STOCKHOLM SCHOOL OF ECONOMICS
Department of Economics
659 Degree project in economics
Spring 2019

Strategic Behavior Among Swedish Distribution Firms: Responsive Pricing of Grid Tariffs to Retail Electricity Costs of Households

Ingrid Löfman (24008) and Emma Hellström (23908)

Abstract. In this thesis paper, we investigate if the divergent trend of grid tariffs in the Swedish electricity market could be linked to electricity price differences between bidding zones. We propose and test an explanatory model in which network operating firms strategically price their grid tariffs as a response to retail electricity costs of households. Our results indicate that there could be a compensatory effect between grid tariffs and household retail electricity costs, and that this effect is stronger for firms with profit-maximization incentives and vertical integration across distribution, retail and production.

Keywords: Strategic pricing, grid tariffs, vertical integration, electricity distribution, bidding zones.

JEL: D10, D42, Q41, Q48

Supervisor:	Chloé Le Coq
Date submitted:	May 14, 2019
Date examined:	June 5, 2019
Discussants:	Shannon Felländer Tsai and Ossian Granit
Examiner:	Andreea Enache

Acknowledgements

We would like to extend our gratitude to our supervisor Chloé le Coq for her great advice and support.

We would also like to thank Ali Dolovac at the Swedish Energy Markets Inspectorate for his great helpfulness in finding relevant data.

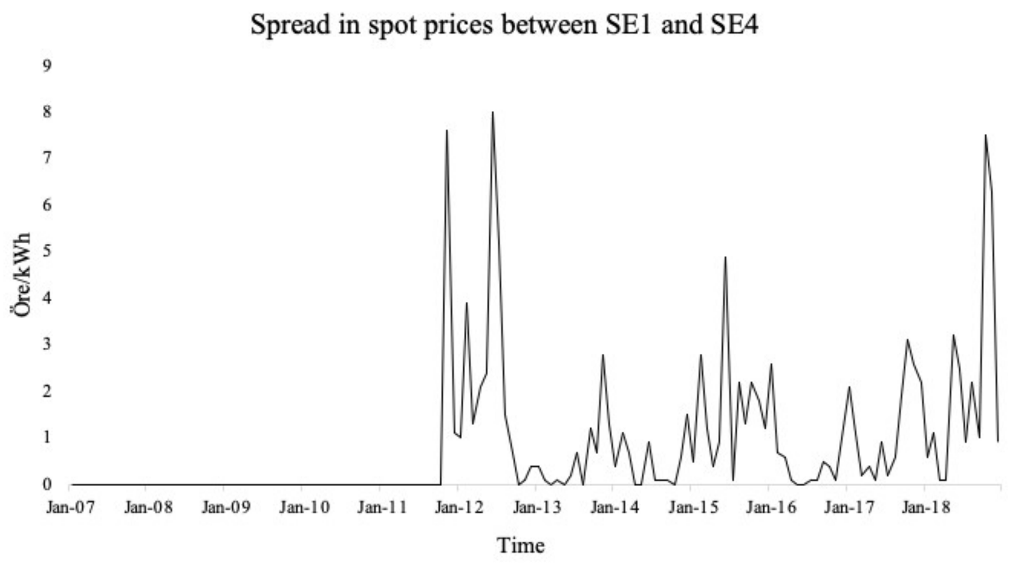
Table of Contents

1. Introduction 4
2. Background 6
   - 2.1. The Bidding Area Reform of the Swedish Electricity Market 6
   - 2.2. Competition in the Swedish Electricity Market 8
   - 2.3. The Structure of the Electricity Distribution Network 8
   - 2.4. The Regulation of Transmission Network Tariffs 10
   - 2.5. Legal Unbundling of Vertically Integrated Firms 11
   - 2.6. The Consumer Electricity Bill 11
3. Related Literature 12
   - 3.1. Strategic Behavior Among Network Operating Companies 12
   - 3.2. Residential Price Elasticity of Demand 14
   - 3.3. Our Contribution 14
4. Theoretical Framework 15
   - 4.1. Model Assumptions 15
   - 4.2. A Household-Centric Model of Retail Electricity Costs and Grid Tariffs 19
   - 4.3. Mathematical Relationship 22
   - 4.4. New Market Conditions 23
   - 4.5. Hypotheses 24
5. Econometric Method and Data Set 25
   - 5.1. The Econometric Model 25
   - 5.2. Variable Descriptions 26
   - 5.3. Data Set 28
   - 5.4. Econometric Considerations 32
   - 5.5. Econometric Method 34
6. Results 36
   - 6.1. Result I: Fixed Effects Regressions Before and After the Zonal Reform 36
   - 6.2. Result II: Correlated Random Effects Regressions 38
   - 6.3. Result III: Fixed Effects Regressions for Ownership and Vertical Integration 40
7. Discussion 41
8. Concluding Remarks 45
   - References 46
   - Appendix I: Revenue Caps 50
   - Appendix II: Variable Calculations 52
   - Appendix III: Breusch-Pagan and Hausman Tests 53
   - Appendix IV: Wald Tests of Interaction Effects 56

1. Introduction

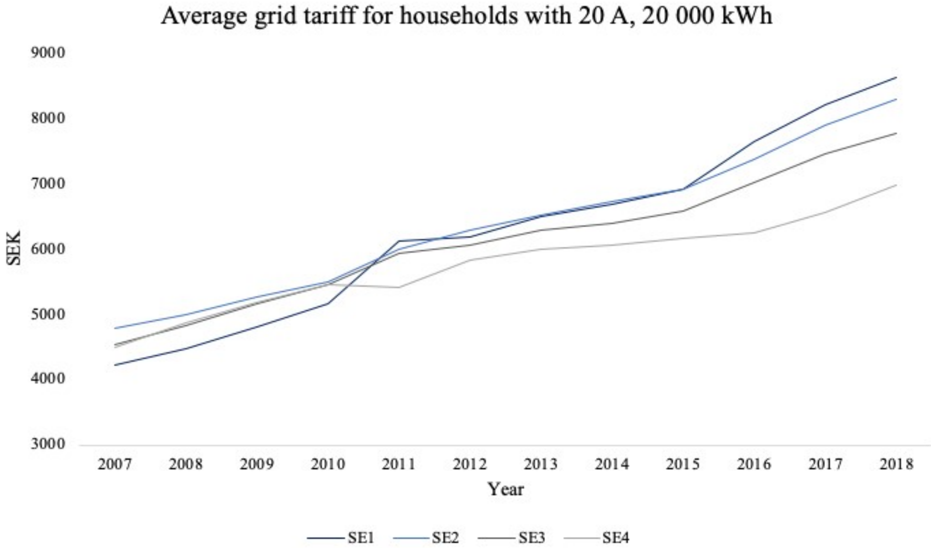
In 2011, the largest reform of the Swedish electricity market since the deregulation in 1996 was implemented. Now, the Swedish electricity market (which previously had one wholesale electricity price for the entire country) consists of four different electricity price areas, also known as bidding zones. As electricity production mainly is located in the north, while most of the consumption takes place in the densely populated areas in the south, electricity prices have diverged across the country. The high electricity prices in Skåne and sometimes Stockholm have attracted attention from media, interest groups and politicians (see Gjörtler, 2017; Larsson, 2012; Haglö, 2013; Müchler & Elander 2019; Isberg, 2011; TT, 2010). In times of high congestion, the electricity prices in Skåne has been up to twice as high as in other parts of the country (Magnusson, 2018; SvD Näringsliv, 2011). It is often perceived as unfair that some consumers pay more than others for such a basic household utility. Households have also seen their electricity network tariffs (also known as grid tariffs) substantially increase in the past few years (Lundin 2018). This has caused further frustration and outrage. While electricity prices are higher in the south than in the north, local grid tariffs have diverged in an inverse manner, with a higher increase in the north than in the south.

Figure 1: Spread in spot prices between SE1 and SE4 over time.



Source: authors' own rendering of data from the Swedish Consumer Energy Markets Bureau.
The data shows that electricity prices have diverged across the country since the zonal reform in 2011

Figure 2: Average grid tariffs for households with 20A, 20 000 kWh per bidding zone



Source: authors' own rendering of data from the Swedish Energy Markets Inspectorate.

While figure 2 indicates that the trend in grid tariff pricing was amplified in 2015, it starts shortly after the zonal reform in November 2011. A following question is whether this *uneven increase* in grid tariffs across the country could be related to the diverging electricity prices between bidding zones.

In this thesis paper, we investigate a potential link between grid tariffs and retail electricity costs of households. Our analysis is based on a microeconomic model where grid connections and retail electricity are regarded as perfect complements. We assume that residential price elasticity of demand for retail electricity is very low and that demand is (nearly) price inelastic for grid connections. Normally, when the price of one complementary good decreases, demand for both goods goes up. But in this case, as the price elasticity of demand is very low, households will be little inclined to adjust their electricity consumption and amperage ratings when electricity prices change. Instead, the decrease in retail electricity prices will lead to a smaller total electricity cost. This provides network operating companies with the opportunity to increase grid tariffs, until the total cost reaches the level of the household's budget constraint.

The bidding zone division, leading to different price levels of electricity across the country, provides us with an opportunity to investigate if this type of strategic behavior is present. In this sense, the bidding zone reform can be regarded as a natural experiment. If the diverge in grid tariffs across the country can be explained by strategic pricing, we would expect an inverse relationship with retail electricity costs when controlling for other factors that may influence network fees. We have built a data set with grid tariff data on all local networks in Sweden, average retail electricity costs per bidding zone, and a selection of other relevant variables. The data contains values from 2007 to 2018, to capture the potential effect of the reform imposed in 2011. We base our analysis on average costs for households with a 20 A grid connection and an annual electricity consumption of 20 000 kWh.

As a large part of the grid tariff is fixed, households could only marginally affect it by reducing their electricity consumption. Electricity is considered to have a low price elasticity of demand, but the demand for the transmission network connection can be regarded as (nearly) inelastic. Consequently, an increase in transmission network fees leads to a redistribution of wealth from households to network companies. Furthermore, the electricity transmission network is a natural monopoly, in which each network firm enjoys a local monopolist status. While households can renegotiate contracts for retail electricity and switch electricity retailer, households cannot change their distribution network operator. Consequently, households have a very low bargaining power relative to their transmission network operators, which adds to the importance of understanding factors that may influence grid tariff pricing.

The paper is organized as follows: In the second section, background information about the Swedish electricity market is provided. In the third section, a compilation of related literature is presented. In section four, a selection of relevant theory and our proposed explanatory model are outlined. In section five, the data set and econometric method are described. In section six, we present the results of our econometric analyses. In section seven, we discuss the implications about our results, to finally reach a conclusion in section eight.

2. Background

2.1. The Bidding Area Reform of the Swedish Electricity Market

Since November 2011, the Swedish electricity market is divided into four bidding areas. The reform followed a European Commission court ruling, in which it was established that Svenska Kraftnät (SvK) had discriminated against Danish consumers by withholding Swedish electricity capacity in times of high congestion (Ei, 2012). The Swedish electricity transmission network is characterized by four so-called bottlenecks, areas where electricity transmission may be hindered (see figure 3). When congestion is high, the bottlenecks reduce the electricity supply available across the country, leading to higher prices in the southern zones. An example of another country with fixed bidding zones is Denmark, which is divided into two electricity price areas. Norway is currently divided into five bidding areas, but these zones can be changed more easily than in the other countries. Prior to the zonal division 2011, Sweden only had one electricity price zone, like Finland, Estonia, Latvia and Lithuania today (Nord Pool, 2018a).

