asked to state the reason behind switching electricity supplier. In the year of 2009 84 percent stated lower price which is consistent with the results from past years - 2008 (83 percent) and 2007 (79 percent). These findings strengthen our assumption of the active electricity consumer as behaving according to the economic perspective.

The Swedish National Audit Office (2001) and the Swedish Consumer Agency (2000; 2002) has shown that an active behaviour on the electricity market is more likely for households with a higher electricity consumption. Even if the relative gain of an active choice can be the same for low-consumption households, studies suggest that the typical active consumer lives in a detached house and therefore yielding a higher electrical bill.

4.2 SHORT RUN CONSUMPTION ALTERATION

As first implied by Taylor (1975) electricity as a commodity has some unique aspects which bears consequences for how it impacts consumption behaviour. One of these being that electricity, rather than being consumed directly, functions as an input to other activities (Bladh 2007). This implies that the consumption of electricity actually involves two elements – the first one concerns how much the consumer uses the devices and the second issue is how energy-efficient that product is. Lindén (2006) uses this reasoning when dividing the households' electricity usage as based upon three factors; i) the amount of devices in the household, ii) how energy-efficient they are and iii) how the devices are used. The first two factors are mainly technical aspects while the third factor is determined by the household's behavioural decisions. The latter is also the factor of primary interest for this paper, being the only determinant of electricity consumption that can yield an immediate response to price variations.

Since the hypothesis for this paper assumes that households can alter their consumption in the short run, that is, reduction in consumption solely based on a behavioural modification, there is a need to look further into this. There have been studies analyzing the amount of influence that behaviour can have on electricity usage. Palmborg (1986) conducted measures over a two year time-period on 78 households with the same technical standard. He found that a high-consumption household could have almost twice the electricity usage of a low-consumption household and approximately a third of the total usage could be derived to behaviour. A large variation between households is also found in a Danish study conducted by Gram-Hansen (2003). Even when the households are categorized by similar technological premises, their consumption differs greatly. Gram-Hansen concludes that it is hard to separate technological and behavioural aspects when dealing with electricity usage but that it is not the energy-efficiency of devices that is essential for the ultimate consumption.

Mullaly (1999) shows other studies attempting to capture the variation in electricity consumption that can be heritage to households' behaviour. Sonderegger (1978) estimates that 18 percent of the variation in the usage is due to behavioural factors whilst Verhallen and van Raaij (1981) in their study instead show a 26 percent variation accounted for by behavioural aspects. These findings indicate that a substantial part of a household's electricity consumption can be controlled by behavioural modifications, thus supporting the prerequisite taken by this paper, that it is possible for households to alter their consumption in the short run.

4.3. NO BIAS

Since this paper will use Ordinary Least Squares (OLS) as an econometrical method to find whether there is a significant relationship between consumption and price, there are certain conditions that must be fulfilled in order for the OLS estimates to be unbiased. The most vital condition is the assumption of a zero conditional mean. For this paper, there are three circumstances where this assumption would not hold.

The first circumstance involves a matter of **measurement error**. This is a rather self-explanatory issue and occurs when an imprecise measure of a variable in the regression model is used. The second circumstance that would lead to an unbiased estimator is referred to as **simultaneity**. If at least one of the independent variables is jointly determined with the dependent variable, we have a dilemma with ceteris paribus - the casual interpretation. The last circumstance involves the **omitted variable bias**. If we believe there are factors in the error term that are correlated to any of the independent variable, then the zero condition mean assumption runs the risk of being violated.

Apart from the above-mentioned risks of creating a regression containing bias, there is also a need to determine the risk of violating another vital condition for this paper hypothesis. Since we are interested in determining if price fluctuations have different effects on consumption by households with different electricity contract, this being the same as change in demand when price varies, we need to assume that all residential household have the same demand curve. Only then can the effect of price changes be correctly measured against changes in the difference in consumption. This assumption will be discussed in the final part of this chapter.

A more detailed presentation of the dataset will be given later in the paper, but in order to ensure no measurement errors are present the nature of relevant data will be accounted for here. The data used involves measures from household electricity meters in Sweden. These are more sophisticated meters that can measure time of use down to hourly consumption. The Swedish Board for Accrediting and Conformity Assessment (Swedac) is the government authority responsible for establishing the standards for meters in Sweden and their regulations are legally valid (Swedac 2006). Svensson (2008) from the SP Technical Research Institute of Sweden states that the margin of error for the Swedish meters on average is 0.1 - 0.2 percent. This would be in direct correspondence to how large our own study's potential measurement error is. The utterly small error is thereby not likely to cause any bias in our estimates.

As for simultaneity, this often arises when we are dealing with an equilibrium mechanism, such as supply and demand equations. This is a matter that could present a problem in our study, since the factors we wish to investigate contains consumption (which in the electricity market should be exactly equal to demand) but also factors that are determined by the supply. If, for instance, the dependent variable would be equal to electricity consumption by households with variable contracts, then simultaneity would occur if an independent variable was the spot price for electricity. To understand how this works, a further presentation of the spot price is required.

