LUND UNIVERSITY
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Real-Time Pricing in the Swedish Electricity Market

Bachelor Thesis, Department of Economics

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ABSTRACT

An introduction of real-time prices of electricity, i.e. prices that correspond to the hourly spot market price, for residential consumers in Sweden has recently been suggested. Support for real-time pricing comes from governmental agencies as well as commercial interests, however without a good understanding of how a shift to real-time prices would affect prices and volumes in the market, and what welfare effects these changes would induce. This thesis addresses these issues by developing a model of the Swedish electricity market. The conclusion is that an introduction of real-time pricing would have a smoothing effect on prices and volumes, which in turn is likely to have positive welfare effects on producers and on the consumers that shift, but a negative effect on the larger consumers that already pay by the hour. The net welfare effect is likely to be positive.

Keywords: Electricity, Real-Time Pricing, Sweden

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1. Introduction

For the past 15 years Swedish electricity consumers have been part of an integrated Nordic electricity market where the price of electricity changes every hour. However, almost all small consumers of electricity, such as residential consumers, never directly face these changing prices. They are instead charged a price that is fixed for at least one month, and is the same for all hours of the day. A consequence of this is that small consumers are given no incentives to move their consumption of electricity from hours where the price of electricity is high to hours when it is lower. As have been stated in previous research (see for example Wellinghoff and Morenoff, 2007 or Borenstein and Holland, 2005), and is confirmed by the results of the model developed in this thesis, this leads to an amplification of highs and lows in the consumption of electricity. A high variance in demand for electricity is problematic for several reasons. First of all, since high peaks in the Nordic electricity market have to be met with production using fossil fuels, a high variance in demand for electricity will have detrimental environmental effects (Holland and Mansur, 2008). Further, higher peaks in demand requires more installed generating capacity which in turn leads to higher average prices for electricity (Alcott, 2011).

Because of recent improvements in electricity metering technologies it has become possible to change this situation. The Swedish Energy Markets Inspectorate recommends in an official report to the Swedish government a shift to time varying prices for small electricity consumers, advising that such a shift should be done stepwise in order to minimize implementation costs (Lundgren et al., 2010). Another report on the issue, by Fridolfsson and Tangerås (2011) at the Research Institute for Industrial Economics[1], suggests that this should be enacted more rapidly by introducing a regulation obliging electricity trading companies to offer hourly pricing to households whenever possible. However, these recommendations are made without a thorough investigation on the consequences on prices, consumed quantities and welfare effects that would result from shifting consumers to time varying prices. The Energy Markets Inspectorate bases their recommendation on a cost-benefit analysis showing a positive net welfare effect, but a major limitation in their analysis is that they take prices as given and thus ignore the fact that shifting the price facing households would affect the spot price itself. This dynamic effect is considered in the report from the Research Institute for

[1] The Research Institute for Industrial Economics (Swedish: Institutet för Näringslivsforskning) is a research institute controlled by Svenskt Näringsliv, the Confederation of Swedish Enterprise.

Industrial Economics by showing that an introduction of hourly prices would have a smoothing effect on spot market prices. The welfare effects from such a smoothing are discussed, and the report concludes that hourly prices are likely to benefit most consumers, industrial as well as residential. However, no detailed explanation for why industrial consumers would benefit are given.

The purpose of this thesis is to investigate the consequences of switching households and other small electricity consumers in the Swedish electricity market from fixed prices to prices that change hourly. How would spot market prices and consumed quantities of electricity be affected? How would these changes affect the welfare for the small consumers that shift, for the larger consumers who already pay by the hour, and for the producers?

To address these questions a model for the Swedish electricity market is developed in which prices and quantities can be simulated for every hour. The representation of demand in the model is inspired by the approach used by Borenstein and Holland (2005) and Borenstein (2005) who analyzes the consequences and welfare effects from shifting consumers to time varying prices. However, the model in this thesis differs in that it allows for a difference in hours of peak demand between small and large consumers. The demand parameters, and a supply curve, are estimated to represent the current market for electricity in Sweden using data on spot market prices and traded volumes as well as estimates of consumption patterns for Swedish consumers.

The focus of this thesis is limited to an investigation of how spot market prices and volumes would change, and to an analysis of the welfare effects caused by these changes. This will be done using data for a relatively short period of time, and the costs of implementing time varying prices for small consumers will not be investigated. Therefore a complete cost-benefit analysis for the implementation of time varying prices is beyond the scoop of this thesis and is left for further research. For simplicity, the model ignores taxation as well as fees charged by electricity trading companies. The possible effects from various designs and magnitudes of taxes and fees are not discussed. Also, whether a high degree of concentration of ownership in the production of electricity leads to imperfect competition in the Swedish electricity market is frequently debated (see for example Andersson, 2007) but this issue, or how an abuse of market power would affect the results obtained in this thesis, will not be considered. Neither will the environmental effects be investigated closer.

The main results returned by the model are that shifting small consumers of electricity to time varying prices would have a smoothing effect on prices and volumes traded, and that the welfare effect from this decrease in variance is positive for small consumers and producers, but likely to be negative for the large consumers who already pay by the hour. The net welfare effect is positive.

The thesis proceeds as follows: Section 2 provides background information including a brief description of the Nordic electricity market and a discussion of the characteristics of supply and demand for electricity. Section 3 presents the model. The parameters of the model are estimated in Section 4 using Swedish data. Section 5 provides the equilibrium results that are obtained when supply equals demand. The sensitivity of these results to modifications of some key assumptions is also investigated here. Section 6 concludes and discusses limitations of the model as well as possible areas for further research.

2. Background

2.1 Electricity as a commodity

Electricity has a set of unique properties distinguishing it from most other goods and services traded. An important difference between electricity and other goods is that electricity must be consumed and produced simultaneously. There is, as of today, no efficient way of storing electricity (Crampes and Moreaux, 2009). For electricity markets this means that supply and demand must be equal at all times. It also means that, for the purposes of economic analysis, electricity at different times is best thought of as different goods. In this sense, electricity has more in common with most services than goods; production and consumption of a haircut also needs to be simultaneous. But unlike a haircut, electricity is a homogeneous good. Once in the grid, one producer's electricity does not differ from another's. This property is important for making electricity suitable for trade on an exchange.

Another important characteristic of electricity markets is that the distribution of electricity from producer to consumer requires a grid. The large initial fixed costs in constructing such a grid, and the close to zero marginal cost for distributing an additional megawatt-hour, make electricity grids a classic example of natural monopolies. This issue has induced many countries to make both the production and distribution of electricity regulated monopolies, often involving state owned firms.

2.2 The Nordic electricity market[2]

The Nordic electricity market is a deregulated common market for electricity in Norway, Denmark, Sweden, Finland and Estonia. Norway was the first of these countries to deregulate its electricity market in 1991 and Sweden followed five years later adapting the Norwegian market model. The Oslo-based Nord Pool exchange became the common exchange for electricity in both Sweden and Norway. The other Nordic countries came to join soon after.

In the Nordic electricity market production of electricity is deregulated and open to competition. This means that firms can produce and sell electricity at whatever time and in whichever quantity they find most profitable. Producers sell most of the electricity they produce over the power exchange Nord Pool Spot, but they can also sell electricity directly to large consumers by bilateral contracts. In either case, the producer needs to feed the electricity into the grid. The grid is a natural monopoly regulated in Sweden by the Energy Markets Inspectorate. At the local and regional levels, the grid is owned by grid operators who are responsible for delivering the electricity to consumers and may charge a fee for this service. The Energy Markets Inspectorate determines how high this fee may be according to a cost model. The main high-voltage national grid is in Sweden owned and operated by state owned Svenska Kraftnät.

Svenska Kraftnät also acts as the transmission system operator (TSO) in Sweden which means that they are responsible for ensuring that the amount of electricity fed into and taken out of the grid equals at all times. To be able to meet this objective, Svenska Kraftnät requires that every consumer and producer has a balance agreement with Svenska Kraftnät. This balance agreement states that for a consumer to take electricity out of the grid they must ensure that someone else is feeding the same amount of electricity into the grid at the same time. Since this would be a way too difficult and time consuming thing to do for most small electricity consumers there are power trading companies specialized in this task. The consumer signs a contract with a trading company who buys the electricity for the consumer.

Since 2002 the Nordic exchange for electricity has been organized as a separate company, Nord Pool Spot AS, owned by the TSOs of the participating countries. Nord Pool Spot runs a

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[2] The description of the Nordic electricity market in this section is based on information from Svenska Kraftnät (2011) and Nord Pool Spot (2011a).

day-ahead market, Elspot, and an intraday market, Elbas. Most trade takes place on the day-ahead market. In this market the price of electricity is set hourly and determined on the day before the electricity is to be produced and consumed. To establish the price for a given hour, market participants place bids on the amount of electricity they want to consume or produce for all possible prices. Bids must be placed no later than at 12:00 CET on the day before delivery. When all bids have been collected they are aggregated to form demand and supply curves for every hour. The price is set where these curves intersect (this price is called the system price). The market participants who placed bets on selling or buying at this price are now obliged to do so. Because of grid capacity constraints, and because of the fact that both production and consumption are unevenly distributed geographically, it is possible that there will be a surplus of electricity in some regions and a shortage in others. To solve this problem the Nordic countries are divided into different bidding areas. The system price is modified in every bidding area until the flow of electricity between the areas is small enough for the grid to handle.

As mentioned above, once the price is settled all market participants are obliged to fulfill their commitments and sell or buy whatever they stated in their bids. But since the price is settled 12 to 36 hours before delivery it is not uncommon that unforeseen events make producers unable to deliver what they promised or that consumers need more. Therefore there is a second market, the intraday market, where electricity is traded up until one hour before delivery. The intraday market works as a complement to the day-ahead market and traded volumes are significantly higher in the later.

Nasdaq OMX Commodities trades forwards, futures, options and other derivatives with electricity in the Nordic market as the underlying asset. These contracts use the system price as the reference price and are settled in cash, i.e. no physical delivery of the electricity takes place. Contracts like these allow producers and consumers in the market to manage risks associated with price fluctuations and they enable trading companies to offer a fixed price of electricity over long periods of time to their customers.

2.3 Market prices and volumes

In this section Nord Pool Spot market data for the first seven days of September 2011 (Nord Pool Spot, 2011b) is described in order to shed light on some main characteristics of the behavior of prices and traded volumes in the market. Figures 2.1a and 2.1b show the average prices and traded volumes for these seven days. The prices are the Nord Pool Spot prices for the bidding area Sweden and volumes are the quantities of electricity bought by Swedish consumers. Both prices and traded volumes in the Nord Pool Spot market tend to follow a recurring day-cycle. At night, when businesses and industries are less active and most people are asleep, prices and volumes are low. In the morning prices and volumes rise sharply and a first peak is reached after which a slightly calmer period follows during midday. A second peak occurs in the evening when lights need to be turned on. A curve like figure 2.1b showing quantities of electricity for every hour of the day will in the remainder of this thesis be referred to as a load curve or load profile.

Figure 2.1a Average spot prices (Nord Pool Spot, 2011b)

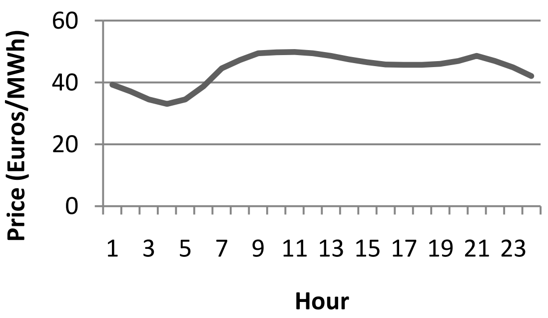
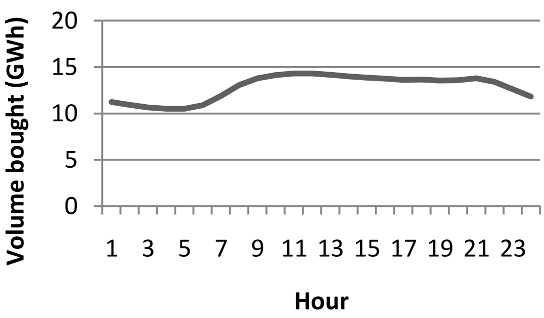


Figure 2.1b Average load profile (Nord Pool Spot, 2011b)



Although the average price and load profiles look similar there is one important difference between the behavior of prices and volumes observable in the market data. The amount of electricity bought in the market follows a predictable pattern where every day looks similar to the average shown in 2.1b, but the prices behave in a more stochastic way. The smooth curve in figure 2.1a only appears when prices are averaged. Figures 2.2a and 2.2b show this difference by plotting the prices and volumes for all hours of the same seven days as above. In 2.2b the nighttime lows and daytime peaks clearly stand out and form a regular pattern. This pattern is much less apparent in the price figure.