Figure 3: The Nordic electricity market

Source: Nord Pool, Bidding Areas

The total electricity price (P) in a bidding zone consists of two components: a system price (SYS), which is the Nordic electricity price in the absence of network congestion, and an electricity price area differential (EPAD). An EPAD is the difference between the bidding zone price and the SYS, which is caused by constraints in the transmission grid and hedging demands (EU Commission, 2010; Nordpool, 2018b).

As most of the electricity production is located in the north while most of the consumption is located in the south, EPADs are often positive in the south and negative in the north. As a result, electricity prices will differ between the bidding zones. In bidding zone i, the wholesale price P_i consists of:

$$P_i = SYS + EPAD_i$$

2.2. Competition in the Swedish Electricity Market

The Swedish electricity market was deregulated in 1996. Since then, the sectors for electricity production and retail have been competitive, while the electricity grid network is a so-called regulated natural monopoly (Konkurrensverket, 2018). Instead of supply and demand-based pricing, grid tariffs are set by firms who act under regulation by the Swedish Energy Markets Inspectorate (Ei).

After the deregulation, large market actors in the retail sector acquired smaller electricity retailers, which led to a high market concentration. But as a trend of new market entrants focusing on electricity retail has sprung up in recent years, the Swedish Competition Authority argue that the retail electricity market is increasingly and sufficiently competitive (Konkurrensverket, 2018). According to the Swedish Energy Markets Inspectorate's consumer website elpriskollen.se, as of May 2019, there are 144 electricity retailers in the market (Ei, 2018a). Following the division of the Swedish electricity market in 2011, there are four retail markets, but nearly all electricity retailers offer electricity contracts to customers in all four bidding areas. There are also some retailers who only act at a local level (Konkurrensverket, 2018; Ei, 2016a). In spite of the high number of firms in the electricity retail sector, the three largest firms (Vattenfall, E.ON, and Fortum) have a combined market share of approximately 45% (Konkurrensverket, 2018). Vattenfall, E.ON, and Ellevio (whose networks were operated by Fortum until 2015) together own roughly 60% of the local networks (Ei, 2015). In the production market, 71% of the market share pertained to Vattenfall, Fortum, and Uniper (which until June 2018 was owned by E.ON). Evidently, the Swedish electricity market features a number of large firms with strong positions across the distribution, retail and production sectors.

2.3. The Structure of the Electricity Distribution Network

The electricity transmission network can be divided into three levels: national grids, regional networks, and local networks. The national grid cables can be seen as "highways" for electricity transmission, transporting electricity from large generators to regional and local grids (Ei, 2016b). Electricity is also transported abroad via grid connections to neighboring countries. Svenska Kraftnät is responsible for the maintenance of the national grid. The regional network is connected to the national grid and to local networks (as well as some energy-demanding large firms). The largest regional grids are owned by Vattenfall, E.ON and Ellevio. In 2017, these firms were responsible for 97,8% of transmitted capacity through regional networks (Ei, 2018b). The local distribution network connects to households and firms, and is managed by different types of organizations: private firms, state-owned firms, municipality-owned firms and economic associations. Vattenfall, E.ON and Ellevio together accounted for about half of the total number of local network customers in Sweden (Ei, 2018b). While E.ON and Ellevio are privately owned, Vattenfall is owned by the Swedish state.

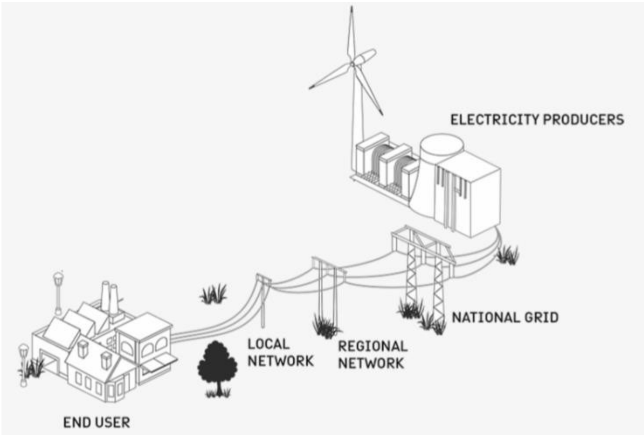


Figure 4, illustrating how electricity is transported to households. Source: SvK, as presented in Lundin (2016)

The number of local networks is rather uneven between the bidding zones. SvK's online database shows that the vast majority of local network areas delivering electricity to households are located in SE3. For the sake of simplicity, as we primarily investigate local networks, we will simply refer to local network operators as network operators, unless anything else is specified.

Table 1: Number of local network areas delivering electricity to households as end consumers

Bidding zone	Number of local network areas
SE1	15
SE2	28
SE3	178
SE4	55

Source: Authors' own rendering of data from SvK's online source

2.4. The Regulation of Transmission Network Tariffs

The local grid tariff is set annually by network operating firms, who act under regulation by the Energy Markets Inspectorate. The network fee has one fixed part and one variable part. The fixed part (*abonnemangsavgift*) depends on the specific fuse size of the property. The variable part (*elöverföringsavgift*) depends on the kWh used by the household (Energimarknadsbyrån, 2019).

Prior to 2012, Ei evaluated grid tariffs ex-post. If the grid tariffs of the past year were deemed excessively high, the firms were obliged to provide their customers with refunds (Lundin, 2016). From 2012 and forward, Ei has instead set ex-ante revenue caps for network operators, intended to ensure that grid tariffs charged to network customers are reasonable (skäliga), objective, and non-discriminatory (Ei, 2016b). The ex-ante method has been applied for two regulative periods (2012-2015 and 2016-2019) and will be applied in the upcoming regulative period of 2020-2023. Revenue caps are based on estimated future costs of transmission network activities, making factors such as depreciation times and discount rates important. For more information regarding how revenue caps are calculated, see Appendix I.

Revenue caps are intended to prevent excessive pricing of grid tariffs, while allowing for a reasonable return to network firms. In 2012-2015, approximately 50% of the revenue caps were appealed against (Ei, 2017). The courts sided with the network operators, who considered their revenue caps to be overly restrictive, which ultimately enabled them to charge their customers a total of 46 billion SEK more than originally determined. Ei considered the discount rates preferred by the firms to be overestimated, based on the low risk-nature of network activities. Electricity network companies were also able to depreciate assets more rapidly than what is now recommended by Ei (Ei, 2017).

In August 2018, the Swedish government revised regulation on grid tariffs, specifying new routines intended to result in a more accurate discount rate, as well as longer depreciation times for network assets. The new rules will apply to the upcoming regulative period of 2020-2023 (Regeringskansliet, 2018).

2.5. Legal Unbundling of Vertically Integrated Firms

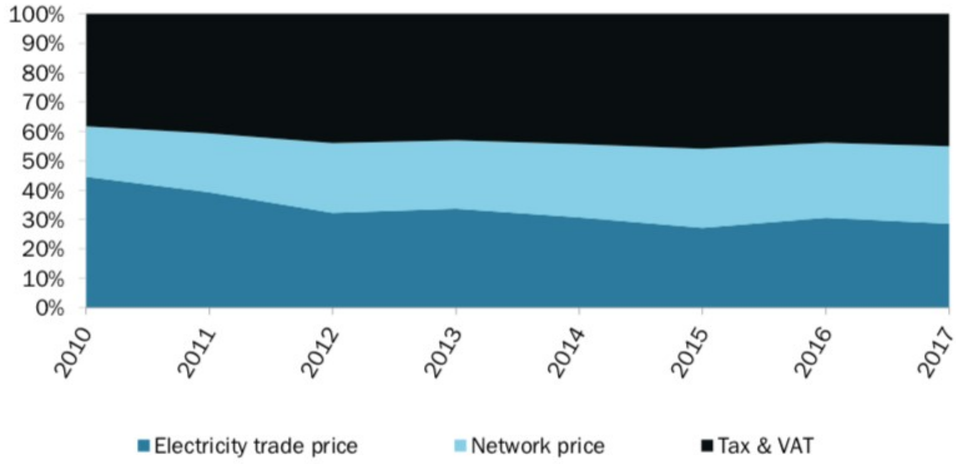
There are several firms in the Swedish electricity market that are active in the entire production chain of electricity, from generation to distribution to retail reaching the end customers. Such companies are referred to as vertically integrated firms. However, the Swedish electricity distribution network is subject to legal unbundling from electricity production and retail. According to the Swedish *Ellag* (SFS 1997:857), distribution services of vertically integrated firms must fall under a separate legal person from retail and production. If the distribution company has at least 100,000 households connected to their networks, the distribution firm must also be organizationally separate (with a separate board) from production and retail. Furthermore, network operating activities cannot be influenced by production and retail considerations. One intention behind the unbundling regulation is to prevent so-called crosssubsidizing, which is when network operating firms subsidize their electricity production or retail activities with the more secure cash-flows from network fees (Ei, 2018). However, law permits transmission firms to be subsidiaries to companies that also produce and sell electricity to consumers.

2.6. The Consumer Electricity Bill

The total electricity cost for a Swedish consumer consists of three components: retail electricity cost, energy taxes and VAT, and transmission fees for transporting the electricity through the grid network. The cost of consumed retail electricity for end-users is determined by their electricity usage (which varies between individual households) and retail electricity prices. 8590% of the retail electricity price is determined by the electricity spot price, which is the retailer’s cost of purchasing electricity (Ei, 2017). Retail price differences between bidding zones tend to be fairly small, measured in öre/kWh, and the differences vary from year to year and between electricity contract forms. For example, in 2015, the difference between SE1 and SE4 was on average 1.64 öre/kWh for flexible electricity contracts, and 2.00 öre/kWh for fixed contracts (Ei, 2017). However, there have been times when the price difference was higher, as indicated by figure 1.

In 2017, tax and network costs had increased as shares of the average consumer electricity bill. This was because taxes and network costs had risen while average retail electricity prices had decreased, as illustrated in figure 4.

Figure 4: Components of the electricity bill over time



Source: Ei and Statistics Sweden, as presented in Ei's report *The Swedish Market for Electricity and Natural Gas 2017*

3. Related Literature

3.1. Strategic Behavior Among Network Operating Companies

Although grid tariffs are subject to revenue caps, network operators can engage in strategic behavior to maximize profits. Riechmann (2000) shows how vertically integrated network operators may strategically price their tariffs based on conditions in the retail market. He uses a game-theoretical model that combines price competition in the retail electricity market with grid operating costs and revenue caps, and tests his model with data from England and Wales. In his model, the firm sets high grid tariffs in areas where it has a weak retail market position. These revenues are used to subsidize low grid tariffs in areas where the firm has a high retail market share, which, assuming demand is elastic, leads to higher retail demand. Consequently, although total tariff income is constrained by revenue caps, strategic pricing of grid tariffs allows the firm to capture additional rents from the retail sector. Similarly, we investigate a possible link between the retail sector and transmission network activities, but unlike Riechmann, we assume that there is a very low residential price elasticity of demand for electricity. Furthermore, Riechmann's article centers around firms that are vertically integrated across distribution and retail. While we acknowledge that vertical integration likely facilitates strategic behavior, we investigate a form of strategic pricing that non-integrated firms also can engage in.