The spot price is the hourly price for electricity given by the Nordic electricity exchange, Nord Pool Spot. The price is determined both in advance with Nord Pool Spot's day-ahead auction market Elspot but there is also a final adjustment made to reflect the real time market. The auction market is of a so called double auction type, where both the sellers and buyers bid. The buyers, id est the electricity suppliers, predict their costumers' usage for the following day and send in a bid offer for the predicted amount. The sellers, id est the electricity producers, send in their sale offers. All the offers need to have reached Elspot before noon, after which an equilibrium price for each hour is calculated. All the sales offers will form the supply curve whilst the bid offers make up the demand curve. The equilibrium price that is formed is the system

price which may be altered with respect to bidding areas – due to grid bottlenecks. Today Sweden as a whole consists of one bidding area, but will as of November 1st 2011 be divided into four areas. The system price might also be adjusted if the buyers' predictions were wrong or if a seller cannot produce the expected volume. Consequently, the final price will always reflect the actual electricity supply and demand of that hour (Nord Pool; Svenska Kraftnät).

Thus, as the spot price is partly determined by consumption, the OLS estimates would be biased if our goal was to explain consumption by including spot price as a variable. This is an important conclusion that requires attention when specifying the regression, saying that the dependent variable cannot solely reflect electricity consumption. In fact, what would be consistent with our hypothesis is defining the dependent variable as a measure for the *difference* in consumption for households with variable contract compared to households with fixed contract.

As for determining if there are factors in the error term that can be correlated with the independent variable, we need to look at what types of factors, other than the spot price, that could explain a difference in consumption between households with different types of contracts. A potential source could for instance be income. A fixed contract has the benefit of not allowing the rate to fluctuate, thereby offering a more stable monthly cost. This feature is likely to appeal to households on a stricter budget without the financial capacity to guard themselves against periods where the electricity rate is higher than usual. Consequently, variable contracts could be preferred by households with a higher income. This is in itself not a problem, since income is not likely to be correlated with the variables in our model, but it does point in the direction of other factors that could be. Such a factor would be house size. The size of one's residence is most probably correlated with electricity consumption and also with wealth, in other words – income. Since the spot price is set after demand, a correlation could now be suspected. If households with variable contracts have higher electricity consumption on average and if this increase in consumption is large enough to have an effect on the spot price, then the model would be biased.

A simple calculation will provide us with an idea of the probability of the above-mentioned scenario. The use of electricity in Sweden last year was calculated to the sum of 147 339 GWh. The share of what used by households was 33 934 GWh, about 23 percent of total sum (SCB 2009a). The mean share for the past year (April 2010 – Mars 2011) of household on variable contract is 29.6 percentage (SCB 2008). A rough approximation would imply that households on variable contract make up for about 6.8 percent of Sweden's total electricity consumption. Although not a negligible number, it would imply that the difference in consumption between

households on variable and fixed contracts needs to be rather large to have an impact on the spot price. Yet this is an issue to needs to be controlled for when conducting the regression.

When turning to the final assumption one may ask - is it likely that residential consumers with different contractual form have the same demand curve? A flaw could be that a price shock due to cold weather has different outcomes simply on households with different forms of contracts, because the consumers have different elasticities. If households with fixed contracts tend to prefer another type of heating system than households with variable contracts, we are likely to deal with two sets of demand curves. Our study is therefore conducted in such a way that it requires of the data collected from the two household groups to be fairly homogenous with regards to some factors, for instance heating systems. These issues call for further attention in the following section of our paper.

5. DATA

5.1 PRESENTATION OF DATASET

The original dataset consists of measurements of hourly consumption for 484 households within the Stockholm region from March 2009 until February 2010, restricted to households with a yearly consumption of 10 000 kWh to 25 000 kWh. This interval has been chosen to further restrict the sample to active consumers. The data has been collected through Vattenfall AB's research and development unit for a different purpose and therefore additional characteristics have been added to fit the purpose of this paper. Primarily the dataset has been extended by including information concerning the type of contract which has been used by the household during the period of data collection. The identification of each household has been made possible with a meter id. In the process of allocating each household to a category depending on contracts, a reduction in the number of observations has occured. First of all there have been some cases where one family has moved out and a new one moved in during the period of data collection. These observations have been excluded because of likely differences in consumption pattern between different families. Secondly some households were excluded due to a different contractual type than the ones relevant for the analysis - each household has been categorized into one of the contractual types given in *Table 2*.