Figure 2.2a Spot prices for seven days in Sept 2011 (Nord Pool Spot, 2011b)

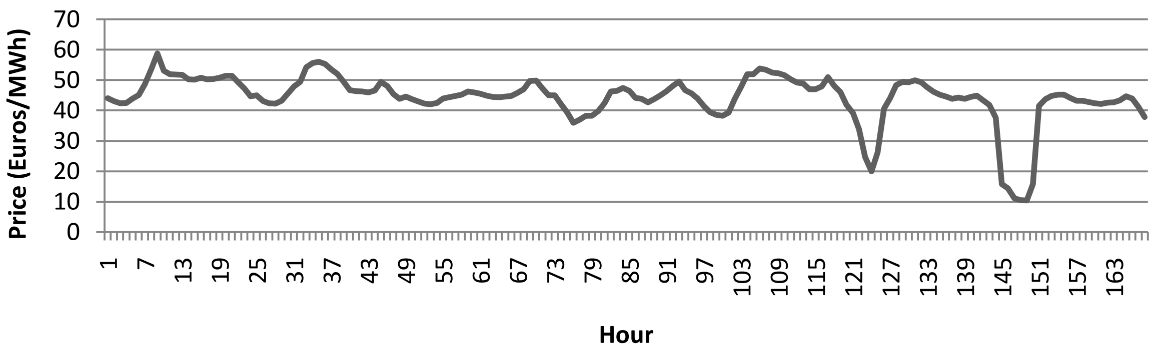
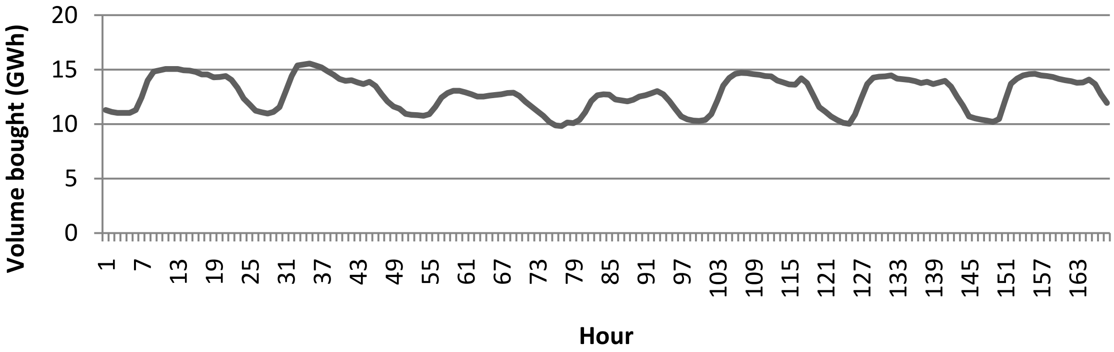


Figure 2.2b Volumes for seven days in Sept 2011 (Nord Pool Spot, 2011b)



Why do volumes follow a predictable pattern while prices do not? A possible explanation relates to differences in short run price elasticity between supply and demand. In a situation where demand is highly inelastic but supply is more willing to respond to prices, all shocks to either demand or supply have to be met by an adjustment on the supply side. If, in a market like this, the demand curve is predictable for every hour while the supply curve is subject to random shocks, the situation observed in 2.2a and 2.2b would occur.

2.4 Pricing schemes

Almost all small electricity consumers in Sweden, such as residential consumers, pay electricity prices that do not vary from hour to hour but rather some kind of average price. Electricity trading companies usually offer small consumers the choice between a floating price which changes monthly and is calculated as a weighted average of the spot price, and a fixed price that is constant for a longer period of time, usually 1, 2 or 3 years (Lundgren et al, 2010). In either way the consumer faces the same price for all hours of the day. In September 2011 29.2 percent of residential consumers had a floating agreement and 42.5 percent had a fixed agreement (SCB, 2011a). The remaining consumers had either not made an active choice, and therefore had a "standard price agreement" (22.2 percent), or had some other kind of pricing scheme (6.1 percent). Larger consumers of electricity, such as industries, commonly pay prices that are different for different hours of the day.

When the Nordic electricity market was created most small electricity consumers had meters which did not transmit information on how much electricity the consumer was using on every hour. It was therefore not feasible to have small consumers paying time varying prices. However, modern meters can meter electricity consumption at any desired frequency and as of 2010 over 90 percent of the meters installed could measure electricity consumption on an hourly basis. There are therefore no longer any major technological constraints stopping time varying pricing plans for small consumers.(Lundgren et al., 2010)

Damsgaard and Fritz (2006) identify three possible pricing models where consumers pay different prices at different times of the day. The most straight forward scheme is real-time pricing (RTP) where consumers pay a price that follows the hourly spot price. In time-of-use pricing (TOU) prices vary over hours but are the same day after day. In other words TOU is the fixed price version of RTP. The third kind of time varying pricing plan is called critical peak pricing (CPP). With CPP the price is set high at some predetermined peak hours and are the same for all others. The only pricing scheme that actually follows the spot price is thus RTP.

2.5 Demand

No one actually demands electricity in itself. It gives you shocks and if it runs through your body you might die. The demand for electricity is derived from the demand of things that electricity can be used for, such as heating, lighting up a room, writing a bachelors thesis on a laptop and an endless list of many other things. This pluralism in the usage of electricity also affects the time aspect of its consumption. For the consumer, electricity at different hours might be substitutes to some degree. I can for example choose to charge my cell phone now instead of later tonight. But the degree of substitutability is in many cases very low; I want my TV to be turned on when I am in front of it, not when I am at work. In some cases electricity at different times can even be thought of as complements. If I want to freeze a piece of food for next week I need electricity for my freezer on every day the following week. I cannot compensate for an absence of electricity in my freezer on Wednesday by using twice as much on Friday. These characteristics make estimating demand difficult but they provide yet another reason for why it is fruitful to think of electricity consumption in different hours as different goods.

What kind of effect would be expected if consumers shifted from fixed prices to RTP? Assume that in an initial state a fraction of consumers pay RTP while the remaining consumers pay some fixed price that is the same for all hours. Borenstein and Holland (2005) show that in this case shifting more consumers to RTP would have the effect of tilting the demand curve for any given hour. The reason for this is that the consumers who initially paid the fixed price did not face the hourly price and were therefore completely inelastic to changes in it. When more consumers pay the hourly price total demand is going to be more elastic and the demand curve will therefore get flatter. The demand curve will rotate around the point on the demand curve that corresponds to the fixed price. In this setting having more consumers pay RTP is going to reduce prices and quantities consumed for hours where the hourly price is higher than the fixed price. The reverse effect will be observed for hours where the hourly price is lower than the fixed price. The magnitude of these changes depends on the price elasticities of the consumers as well as the shape of the supply curve. The price elasticity of demand will be further discussed in section 4.1.4.

2.6 Supply[3]

The two most important sources for production of electricity in the Nordic market are hydropower and nuclear power. Producing electricity with nuclear power is associated with a large initial fixed cost but a very low marginal cost. Because of the low marginal cost, nuclear power producers supply the maximum amount of electricity possible at any given time. In addition, it is not possible to efficiently and quickly alter the amount of electricity produced in different hours. This means that the supply of electricity from nuclear power does not respond much to differences in prices between different times of the day. The supply curve from nuclear power producers is basically vertical in the short run.

The supply from hydropower is more sensitive to price changes. The reason for this is that the owner of a hydro power plant can easily adjust the amount of electricity produced in different hours and is thus capable of responding to high or low prices. The owner also has a reason to do so since there is an opportunity cost in letting water falling down the turbines and producing electricity. This is because in any given season there is only a fixed amount of water in the reserves and so using some water now means that it cannot be used later when prices might be higher. Sophisticated hydro plant owners calculates a “value of water” using stochastic models of future market prices and future precipitation. This value of water is taken as the marginal cost of the hydro power plant; if the market price is higher than the value of water for a given hour the producer will choose to produce. This results in an upward sloping supply curve from hydro power.

Electricity produced with fossil fuels is needed at times when demand is high. All together, the different sources of electricity production aggregate to create a short-run supply curve that is vertical for low prices, gets flatter after a certain threshold price that equals the value of

[3]The description of the characteristics of electricity production in this section is based on an interview (28th of October 2011) with Set Persson, Head of Operational Management, Asset Optimization Nordic, Vattenfall AB.

water, and then gets more vertical again as high marginal cost electricity from fossil fuels is needed to reach large quantities. As opposed to the demand curve, the supply curve does not shift in a predictable way for different hours of the day. The only reason why production might be systematically higher for some hours and lower for others is because of differences in demand.

3. The Model

The following model aims at providing a tool to analyze what would happen to equilibrium prices and quantities of electricity if small electricity consumers, such as households, switched to real time pricing in the Swedish electricity market. To keep the model simple a range of assumptions are made about the structure of the market and the behavior of its participants. Some of the assumptions will be discussed in greater length in sections 5 and 6.

The model assumes two different kinds of electricity consumers. The first kind, "Household", is assumed to currently all be on a time invariant pricing scheme, i.e. they all pay some fixed rate that is the same for all hours of the day. The second kind of consumer, called "Industry", is assumed to already pay real time prices. In what follows, Household and Industry (with capitalized H and I) refers to these two groups of consumers in the model. The goal of this model is to analyze the consequences of having Household paying real time prices as well.

The model treats electricity at different times of the day as different goods, i.e. electricity between 1.00 and 2.00 is treated as one good and electricity between 15.00 and 16.00 as another. The cut-offs are hourly to reflect the pricing at Nord Pool Spot.

3.1 Modeling demand

To model the demand of electricity it is necessary to make assumptions on how electricity consumers respond to prices. One crucial distinction is whether consumers, when paying real-time prices, respond to prices immediately on an hour by hour basis or if they respond to average prices. We could assume that consumers stay up to date with price changes continuously and change their behavior depending on the spot price every hour. However, it seems unlikely that small electricity consumers, such as households, would spend that much time and energy on making optimal electricity consumption decisions. Even for larger industrial consumers it has been shown that the response to price changes in the very short run is extremely small (Patrick and Wolak, 2009). Therefore, in this model it is assumed that electricity consumers respond to average prices. This means that if the price of electricity between 1.00 and 2.00 is very low for one day only we do not expect to see a significant demand response, but if the *average* price of electricity between 1.00 and 2.00 changes it is assumed that consumers eventually will change their behavior.

The approach for modeling demand in this thesis is similar to that of Borenstein (2005) and Borenstein and Holland (2005) who investigate the effects of a switch to RTP by different fractions of consumers using US data. However, while allowing for some consumers to have more peaky demand than others, Borenstein and Holland (ibid) assume that the hours of peak demand coincide for all consumers. By assuming two different kinds of consumers, the model in this thesis allows for a difference in peak hours for the consumers who in the initial state are paying time invariant prices and those who are not, which is meant to capture the difference between large and small consumers in the current Swedish electricity market.

Demand is assumed to take a constant-elasticity form, which means that the own-price elasticity does not change with the price. The price elasticities will not be estimated in this thesis but instead simulations will be done for a range of different likely elasticities. All consumers within Household and Industry respectively are assumed to have the same price elasticity and the same load profile. In other words, it is assumed that it is possible to identify two kinds of representative consumers, one for Household and one for Industry.

Assuming constant price elasticity of demand for both Household and Industry implies that the demand functions have the form:

$$D_i^H(\bar{p}) = A_i\bar{p}^{\epsilon_H} \text{ and } D_i^I(p_i) = B_i {p_i}^{\epsilon_I}$$

where D_i^H and D_i^I are quantity of electricity demanded by Household and Industry respectively in hour $i = 1,2,3,\dots,24$. The price of electricity in hour i is p_i and $\bar{p}$ is the weighted average price facing the household consumer on time invariant pricing. ϵ_H and ϵ_I are the price elasticities for Household and Industry respectively and are assumed to be the same for all hours of the day. A_i and B_i are constants which will be estimated (along with $\bar{p}$) in section 4.