Another author who investigates network operators is Lundin (2016). Using data from 2000 - 2011, he examines effects of the privatization of the Swedish electricity market on network prices and labor efficiency (where labor efficiency is defined as the number of customers per unit of labor). He finds that there is a positive effect of privatization on labor efficiency in local networks. But the efficiency gains are explained by economies of scale rather than private ownership per se, as the firms acquired bordering networks that previously were separately operated (Lundin, 2016). The data suggests substantial efficiency gains, but as prices are not affected, these are not fed through to consumers. Instead, they benefit the private network operating firms by improving their margins. Like in Lundin's article, we expect the behavior of a network operating firm to be strongly influenced by its ownership type. As private companies have profit maximization incentives, they may be more likely to engage in certain strategic behavior than non-private actors. We investigate this in the context of strategic pricing of grid tariffs as a response to prices in retail market.

Niesten & Jolink (2012) study opportunistic behavior of firms in the Dutch and French electricity markets. As explained by the authors, opportunistic behavior involves self-interest seeking, calculative and sometimes dishonest behavior. Opportunism is also linked to information asymmetries, as it may involve efforts to mislead the other contracting party and distort or hide information. Using data on dispute resolutions and enforcement of regulation from energy regulators, the authors investigate the influence of incentive alignment on such behavior. They found that some network operators engage in opportunism in relation to their customers by providing partially incorrect or incomplete information about tariff structures and network costs, which allowed them to capture higher rents. The authors point out that incentives among consumers and network operators are not aligned, as network firms want to charge high tariffs, while consumers want their tariffs to be as low as possible. Furthermore, several network operators did not fully disclose information to the regulator about their grid tariffs or customer complaints, as this enabled them to receive a higher tariff income. Like Niesten & Jolink, we recognize that information asymmetries between network operating firms and regulators or customers may facilitate strategic behavior. For example, the cost structure of network activities is difficult to assess (Willems & Ehlers, 2008). This makes it harder for customers and regulators to evaluate whether a certain tariff level is reasonable or not.

3.2. Residential Price Elasticity of Demand

When investigating effects of electricity price changes, it is important to account for how consumers react. Price sensitivity of electricity is regarded as low, according to Mark G. Lijesen's compilation of research on the topic (2016). In his meta-study of price-demand elasticities for various energy sources, he finds that electricity has a short-term price elasticity of -0.231 and a long-term price elasticity of -0.677. These estimates are similar to the numbers used in Andersson & Bergman's article (1995), where they (ex-ante) explore possible effects of the deregulation of the Swedish electricity market on electricity prices. The article includes a description of equilibrium electricity prices as an outcome of consumers' demand elasticity and the number of electricity producing firms in the market. First, they assume that the price elasticity of demand for electricity is -0.30, but as the electricity market opens up for crossborder trade, they expect demand elasticity to increase. They use an assumed demand elasticity of -0.6 to describe such scenarios. They find that with a low market concentration (meaning few electricity producing-firms), the expected electricity price is higher. They also show that the expected electricity prices increase when price elasticity of demand is low. They conclude that "...the possibility for firms to capture monopoly rents is strongly related both to the price elasticity of demand and to the number of competing firms on the market" (p. 107). Similar to Andersson & Bergman, we investigate pricing behavior when competition and demand elasticity is low. However, instead of focusing on producers, we explore these mechanisms in the context of the transmission networks - where each firm operates in a natural, local monopoly and price elasticity of demand for grid connections is (nearly) inelastic.

3.3. Our contribution

Following the zonal reform in 2011, when the Swedish electricity market was divided into four bidding areas, electricity prices have diverged across the country. This provides us with an opportunity to investigate whether this type of stable, long-term change in retail electricity prices could have any impact on network operators' pricing of grid tariffs. To our knowledge, no such analysis has previously been performed. Furthermore, while there is extensive research about the effect of zonal reform on electricity prices, to our knowledge, there has not been any analyses of the effects on the pricing of transmission network services. Another contribution is that we, unlike in Riechmann's study of strategic behavior in the retail and distribution sectors, use a household-centric approach based on consumer costs for electricity consumption and transmission networks. There are several reasons why such an approach is relevant. First, households have a very low bargaining power relative to network operators. As the transmission network is a natural monopoly, each network firm operates in a local monopoly setting. Unless consumers decide to actually move from their current housing, they cannot switch electricity network provider, regardless of their level of (dis)satisfaction. Second, there is a low price elasticity of demand not only for electricity but also for grid connections (which we explain further in our theoretical framework). In effect, price increases of grid tariffs lead to a redistribution of wealth from households to network operating companies. Thus, to investigate strategic pricing of grid tariffs with an analysis based on household costs is highly motivated from a household welfare perspective.

4. Theoretical Framework

4.1. Model Assumptions

To explain the grid tariff development across bidding zones with a model where distribution firms price their grid tariffs as a response to retail electricity prices, the following assumptions must hold true:

Assumption (1): From a consumer perspective, the grid connection and retail electricity are perfect complements

"When the utility a consumer receives from a good depends on it being used in fixed proportion with another good, the two are perfect complements" (Goolsbee et al, 2013, p. 129).

Consumers derive utility from using electricity, for example, to light lamps, heat the house, or use an electric stove or oven. To use electricity, a household needs i) a grid connection, so that electricity can be transported to the house in the first place, and ii) retail electricity, the electricity delivered through the wires by an electricity retailer. The household is likely to select their grid connection's fuse size based on expected electricity usage and is unlikely to (except for in rare occasions) change their ampere rating. Any amperage in excess of what is required for their current electricity usage will not provide additional utility. That households are unlikely to derive utility from using additional electricity is supported by the fact that the electricity usage (in kWh) must be permitted by the fuse size. But even for small increases in the amount of retail electricity delivered to the house, the household is unlikely to gain much additional utility. This is because electricity demand is considered to be rather inelastic, which Lijesen and Andersson & Bergman showed. That electricity and grid connections can be regarded as perfect complements is also mentioned in e.g. Willems & Ehler (2008).

Assumption (2): The residential price elasticity of demand for electricity and grid connections is very low

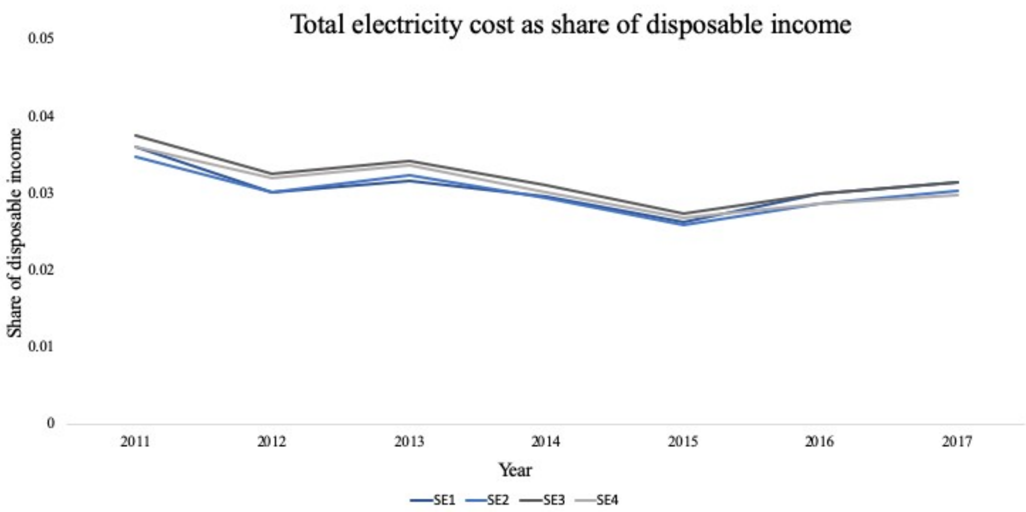
As explained in Goolsbee et al (2013), price elasticity of demand measures how consumption patterns change as a response to changes in the price of a good. If consumers have a high price elasticity of demand for a certain good, even a small price increase can lead to a large decrease in the quantity demanded.

As mentioned above, households select their fuse size based on their expected electricity consumption. Households are unlikely to change their amperage rating, as it is directly related to their level of electricity usage, which can be regarded as stable due to the low demand elasticity of electricity. Generally, goods that have easily accessible substitutes have a higher demand elasticity. However, grid connections do not have any readily accessible substitutes.

Although some households manage to go "off-grid" (see e.g. Dickson, 2019), this is not a viable option for the vast majority of households. Thus, grid connections can also be considered to have a very low price elasticity of demand.

Assumption (3): The household budget for electricity is constant

Figure 6: Total electricity cost as share of disposable income



Source: authors' own rendering of data from The Swedish Tax Agency, Ei, and SCB (for retail prices per bidding zone and regional disposable income). Total electricity cost is calculated as the sum of grid tariffs, retail electricity cost and energy tax for a household with 20 000 kWh, 20 A. Values are based on average costs and average annual disposable income for each bidding zone.

For there to be a compensatory effect between grid tariff pricing and retail electricity costs, we must assume that the household electricity budget is constant. It is difficult to assess how large the household budget for electricity really is, but assuming that firms in the electricity market strive to maximize their revenues, the total electricity cost of households may provide us with an indication of it. In figure 6, we have calculated total electricity costs as a share of disposable income for each bidding zone from 2011-2017. The data on disposable income was extracted from Statistics Sweden's online data source *Statistikdatabasen* and contained values for regional disposable income of households consisting of two cohabiting adults with children 019 years. The data was converted to reflect average values for each bidding zone. Further information about the cost data is given in the data section.

While the data from Statistics Sweden contained values for relatively few years, the variations between years seem to be fairly small, and the share of disposable income spent on electricity is rather even between the bidding zones. Realistically, we would not expect the electricityrelated consumer expenses to equal the budget constraint every year, as especially retail electricity costs may fluctuate due to arbitrary factors such as the weather. We rather assume that there is a household budget constraint for electricity-related costs, that this budget constraint is fairly constant as a share of disposable income, and that firms in the electricity market aim to maximize their cost share of this budget.