Table 2. Contractual categories

Fixed - Fixed:	312
Variable - Variable:	75
Fixed - Variable:	24
Variable - Fixed	10
Default - Default:	1
Default - Fixed:	3
Default - Variable:	4
Default - Default:	8
Lost customers:	47
	484

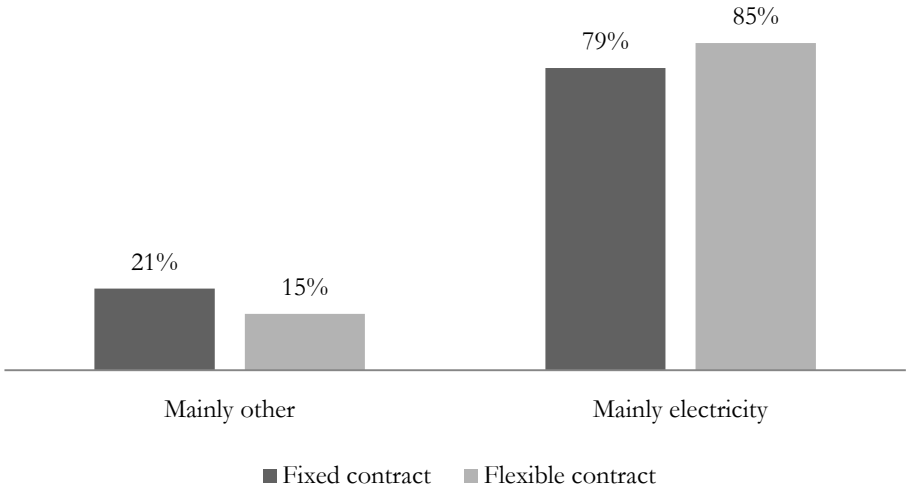
The categories are based on the contractual type at the beginning and end of the period.

In accordance with the definition set for an active consumer, only households with flexible and fixed contracts are to be included. Further, some households have decided to change electricity supplier during the period. In these cases Vattenfall AB cannot provide information concerning

the contractual type of the household and therefore these observations have also been excluded. The dataset used for the analysis therefore consist of a total of 387 households, of which 312 have a fixed contract and 75 have a variable contract. This division is also an accurate representation of the total population's division of variable contract since 22.3 to 30.2 percents of the Swedish households has been charged by a variable rate between January 2009 and December 2010 (SCB 2010).

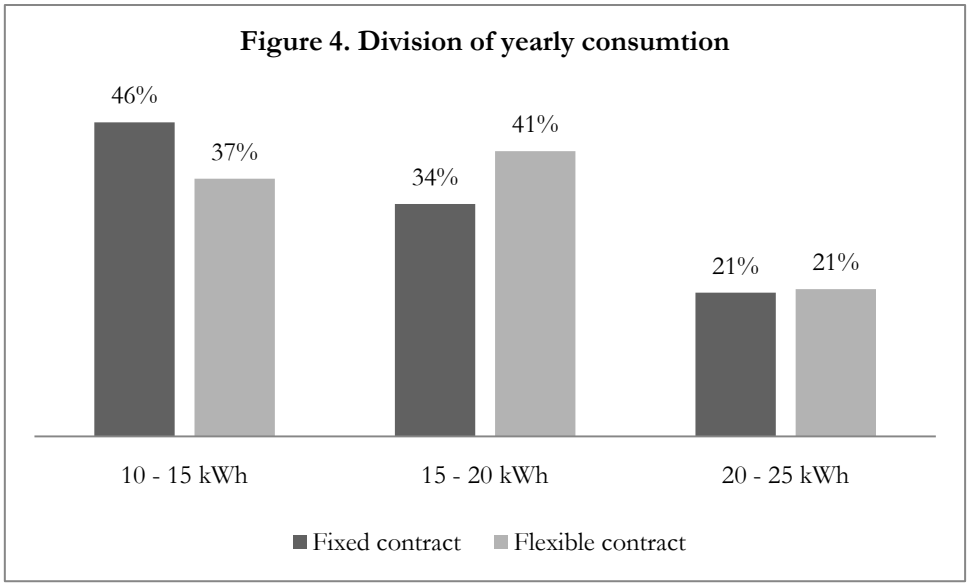
An additional feature of the data has been the identification of heating systems for approximately half of the households in the dataset. The importance of the heating system mainly concerns ruling out potential bias; to see that neither of the contractual forms is overrepresented with a specific heating system. Households were classified into five different categories, whereas two can be defined as not having electricity as the main heating and the other three categories consist of households mainly heated with direct electricity. The division between the different contractual forms can be seen in *Figure 3*.

Figure 3. Division of heating systems



Although there is a slight overrepresentation of electricity as a main heating system for households on variable contracts, the division is quite equal and should not cause any bias in the regressions.

The representation of yearly consumption categories, as divided into three consumption intervals ranging between 10-15 000 kWh, 15-20 000 kWh and 20 – 25 000 kWh, is shown in *Figure 4*.



Also with regard to the total annual electricity consumption, which provides us with information on how large average consumption we can expect a household to have, the division is rather equally spread out on the contractual forms. There are somewhat fewer low-consumption households with fixed contracts; however the most intensive consumption group holds exactly equal shares.