Total demand in hour i is then simply the sum of the two:

$$D_i(\bar{p}, p_i) = D_i^H(\bar{p}) + D_i^I(p_i) = A_i\bar{p}^{\epsilon_H} + B_i {p_i}^{\epsilon_I}$$

The only thing that would change in these functions if Household switched to RTP is that $\bar{p}$ should be replaced by p_i. The estimate of A_i obtained by using $\bar{p}$ would still be valid.

Note that modeling demand in this way means that cross-price elasticities are zero. This assumption clearly seems unrealistic since electricity at different hours of the day is likely to substitute to some degree. However, not including a 24×24 matrix with estimates of cross-price elasticities greatly simplifies the model. Borenstein (2005) argues that including this in the model would probably increase the effects of RTP.

3.2 Modeling supply

To capture the nonlinearities of the supply curve discussed in section 2.6, the model features a third degree polynomial function. The supply curve will thus be specified as

$$S_i(p_i) = \beta_0 + \beta_1 p_i + \beta_2 p_i^2 + \beta_3 p_i^3$$

WhereS_i is the supplied quantity of electricity in hour i which is a function of the price of electricity p_i in hour $i = 1,2,3, \dots ,24$. $\beta_0, \dots , \beta_3$ are parameters to be estimated in Section 4.

Note that this specification assumes that the supply curve is the same for all hours of the day (the βs are not different for different hours). This is a reasonable assumption since, as stated in section 2.6, there is nothing time dependent in electricity production.

3.3 Equilibrium profiles

Imposing the condition that supplied and demanded quantity of electricity must equal for every hour, while also letting Household consumers pay by the hour, means that we get 24 equations (one for each hour):

$$D_i(p_i) = S_i(p_i) \Leftrightarrow A_i {p_i}^{\epsilon_H} + B_i {p_i}^{\epsilon_I} = \beta_0 + \beta_1 p_i + \beta_2 p_i^2 + \beta_3 p_i^3$$

If all parameters have been estimated these equations can be solved for p_i. There will be a unique solution for every hour as long as the supply curve is estimated in a way that makes it increasing for all values of p_i and the elasticities are chosen so that the demand curve is decreasing.

The resulting p_is are the new price profile that the model predicts would be the spot market prices if all households shifted to RTP. Plugging the p_is back into either the demand or supply function yields the predicted load curve. By comparing this to values obtained when household consumers pay average prices, we can investigate what the likely consequences of a shift to RTP by all households would be.

4. Estimation of model parameters

Publically available data for prices and traded volumes at the Nord Pool Spot exchange for every hour of September 2011 is used for estimating the supply and demand parameters (Nord Pool Spot, 2011b).A relatively short time period is chosen for two reasons. First, estimating a good supply function empirically requires that the supply does not shift too much. If a longer period is used it is likely that, for example, changing weather conditions may cause a major and persistent shift in supply making it difficult to decide on an estimate that can represent the whole period. The second reason concerns the demand for electricity for heating purposes. Since demand for electricity in a given hour is going to be higher if it is cold outside, a reasonable estimate of demand for a longer period of time would have to take outdoor temperature into account. But since the objective of this thesis is to investigate the consequences of having households on RTP, not to estimate perfect supply and demand functions that will work under all conditions, the complications caused by seasonal variations in demand can be ignored. The estimates obtained for supply and demand therefore only represent September 2011 and cannot be used for other months. September was chosen to avoid the difficulties from demand for heating in the winter, while also avoiding summer data that might differ systematically from the rest of the year due to vacations.

The quantity of electricity bought by Swedish consumers at Nord Pool Spot is used as a proxy for the quantity consumed and produced. The listed prices from the exchange are used as the price facing consumers and producers which means that taxes, fees charged by trading companies etc. are not taken into account.

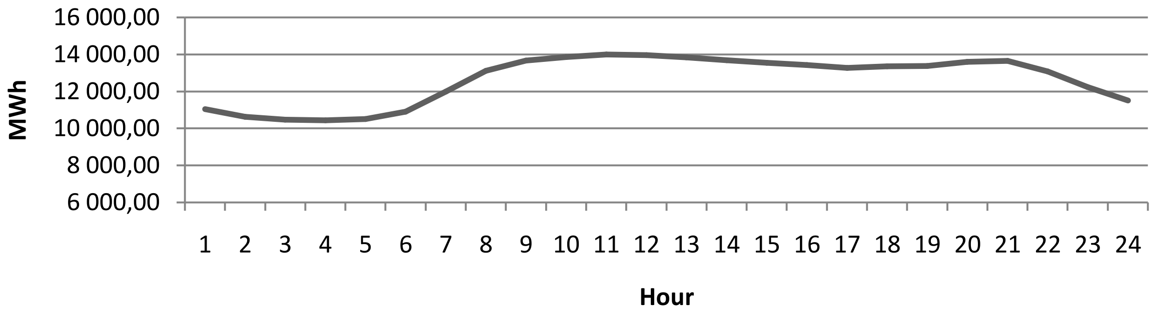
4.1 The demand parameters

In this section, 48 demand parameters will be estimated, one for every hour of the day for both Household and Industry. These are the A_is and B_is in section 3.1. To achieve this using data on quantities and prices for September 2011 it is necessary to first divide the total quantities consumed into quantity consumed by Industry and quantity consumed by Household for every hour. Also $\bar{p}$ needs to be calculated.

4.1.1 Dividing total consumption into Household consumption and Industry consumption

Figure 4.1 shows the average load profile for all consumers in Sweden in September 2011. This profile needs to be divided into one for Household and one for Industry in such a way that Industry represents the consumers currently paying RTP while Household represents the ones who do not. In what follows this is done by letting Household be all residential consumers and Industry all nonresidential. Parts 6.1 and 6.2 will investigate the effects of altering this assumption.

Figure 4.1 Average load profile for all consumers September 2011 (Nord Pool Spot ,2011b)



The Swedish Energy Agency has estimated the structure of the average hourly load curve for a family living in a house without direct electric heating (Zimmerman, 2009). For estimating Household demand this load curve is used as a proxy for the average load curve of all households. The load curve is shown in figure 4.2.

Figure 4.2 Average hourly load curve for households (Zimmerman, 2009)

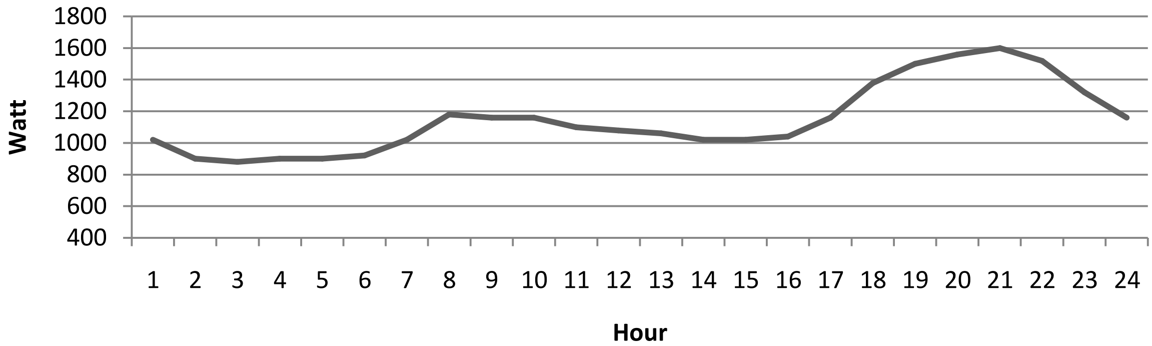


Figure 4.2 shows the shape of the Household load curve but for the estimation we also need to decide on the fraction of total consumption in September that the Household category may account for. Statistics Sweden publishes data on how electricity consumption breaks down between different kinds of consumers. For every month they publish the amount of electricity

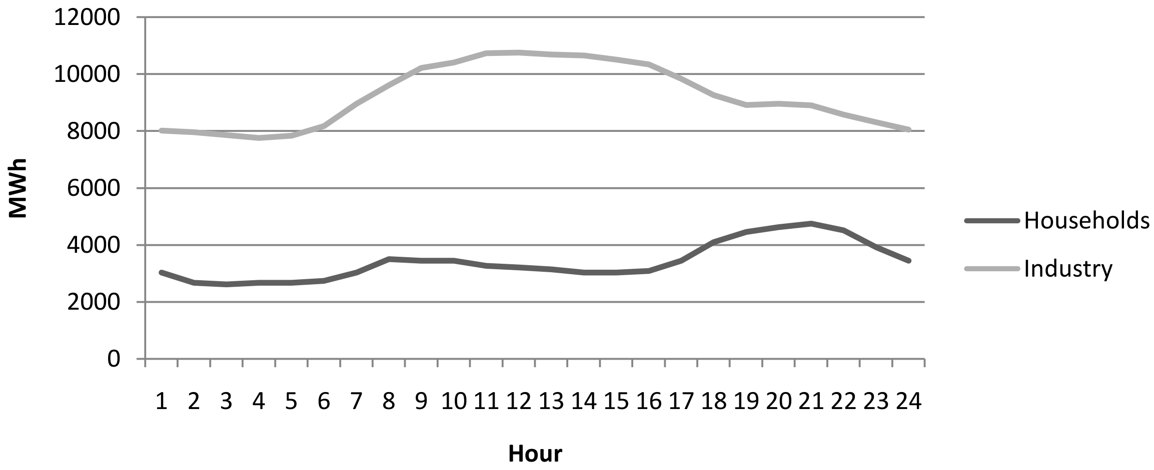
consumed by, among other categories, “Households, services etc” as well as total electricity consumption (SCB, 2011b). For September 2011 the amount of electricity consumed by “Households, services etc” was 4 570 GWh while the total domestic consumption was 10 178GWh which means that about 44.9 percent of the domestically consumed electricity was consumed by “Households, services etc”. This is however a bit of an overestimate for household consumption since it includes more than just households.

Nordel, a collaboration organization of the transmission system operators of the Nordic countries published data on the share of electricity consumption for households (not including services) until 2008 when it merged with its European counterparts. For 2008 Nordel estimated that households accounted for 29 percent of the total electricity consumption in Sweden (Nordel, 2008). In the data from Statistics Sweden the amount of electricity consumed by “Households, services etc” as a fraction of total domestic consumption in 2008 was about 48.2 percent. This leads to the approximation that about 29/48.2≈60.2 percent of the value for “Households, services etc.” is household consumption only. Thus, the final estimate for the fraction of electricity consumed by residential consumers in September 2011 is 44.9*0.602≈27.0 percent.

Let c_{ij} be the total consumption of electricity in hour i on day j ($i = 1,2,3,..,24$ and $j = 1,2,3,\dots,30$). Further, let c_{ij}^H and c_{ij}^I be the consumption in hour i on day j for Household and Industry respectively. c_{ij} is given in the Nord Pool Spot data for every hour of every day in September 2011. c_{ij}^H and c_{ij}^I are unknown and need to be estimated. Also, let c_j be the total consumption for all hours of day j and c_j^H the total consumption for Household for all hours of day j ($c_j = \sum_{i=1}^{24} c_{ij}$ and $c_j^H = \sum_{i=1}^{24} c_{ij}^H$).

c_j^H is calculated as $c_j \times 0.27$. c_{ij}^H is then calculated as $c_j^H \times b_i$ where b_i is the fraction of electricity consumed in hour i according to figure 4.2 above. c_{ij}^I is estimated as $c_{ij} - c_{ij}^H$. This gives estimates of c_{ij}^H and c_{ij}^I that can be used to calculate $a_i^H = (\sum_{j=1}^{30} c_{ij}^H)/30$ and $a_i^I = (\sum_{j=1}^{30} c_{ij}^I)/30$ for Household and Industry respectively. These averages are the estimated load profiles for Household and Industry presented in figure 4.3.

Figure 4.3 Estimated load profiles for Household and Industry



Note that the Household curve in figure 4.3 has the same shape as the curve in figure 4.2 but now show the value for all households in September 2011 instead of values for an average household. The curve labeled Industry is really showing the consumption of all consumers who are not households. The shape of the Industry curve looks reasonable with a peak during regular working hours.

4.1.2 Household demand

With the average load curve for Household shown in figure 4.3 the A_is in the Household demand function $D_i^H(\bar{p}) = A_i \bar{p}^{\epsilon_H}$ can be estimated for any given ϵ_H and a given time invariant price $\bar{p}$ facing household consumers. To get an estimate of $\bar{p}$ the weighted average of all the spot prices for September are calculated:

$$\bar{p} = \sum_{j=1}^{30} \sum_{i=1}^{24} (c_{ij}^H p_{ij} / S) \text{ where } S = \sum_{j=1}^{30} \sum_{i=1}^{24} c_{ij}^H$$

Here c_{ij}^H is the same as above and p_{ij} is the spot market price on hour i in day j. Using the Nord Pool Spot market data for September 2011 this gives a value of $\bar{p} = 33.23$ €$/MWh$.