Assumption (4): The network operating firm is informed about the retail market for electricity and changes in the consumer's total electricity cost

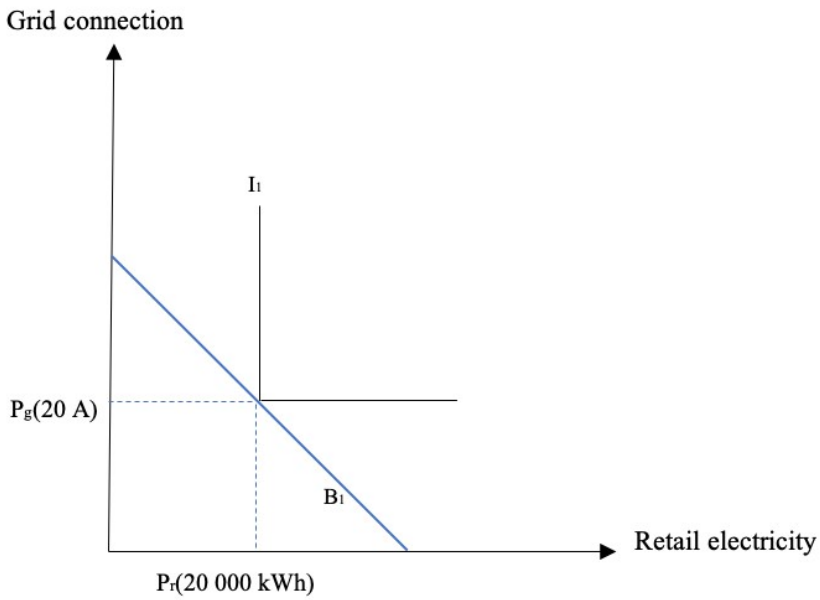
That network operating firms are informed about current conditions on the retail market is not unlikely, as distribution operators should be informed about the consumer market for electricity in general. The spot and retail markets for electricity are very transparent, with prices continuously updated on Nord Pool and websites such as elpriskollen.se. Thus, network operators should have some idea of how their customers' total electricity costs vary according to changes in retail electricity prices.

It is also possible that vertically integrated network operators are particularly knowledgeable about their customers' retail costs, as their own activities in the retail sector allow them to gather more information about changes in prices. Although vertically integrated actors in the Swedish electricity market are subject to legal unbundling, as Bolle and Breitmoser (2006) point out, this does not eliminate their ability to engage in strategic behavior such as cross-subsidization altogether. As previously mentioned, cross-subsidization occurs when firms subsidize their retail or production activities with revenues from the distribution sector. The fact that firms can (to some degree) engage in such behavior in spite of legal unbundling raises questions about whether there can be other strategic aspects of being active in the retail or production sectors while operating local distribution networks.

4.2. A Household-Centric Model of Retail Electricity Costs and Grid Tariffs

We are investigating a household with a 20 A grid connection and an electricity consumption of 20 000 kWh per year.

Figure 7: Graphical description of a household budget for 20 A, 20 000 kWh (I)

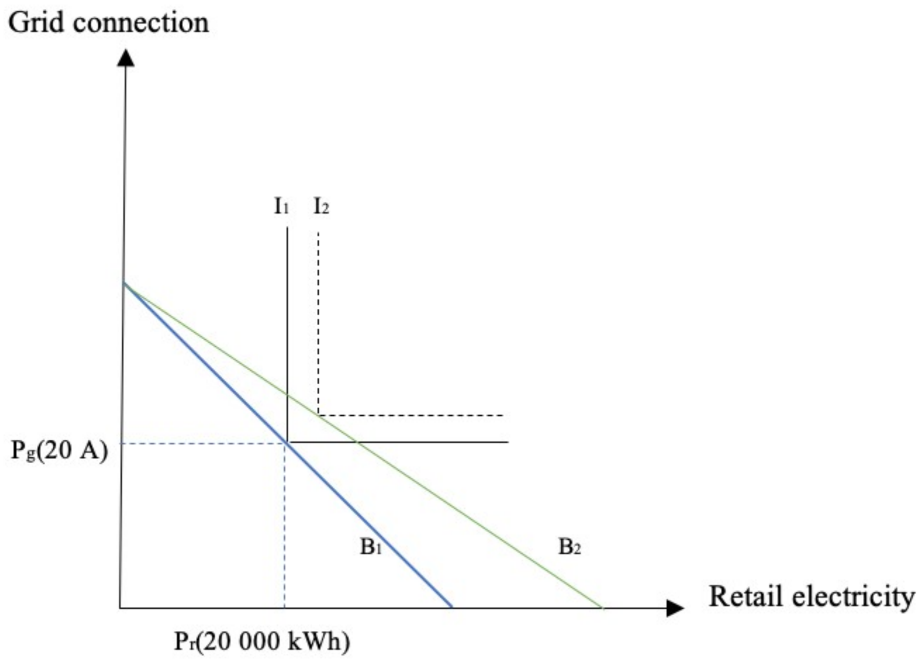


Source: authors' own graphical description of the indifference curve (I_1) and budget constraint (B_1) of a household with 20 A, 20 000 kWh.

As mentioned, one special aspect of the electricity market is that the price elasticity of demand is very low, especially in the short-term. Increases in the price of electricity or grid tariffs is expected to lead to a redistribution of wealth from households to electricity companies, instead of altered consumption patterns. With the same logic, decreases in electricity prices will not lead to higher consumption of electricity - instead, it will lead to an income effect, as the household is able to spend the money that otherwise would have gone to electricity on something else. The lack of substitutes for electricity minimizes the substitution effect when prices change, consequently, only the income effect will be present.

Now, imagine that the price of electricity decreases, and is expected to stay at this lower level for a long time. This shifts the budget constraint from B_1 to B_2.

Figure 8: Graphical description of a household budget for 20 A, 20 000 kWh (II)

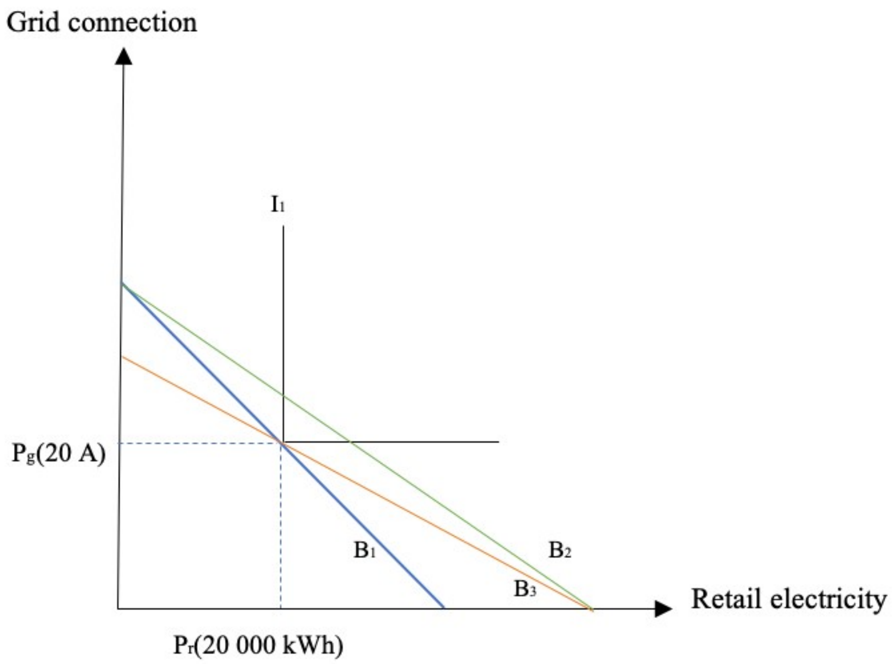


Source: authors' own graphical description of how the budget constraint changes due to lower retail electricity prices. The decrease in retail electricity prices result in a new budget constraint, B_2.

For the typical case with perfect complements, when the price of one good decreases, demand for both goods will go up. Had this been the case, the household would have shifted its electricity usage and ampere rating upward, reaching the dotted indifference curve I_2 tangent to B_2. But as electricity and grid connections have a very low price elasticity of demand, the electricity usage may perhaps go up marginally but the amperage rating will stay the same. For the sake of argument, assume that the household stays at the indifference curve I_1, which is now below the budget constraint.

Now, imagine that the grid operator has an idea of what the budget constraint of a household really is, and is aware that the consumer's total electricity cost currently is below this budget constraint (and is expected to stay at this lower level for a long time). This gives the distribution firm the opportunity to raise its grid tariffs, so that the total cost of electricity increases to the original level (before any retail price changes occurred).

Figure 9: Graphical description of a household budget for 20 A, 20 000 kWh (III)



Source: author's own graphical description of how the budget constraint shifts following higher grid tariffs. The new budget constraint B_3 is tangent to the original indifference curve.

The budget constraint changes to B_3, tangible to the indifference curve at 20 A, 20 000 kWh. Instead of allowing the consumer to capture surplus resulting from lower electricity prices, this extra "space" within the budget now goes to distribution companies. As electricity and grid connections are complementary goods with a very low price elasticity of demand, long lasting decreases in the price of one of the goods is unlikely to lead to more consumption - instead, it offers opportunities for price increases of the other good.

The consumer bill for electricity also includes taxes. If taxes change at the same time as retail electricity prices, the change in grid tariffs should, according to the logic of the model, take this into account as well.

We describe the mathematical relationship between the variables below. In our example, taxes are constant throughout the three periods.

4.3. Mathematical Relationship

Table 2: Variable description of the mathematical household electricity budget model

Variable	Description
T	Total cost of electricity (SEK)
B	Household budget constraint (SEK)
r	Retail price of electricity (SEK/kWh)
g	Variable part of the grid tariff (SEK/kWh)
G	Fixed part of the grid tariff (SEK)
t	Electricity tax (SEK/kWh)
q	Quantity of consumed electricity (kWh)

Source: authors' own variable description.

Since we have assumed that the price elasticity of demand is very low, q can be regarded as constant.

A household's total electricity cost can be described mathematically as:

$$T = \mathrm{rq} + (\mathrm{gq} + \mathrm{G}) + \mathrm{tq} = \mathrm{q}(\mathrm{r} + \mathrm{g} + \mathrm{t}) + \mathrm{G}$$

Electricity firms maximize their profits when the household's total electricity cost is equal to the household budget constraint. At this total electricity cost, electricity companies capture all surplus, while consumers capture zero surplus. Assume that this is the case in period 0.

Period 0: Total electricity cost is equal to the budget constraint.

$$B - T = \mathrm{B} - (\mathrm{q}\ (\mathrm{r} + \mathrm{g} + \mathrm{t}) + \mathrm{G}) = 0$$

Period 1: Retail electricity costs decrease by c, such that $r_c = \mathrm{r} - \mathrm{c}$, $r_c < r$

Then total electricity cost changes such that;

$$T_c = \mathrm{q}(r_c + \mathrm{g} + \mathrm{t}) + \mathrm{G} = \mathrm{q}(\ \mathrm{r} - \mathrm{c} + \mathrm{g} + \mathrm{t}) + \mathrm{G} = \mathrm{T} - \mathrm{qc}$$

$$B - T_c = \mathrm{B} - (\mathrm{T} - \mathrm{qc}) > 0$$

more precisely,

$$B - T_c = qc$$

Thus, the retail electricity price decrease has led to an income effect, allowing the consumer to capture surplus qc.

Period 2: The network operator adjusts $qg + G$ upwards with d, to maximize its surplus (this is done by increasing either g, G, or both).

Again, electricity firms maximize their combined surplus when $B - T = 0$. For this to occur, grid tariffs must change so that $qg_d + G_d = qg + G + qc$, as shown below

$$T = T_c + qc = q(r - c + g + c + t) + G = B$$

Thus, by raising their grid tariffs, the network operator is able to capture the surplus qc that the customer previously enjoyed.