Adjustments to the data have been made regarding missing values where all hourly observations belonging to a daily mean below a realistic consumption value has been removed. Too low observations are most likely the result of a power failure or similar and thus not relevant. Missing values have been removed from the whole dataset, including households on both contractual forms.

The data on the electricity rates from March 2009 until February 2010 have been provided from the Nordic market for electricity, Nord Pool Spot. The collected figures are the area prices for the Swedish region on a daily average. The area price represents the actual price paid by the electricity supplier and is also the one used when setting the variable electricity rate for households.

5.2 METHOD

Existing research has focused on modeling a demand function for electricity and quantifying demand sensitivity through elasticities. This requires special attention to variables affecting consumer demand; price of the good, price of substitutes and complementary goods, consumer's income, individual's characteristics and so forth. Another dimension that complicates the analysis and modeling of the demand function is the fact that the electricity rate - for Swedish households

with variable contracts - varies depending on the prevailing market price at Nord Pool. Thereby the linear relationship between price and demand is not applicable in this situation. The overall result of such modeling therefore depends on the approach used by the researcher concerning these variables, which questions the relevance of a single number quantifying the sensitivity in demand.

This study will therefore take a different approach to the analysis of consumer demand. This is based on the above mentioned complications that are related to the modeling of a consumer demand equation and furthermore the character of elasticity as measure. Instead the analysis is based on the daily consumption data for households with fixed and variable contracts and relates the difference between these to the electricity rate at the Nordic electricity spot market – Nord Pool Spot. By using an assortment of households within the same geographical area and same consumption interval, the comparison of consumption between the contractual forms is expected to function as a form of detrending – controlling for other variables such as weather, income, stock of household appliances et cetera (see the above discussion on bias). Using econometric terms, a new variable representing the difference in consumption between the contractual forms will be regressed on the spot price. The equation can be described as the following;

$$y_{i,t} = \beta_o + \beta_1 x_t + u_{i,t} \,,$$

$$y_{i,t} = \frac{z_{i,t}}{v_t}$$

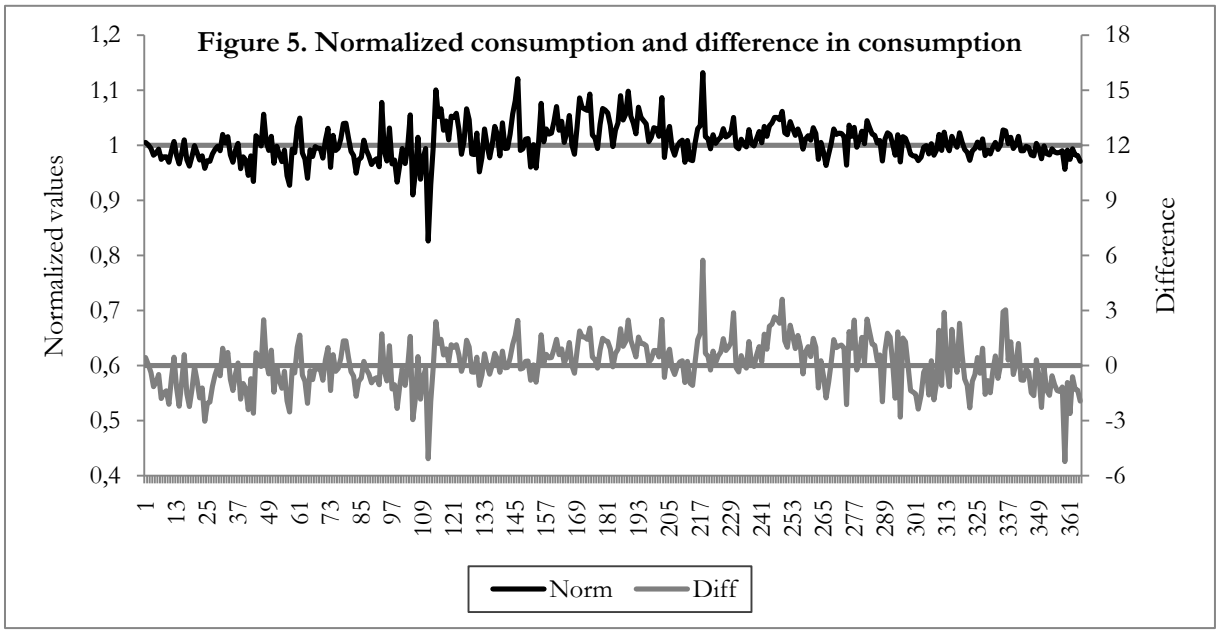
z is the variable representing all households i with variable contracts over each point in time t while v is the average consumption for all households with fixed contracts over each point in time t. The variable y is therefore a function for the consumption for all households i and x is the spot price for electricity at time t.

The purpose of this analysis is to find whether the difference in consumption between the contractual forms actually depends on the spot prices or not – id est if this is statistically significant rather than focusing on the magnitude of the elasticity. In doing so, we hope to be able to either confirm or dismiss the working hypothesis of this paper.