The A_is can now be calculated as

$$A_i = \frac{a_i^H}{(\bar{p})^{\epsilon_H}}$$

where $a_i^H = (\sum_{j=1}^{30} c_{ij}^H)/30$ is the average load profile for households shown in figure 4.3.

Table A1 in the appendix gives the estimates of the $A_i s$ for four different values of ϵ_H.

4.1.3 Industry demand

A similar approach is used to estimate the B_is in the demand function for Industry. The model is assuming that consumers in Industry are paying RTP, therefore p_i is used instead of $\bar{p}$ for estimating the B_is:

$$B_i = \frac{a_i^I}{(p_i)^{\epsilon_I}}$$

Here $a_i^I = (\sum_{j=1}^{30} c_{ij}^I)/30$ is the average load profile for Industry. $p_i = \sum_{j=1}^{24} p_{ij}$ is the average price at time i.

Table A2 in the appendix gives the estimates of the $B_i s$ for four different values of ϵ_I using the data for September 2011.

4.1.4 The elasticity parameters

The model used in this thesis specifies demand functions so that the price elasticity of demand is constant for all price levels. This simplifies the estimation of the demand functions significantly since all that needs to be done is to estimate this elasticity plus one more constant. In the previous sections of this chapter the elasticities have been taken as given so that the constants could be estimated. But how do we decide on a good level for the elasticity in the model?

Reiss and White (2005) suggest a distinction between long-run and short-run price elasticities for electricity. The short-run elasticity measures consumers' behavior for a fixed level of electricity consuming appliances. It thus measures how willing consumers are to turn the lights off, adjust heating settings or watch less TV when the price goes up. The long-run elasticity incorporates both this behavior and the consumers' choices of which appliances to install. We therefore assume that the long-run elasticity will be significantly higher (in absolute value) than the short-run one.

Previous research that has attempted to estimate price elasticity for the demand of electricity has reached very different conclusions. This is partly due to the fact that, as discussed in section 2.5, demand for electricity is derived from demand for a wide range of different appliances. A meta study (Espey and Espey, 2004) summarizes estimates of price elasticities for electricity made in previous research focusing on residential electricity. The estimates vary greatly. For example estimates of short-run price elasticity range from 0.076 to -2.01 making electricity everything from an inferior good to a very elastic one. The mean short-run elasticity in the studies considered by Espey and Espey (ibid) is -0.35 and the mean long run elasticity is -0.85. However, most studies considered are based on US data and are not based on consumers paying real time prices.

Bernstein and Madlener (2011) estimate price elasticities for 18 OECD countries assuming constant price elasticity of demand. Unfortunately they do not provide any estimates for Sweden, but they do estimate the elasticities for several other similar Northern European countries. However, the estimates for these countries are very different. This could reflect that consumers in different countries respond to prices in very different ways, but it could also be a consequence of the difficulty in estimating these elasticities. Their results show an overall average elasticity of -0.4 in the long run and -0.1 in the short run.

Patrick and Wolak (2001) estimates both own-price and cross-price elasticities for five different industrial sectors in England and Wales using real time pricing data. Their focus is on how industries respond to prices of electricity for different times of the day in the very short run. They find that elasticities vary across industries but that most industries do not respond much to electricity price changes at all. However, this is only in the short run. In the longer run industries are expected to adjust to consistent price changes between different hours of the day.

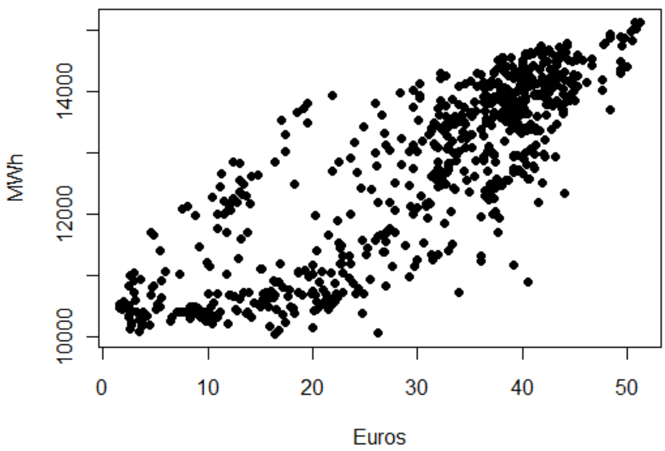
In accordance with similar previous research (e.g. Borenstein, 2005) the model in this thesis does not specify one elasticity but consider a range of different elasticities. The results from simulations with the lower (in absolute value) elasticity estimates can be interpreted as short-run effects while the results obtained with higher elasticity estimates will represent what we would expect to see in the longer run. In this model it is assumed for simplicity that the elasticity is the same for all hours.

The elasticities used in the simulations in this thesis are -0.025, -0.1, -0.25 and -0.5. These span the same range as the elasticities used in Borenstein (2005).

4.2 The supply parameters

The supply function in the model is specified as $S_i(p_i) = \beta_0 + \beta_1 p_i + \beta_2 p_i^2 + \beta_3 p_i^3$ where the βs are constants to be estimated to get a representation of the supply facing Swedish consumers in September 2011. To estimate the βs we use hourly data for price and traded volumes at Nord Pool Spot for September 2011 (Nord Pool Spot, 2011b). Figure 4.4 displays this data.

Figure 4.4 Prices and traded volumes



There is an apparent positive relationship between price and quantity in figure 4.4. Similar relationships but with much fewer data points can be seen if we plot the same picture for individual days instead. The positive relationship must be the supply curve, traced out by a shifting demand curve. This is what we expect to see since demand for electricity is different at, for example, day and night while we expect the supply curve to be roughly constant for short time periods. The observations at the bottom left of figure 4.4 represent the nighttime hours while the ones in the top right corner are peak hour observations. However, the supply curve was not completely constant throughout September. For example, a handful of observations lay on the left of the main cluster. These represent a few exceptionally cheap days around September 15-18. The reasons for these shifts in the supply curve are mostly due to varying water levels in the hydro power reservoirs caused by heavy rains (Nylander, 2011).

Table 4.1 shows the results from estimating a third degree polynomial using the ordinary least squares method on the data in figure 4.4.

Table 4.1 Parameter estimates

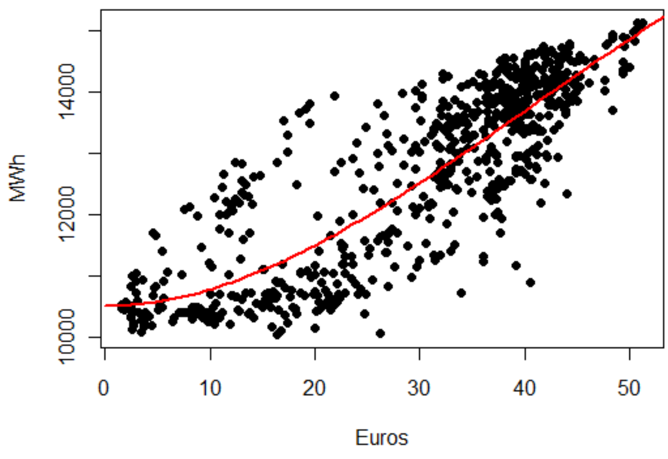
Parameter	Estimate	p-value
β_0	10760	2,00E-16
β_1	– 41,82	9,96E-02
β_2	4,712	1,66E-05
β_3	– 0,04557	1,03E-03

The regression gives a R^2 of 0.7339. The values in the p-value column show the p-values for the two-sided t-test with null hypothesis that the true value of the parameter is zero. We can, on a 5 % significance level, reject the null hypothesis for all parameters except for β_1. Since the estimate for $\beta_1$is statistically insignificant, it is removed from the model and the remaining parameters are estimated again. The results are shown in Table 4.2.

Table 4.2 Parameter estimates		
Parameter	Estimate	p-value
β_0	10510	2,00E-16
β_2	2,970	2,00E-16
β_3	– 0,02461	7,69E-06

This regression gives a R^2 of 0.7329, almost identical to when β_1 was included. The p-values show that all the estimates are significant. Therefore, the estimates used in the model are the ones in Table 4.2 (with $\beta_1 = 0$). Figure 4.5 shows the same data as in figure 4.4 with the regression curve using the estimates in table 4.2 superimposed.

Figure 4.5 The estimated supply curve



As mentioned in section 3.2 the regression line obtained for estimating supply needs to be increasing to avoid multiple equilibrium prices. Using the estimates in table 4.2, the supply curve is not increasing for all prices but it is increasing for all positive prices less than 80.49 €/MHh. This turns out to be good enough for the purposes of this model.

5. Results

In this section the supply and demand functions introduced in section 3 and estimated in section 4 are equaled to obtain equilibrium prices and quantities for every hour. Prices and load profiles are calculated for all combinations of the four price elasticities considered for Household and Industry. These simulations provides a picture of what September 2011 would have been like if households where paying RTP.

5.1 September 2011 according to the model

Since the model is not a perfect description of reality, interpreting the outcome of the model is difficult if it is compared with actual September 2011 data. Therefore, for the sake of comparison, the model is first used to estimate prices and the load profile for when household consumers are not paying RTP. In other words, this is what the model would claim September 2011 looked like.

For every hour i the price p_i is set so that $A_i\bar{p}^{\epsilon_H} + B_i{p_i}^{\epsilon_I} = \beta_0 + \beta_1 p_i + \beta_2 p_i^2 + \beta_3 p_i^3$. Here $\bar{p}$ needs to be determined endogenously such that it ends up being the weighted average price paid by Household. This is achieved by setting $\bar{p} = \sum_{i=1}^{24}(c_i^H p_i \,/\, \sum_{i=1}^{24} c_i^H)$ where c_i^H is the quantity consumed by Household in hour i. If c_i^H is calculated as $c_i^H = c_i - c_i^I = \beta_0 + \beta_1 p_i + \beta_2 p_i^2 + \beta_3 p_i^3 - B_i{p_i}^{\epsilon_I}$ we get a system that allows us to solve for all $p_i s$. Since there is a circular dependence structure between these equations they all have to be solved simultaneously.

Figures 5.1a and 5.1b shows the results for when the price elasticity is -0.5 for both Household and Industry. The actual values for September 2011 are included for comparison. The figures show that the model returns values close to the actual values from the data. The error is due to the simplifications done in the model. Since Household is paying average prices the elasticity used for Household turns out to have only very small effects on prices and quantities. The elasticity used for Industry does however affect prices significantly. Lower elasticities for Industry returns even lower night time prices.

Figure 5.1a Actual and predicted prices

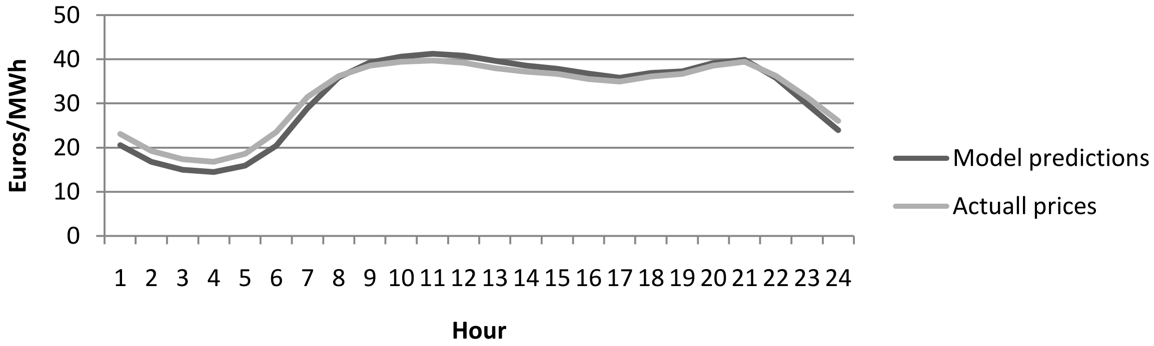


Figure 5.1b Actual and predicted load profile

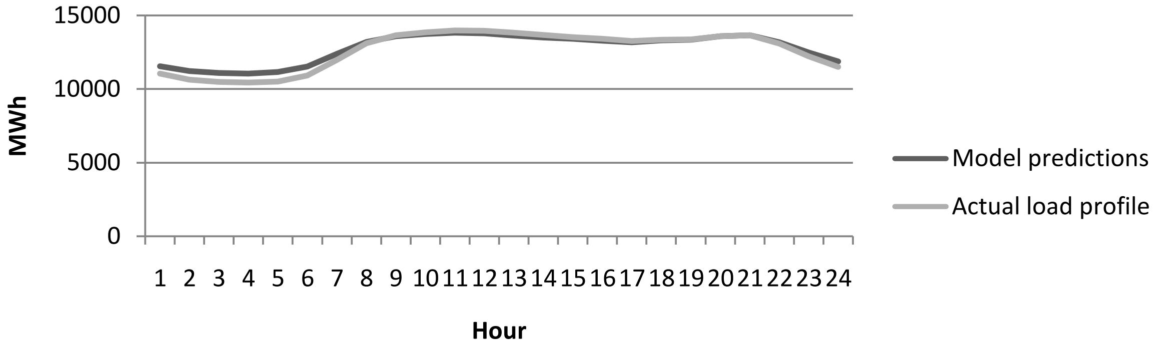


Table A3 in the appendix provides all the prices and quantities returned for all 16 combinations of Household and Industry elasticity.