4.4. New market conditions

The division of Sweden into four bidding areas has changed the electricity market conditions for firms and consumers. While the total electricity cost may fluctuate from year to year due to arbitrary factors, as a result of the reform, the average annual retail electricity costs of households have diverged between bidding zones in a non-temporary manner. Actors can expect average annual retail prices to differ between the zones in a relatively stable manner and that the difference will prevail for a long time. In this sense, the bidding zone reform provides us with an opportunity to investigate if the kind of strategic behavior described in the model takes place.

4.5. Hypotheses

H1. Network operating firms adjust their grid tariffs as a response to retail electricity costs of households to maximize their total income within the household budget constraint.

If this hypothesis holds true, we expect to find a negative relationship between retail electricity costs and grid tariffs when controlling for relevant factors such as reinvestment, structural differences between bidding zones, taxes, and various characteristics of network areas and network operating firms. However, we expect some firms to be more likely to engage in this sort of strategic behavior than others, leading to our next hypothesis.

H2. a. Profit-maximizing firms are more likely than non-profit maximizing firms to adjust their grid tariffs as a response to retail electricity costs of households.

H2. b. Vertically integrated firms are more likely than non-integrated firms to adjust their grid tariffs as a response to retail electricity costs, as they are more informed about conditions in the retail market.

If this hypothesis holds true, we expect the estimated coefficient for retail electricity cost to be larger (in absolute values) for profit-maximizing firms vs. non-profit maximizing firms and vertically integrated firms vs. non-integrated firms when controlling for the factors mentioned above.

5. Econometric Method and Data Set

5.1. The Econometric Model

To evaluate whether our hypotheses are supported by the data, we will base our analyses on the following econometric model:

$$Y_{ijct} = \beta_0 + \beta_1 C_{jt} + \beta_2 T_{ijt} + \beta_3 Z_{it} + \beta_4 X_c + \beta_5 V_j + \varepsilon_{it}$$

where

- Y_{ijct} is the grid tariff for a household with a fuse size of 20A in network area i, operated by company c, in bidding zone j, at year t.

- C_{jt} the retail electricity cost, our independent variable of interest. Reported as an average value per bidding zone, the variable represents the average annual electricity cost for a household with 20 000 kWh annual consumption in bidding zone j, at year t.

- T_{ijt} the tax variable, representing taxes paid by consumers in network area i at time t.

- Z_{it} a time varying vector of network area characteristics, consisting of effect delivery (in mWh), reinvestments (in million SEK) and revenue caps (in million SEK) for local network area.

- X_c is a vector of grid operator characteristics for company c, including ownership structure and vertical integration. This variable is not time varying.

- V_j the bidding zone dummy variable.

5.2. Variable Descriptions

5.2.1. Household cost variables

As our model centers around strategic pricing of grid tariffs based on household costs, we have two distinct independent variables representing such electricity-related consumer expenses. Together with our dependent variable - grid tariffs - retail electricity costs and taxation are the components of the consumer electricity bill.

5.2.2. Network area characteristics

Local network areas may have different characteristics that also influence the pricing of grid tariffs. The variables intended to capture such effects are effect delivery, reinvestments and revenue caps. Effect delivery, which measures the size of local networks in mWh, describes the potential effect of economies of scale on grid tariffs. As Lundin (2016) demonstrated, the costs of operating network areas are subject to economies of scale. While he found that private owners were reluctant to let these effects transfer into lower grid tariffs, we argue that the size of networks may offer some explanatory value for the grid tariff, especially combined with ownership type dummies (which are further explained below) that capture effects of whether a firm is profit maximizing or not.

Reinvestments are often referred to by grid owning companies as the main contributor to increased grid tariffs. As reinvestments really are maintenance costs of the networks, increases in grid maintenance costs due to storms, that potentially could affect grid tariffs, should be reflected in this data. Maintenance costs following storms should be projected into the following annual reinvestments, and as grid tariffs are set annually, it is likely that any grid tariff changes stemming from such maintenance costs will be reflected in this data.

Regarding revenue caps, it is highly possible that the diverging grid tariffs across zones are related to diverging revenue caps. But revenue caps are difficult to control for as companies do not always use their entire revenue cap, meaning that they do not always reflect the grid tariffs that are actually paid by customers. Furthermore, it is possible that the tariff income of companies is unevenly distributed across their customer groups - grid operators could for example raise tariffs more for apartment customers with low amperage levels than for customers in larger housing, or vice versa. As we only study one customer group, any estimated effects of revenue caps are not necessarily representative of actual grid tariff pricing. We further discuss revenue caps in Appendix I. As we recognize these potential problems with revenue caps, we only include it in one regression specification, and we are careful not to put too much weight into any estimated effects of this variable. We include it in one regression because it is a heavily debated subject – which makes it interesting to see how it affects our dependent variable as well as our other control variables.

5.2.3. Grid operator characteristics

To control for grid operator characteristics, we have included dummy variables for ownership types (municipality operation and economic association) and dummy variables for vertical integration (electricity production and retail). We base these variable choices on the assumption that the incentives of non-private network operators differ from those of private network operators. As Lundin (2016) points out, economic associations may be less likely than private companies to overcharge their customers. It is also possible that municipality operated network firms are less inclined to raise grid tariffs to maximize profits. While we believe that both economic associations and municipality operations on average would be less likely to overcharge their customers than private firms, it is possible that there are other systematic differences between economic associations and municipality operations. Characteristics that may differ on average could for example be governance structures or access to resources, as municipality-owned firms often are part of a larger, organizational complex of municipalityowned firms. In our second econometric analysis, we will therefore include both variables, to see how they influence the level of grid tariffs charged to customers. In our third analysis, we merge the ownership variables into one, to compare how profit maximizing and non-profit maximizing grid companies respond to prices in the retail market. As we include the dummy variables for ownership types mentioned above, private companies *and* state-owned Vattenfall pertain to the base category. The reasoning behind grouping state-owned and private companies is that, like Lundin (2016), we assume that Vattenfall acts as a profit maximizer. This is because Vattenfall does not have any direct connections to the local community in which it serves as network operator.

The study by Riechmann (2000) suggests that there may be strategic aspects of acting in the retail or production sector while operating electricity transmission networks. By including dummy variables for production and retail, we control for any effect of such behavior on grid tariffs, and we also investigate whether vertically integrated firms are more likely than others to engage in the type of strategic tariff pricing proposed in this thesis paper. The scope of electricity production may differ between firms, as some firms engage in large-scale production with a diversified set of electricity generation methods, while others have a more local production. This is also the case for retailers, as some engage in electricity retail across the country while others act at a more local level.

5.2.4. Bidding area characteristics

We included a bidding area dummy variable to control for e.g. the density of the electricity network, as the sparseness of the grid in the northern regions is expected to lead to higher network costs per customer.

5.3. Data Set

5.3.1. The typical household in our analysis

We have based our analysis on average costs for a household with a 20 A network connection, 20 000 kWh electricity usage per year, and a variable (per-unit) retail electricity contract. This “average-customer” type is used by Swedish Energy Markets Inspectorate and Swedenergy in several reports, (see Ei, 2018c; Swedenergy, 2018). There are also households with smaller or larger Ampere connections and electricity consumption levels and we recognize that it is possible that potential strategic behavior affects some consumers more than others. We calculate expected electricity consumption costs based on variable (per-unit) retail electricity contracts since it is the most common contract among electricity consumers in all bidding zones (STEM & SCB, 2016).

5.3.2. Data selection

Grid tariffs

Our data on annual grid tariffs (SEK) from 2005-2018 was given by the Energy Markets Inspectorate. However, the REL-numbers reported in this data do not accurately reflect the amount of actual local networks, as several network areas can belong to one accounting unit. Also, many distribution companies have merged some of their accounting units throughout our selected time period, implying that our list of REL-numbers is larger than the actual number of local networks. To receive a more accurate picture of the local networks and the grid tariff development per network, we matched our data set from Ei with data on current local network areas extracted from Svenska Kraftnät's online data source. The data originally contained 292 local grid networks. The data also included the network owner and bidding zonal location of each network area. As we were interested in networks with household connections, we only used data on local networks and excluded those belonging to companies solely for industrial purposes.

Retail electricity cost

We extracted data on the average per-unit electricity price (reported in öre/kWh) from Statistics Sweden. The data contained monthly average values of retail electricity prices for consumers with 20,000 kWh and was reported per bidding zone from April 2013. Before the zonal division in November 2011, the data described the average price across the country and between November 2011 and March 2013, the average price in SE3 was given. We estimated retail electricity costs for all bidding areas from 2011 to 2013 based on the reported values for SE3 and an average of the reported differences between bidding areas over time. For more information about how the calculations were made, please see Appendix II.

The retail prices were compiled into annual values, converted to SEK/kWh and multiplied with 20 000 to reflect the annual retail electricity cost (excluding taxes) for a household using 20 000 kWh per year.

Electricity taxes

Information about the annual energy tax on electricity 2007-2018 was given by the Swedish Tax Agency. The data (reported in öre/kWh) contained the taxation levels applicable to certain northern regions and municipalities that have a reduced taxation level as well as the taxation level for the rest of Sweden. The reduced tax rates were applicable to all networks in SE1 and SE2 and networks located in five municipalities in SE3. The tax was converted to SEK and multiplied with 20 000 to reflect the annual retail electricity taxation cost for a typical household.

Effect delivery

To control for the size of the local networks, we used the time-varying effect (mWh) delivered through each network. The data, originally from SvK's online data source, contained the standard-estimated effect delivery through each local network. It was compiled into monthly values by SvK. To match the rest of our data set, we further compiled the effect delivery into annual values.

Reinvestments

In a report from Ei (2017), reinvestments in the electricity grid network was calculated at an aggregate level. We asked Ei to instead calculate the reinvestments for each accounting unit. We received data on annual reinvestments from 2006-2011 and projected investments between 2012-2019, reported per REL number. To obtain an approximate measure of the annual reinvestments per local network, we divided the reinvestments of each accounting unit between its local networks and weighted the shares by mWh, to account for the size of the network. The reinvestments are reported in thousands of SEK.

Revenue caps

We expanded our data set with revenue caps, given to us by the Swedish Energy Markets Inspectorate. The data contained revenue caps for the periods 2012-2015 and 2016-2019 per REL number. To obtain an approximate measure of the annual revenue cap per local network area, we used the annual revenue cap per REL-number and divided each revenue cap between the network areas, weighted by mWh. The revenue caps are reported in million SEK.

Municipality operation and economic association

To create dummy variables for ownership types, we researched each network owner. A distribution company is considered to be a municipality operation if the majority owner is a municipality, or an economic association if the majority owner is an economic association.

Electricity production and retail

To create a dummy variable for whether a distribution company is included in a vertically integrated ownership structure that engages in electricity production or retail, we researched each network owner. In our data set, a network operator is considered to also be a producer or retailer if it holds a majority ownership share in an electricity production or retail company.

Bidding zone

We received information about the bidding zone of each local network from SvK's online source. From this, we created three dummy variables: SE2, SE3, and SE4 (with SE1 as base category).