5.3 MODEL

The regression in this study has been thoroughly derived through a process involving an analysis of the characteristics of data. First of all, consumption data has been analysed by plotting the normalized values for households with variable consumption – a quotient between consumption

for households with flexible and fixed contracts - and the difference between consumption in households with variable and fixed contracts at a daily basis – this is shown in *Figure 5*. This has been conducted to find the proper definition of the dependent variable. The time line on the x-axis represents each day in our study where day 1 corresponds to March 1st 2009 and day 365 is February 28th 2010.



As seen by the graph the characteristic of each curve is different. The curve that represents normalized consumption data has a greater bias towards summer consumption, since the absolute consumption is smaller this time over a year an actual difference between variable and fixed consumption would yield a greater change in the quotient. The difference curve, given as variable consumption subtracted by fixed consumption, is however biased towards the winter period. This is because the absolute difference is more variable during winter time and therefore more likely to give a larger magnitude in difference. The residuals of the different functional forms of the OLS -regression - *Figure 6, Figure 7 and Figure 8* – follow the same pattern; residuals are greater in magnitude during winter time when the dependent variable is defined as y and the opposite is true when this variable is defined as the logarithm of y.

Figure 6. Residuals: Level - Level

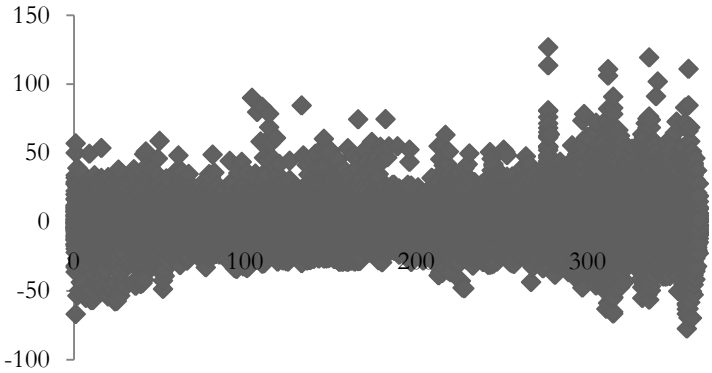


Figure 7. Residuals: Level - Log

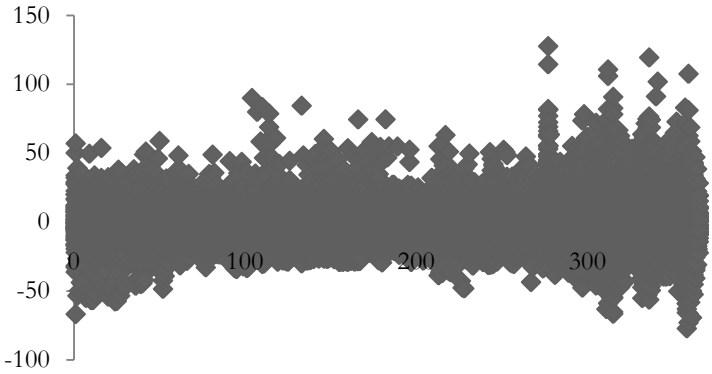


Figure 8. Residuals: Log - Log

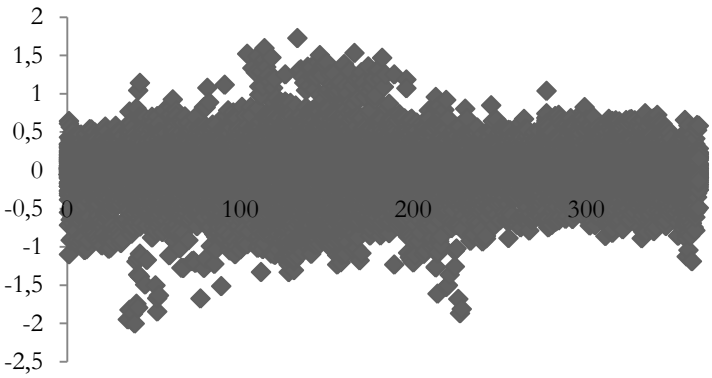


Figure 6 – 8 show the residual for all observations each day over a year; starting at 2009-03-01.

With larger residual, changes in y are explained by factors left outside the regression to a greater extent. Following this reasoning there is a need to look at variation in electricity rates. As given by *Figure 9* there is a larger variance in prices during the winter period – three outlier values have been excluded in the plotting of this line to see the variation more easily.