5.2 Prices and quantities when Household pay RTP

We can now use the model to calculate how prices would change if Household paid real time prices instead of average prices. The price for hour i is given by the solution to the equation $A_i {p_i}^{\epsilon_H} + B_i {p_i}^{\epsilon_I} = \beta_0 + \beta_1 p_i + \beta_2 p_i^2 + \beta_3 p_i^3$. These prices are plugged back into either side of the equation to obtain equilibrium load profiles. This is calculated for all combinations of Household and Industry elasticity. The results are presented in table A4 in the appendix.

Figures 5.2 and 5.3 show the results for when the price elasticity is -0.5 for both Household and Industry. The price and load profiles for when Household did not pay RTP, as calculated in the previous section using the same elasticities, are also included. As expected, the figures show that having Household switch to RTP has the effect of reducing prices and consumption during peak hours while increasing prices and consumption at night.

Figure 5.2 Load profiles

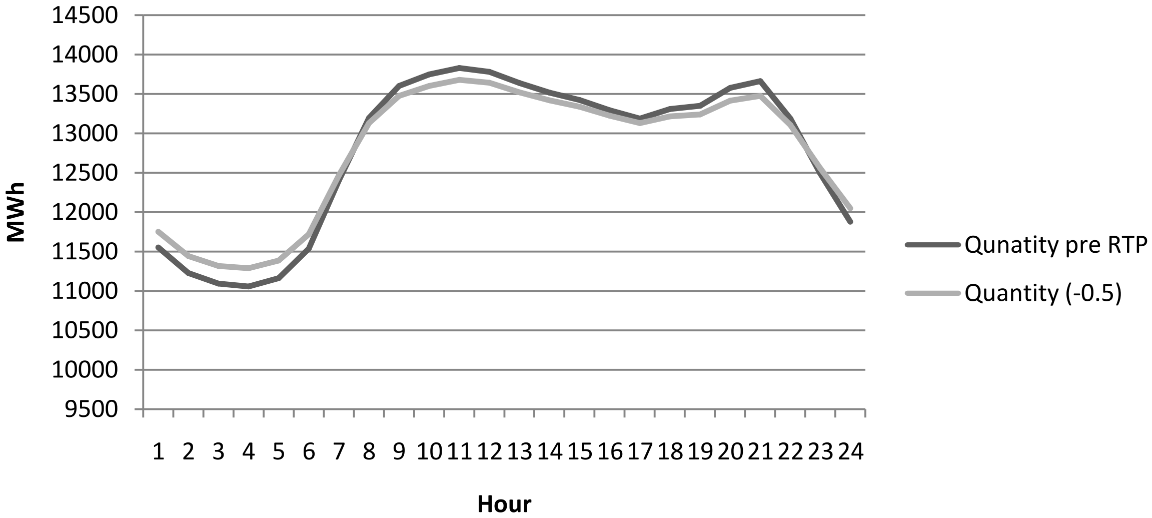
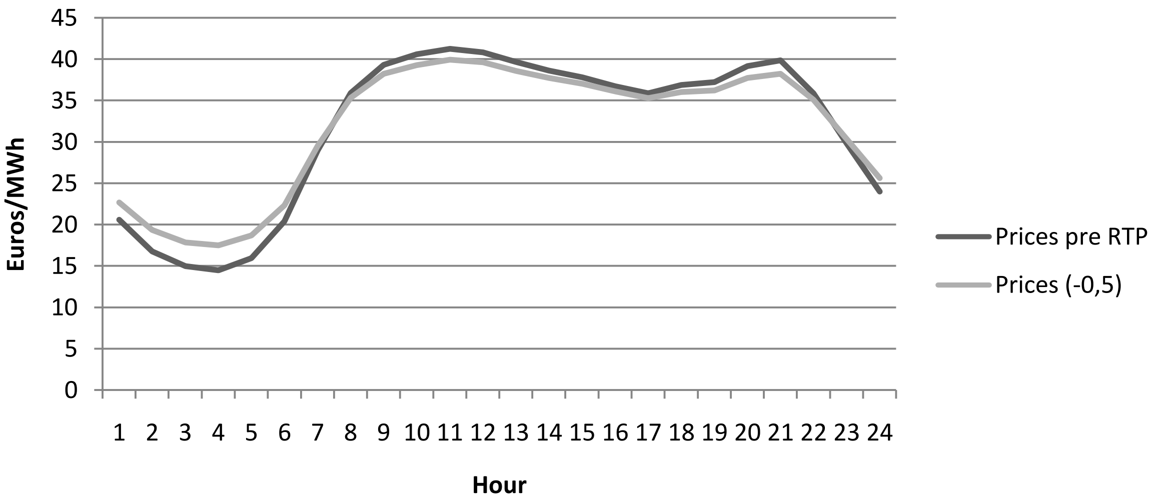


Figure 5.3 The price profile



No matter which combination of price elasticities is used, the results of having Household on RTP follow the same general pattern. Prices and quantities are smoothed with higher lows at night and lower daytime peaks. The magnitude of this smoothing depends on the elasticities used. In general, the effects of having Household on RTP get larger when Household consumers are sensitive to price changes (high absolute value of price elasticity). On the other hand, highly sensitive Industry consumers have the reverse effect. Higher elasticities for Industry consumers reduce the smoothing of prices and quantities. The reason for this is that when Household shift to RTP they will consume less during peak hours which will result in lower peak hour prices, which in turn will make Industry want to increase their peak hour consumption. This will reduce the decrease in price during peak hours. If the absolute value of the price elasticity for Industry is high, Industry respond more to prices and this offsetting effect gets stronger.

5.3 Welfare effects

With the results from 5.2 and 5.3 the welfare effects from changing to RTP for Household consumers can be investigated. To do this the change in consumer and producer surpluses are calculated.

The consumer surplus for all consumers from the consumption of electricity in hour i when the price of electricity in hour i is $p_i^{'}$ is here defined as $CS_i = \int_{p^{'}}^{\infty} D_i(p_i)dp_i$ where $D_i(p_i)$ is the demand function. The consumer surpluses for Household and Industry respectively are:

$$CS_i^H = \int_{p^{'}}^{\infty} A_i {p_i}^{\epsilon_H}\, dp_i \text{ and } CS_i^I = \int_{p^{'}}^{\infty} B_i {p_i}^{\epsilon_I} dp_i$$

The demand functions used in this model are continuous and defined for all positive real values of p_i. This implies that for the integrals above to be finite it is necessary that the demand functions go to zero "fast enough" when p_i goes to infinity. This is only going to be the case if the elasticity is less than -1. But for elasticities larger than -1 the above integrals are not convergent and consumer surplus is infinite for all prices. Since the elasticities considered in this thesis are all larger than -1 consumer surpluses cannot be explicitly calculated using the definition of consumer surplus above. But the *change* in consumer surplus when prices rise or fall can be calculated.

The change in consumer surplus when the price of electricity in hour i changes from $p^{'}$ to $p^{''}$ are, for Household and Industry respectively:

$$\Delta CS_i^H = \int_{p^{''}}^{\infty} A_i {p_i}^{\epsilon_H}\, dp_i - \int_{p^{'}}^{\infty} A_i {p_i}^{\epsilon_H}\, dp_i = -\int_{P^{'}}^{P^{''}} A_i {p_i}^{\epsilon_H} dp_i = \frac{A_i}{\epsilon_H + 1}\left({p^{'}}^{(\epsilon_H+1)} - {p^{''}}^{(\epsilon_H+1)}\right)$$

and

$$\Delta CS_i^I = \int_{p^{''}}^{\infty} B_i {p_i}^{\epsilon_I}\, dp_i - \int_{p^{'}}^{\infty} B_i {p_i}^{\epsilon_I}\, dp_i = -\int_{P^{'}}^{P^{''}} B_i {p_i}^{\epsilon_I} dp_i = \frac{B_i}{\epsilon_I + 1}\left({p^{'}}^{(\epsilon_I+1)} - {p^{''}}^{(\epsilon_I+1)}\right)$$

The total surpluses are just the sum of the surpluses for all hours:

$$\Delta CS^H = \sum_{i=1}^{24} \Delta CS_i^H \text{ and } \Delta CS^I = \sum_{i=1}^{24} \Delta CS_i^I$$

The changes in consumer surplus can now be calculated using the prices from before Household paid RTP given in table A3 as $p^{'}$ and the RTP prices in table A4 as $p^{''}$. The $\bar{p}$ described in section 5.1 is used as the $p^{'}$ for Household and the p_is as the $p^{'}$ for Industry. This is done for all combinations of the four elasticities.

The producer surplus from the electricity sold in hour i when the price is $p^{'}$ is here defined as $PS = \int_0^{p^{'}} S(p_i)dp_i$ where $S(p_i)$ is the supply function. For the supply function used in this thesis this integral will be finite for any finite $p^{'}$ and producer surpluses could thus be calculated. But for the purposes of this thesis only the change in producer surplus resulting from a change in price is of interest. The change in producer surplus as the price of electricity changes from $p^{'}$ to $p^{''}$ is:

$$\Delta \mathrm{PS}_i = \int_0^{p^{''}} S(p_i)dp_i - \int_0^{p^{'}} S(p_i)dp_i = \int_{p^{'}}^{p^{''}} S(p_i)dp_i = \int_{p^{'}}^{p^{''}} (\beta_0 + \beta_2 p_i^2 + \beta_3 p_i^3)dp_i$$

$$= \beta_0(p^{''} - p^{'}) + \frac{\beta_2}{3}\left(p^{''3} - p^{'3}\right) + \frac{\beta_3}{4}(p^{''4} - p^{'4})$$

The total change in producer surplus for all hours is $\Delta PS = \sum_{i=1}^{24} \Delta \mathrm{PS}_i$.

Figures 5.4a-d show the changes in consumer and producer surplus as functions of the (absolute value) of price elasticity for both Household and Industry. The vertical axes show the change in surplus in thousands of units. Consumer surplus only reflects consumers' total utility from consumption perfectly in the case of quasilinear preferences (for example Varian, 2006, pp. 252), which is not what we are dealing with here. If preferences are not quasilinear, there will be an income effect affecting consumers' utility. This means that there is no clear interpretation for the units of consumer surplus. The only thing we can say is that a high number is better than a low one.

Figure 5.4b shows that the change in consumer surplus for Household consumers is positive except for very low values of Industry elasticity. Higher elasticities, both for Household and Industry, yields larger increases in Household consumer surplus. But for Industry consumers the welfare effect is likely to be negative. Figure 5.4c shows that the change in consumer surplus would be very negative if Household consumers are elastic but Industry are not. More elastic Industry consumers make the change less negative. Producer surplus (figure 5.4d) is likely to increase. If elasticities are high for Household but low for Industry this increase will be very large.