5.3.3. Summary statistics

Table 3: Summary statistics (2007-2018)

	(1)	(2)	(3)	(4)	(5)
Variables	N	mean	sd	min	max
Grid tariff	3,075	6,134	1,531	2708	11,395
Retail electricity cost	3,312	8,945	2,128	5,582	12,843
Tax	3,312	5,009	1,097	3,560	6,620
mWh	3,236	164,530	250,699	100.8	2.781e+06
Reinvestment	3,312	48.37	230.9	-123.2	2,105
Revenue cap	1963	905,962	3.033e+06	802.6	5.383e+07
Production	3,312	0.616	0.486	0	1
Retail	3,312	0.841	0.366	0	1
Municipality operation	3,312	0.449	0.497	0	1
Economic association	3,312	0.109	0.311	0	1
BA	3,312	2.989	0.720	1	4
No. of network areas	265				

5.4. Econometric Considerations

5.4.1. Random effects versus fixed effects

After performing a Breusch-Pagan test that rejected OLS as an appropriate method, the choice was between a fixed effects (FE) model and a random effects (RE) model (see table 7 in Appendix III). FE only uses variation within each network area over time, as opposed to RE that includes variation between network areas as well. Which one of the methods that is more appropriate depends on what we can expect from the fixed error term, a_i (Woolridge 2016). The error term u_{it} consists of one fixed part and one idiosyncratic error, so that $u_{it} = a_i + v_{it}$ In a random effects regression, we must assume that $Cov(a_i, x_{ijct}) = 0$, meaning that the fixed error term must be uncorrelated with our explanatory variables x_{ijct}. In our case, this implies that the retail electricity cost and our other independent variables would have to be uncorrelated with any fixed effects that also affect the level of grid tariffs. With a fixed effects method, we do not have to make this assumption, as we exclude all time-invariant factors. But this implies that some of our variables - namely the dummy variables for network operator characteristics and bidding zones - would be omitted as well. We very much face a trade-off; with FE, we cannot draw any conclusions about the potential explanatory value of our time-invariant dummy variables, but with RE, we risk obtaining less efficient estimates.

The question is then whether we can expect there to be zero covariance between fixed errors and our independent variables. We likely remove some correlation with the fixed error term by including dummy variables for ownership characteristics, vertical integration and bidding zones. But it is highly likely that there are other factors that violate the assumption of

$Cov(a_i, x_{ijct}) = 0$.

We performed a Hausman test for the data from 2007-2018 (see table 8 in Appendix III), which showed that fixed effects is preferred to random effects. Following these results, we performed fixed effects regressions of data from 2007-2018, 2011-2018, and 2007-2010. The results are presented in our results section.

However, we were still interested in seeing how ownership characteristics, vertical integration and bidding zone characteristics affect the level of grid tariffs. But as these variables are timeinvariant, they will be omitted in fixed effects. We therefore decided to perform a correlated random effects estimation. As explained by Woolridge (2016), this approach allows us to include time-invariant variables, while we are not required to make the strong assumption of zero correlation between our explanatory variables and unobserved fixed effects. The approach is based on the idea that a_i is correlated with the mean value of each independent variable. By creating between-variation variables from the mean of each of our time-varying regressors and including them in our random effects regressions, we controlled for the correlations between fixed effects and our independent variables. We also performed an additional Hausman test, which now showed that RE was preferable to FE (see table 9 in Appendix III). The outcomes from our correlated random effects regressions are presented in the results section.

5.4.2. Attrition

In our data set, there are some observations of network areas and years where there are missing values of grid tariffs, mWh, revenue caps or investment. Thus, we have an unbalanced panel data set. This raises concerns about whether these missing values are correlated with idiosyncratic errors, as this would lead to problems with systematic attrition. Such attrition could potentially lead to biased results (Woolridge, 2016). For us, much of the attrition is caused by network companies changing REL numbers of their networks (as several networks can be part of the same accounting unit, but this structure may also change over time depending on decisions by the firm or Ei). Another potential source to attrition in our data set could stem from the process of matching REL numbers to network areas, as the current information may not always be representative of how network areas were organized a few years ago. We do not expect these sorts of missing values to occur on a systematic level.

When performing our correlated random effects regressions, however, missing values may create problems, as time averages require data from all years for results to be correct (Woolridge, 2016). To avoid incorrect results, we dropped all network areas with missing values by using Stata's mark and markout commands, similar to in Schunck (2013).

5.4.3. Heteroskedasticity

As explained by Woolridge (2016), heteroskedasticity occurs when the variance of error terms depends on the value of our explanatory variables. While this does not cause inconsistency in the estimated coefficients, it may affect standard errors and t-statistics. To prevent such issues from arising, we used robust standard errors in all of our regressions.

5.5. Econometric Method

5.5.1. Fixed effects regressions I

To evaluate whether there is a compensatory effect between grid tariffs and retail electricity costs, we performed a set of fixed effects regressions for three time periods: 2007-2018, 20072010, and 2011-2018. If network operators set their grid tariffs as a response to non-temporary changes in retail electricity prices and the bidding zone division resulted in such price changes, we expect to find a negative relationship between retail electricity costs and grid tariffs after the bidding zone division 2011. We also expect the estimated effect to be stronger and more negative than for the regressions with data from 2007. The results from the regressions are presented in table 4 in our results section.

5.5.2. Correlated random effects regressions

After our fixed effects regressions, we wanted to perform an economic analysis that allowed us to include our time-invariant dummy variables, as this hopefully would further our understanding of the other factors that may have contributed to the difference in grid tariffs between bidding zones. We performed a set of correlated random effects regressions, as this allowed us to include our time-invariant independent variables while controlling for correlations between our other explanatory variables and fixed error terms. We used data from 2011-2018. The results from our CRE regressions are presented in table 5.

5.5.3. Fixed effects regressions II

After our correlated random effects regressions, which allowed us to evaluate if ownership types and vertical integration have affected the level of grid tariffs, we wanted to perform an econometric analysis that allowed us to evaluate the role of ownership types and vertical integration in strategic pricing. More specifically, we wanted to see if the estimated effect of retail electricity prices on grid tariffs differed between profit maximizing firms versus nonprofit maximizing firms, and vertically integrated firms versus non-integrated firms. We performed two fixed effects regressions with interaction effects for profit maximizers and vertical integration, including data from 2011-2018. The results are presented in table 6 in the results section. We then performed a Wald test to see if the differences in estimated coefficients between profit maximizers versus non-profit maximizers and vertically integrated versus nonintegrated firms were statistically significant. The results are presented in Appendix IV.

6. Results

6.1. Result I: Fixed Effects Regressions Before and After the Zonal Reform

Table 4: Fixed effects results from time periods 2007-2010, 2007-2018 and 2011-2018

Grid tariff	(1) Fixed Effects	(2) Fixed Effects	(3) Fixed Effects	(4) Fixed Effects	(5) Fixed Effects
Retail electricity cost	0.1736***	0.0428***	-0.0887***	-0.0918***	-0.139***
	(0.007)	(0.005)	(0.004)	(0.0046)	(0.005)
Tax	1.048***	0.756***	2.140***	2.107***	2.348***
	(0.072)	(0.024)	(0.085)	(0.084)	(0.092)
mWh	0.00092	0.0013*		0.000710	0.00067
	(0.001)	(0.001)		(0.001)	(0.0005)
Reinvestment	-0.116	-0.771*		3.001**	4.638*
	(0.223)	(0.411)		(1.419)	(2.612)
Revenue cap					-1.32e-05***
					(4.27e-06)
Constant	-842***	1,743***	-4,721***	-4,674***	-5,670***
	(140.4)	(189.36)	(465.0)	(458.4)	(492.0)
Observations	946	3,025	2,079	2,079	1,869
R-squared	0.471	0.510	0.552	0.559	0.550
No. of network areas	249	267	265	265	264
Time period	(2007 -2010)	(2007 -2018)	(2011 -2018)	(2011 -2018)	(2011-2018)

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In specification (1), between 2007-2010, the estimated coefficient of retail electricity cost was significant and positive at 0.1736. This implies that a 1 SEK increase in the retail electricity cost of a household is associated with an average increase of 17 öre in grid tariffs. In regard to our proposed model, this positive relationship between grid tariffs and retail electricity costs is quite puzzling. However, it should not be taken too heavily as this specification includes few years. The tax coefficient is positive in all specifications. The coefficient for mWh was positive in all specifications, but insignificant. The coefficient for reinvestment was negative in both specification (1) and (2), which was not an expected outcome. We offer a potential explanation in our discussion section. In specification (3), using data from 2011-2018, the estimated coefficient of -0.0887 for retail electricity cost was negative and statistically significant.

The coefficients of retail electricity cost in specification (4) and (5), using data from the same time period but including more variables, were estimated to -0.0918 and -0.139. The results imply that a 1 SEK increase in household retail electricity costs is associated with an average decrease in grid tariffs of between 8.87 and 13.90 öre. The results will be discussed further in our results section. In specification (5), revenue caps were also included. According to the results, if revenue caps increase by 1000 SEK, grid tariffs are expected to slightly decrease, holding all other variables fixed. This implies that there may be little *economic* significance of revenue caps on grid tariffs, which is quite unexpected, but may be caused by measurement problems as previously explained in the method section.

6.2. Result II: Correlated Random Effects Regressions

Table 5: Correlated random effects results from 2011-2018

Grid tariff	(1) Correlated re	(2) Correlated re	(3) Correlated re	(4) Correlated re	(5) Correlated re
Retail electricity cost	-0.0889***	-0.0918***	-0.0918***	-0.0917***	-0.0918***
	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
m.Retail electricity cost	-1.976**	-1.995***	-0.897	-0.206	-0.732
	(0.790)	(0.763)	(0.636)	(0.803)	(0.984)
Tax	2.139***	2.106***	2.106***	2.105***	2.105***
	(0.0853)	(0.0843)	(0.084)	(0.0843)	(0.084)
m.Tax	-2.314***	-2.263***	-2.208***	-2.282***	-2.434***
	(0.164)	(0.156)	(0.131)	(0.151)	(0.379)
Reinvestment		3.001**	2.998**	3.001**	2.999**
		(1.419)	(1.418)	(1.420)	(1.420)
m.Reinvestment		9.377***	-0.536	6.584**	-1.197
		(3.479)	(2.951)	(3.213)	(2.873)
mWh		0.000709	0.000709	0.000710	0.000709
		(0.001)	(0.001)	(0.001)	(0.001)
m.mWh		-0.00180***	-0.00144**	-0.00199***	-0.00151**
		(0.001)	(0.001)	(0.001)	(0.001)
Economic association			-1,061***		-790.3***
			(204.4)		(261.1)
Municipality operation			-1,814***		-1,669***
			(128.9)		(146.4)
Production				844.4***	416.1***
				(159.4)	(154.8)
Retail				352.7*	51.97
				(181.7)	(167.0)
SE2					-155.5
					(374.0)
SE3					369.8
					(807.8)
SE4					480.1
					(873.3)
Constant	24,621***	24,718***	16,353***	9,345	15,571*
	(6,233)	(6,012)	(5,009)	(6,388)	(8,091)
Observations	2,079	2,079	2,079	2,079	2,079
R-squared	0.176	0.559	0.494	0.289	0.508
No. of network areas	265	265	265	265	265

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The estimated effects of retail electricity costs in our random effects regressions were approximately -0.0889 and -0.0918 at 1% significance level. As expected, they were (nearly) identical to the estimated effects in specification (3) and (4) from table 4. The estimated coefficients for economic association and municipality operation in specification (3), were statistically significant and negative by -1061.0 and -1814.0 respectively. This implies that the grid tariffs of economic associations and municipality-run grid operators are expected to on average be about 1000 and 1800 SEK lower than those of state-run or private companies. In specification (4), the coefficient for production was 844.4 and statistically significant, while the estimated effect of retail also was positive and statistically significant at 10%.