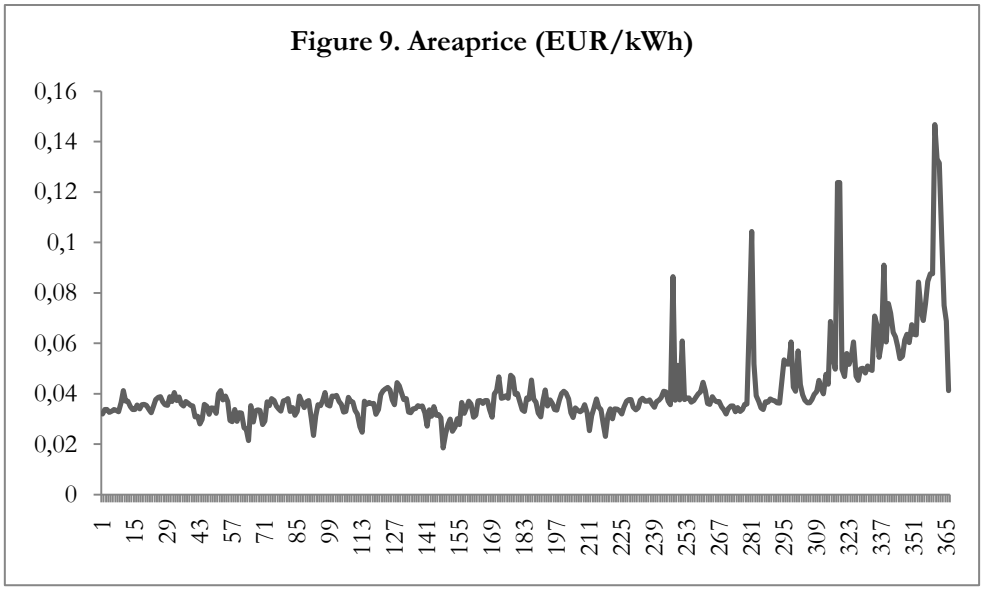


Figure 9 shows variation of Swedish area price during the period 2009-03-01 to 2010-02-28.

Therefore, because of greater variance during the winter season it is argued that it is more relevant with a proper estimate during this time of year. Thus in selecting the characteristics of the regression the logarithm of y has been chosen as the dependent variable despite the fact that an interpretation of this variable might be more difficult since the logarithm of y implies the logarithm of the quotient between households with variable and fixed contracts.

$$\log y = \log Variable - \log Flexible = \log \frac{Variable}{Flexible}$$

Due to the specification of the independent variable, the functional form of the explanatory variable has also been set as the natural logarithm of the independent variable. This combination is a more intuitive form since the interpretation of the coefficient is simplified.

The final adjustments to the model are more straight-forward and involves the fixed effects of certain factors involved. Since the aim of this study is to identify changes in consumption related to changes in the spot price, it is necessary to control for other factors explaining variation in the dependent variable. The OLS regression therefore includes dummy variables for households, week, weekdays and extreme prices. These adjust for fixed effects related to specific households such as technology used for heating and specific household characteristics, seasonal changes and weekly consumption patterns. The necessity to adjust for extreme prices is that these would otherwise have an uncalled large effect on the estimation of the regression.

6. CONSUMER DEMAND RESPONSE ON DAILY DATA

Contrary to what the basic theory of supply and demand suggests the results do not support that the spot price should have a significant explanatory effect on changes in relative daily consumption of electricity. As shown in *Table 3* the price variable is not statistically significant – the probability for the coefficient attaining the value - 0.014 when it is in fact zero is 43.9 percent. The confidence interval is slightly more skewed towards negative numbers which implies a greater possibility of a negative coefficient value. The estimated coefficient for the spot price also attains a negative number – giving us the interpretation that a price change of one percent leads to a 0.014 percent decrease in the quotient between consumption for households on different contractual forms. In the case of this coefficient being statistically significant there would still be issues regarding the interpretation of this change in the dependent variable. A decrease in the quotient could either be i) a result of a relatively larger decrease in consumption by households with variable contracts, ii) an increase by households with fixed contracts with no change in the counterpart, or iii) a decrease in consumption for households with variable contracts keeping the other constant. The R-squared value usually calls for attention in econometrical studies. In this study it is of less interest due to the influence from the additional number of dummy variables – which automatically lead to a higher R-squared value. A solution to this would be to derive the adjusted R-squared. This would nonetheless be of little contribution to the purpose of this essay – R-squared shows the degree to which the independent variables explain the dependent variable – since the working hypothesis is to seek whether there actually is an effect from price on differences in daily consumption rather than measuring the magnitude of such an effect.

Table 3. OLS – regression: Log y on log price, household, weekday, week and winter price

log y	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
log price	-0.0141384	0.0181568	-0.78	0.439	-0.0503333	0.0220564
Cons	0.1260549	0.0721062	1.75	0.085	-0.0176862	0.2697959

Log y is the natural logarithm of the quotient between daily consumption for households with fixed and flexible contracts. Log price is the natural logarithm of the daily area price. Household is a dummy variable for each household. Weekday and winter are dummies for each weekday and week. Winter price is a dummy for three exceptionally high area prices during the winter 2009 - 2010.

Therefore it is not possible to draw any conclusions as to the effects of price changes to difference in consumption on a daily basis. There is still a possibility that there exists a difference in consumption, but that this difference is not particularly large. Those finer patterns could be spotted with a larger sample – although there is of course no guarantee that even a larger dataset would show any significant relationship.