Figure 5.4a Net Effect

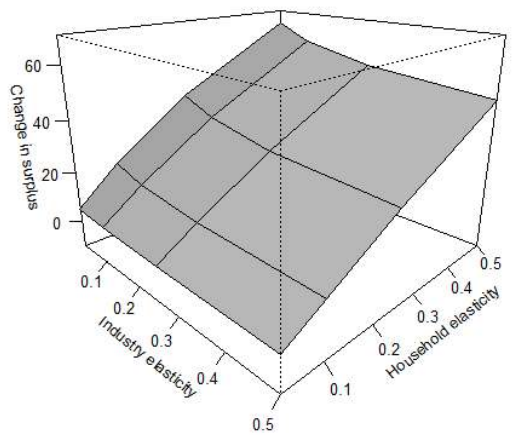


Figure 5.4b Consumer Surplus Household

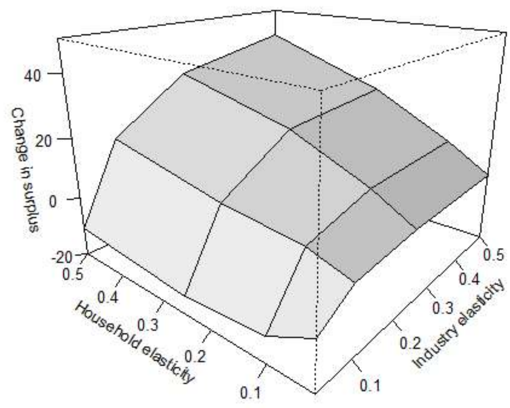


Figure 5.4c Consumer Surplus Industry

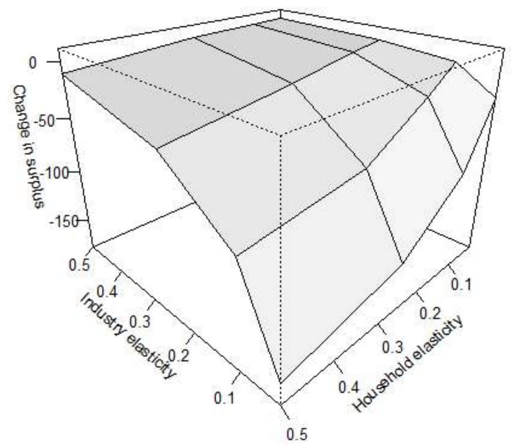
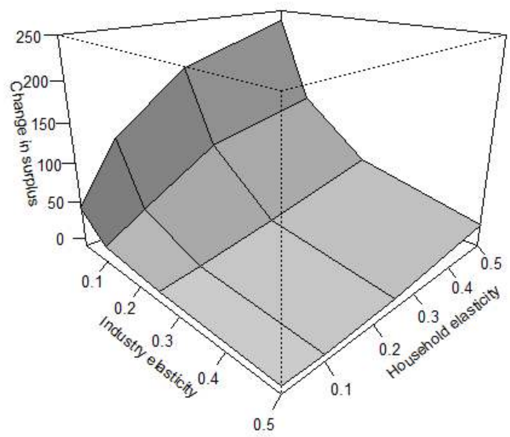


Figure 5.4d Producer Surplus



The negative welfare effect for Industry might seem somewhat contradictory, why would a smoothing of prices be likely to be detrimental for Industry consumer surplus when it is good for Household? The only thing that has changed for Industry consumers is the spot market prices. Prices get lower during Household peak hours, with the largest effect in the morning and evening, and higher at night when Household do not consume much (see figure 5.6 on page 31). Lower prices during Household peak hours will have a positive effect on Industry surplus while higher prices in off-peak hours have a negative effect. The negative effect is likely to dominate since the peak hours for Industry do not coincide with the peak hours for Household. Industry has a more even distribution of its consumption then has Household, and therefore the positive effects from lower peak hour prices are not going to be high enough to offset the negative effects from higher nighttime prices.

The net welfare effect is calculated as the sum of the three surpluses and shown in figure 5.4a. The net welfare effect of switching Household to RTP is positive for all combinations of elasticities. It is more positive the more elastic Household consumers are.

5.4 Sensitivity analysis

The results presented so far in this section rely on a range of assumptions, both concerning the specification of the model and for the estimation of model parameters. Some of these assumptions are rather rough, mainly in the cases where no good data has been found. In these cases more ad-hoc solutions have been necessary. In this section some of these assumptions will be modified so that the sensitivity of the results to changes in assumptions can be investigated.

5.4.1 The Household load profile

In section 4.1.1 it is assumed that the load curve presented in figure 4.2 can be used to represent the load curve of an average Household consumer. This is a bold assumption since all we know is that figure 4.2 is a good representation of the load profile for families living in houses without direct electrical heating. For the sake of our model we want Household to represent the consumers of electricity that does not currently pay real time prices. Since there are many different kinds of consumers and no good data on what the average load profile looks like for all consumers who pay average prices, it is of interest to know how important this assumption is for the results obtained. To investigate this, the load profile for families in houses without electrical heating is replaced by the load profile for families in houses *with* direct electrical heating. Again, this load profile is taken from the Swedish Energy Agency (Zimmerman, 2009). This load profile differs from the previous one by putting a somewhat larger weight on off-peak hours and can therefore, for example, be thought of as including some non-household consumers as well. Using the load profile for houses with direct electrical heating would otherwise not make much sense since not much electricity is used for heating in September.

If the exact same procedure for estimating parameters and calculating results described in chapters 4 and 5 is repeated but using the direct heating load profile instead of the one without direct heating, the numbers obtained are somewhat different, but the general structure of the results does not change. We still observe a smoothing of prices and quantities consumed with lower peaks and higher lows. Also the magnitude of this smoothing effect depends on the elasticities of Household and Industry in the same way as before: higher Household elasticity yields more smoothing while higher Industry elasticity offsets this effect. Also the welfare effects look very much the same. Figures 5.5a-d shows the welfare effects using the new load profile. If compared to figures 5.4a-d we can tell that the numbers have changed slightly but that the shapes are very similar.

Figure 5.5a Net Effect

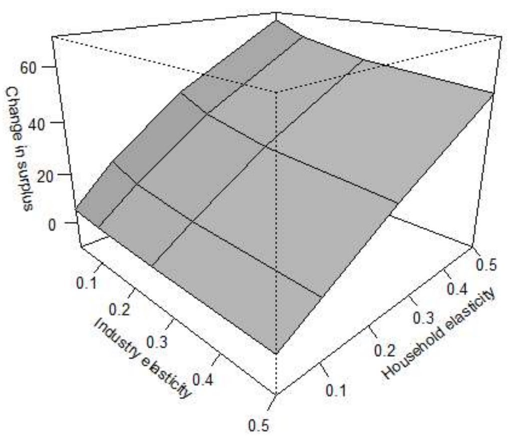


Figure 5.5b Consumer Surplus Household

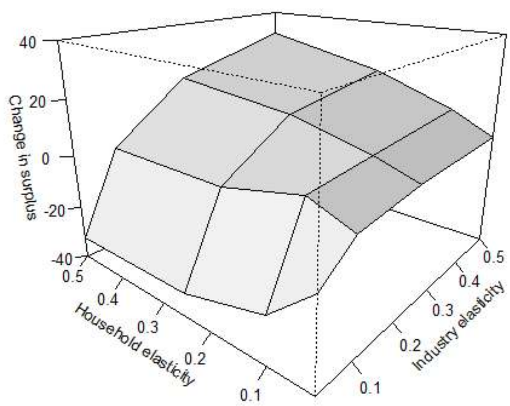


Figure 5.5c Consumer Surplus Industry

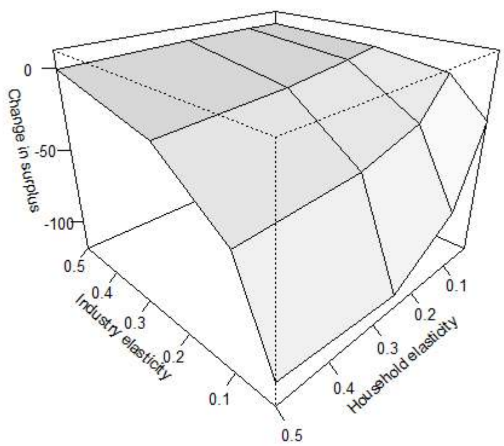
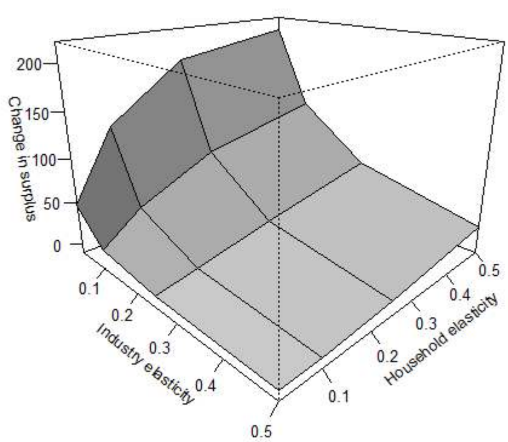


Figure 5.5d Producer Surplus



The reason for this robustness in the results to the load profile assumption is likely to be that the exact shape of the Household and Industry load profiles are not important as long as Industry and Household have their peaks at different hours. As long as Household has its peak hours in the evening and in the morning while Industry have theirs during regular work hours the results from the model will be similar.

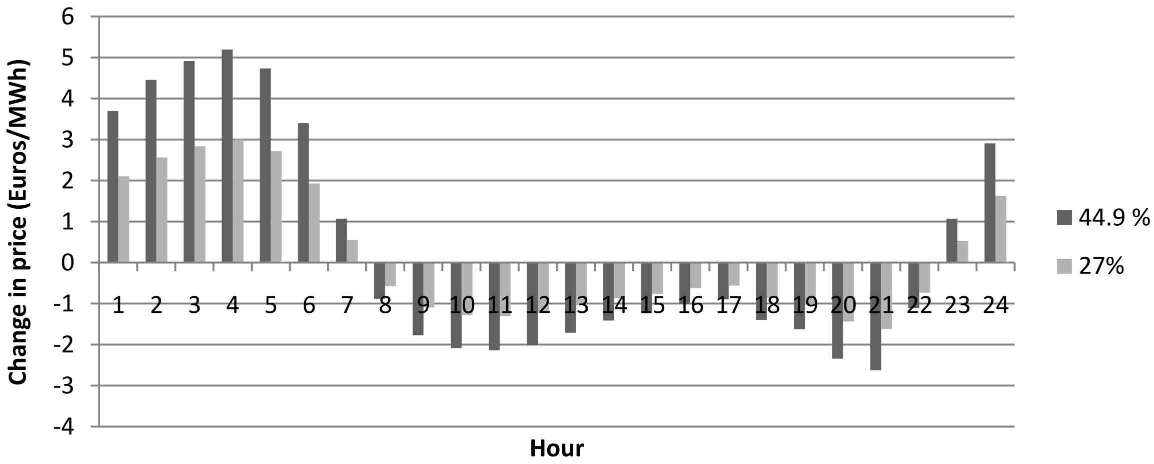
5.4.2 The fraction of consumers in Household

A second assumption made in section 4.1.1 concerns the fraction of total consumption that is consumed by the Household consumers. Section 4.1.1 argues that 27 percent is a reasonable assumption for the fraction of total electricity consumption that was consumed by residential consumers in September 2011. But if we want the category Household to include not only residential consumers, but all consumers who currently pay average prices instead of real time prices, then 27 percent is likely to be an underestimate. In that case the 44.9 percent estimate presented by Statistics Sweden for “Households, services etc” might be a more reasonable estimate.

Raising the fraction of total consumption consumed by Household from 27 to 44.9 percent, other things equal, does not change the general pattern of the results of the model. The model still predicts a smoothing of prices and consumption, changing with the elasticities in the same way as before. But, as expected, there is one major difference. When the fraction of consumers who initially pay average prices increases the effect of switching this group to RTP gets stronger. This makes good intuitive sense, if we change the pricing scheme of larger fraction of consumers, the effects will get stronger. Figure 5.6 illustrates this difference in magnitude. The difference in price before and after Household pay RTP are shown for every hour for when Household are assumed to consume 27 and 44.9 percent of the total electricity consumption. In both cases the daytime prices decrease and nighttime prices increase but the changes are larger when more consumers are assumed to be in Household.

The same thing is true for the welfare effects. The direction of the changes is the same but the numbers get larger. The net welfare gain from having household consumers changing to RTP will thus increase as the fraction of consumers that shift to RTP gets larger.