In specification (5), the effects of ownership types and vertical integration became smaller (in absolute numbers) when including all of them into one regression, implying that there are correlations between these variables that are controlled for. Then, the estimated effects the economic association and municipality operation dummies were -790.3 and -1669 respectively. These estimated coefficients were statistically significant at 1%. The results imply that economic associations and municipality operations are associated with about 800 SEK and 1700 SEK lower grid tariffs compared to private or state-run network operators, controlling for the variables included in the specification. The effect of the retail dummy was estimated to 51.97 and statistically insignificant, while the effect of production was estimated to 416.1 and significant at 1%. This implies that the grid tariffs of electricity-producing network owners are expected to be about 416 SEK higher than those of companies who do not engage in electricity generation, when controlling for the factors included in the specification. None of the estimated effects of the bidding zone dummies were statistically significant, implying that much of the variation between bidding zones was controlled for by the other variables in the regression.

6.3. Result III: Fixed Effects Regressions for Ownership and Vertical Integration

Table 6: Fixed effects results for ownership and integration from 2011-2018

Grid tariff	(1) Fixed Effects	(2) Fixed Effects
Retail electricity cost	-0.0765***	-0.0795***
	(0.006)	(0.007)
Tax	1.225***	1.375***
	(0.059)	(0.078)
mWh	0.000611***	0.000667
	(0.000)	(0.003)
Reinvestment	7.079**	2.441
	(2.935)	(2.085)
Profitmax_Retail EC	-0.0354***	
	(0.009)	
Profitmax.Tax	1.945***	
	(0.121)	
Profitmax _mWh	5.85e-05	
	(0.001)	
Profitmax_Reinvestment	-5.621*	
	(3.242)	
VI_Retail EC		-0.0207**
		(0.009)
VI_Tax		1.236***
		(0.138)
VI_mWh		-0.000389
		(0.003)
VI_Reinvestment		-0.295
		(2.453)
Constant	-4,560***	-4,592***
	(317.5)	(411.1)
Observations	2,079	2,079
R-squared	0.679	0.606
No. of network areas	265	265

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In specification (1), retail electricity cost had a significant estimated coefficient of -0.0765. The corresponding interaction effect with profit maximizing companies was estimated to -0.0354 and also significant. Thus, the estimated effect of retail electricity costs on grid tariffs is -0.1119 for profit maximizing firms and -0.0765 for non-profit maximizers. The results imply that a 1 SEK increase in retail electricity costs is associated with an average decrease in grid tariffs of about 11 öre for profit maximizing firms and 8 öre for non-profit maximizing firms on average, when controlling for the factors included in the specification. To assess whether this difference has any explanatory value, we performed a Wald test. The test (presented in table 9 in Appendix IV) showed that the difference was significant below 1% level.

In specification (2), the estimated coefficient for retail electricity cost was -0.0795, while the corresponding interaction effect with vertical integration was estimated to -0.0207. Thus, the estimated effect of retail electricity cost on grid tariffs was -0.1002 for vertically integrated firms and -0.0795 for non-integrated distribution firms. This implies that a 1 SEK increase in household retail electricity costs is associated with a decrease in grid tariffs of about 10 öre for vertically integrated firms and close to 8 öre for non-integrated firms. The difference was tested with a Wald test, which showed that it was statistically significant at 5% (see table 10 in Appendix IV).

7. Discussion

Our regressions showed a statistically significant inverse relationship between grid tariffs and average retail electricity costs of households following the bidding zone reform. The question is whether the estimated coefficients for retail electricity cost are large enough in magnitude to support our model.

To understand how strategic pricing among grid operators would play out, it is important to consider some special aspects about grid tariff pricing. First, network operators set tariffs at an annual basis. They report their tariffs to the Swedish Energy Markets Inspectorate. The size of grid tariffs is constrained by revenue caps, which limits the potential change in tariffs from one year to another. This speaks for grid tariffs to be regarded as rather price rigid. The reasoning is that (1) grid tariffs change rather infrequently and (2) the changes that do occur are limited in size. From this, we expect that any strategic pricing behavior of network operators as a response to retail prices will be based on long-term conditions instead of short-term fluctuations that are difficult to predict. The 2011 reform resulted in such long-term changes, leading to different electricity prices across the country. While some of the variation in retail electricity costs in our data can be explained by this reform or other long-term factors, a great deal of variation is made up of temporary spikes or price drops. These types of retail price fluctuations, often affecting the system price, may be caused by for example weather conditions or temporary events in neighboring countries. This implies that our data set contains a high degree of variation in electricity prices that grid tariff operators would not be able to respond to - consequently, we would expect the estimated coefficient to be negative but not very large (in absolute numbers).

Another aspect worth considering is that network operators may be more likely to adjust their prices upwards rather than downwards. This may especially be true for private firms as opposed to economic associations and some municipalities. Firms with profit-maximizing incentives are likely to be reluctant to adjust prices downwards, even if conditions on the retail market have led to higher retail electricity prices. Conversely, when retail prices decrease, firms may be more eager to raise their tariffs to capture available surplus. Thus, we expect that any strategic grid tariff adjustments to a greater extent occur upwards than downwards. This would also decrease the size of the expected estimated coefficient of retail electricity costs.

The fact that the estimated coefficient for retail electricity cost changes to become negative after 2011 (as seen in our first set of fixed effects regressions) could indicate that something has happened, something that allows grid operating firms to react to electricity prices in a different way than before. Our suggestion is that the zonal reform, as it resulted in long-term price differences across the country, created some variation in retail electricity costs that network operating firms react to. In this sense, the data supports our first hypothesis - that network operating firms respond to retail electricity costs of households by adjusting their grid tariffs.

Our results further show that the effect of retail electricity costs is stronger among profitmaximizing firms than non-profit maximizing firms, and also among vertically integrated firms versus non-integrated firms, which supports our second hypothesis. The differences in estimated coefficients were significant at 1% level and 5% level respectively. This further supports strategic behavior as the potential explanation behind our results. That profit maximizing grid operators would be more likely to engage in the sort of strategic pricing proposed in this thesis paper, intended to maximize the firm's surplus, was expected. That the effect was stronger for vertically integrated companies than for non-integrated firms could, according to the logic of our model, be explained by their informational advantage. As vertically integrated companies operate in all sectors of the electricity market, it is likely that they are more informed about electricity related consumer expenses in general than non-integrated network operators. This would benefit them in strategic pricing of grid tariffs as a response to price changes in the retail market. However, it is possible that vertical integration is strongly correlated with private ownership, which also could explain the results.

Regarding the results for some of our other explanatory variables, the coefficient for tax was positive (and significant) in all of our regressions. If there is any compensatory effect from grid tariffs to taxes, we would expect this coefficient to be negative. However, as mentioned above, it is likely that network operators would be more inclined to raise their grid tariffs when other electricity-related expenses go down, as opposed to lowering grid tariffs when other costs go up. As energy taxes have increased for all years in our data set (except for 2008 when the tax rate was reduced for northern regions), it is unreasonable to expect network operators to respond by decreasing their tariffs. It is still possible that grid operators to some degree respond to taxation levels, but our data does not show that this is the case. The estimated coefficients for reinvestments were negative in our fixed effects regressions of data from 2007 and forward. This could be attributed to different measurement methods of reinvestment in the two time periods. Between 2007 to 2011, reinvestments were reported ex-post, while from 2012, they were reported ex-ante as estimated upcoming annual values. While ex-post values reflect actual reinvestments, we argue that ex-ante estimated reinvestments better predict the value of grid tariffs. This is because grid tariffs are set annually and should thus reflect *expected* reinvestments and costs in the upcoming year.

Regarding the outcomes of our correlated random effects regressions, we found that stateowned and private network operators tend to have larger grid tariffs than municipality-owned firms and economic associations. Our results also suggest that vertically integrated firms in general have higher grid tariffs than non-integrated firms (although the coefficient for retail was insignificant). If this is the case, it may be indicative of cross-subsidization from distribution to other electricity sectors. While legal unbundling of transmission services from production and retail is intended to hinder cross-subsidizing behavior, it is acknowledged by Bolle & Breitmoser (2006) that legal unbundling does not eliminate cross subsidization opportunities altogether. As mentioned earlier, it is possible that the results simply display a correlation and that the causality runs between private firms and higher grid tariffs, not the fact that they produce and sell electricity as well. Another interesting result from our correlated random effects regressions is that the estimated effects for the bidding zone dummies were unexpectedly positive for SE3 and SE4, but as they also were statistically insignificant, they should not be interpreted as representative of any real effects. Instead, the results indicate that the difference in grid tariffs between bidding areas to a large extent could be explained by our other variables in the regression.

All in all, the data supports our two hypotheses. This implies that (at least some of) the variation in grid tariffs across the country is caused by strategic pricing based on household retail electricity costs. But more research is needed, as we cannot say for certain that the data describes a causality rather than a correlation. While we have a large sample of network areas, our data covers a relatively short time period. It is possible that the current trend in grid tariffs is caused by something other than the explanation suggested by this thesis paper. We would also benefit from more detailed data on household costs. The electricity market is highly complex - with a myriad of different actors and regulations. Strategic pricing of grid tariffs would most likely occur as a response to multiple factors and conditions, of which household retail electricity costs may be one.

Based on our findings, it is possible that network operators (partly) set their grid tariffs as a response to retail costs of households. Future research should investigate this further. For example, it would be interesting to examine whether a similar pattern of grid tariff pricing has occurred in other countries with bidding area divisions of the electricity market. Another interesting approach would be to investigate the topic with qualitative research methods, for example by conducting in-depth interviews with representatives from network operating firms and regulators about considerations in grid tariff pricing.

8. Concluding Remarks

In this thesis paper, we have investigated if network operating firms respond to changes in household retail electricity costs by adjusting their grid tariffs. To our knowledge, this topic has never been studied before. We performed two sets of fixed effects regressions and one set of correlated random effects regressions. Our results indicate that after 2011, there could be a compensatory effect between grid tariffs and retail electricity costs. We suggest that this can be explained by network operators responding to price differences caused by the 2011 bidding zone reform. Our results further show that the negative relationship between grid tariffs and retail electricity costs is stronger for profit-maximizing firms versus non-profit maximizers and vertically integrated firms versus non-integrated firms. This further supports strategic pricing based on retail electricity costs as a potential explanation behind the diverging grid tariffs across the country. However, more research is needed to draw any definitive conclusions.

References

Articles

Andersson, B. & Bergman, L. (1995). Market structure and the price of electricity: an ex ante analysis of the deregulated Swedish electricity market. *The Energy Journal, 16(2),* p. 97-110.