7. IMPLICATIONS AND FURTHER DISCUSSION

The economic theory provided in this paper suggests that a change in price should be followed by consumer reactions, in the case sufficient economic incentives are provided. We would therefore expect the quotient between consumption for households with variable and fixed contracts to decrease as a higher price would lead to a larger change in demand for households with the former contract. This is also the expected results when reviewing the previous research within the field of electricity demand, where negative elasticities are often statistically significant. In spite of these facts the results from our study still do not support the hypothesis that households on different contractual forms react differently to price variations, although they are provided with different economic incentives. As implied the price is statistically insignificant – with a p-value of 0.439 - as an explanatory factor to difference in consumption between households with different electricity contracts. With a small sample size the OLS regression only allows price to be statistically significant when this factor has a greater impact on the difference in daily consumption than it has in the provided regression. To understand why, it is necessary to recapitulate the assumptions made by neoclassic economic theory and the specific characteristics of electricity as described Taylor (1975).

By having established the notion that electricity is an input to other consumption processes rather than being a consumable good in itself, we have indirectly been able to derive the important implications that the time horizon might have for the result. The number of household devices is not expected to change in the short run and therefore providing less room for adapting consumption behaviour in the short run. Other important factors are consumer behaviour and characteristics. It is hard to argue that consumers should adapt consumption to prevailing market prices, when prices in large depend on consumer demand. High prices imply high demand and high demand is usually a result of certain consumption patterns – consumers use electricity at specific times a day. In the short run it is therefore not realistic to expect consumers to change their behavioural habits completely. With a shorter time perspective demand response is consequently expected to be smaller in comparison to long run response.

For the market mechanisms to function well, the underlying assumption concerning consumers as rational choosers needs to be fulfilled; individuals have to pay attention to prevailing market prices and have enough incentives to adapt consumption accordingly. As described earlier in this paper, the incentive structure for individuals with variable contracts is not ideal. The invoice is based on the average monthly spot price matched with each month's consumption. Therefore it is unlikely that the majority of consumers update themselves on the prevailing hourly price.

Consumers are more likely to be informed through the monthly invoice and one should therefore expect demand reactions to be delayed until then. Even though the hourly consumptions prices are available for consumers, there is still a problem of imperfect information which limits the incentives for consumers to react to price changes. With this dilemma the ability of the demand side to respond to price changes is undermined, which in turn restricts a well functioning of the whole market.

Overall we see that the underlying assumptions from basic theory on supply and demand used in this study's hypothesis are hard to apply to the Swedish electricity market as of today. The incentives for changes in consumer demand are not optimal, leading to lower consumer demand response than necessary. One of the effects from this dysfunction is more volatile electricity prices during periods of excess demand. The results from this paper suggest that price is not statistically relevant as an explanatory variable to daily changes in consumption between households with variable and fixed contracts, which could possibly support the contention regarding a lacking incentive structure. Yet there are potential methodological problems that can be derived from the decisions regarding functional form of the applied regression. It is possible that the relationship between relative consumption and price is different from the one used in this study and furthermore that a difference exists but is too small to be captured by the OLS due to a small sample size.

In conclusion this paper has studied the effect on the relative difference between consumption for households with two different contractual forms existing on the Swedish market. The data sample consisted of 73 households on a concentrated geographical area. Unlike previous studies on demand for electricity, the applied regression attempts to rule out undefined factors affecting consumption by defining the dependent variable as a quotient. The results showed that spot price is not statistically significant as an explanatory factor for differences in daily consumption.

BIBLIOGRAPHY

Aldridge, A. (2003): *Consumption*. Blackwell, Oxford.

Bergman, L & Andersson, B. (1995): *Market Structure and the Price of Electricity: An Ex Ante Analysis of the Deregulated Swedish Electricity Market*, *The Energy Journal*, Vol. 16, No. 2

Bladh, M (2007): *El nära och långt borta. Hur kan hushållen agera på elmarknaden?,* Perspektiv på tekniken 3. Tema Teknik och social förändring

Börgesson, L. et al. (2004): *Elförbrukningens karaktär vid kall väderlek*: Elforsk Report 04:18, Elforsk AB, Stockholm

Carlsson-Kanyama, A & Lindén,A-L (2002): *Hushållens energianvändning. Värderingar, beteenden, livsstilar och teknik. En litteraturöversikt*. Fms-rapport 176, FOI, Stockholm

Damsgaard, N & Fritz, P (2006): *Affärsmodeller för ökad efterfrågerespons på elmarknaden*: Elforsk Report 06:16, Elforsk AB, Stockholm

Goldman, C et al. (2004): *Does Real-Time Pricing Deliver Demand Response? A Case Study of Niagara Mohawk's Large Customer RTP Tariff*, University of California Berkeley, California

Mullaly C. (1999): *Home energy use behaviour: a necessary component of successful local government home energy conservation* (LGHEC) programs. Energy Policy, Vol. 26, No. 14, pp. 1041-1052.