Figure 5.6 Change in price for two values of Household's fraction of consumption



6. Limitations and conclusions

6.1 Conclusions

If small consumers of electricity, such as residential consumers and small business, were to change their pricing plans for electricity from a fixed average price to RTP this would lead to a reduction in prices and quantities consumed during peak hours and an increase of the same during off-peak hours. The magnitude of this effect depends on three factors: (1) the fraction of consumers that shift to RTP, (2) the price elasticity of the consumers who shift to RTP, and (3) the price elasticity of consumers who are already on RTP. The larger the fraction of consumers that shift to RTP is, the greater the effect of such a change. A high price elasticity of the consumers that shift will increase the effect of the change while a high price elasticity of the consumers who are already on RTP will have the reverse effect.

The net welfare effect from a shift to RTP is positive, and the societal gains will be larger the more elastic the consumers who shift are. It is however likely that a shift like this will cause a redistribution of welfare with a negative effect for the consumers that are already paying RTP and a positive welfare effect for producers and for the consumers that shift to RTP. A shift to RTP for small consumers is therefore unlikely to be a Pareto improvement. The negative effect on consumers already paying RTP will be relatively small unless these consumers are very inelastic. The welfare affect for the consumers who shift will be greater the higher the elasticity of both groups of consumers. It is therefore in the interest of all consumers that the consumers currently on RTP are relatively elastic.

6.2 Limitations of the model and suggestions for future research

The fact that a large fraction of consumers today choose to fix the price they pay for electricity for periods longer than one month reveals that many consumers have a risk aversion to fluctuating electricity prices, but calculating welfare effects based on average prices, as done in this thesis, implicitly assumes risk neutrality. This might seem like a problem since a shift from a fixed price to RTP would certainly expose the consumer to a higher price risk, but with well-functioning derivatives markets this risk could be hedged. For example, electricity trading companies could offer risk averse customers a TOU plan. Such hedging behavior would not affect the consequences of a shift to RTP (Holland and Borenstein, 2005).

When demand is highly inelastic all shocks have to be absorbed by the supply side which creates a situation with high volatility in prices. As explained in 2.5 a shift to RTP would increase the elasticity of total demand and a shift to RTP should therefore make prices less volatile. This would however require that consumers respond to prices immediately which, as discussed in section 3.1, might not be the case. If consumers only respond to the average hourly prices there is no reason to believe that the price volatility would be affected. However, with consumers on RTP there might be a demand for automatic response appliances that receive spot market prices in real time and adjust the amount of electricity consumed thereafter. If a large enough fraction of consumers where to install products like this, demand would become more elastic also in the very short run and there should thus be a decrease in price volatility. The effect on price volatility from a shift to RTP could be investigated using the model developed in this thesis, with a stochastic variable added to the supply function. The assumption that consumers only respond to average prices is only necessary for the estimation of the model parameters and could therefore be altered.

Welfare effects have been calculated in this model for two representative types of consumers and for producers. This is a significant limitation since there is likely to be heterogeneity within these groups which has not been accounted for in the model. For example, even if total producer surplus is likely to increase, the model does not let us investigate the distribution of this increase. It might be that some producers would experience a negative change in surplus while others gain a lot. It is also possible that the behavior of consumers or producers within the groups is so different that the representative consumer assumption is unreasonable in the first place. The effect of this limitation has not been considered in this thesis.

Another limitation of the model is that the conclusions that can be made only concern the pattern and relative magnitude of the effects but does not let us make any precise statements regarding the exact numbers. This is mainly due to two uncertainties; the lack of data on load profiles for consumers categorized after which type of prices they pay, and a poor understanding of how consumers respond to prices. The first problem is a question of data collecting, while the second requires economic research on consumer behavior. If these two uncertainties are overcome a more exact statement about welfare effects could be made. To estimate the present value of the total societal gains from a shift to RTP, which would be required in a cost-benefit analysis, the welfare effects needs to be calculated using data from all seasons. However, if the cost of implementing RTP for small consumers is modest, it might be that the benefits outweigh the costs by so much that an exact estimate is not necessary for policy purposes.

For simplicity the model assumes that elasticity of demand is the same for all hours of the day. In a more detailed model of the electricity market the realism of this assumption should be investigated. The reason for this is that demand for electricity in one hour is not necessarily derived from the demand of the same appliances as demand for electricity in another hour. There is no reason to believe that the price elasticity of demand with respect to the price of electricity would be the same for all electricity-using appliances. Reliable estimates of price elasticities (both own-price and cross-price) for all hours of the day for different groups of consumers, based on the demand for electricity-using appliances, would allow for the creation of much more realistic and detailed models.

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Appendix A: Tables

Table A1 Estimates of A									
Hour	ϵ = -0.025	ϵ = -0.1	ϵ = -0.25	ϵ = -0.5	Hour	ϵ = -0.025	ϵ = -0.1	ϵ = -0.25	ϵ = -0.5
00 - 01	3308	4302	7276	17468	12 - 13	3437	4470	7561	18153
01 - 02	2918	3796	6420	15413	13 - 14	3308	4302	7276	17468
02 - 03	2854	3711	6277	15071	14 - 15	3308	4302	7276	17468
03 - 04	2918	3796	6420	15413	15 - 16	3372	4386	7418	17811
04 - 05	2918	3796	6420	15413	16 - 17	3762	4892	8274	19866
05 - 06	2983	3880	6562	15756	17 - 18	4475	5820	9843	23634
06 - 07	3308	4302	7276	17468	18 - 19	4864	6326	10699	25689
07 - 08	3826	4976	8417	20209	19 - 20	5059	6579	11127	26716
08 - 09	3762	4892	8274	19866	20 - 21	5188	6748	11413	27401
09 - 10	3762	4892	8274	19866	21 - 22	4929	6410	10842	26031
10 - 11	3567	4639	7846	18838	22 - 23	4280	5567	9415	22606
11 - 12	3502	4555	7704	18496	23 - 00	3762	4892	8274	19866

Table A2 Estimates of B									
Hour	ϵ = -0.025	ϵ = -0.1	ϵ = -0.25	ϵ = -0.5	Hour	ϵ = -0.025	ϵ = -0.1	ϵ = -0.25	ϵ = -0.5
00 - 01	8678	10981	17586	38550	12 - 13	11705	15377	26534	65871
01 - 02	8572	10701	16675	34928	13 - 14	11660	15294	26310	64980
02 - 03	8443	10458	16046	32748	14 - 15	11507	15078	25888	63731
03 - 04	8332	10295	15718	31820	15 - 16	11307	14781	25256	61680
04 - 05	8435	10502	16282	33813	16 - 17	10748	14031	23914	58154
05 - 06	8853	11218	18015	39671	17 - 18	10134	13263	22718	55709
06 - 07	9768	12653	21230	50298	18 - 19	9760	12788	21952	54029
07 - 08	10515	13764	23583	57858	19 - 20	9825	12922	22352	55712
08 - 09	11200	14729	25474	63481	20 - 21	9765	12864	22326	55962
09 - 10	11417	15041	26104	65432	21 - 22	9383	12284	21052	51667
10 - 11	11765	15507	26942	67648	22 - 23	9060	11733	19679	46593
11 - 12	11791	15527	26925	67389	23 - 00	8744	11166	18208	41137

	Table A3 Prices and Quantities when Household is not paying RTP							
	Industry elasticity = -0,025							
	Prices (Euros/MWh)				Quantities (MWh)			
	Household elasticity:							
Hour	-0,025	-0,1	-0,25	-0,5	-0,025	-0,1	-0,25	-0,5
00 - 01	15,57	15,71	15,93	16,21	11137	11147	11165	11186
01 - 02	9,83	9,98	10,23	10,53	10774	10782	10794	10810
02 - 03	7,20	7,36	7,62	7,93	10655	10661	10671	10685
03 - 04	6,50	6,66	6,93	7,26	10629	10635	10645	10657
04 - 05	7,96	8,12	8,38	8,70	10686	10693	10704	10719
05 - 06	14,00	14,13	14,35	14,61	11025	11034	11049	11067
06 - 07	25,59	25,70	25,88	26,10	12043	12054	12073	12095
07 - 08	35,31	35,42	35,61	35,84	13129	13143	13165	13192
08 - 09	39,82	39,93	40,11	40,34	13665	13679	13700	13727
09 - 10	41,39	41,51	41,69	41,91	13853	13867	13889	13915
10 - 11	42,49	42,60	42,77	42,99	13985	13997	14018	14043
11 - 12	42,21	42,32	42,49	42,70	13951	13964	13984	14009
12 - 13	41,12	41,22	41,39	41,59	13821	13833	13853	13877
13 - 14	39,85	39,95	40,11	40,30	13669	13680	13700	13723
14 - 15	38,74	38,84	39,00	39,20	13537	13548	13568	13591
15 - 16	37,76	37,86	38,03	38,23	13420	13432	13452	13475
16 - 17	36,54	36,65	36,83	37,06	13275	13288	13310	13336
17 - 18	37,29	37,42	37,64	37,90	13363	13379	13405	13437
18 - 19	37,41	37,55	37,79	38,08	13378	13395	13423	13458
19 - 20	39,31	39,46	39,71	40,01	13605	13623	13652	13688
20 - 21	39,82	39,98	40,23	40,54	13666	13684	13714	13751
21 - 22	35,12	35,26	35,51	35,81	13107	13124	13153	13188
22 - 23	27,70	27,83	28,06	28,34	12265	12280	12305	12335
23 - 00	20,63	20,77	20,99	21,27	11558	11570	11591	11617
	Industry elasticity = -0,1							
	Prices (Euros/MWh)				Quantities (MWh)			
	Household elasticity:							
Hour	-0,025	-0,1	-0,25	-0,5	-0,025	-0,1	-0,25	-0,5
00 - 01	17,45	17,52	17,63	17,77	11284	11289	11298	11310
01 - 02	12,99	13,05	13,14	13,27	10957	10961	10967	10976
02 - 03	11,07	11,12	11,22	11,34	10840	10844	10849	10856
03 - 04	10,54	10,60	10,69	10,82	10811	10814	10820	10826
04 - 05	11,79	11,85	11,94	12,07	10882	10886	10892	10899
05 - 06	16,53	16,59	16,69	16,81	11210	11215	11223	11233
06 - 07	26,59	26,65	26,76	26,89	12148	12154	12165	12179
07 - 08	35,42	35,49	35,60	35,75	13143	13151	13164	13182
08 - 09	39,64	39,70	39,82	39,96	13644	13652	13665	13682
09 - 10	41,13	41,19	41,30	41,45	13821	13829	13843	13860
10 - 11	42,11	42,17	42,28	42,42	13939	13947	13959	13976
11 - 12	41,80	41,86	41,96	42,10	13902	13909	13921	13938
12 - 13	40,67	40,73	40,84	40,97	13767	13775	13787	13803

13 - 14	39,47	39,52	39,62	39,75	13623	13630	13642	13657
14 - 15	38,45	38,50	38,60	38,73	13501	13508	13520	13535
15 - 16	37,44	37,50	37,60	37,73	13381	13388	13400	13416
16 - 17	36,30	36,37	36,48	36,63	13247	13255	13268	13285
17 - 18	37,12	37,20	37,34	37,51	13344	13353	13369	13390
18 - 19	37,30	37,39	37,54	37,73	13365	13376	13393	13416
19 - 20	39,21	39,30	39,45	39,65	13592	13603	13622	13645
20 - 21	39,76	39,86	40,01	40,22	13659	13670	13689	13713
21 - 22	35,25	35,34	35,49	35,68	13122	13133	13150	13173
22 - 23	28,26	28,33	28,47	28,64	12326	12335	12349	12368
23 - 00	21,71	21,78	21,90	22,06	11658	11664	11676	11691

	Industry elasticity = -0,25							
	Prices (Euros/MWh)				Quantities (MWh)			
	Household elasticity:							
Hour	-0,025	-0,1	-0,25	-0,5	-0,025	-0,1	-0,25	-0,5
00 - 01	19,21	19,24	19,30	19,37	11432	11434	11439	11445
01 - 02	15,25	15,28	15,32	15,38	11114	11115	11118	11123
02 - 03	13,48	13,51	13,54	13,60	10990	10991	10994	10997
03 - 04	12,98	13,00	13,04	13,10	10957	10958	10961	10964
04 - 05	14,31	14,34	14,38	14,44	11046	11048	11051	11055
05 - 06	18,75	18,78	18,82	18,88	11392	11394	11398	11403
06 - 07	27,81	27,84	27,89	27,96	12277	12281	12286	12294
07 - 08	35,59	35,63	35,69	35,78	13163	13167	13175	13185
08 - 09	39,40	39,44	39,50	39,59	13616	13620	13628	13638
09 - 10	40,77	40,81	40,87	40,96	13779	13783	13791	13801
10 - 11	41,60	41,64	41,70	41,78	13878	13882	13889	13899
11 - 12	41,24	41,27	41,33	41,41	13835	13839	13846	13856
12 - 13	40,08	40,11	40,17	40,25	13697	13700	13707	13716
13 - 14	38,96	38,99	39,05	39,12	13563	13567	13573	13582
14 - 15	38,06	38,09	38,14	38,22	13455	13459	13465	13474
15 - 16	37,01	37,05	37,10	37,18	13331	13335	13341	13350
16 - 17	36,00	36,04	36,10	36,18	13211	13215	13223	13233
17 - 18	36,91	36,96	37,03	37,14	13319	13324	13333	13346
18 - 19	37,17	37,22	37,30	37,42	13350	13355	13365	13379
19 - 20	39,08	39,13	39,22	39,34	13577	13583	13594	13608
20 - 21	39,70	39,75	39,84	39,96	13651	13657	13668	13683
21 - 22	35,45	35,50	35,58	35,70	13146	13152	13162	13175
22 - 23	28,98	29,02	29,09	29,19	12406	12410	12418	12429
23 - 00	22,90	22,93	23,00	23,08	11772	11775	11781	11790

	Industry elasticity = -0,5							
	Prices (Euros/MWh)				Quantities (MWh)			
	Household elasticity:							
Hour	-0,025	-0,1	-0,25	-0,5	-0,025	-0,1	-0,25	-0,5
00 - 01	20,50	20,51	20,54	20,57	11546	11547	11550	11553
01 - 02	16,70	16,71	16,73	16,75	11223	11224	11226	11228
02 - 03	14,93	14,94	14,96	14,99	11090	11091	11092	11094

03 - 04	14,42	14,43	14,45	14,48	11054	11055	11056	11058
04 - 05	15,88	15,89	15,91	15,94	11160	11161	11163	11165
05 - 06	20,34	20,35	20,37	20,40	11531	11532	11534	11537
06 - 07	28,87	28,88	28,91	28,95	12393	12395	12398	12402
07 - 08	35,76	35,78	35,81	35,86	13183	13185	13189	13195
08 - 09	39,18	39,20	39,24	39,28	13589	13592	13596	13602
09 - 10	40,43	40,45	40,48	40,53	13738	13741	13745	13751
10 - 11	41,11	41,13	41,16	41,21	13820	13822	13826	13832
11 - 12	40,71	40,73	40,76	40,81	13772	13774	13778	13783
12 - 13	39,52	39,53	39,56	39,61	13629	13631	13635	13640
13 - 14	38,49	38,50	38,53	38,57	13506	13508	13512	13517
14 - 15	37,70	37,71	37,74	37,78	13412	13414	13417	13422
15 - 16	36,62	36,63	36,66	36,71	13284	13286	13290	13295
16 - 17	35,72	35,74	35,77	35,82	13178	13180	13184	13190
17 - 18	36,72	36,74	36,78	36,84	13296	13298	13303	13310
18 - 19	37,05	37,07	37,12	37,19	13335	13338	13343	13351
19 - 20	38,96	38,99	39,03	39,11	13563	13566	13572	13580
20 - 21	39,64	39,67	39,72	39,79	13644	13647	13653	13662
21 - 22	35,66	35,68	35,73	35,80	13170	13173	13179	13187
22 - 23	29,65	29,67	29,71	29,77	12480	12482	12486	12492
23 - 00	23,87	23,89	23,92	23,96	11868	11869	11872	11877

Table A4 Prices and Quantities when Household is paying RTP								
	Industry elasticity = -0,025							
	Prices (Euros/MWh)				Quantities (MWh)			
	Household elasticity:							
Hour	-0,025	-0,1	-0,25	-0,5	-0,025	-0,1	-0,25	-0,5
00 - 01	16,14	17,69	19,93	22,38	11180	11304	11495	11722
01 - 02	10,82	13,18	16,28	19,46	10827	10970	11191	11453
02 - 03	8,48	11,35	14,89	18,41	10709	10857	11087	11363
03 - 04	7,91	10,97	14,67	18,29	10684	10835	11071	11353
04 - 05	9,18	11,92	15,35	18,78	10741	10890	11121	11395
05 - 06	14,62	16,28	18,67	21,27	11068	11191	11385	11617
06 - 07	25,72	26,20	26,98	27,95	12056	12106	12188	12292
07 - 08	35,22	35,11	34,92	34,67	13119	13106	13084	13055
08 - 09	39,66	39,32	38,75	38,00	13646	13606	13537	13449
09 - 10	41,21	40,80	40,10	39,19	13831	13782	13699	13590
10 - 11	42,30	41,86	41,11	40,12	13961	13909	13819	13701
11 - 12	42,03	41,61	40,89	39,94	13929	13879	13793	13680
12 - 13	40,95	40,59	39,96	39,12	13801	13757	13682	13582
13 - 14	39,71	39,41	38,89	38,20	13652	13616	13554	13472
14 - 15	38,62	38,36	37,93	37,34	13522	13492	13439	13370
15 - 16	37,65	37,44	37,07	36,58	13407	13381	13337	13279
16 - 17	36,43	36,26	35,96	35,57	13262	13241	13206	13161
17 - 18	37,15	36,90	36,48	35,96	13347	13317	13268	13207
18 - 19	37,25	36,98	36,52	35,97	13360	13327	13273	13207
19 - 20	39,11	38,70	38,03	37,22	13580	13531	13452	13355
20 - 21	39,60	39,15	38,41	37,52	13639	13585	13498	13392
21 - 22	35,01	34,89	34,68	34,42	13095	13080	13055	13026
22 - 23	27,80	28,21	28,86	29,63	12276	12321	12392	12477
23 - 00	20,97	22,00	23,55	25,31	11589	11685	11836	12014
	Industry elasticity = -0,1							
	Prices (Euros/MWh)				Quantities (MWh)			
	Household elasticity:							
Hour	-0,025	-0,1	-0,25	-0,5	-0,025	-0,1	-0,25	-0,5
00 - 01	17,80	18,81	20,45	22,47	11312	11397	11542	11730
01 - 02	13,44	14,74	16,86	19,43	10987	11077	11236	11451
02 - 03	11,58	13,04	15,40	18,25	10870	10960	11125	11350
03 - 04	11,09	12,63	15,11	18,07	10842	10934	11103	11334
04 - 05	12,29	13,71	16,00	18,76	10913	11005	11169	11392
05 - 06	16,87	17,86	19,51	21,57	11237	11317	11457	11645
06 - 07	26,69	27,02	27,60	28,35	12158	12193	12255	12337
07 - 08	35,36	35,26	35,08	34,84	13136	13123	13102	13074
08 - 09	39,51	39,22	38,73	38,06	13629	13594	13535	13456
09 - 10	40,98	40,63	40,02	39,22	13804	13762	13690	13594
10 - 11	41,96	41,59	40,94	40,08	13921	13877	13800	13697
11 - 12	41,65	41,30	40,69	39,86	13884	13842	13769	13670
12 - 13	40,54	40,24	40,69	39,00	13752	13716	13769	13567

13 - 14	39,36	39,11	38,68	38,08	13610	13581	13529	13458
14 - 15	38,35	38,14	37,77	37,27	13490	13465	13421	13362
15 - 16	37,36	37,18	36,88	36,46	13372	13351	13315	13266
16 - 17	36,23	36,09	35,84	35,51	13238	13221	13192	13153
17 - 18	37,02	36,81	36,44	35,98	13332	13306	13264	13209
18 - 19	37,18	36,94	36,54	36,03	13351	13323	13275	13215
19 - 20	39,05	38,69	38,09	37,34	13573	13530	13459	13369
20 - 21	39,58	39,18	38,52	37,69	13637	13589	13510	13412
21 - 22	35,17	35,05	34,84	34,59	13113	13099	13075	13045
22 - 23	28,34	28,65	29,16	29,80	12335	12369	12426	12497
23 - 00	21,95	22,69	23,91	25,39	11681	11752	11871	12022

	Industry elasticity = -0,25							
	Prices (Euros/MWh)				Quantities (MWh)			
	Household elasticity:							
Hour	-0,025	-0,1	-0,25	-0,5	-0,025	-0,1	-0,25	-0,5
00 - 01	19,41	20,01	21,10	22,59	11449	11502	11601	11742
01 - 02	15,49	16,20	17,52	19,39	11131	11185	11289	11447
02 - 03	13,74	14,52	15,97	18,05	11007	11061	11167	11333
03 - 04	13,25	14,07	15,60	17,78	10974	11029	11139	11310
04 - 05	14,56	15,32	16,73	18,72	11064	11119	11226	11390
05 - 06	18,94	19,49	20,52	21,97	11408	11456	11548	11682
06 - 07	27,87	28,07	28,43	28,94	12284	12306	12345	12401
07 - 08	35,55	35,46	35,30	35,08	13158	13147	13128	13102
08 - 09	39,31	39,09	38,70	38,15	13605	13578	13531	13466
09 - 10	40,66	40,39	39,92	39,26	13766	13734	13677	13599
10 - 11	41,49	41,21	40,71	40,02	13865	13832	13772	13689
11 - 12	41,14	40,87	40,40	39,75	13823	13791	13735	13657
12 - 13	39,99	39,77	39,37	38,81	13686	13659	13611	13545
13 - 14	38,89	38,71	38,38	37,92	13554	13532	13493	13439
14 - 15	37,99	37,84	37,56	37,17	13448	13429	13396	13350
15 - 16	36,96	36,83	36,61	36,30	13325	13310	13283	13246
16 - 17	35,95	35,85	35,67	35,41	13205	13193	13172	13142
17 - 18	36,84	36,68	36,39	36,01	13310	13291	13257	13212
18 - 19	37,09	36,90	36,57	36,14	13340	13317	13278	13227
19 - 20	38,96	38,67	38,17	37,53	13563	13528	13469	13392
20 - 21	39,56	39,24	38,68	37,95	13635	13596	13529	13443
21 - 22	35,39	35,28	35,09	34,84	13139	13126	13104	13075
22 - 23	29,04	29,24	29,60	30,07	12412	12434	12474	12526
23 - 00	23,06	23,53	24,38	25,51	11787	11834	11918	12035

	Industry elasticity = -0,5							
	Prices (Euros/MWh)				Quantities (MWh)			
	Household elasticity:							
Hour	-0,025	-0,1	-0,25	-0,5	-0,025	-0,1	-0,25	-0,5
00 - 01	20,62	20,98	21,67	22,71	11557	11590	11654	11754
01 - 02	16,83	17,24	18,06	19,35	11234	11267	11334	11444
02 - 03	15,08	15,52	16,41	17,85	11101	11133	11201	11317

03 - 04	14,57	15,04	15,99	17,51	11065	11098	11169	11288
04 - 05	16,02	16,45	17,32	18,69	11171	11204	11273	11387
05 - 06	20,44	20,77	21,39	22,36	11541	11570	11628	11720
06 - 07	28,90	29,02	29,23	29,54	12397	12409	12433	12468
07 - 08	35,73	35,66	35,52	35,34	13179	13170	13155	13133
08 - 09	39,12	38,96	38,66	38,24	13582	13562	13527	13477
09 - 10	40,36	40,16	39,81	39,31	13729	13706	13664	13605
10 - 11	41,04	40,84	40,48	39,96	13811	13787	13744	13682
11 - 12	40,64	40,45	40,12	39,63	13763	13741	13701	13643
12 - 13	39,46	39,30	39,02	38,61	13622	13604	13570	13522
13 - 14	38,44	38,31	38,08	37,75	13500	13486	13458	13419
14 - 15	37,65	37,55	37,35	37,07	13407	13394	13371	13337
15 - 16	36,58	36,50	36,35	36,12	13280	13270	13252	13226
16 - 17	35,69	35,62	35,49	35,31	13174	13166	13151	13130
17 - 18	36,67	36,55	36,34	36,04	13290	13276	13251	13216
18 - 19	36,99	36,85	36,60	36,25	13328	13311	13281	13240
19 - 20	38,87	38,65	38,27	37,74	13552	13526	13480	13417
20 - 21	39,54	39,29	38,85	38,25	13632	13602	13550	13478
21 - 22	35,61	35,52	35,36	35,13	13165	13155	13135	13109
22 - 23	29,69	29,81	30,04	30,36	12484	12498	12523	12559
23 - 00	23,97	24,27	24,82	25,64	11877	11907	11964	12048