Nord Pool Spot (2009): *Price formation at Nord Pool Spot*. Nord Pool Spot, Oslo. Available [online]: http://www.nordpoolspot.com/PowerMaket/The-Nordic-model-for-a-liberalised-power-market/ [2011-04-26]

Pindyck, R.S. & Rubinfeld, D.L. (2009): *Microeconomics,* 7th edition, Prentice Hall, Upper Saddle River, N.J. ; London

van Raaij W.F. & Verhallen T.M.M. (1983): *Patterns of residential energy use behaviour*. Ester P., Gaskell G., Joerges B., Midden C., Van Vriejs W.F. (Eds) Consumer behaviour and energy policy Selected Proceedings of the 1st International Conference Noordwijkerhout, September 1982. Elsevier Science Publishers, Amsterdam, pp. 97-118.

Reiss, C.P & White, W.M (2004): *Household Electricity Demand, Revisited*, Review of Economic Studies, Vol. 72, No. 1, pp. 853 - 883

Slater, D. (1997): *Consumer culture and modernity*. Polity Press, Cambridge

Sonderegger R.C. (1978): *Movers and stayers: the resident's contribution to variations across houses in energy conservation for space heating*. Socolow Ballinger Publishing Company, Cambridge, Massachusets

Statistics Sweden (2010): *Energy prices and switching of suppliers, 4th quarter 2010,* Statistics Sweden, Örebro. Available [online]: http://www.scb.se/Statistik/EN/EN0304/2010K04/EN0304_2010K04_SM_EN24SM1101.pdf [2011-04-26]

Statistics Sweden (2009a): *Electricity supply, district heating and supply of natural and gasworks gas 2009,* Statistics Sweden, Örebro. Available [online]: http://www.scb.se/statistik/EN/EN0105/2009A02/EN0105_2009A02_SM_EN11SM1101.pdf [2011-04-26]

Statistics Sweden (2009b): *Renegotiations and changes of contract with electricity suppliers,* Statistics Sweden, Örebro. Available [online]: http://www.scb.se/statistik/_publikationer/EN0305_2009A01_BR_ENFT1001.pdf [2011-04-26]

Statistics Sweden (2008): *Renegotiations and changes of contract with electricity suppliers,* Statistics Sweden, Örebro. Available [online]: http://www.scb.se/statistik/_publikationer/EN0305_2008A01_BR_ENFT0901.pdf [2011-04-26]

Statistics Sweden (2007): *Renegotiations and changes of contract with electricity suppliers,* Statistics Sweden, Örebro. Available [online]: http://www.scb.se/statistik/_publikationer/EN0305_2007A01_BR_ENFT0801.pdf [2011-04-26]

Sturleson, J. T. (2008): Topics in the Industrial Organization of Electricity Markets. EFI – The Economic Research Institute, Stockholm.

Svensson, S. (2008) in the article *Vad är sanningen om de nya elmätarna?* by Svensk Energi. Svensk Energi, Stockholm. Available [online]: http://www.svenskenergi.se/sv/Aktuellt/Nyheter/Vad-ar-sanningen-om-de-nya-elmatarna-Nya-matare-mater-mer-exakt-an-de-gamla/ [2011-04-26]

Svenska Kraftnät (2009): *Anmälningsområden på den svenska elmarknaden* by Svenska Kraftnät, Stockholm. Available [online]: http://www.svk.se/PageFiles/42953/091019_Slutrapport_prisomraden_bilaga%5b1%5d.pdf [2011-05-23]

Swedac (2006): *Styrelsens för ackreditering och teknisk kontroll (SWEDAC) föreskrifter och allmänna råd (STAFS 2006:7) om mätare för aktiv elenergi*. Available [online]: http://swedac.se/PageFiles/271/STAFS%202006_7%20konsol.pdf [2011-04-26]

Swedish consumer agency (2000): *Tjänste bra? Marknad, kvalitet och klagomål - konsumenter om niotjänstebranscher*. Govermental Rapport 2000:20, Stockholm.

Swedish consumer agency (2002): *Konsekvenser för konsumenter av nyligen konkurrensutsatta marknader – elmarknaden*. Govermental rapport, Stockholm.

Swedish National Audit Office (2001): *Att skapa aktiva konsumenter: Energimyndighetens och Konsumentverkets stöd till konsumenterna på elmarknaden* . RRV 2001:10. Stockholm.

Taylor, L. (1975): *The Demand for Electricity: A Survey*. The Bell Journal of Economics, Vol. 6, No. 1, pp. 74-110

Thelander, Å. (2008): *Hushåll på elmarknaden – Information och agerande*. Elforsk, Stockholm. Available [online]: http://www.elforsk.se/Rapporter/?rid=09_08_ [2011-04-26]

Weizsäcker,C. C. V. (1984): *The cost of substitution*, Econometrica 52, p. 1085-116