Bolle F. & Breitmoser Y. (2006). On the allocative efficiency of ownership unbundling. *Econstor, No. 255*, p. 2-23.
Lijesen, M. G. (2006). The real-time price elasticity of electricity. *Energy Economics, 29(2),* p.249–258. doi:10.1016/j.eneco.2006.08.008

Lundin, E. (2016). Effects of privatization on price and labor efficiency: the Swedish electricity distribution sector. *Institutet för näringslivsforskning, No.1139.*

Niesten, E. Jolink, A. (2012). Incentives, opportunism and behavioral uncertainty in electricity industries, *Journal of Business Research,* 65(7), p. 1031-1039. doi:10.1016/j.jbusres.2011.03.012

Riechmann, C. (2000). Strategic pricing of grid access under partial price-caps - electricity distribution in England and Wales. *Energy Economics,* 2(22), p. 187-207.

Schunck, Reinhard, (2013). Within and between estimates in random-effects models: advantages and drawbacks of correlated random effects and hybrid models. *Stata Journal*, 13, issue 1, p. 65-76.

Willems, B., & Ehlers, N. (2008). Cross-subsidies in the electricity sector. *Competition and Regulation in Network Industries*, 9(3), p. 201-227.

Books

Goolsbee, A. & Levitt S. & Syverson C. (2013). Microeconomics (First international ed.). New York: W.H.Freeman Co Ltd.

Woolridge, J. (2016). Introductory econometrics. A modern approach (Sixth edition). Mason, OH: South-Western Cengage Learning

Electronic newspaper articles

Dickson, S. (2019, 19 April). Gick “off-grid” - slipper dyra elräkningar. *Svenska Dagbladet* [SvD]. Retrieved 2019-04-30 from: https://www.svd.se/gick-off-grid-slipper-dyra-elrakningar

Isberg, A. (2011, 18 November). Husägare rasar mot nya elprisområden. *Skånska Dagbladet* [SkD]. Retrieved 2019-05-05 from: https://www.skd.se/2011/11/18/husagare-rasar-mot-nyaelprisomraden/

Lundin, K. (2018, 31 May). Dubbel smäll för elkunderna - och till hösten hotar ny chock. *Dagens Industri* [Di]. Retrieved 2019-04-05 from: https://www.di.se/nyheter/dubbel-smallfor-elkunderna-och-till-hosten-hotar-ny-chock/

Magnusson, E. (2018, 1 December). Elbristen kan dubbla elpriset i Skåne. *Sydsvenskan.* Retrieved 2019-04-05 from: https://www.sydsvenskan.se/2018-12-01/elbristen-kan-dubblaelpriset-i-skane

Müchler, S. Elander, J. (2019, 29 April). Ta bort sydsveriges prisdiskriminering på el. *Expressen*. Retrieved 2019-05-03 from: https://www.expressen.se/kvallsposten/debatt-kvp/ta-bort-sydsveriges-prisdiskriminering-pael/

TT (2010, 8 November). En tusenlapp mer för elen i syd. *Aftonbladet*. Retrieved 2019-05-03 from: https://www.aftonbladet.se/teknik/a/A27A4E/en-tusenlapp-mer-for-elen-i-syd

(Unsigned) Svenska Dagbladet Näringsliv (2011, 23 November). Skillnaden i elpriser blev dubbelt så stor. *Svenska Dagbladet* [SvD]. Retrieved 2019-05-03 from: https://www.svd.se/skillnaden-pa-elpris-blev-dubbelt-sa-stor

Electronic reports

Konkurrensverket (2018). *Konkurrensen i Sverige 2018* (ch. 27). p. 262-276.

EU Commission. (2010). *Commission decision relating to a proceeding under Article 102 of the Treaty on the Functioning of the European Union and Article 54 of the EEA Agreement,*

The Swedish Energy Agency and Statistics Sweden. (2016). *Energy prices and switching of suppliers, 2nd quarter 2016.*

The Swedish Energy Markets Inspectorate. (2012). *Elområden i Sverige - analys av utvecklingen och konsekvenserna på marknaden.*

The Swedish Energy Markets Inspectorate. (2014a). *Utvärdering av effekterna av elområdesindelningen.*

The Swedish Energy Markets Inspectorate. (2015). *Underlagsrapport till energikommissionen.*

The Swedish Energy Markets Inspectorate. (2017). *Nya regler för elnätsföretagen inför perioden 2020-2023.*

The Swedish Energy Markets Inspectorate. (2018b). *Leveranssäkerhet i Sveriges elnät 2017.*

The Swedish Energy Markets Inspectorate. (2018c). *The Swedish Electricity and Natural Gas Market 2017*.

Villaägarna (2016). *Elnätsavgifterna i Sverige fram till januari 2016*.

Legal or public sources

Ellag (SFS 1997:857).

Larsson , H (2012). Motion 2012/13:N376. Elprisområden i Sverige.

Haglö, K (2013) Motion 2013/14:N407. Elprisområden.

Gjörtler, J (2017). Motion 2017/18:3432. Elområden – en dyr historia för Sydsverige.

Webpages

Nord Pool. (2018a). Bidding areas. Retreived 2019-03-05 from: https://www.nordpoolgroup.com/the-power-market/Bidding-areas/

Nord Pool. (2018b). Price calculation. Retreived 2019-03-15 from: https://www.nordpoolgroup.com/trading/Day-ahead-trading/Price-calculation/

Regeringskansliet. (2018). Regeringen skärper regleringen av elnätsavgifterna. Retrieved 2019-03-26 from: https://www.regeringen.se/pressmeddelanden/2018/08/regeringen-skarperregleringen-av-elnatsavgifterna/

Swedenergy (2018). Kundens elkostnader. Retrieved 2019-04-18 from: https://www.energiforetagen.se/sa-fungerar-det/elsystemet/elhandel/for-dig-somelkund/kundens-elkostnader/

The Swedish Consumer Energy Markets Bureau. (2018). Nätavgifter. Retrieved 2019-03-15 from: https://www.energimarknadsbyran.se/el/dina-avtal-ochkostnader/elkostnader/natavgifter/

The Swedish Energy Markets Inspectorate. (2016a). Elmarknader och elhandel. Retrieved 2019-03-14 from: https://ei.se/sv/ei-s-verksamhet/Elmarknader-och-elhandel/

The Swedish Energy Markets Inspectorate. (2016b). De olika delarna i intäktsramen. Retrieved 2019-03-14 from: https://www.ei.se/sv/for-energiforetag/el/Elnat-ochnatprisreglering/de-olika-delarna-i-intaktsramen/

The Swedish Energy Markets Inspectorate. (2016d). Elnät och reglering av elnätsavgifter. Retrieved 2019-03-15 from: https://www.ei.se/sv/for-energiforetag/el/Elnat-ochnatprisreglering/?faq=all

The Swedish Energy Markets Inspectorate. (2018a). Elpriskollen - Sök efter elhandlare. Retrieved 2018-05-01 from: https://www.ei.se/sv/Elpriskollen/elbolag/

Appendix

Appendix I: Revenue Caps

The components of the revenue cap

Revenue caps are set individually for each accounting unit. One distribution company can have several accounting units and one accounting unit can include several local network areas. The revenue caps are determined by three components according to the standard method (*schablonmetoden*) in 5 kap. *Ellagen (SFS 1997:857)*. As explained by the Energy Markets Inspectorate (Ei, 2016b; Ei 2017), the revenue caps consist of:

(1) Costs of capital: this includes costs associated with tangible assets, such as depreciation costs, but also capital commitment costs. Depreciation times matter, as shorter depreciation times leads to higher depreciation costs, thus higher costs of capital and in the end, higher revenue caps allowing for higher grid tariffs. The discount rate is given by the standard financial WACC-method, short for weighted average cost of capital. In Ei's WACCcalculations, a firm's average debt interest rate is weighted with their return on equity (which is given by the standard CAPM-method).

(2) Fixed (*opåverkbara*) operating costs: this includes costs for network losses, connections to other networks, and agency fees.

(3) Floating (*påverkbara*) operating costs: this is determined by historical floating operating costs, 1% of the previous year's costs are subtracted according to the so-called effectivization requirement.

These estimated future costs are discounted to present value. The sum of these three components serve as the basis for the revenue caps for the upcoming regulative period.

The problematic case of the revenue cap as a control variable

Revenue caps may seem like an important factor to include when investigating any potential causes of the divergent trend in grid tariff pricing across bidding zones. However, in the context of strategic behavior of network operating firms, revenue caps may not be a suitable control variable to include, as it likely leads to the problem of over controlling.

Approximately 50% of the revenue caps applicable to the regulative period of 2012-2015 were appealed against by the network operating firms. This led to extensive and costly court processes, finally resulting in significantly higher revenue caps and higher grid tariffs. From this, one can conclude that (1) firms that appeal against their revenue caps must have an incentive to do so and (2) they must also have the financial capabilities to cover any potential legal costs. While it is possible that firms consider the original revenue caps to insufficiently reflect their financing needs, reports by Ei have concluded that investment needs predict an annual increase of grid tariffs by 1%, but the actual average increase in grid tariffs was close to 7% (Ei 2017) . Ei have also argued that lower discount rates are motivated, as network operating firms receive steady, low-risk cash flows. These are some indicators that appeals against revenue caps are not motivated by the need to cover costs - instead, it is most likely done with the purpose of maximizing profits. Thus, firms who decide to enter extensive legal processes must have enough of a profit incentive to do so. This most likely rules out economic associations, that exist to act in the economic interest of their members, and perhaps some municipality-owned network operators as well. The firms must also have financial resources for legal costs. For this reason, we expect large firms to be more likely to appeal against their revenue caps, and this may also rule out especially economic associations but also some municipality operations.

All in all, revenue caps are anything but exogenously imposed - they are the outcome of profit-maximizing behavior of firms. First, the costs that are used in calculating the revenue caps are based on self-reported values by firms. Second, appealing against revenue caps can be seen as a strategic choice by firms, where the outcome is the final revenue cap and higher grid tariffs. It is likely that profit-maximizing firms, who have stronger incentives to appeal against their revenue caps than municipalities and economic associations, also will end up with the highest revenue caps and consequently, the highest grid tariffs. Informational advantages of network operators in relation to regulators can thus be exploited for strategic reasons, similar to in Niesten & Jolink, but in the context of revenue caps instead of customer complaints. Controlling for revenue caps could then very well lead to the problem of over controlling, which in addition to the measurement problems described in our methods section, is why we exclude it from all of our regressions except for one (which is our final CRE regression). In that regression, we included it to see how it would affect the estimated effects of our other independent variables, such as our ownership characteristics variables.

Appendix II: Variable Calculations

Retail electricity cost

We extracted data on the average per-unit electricity price (reported in öre/kWh) from Statistics Sweden. The data contained monthly average values of retail electricity prices for consumers with 20,000 kWh and was reported per bidding zone from April 2013. Before the zonal division in November 2011, the data described the average price across the country. Between November 2011 and March 2013, the average price in SE3 was given.

To estimate the retail prices in SE1, SE2, and SE4 between the zonal reform and March 2013, we divided the zonal retail prices from April 2013 to December 2018 with the corresponding monthly prices for SE3, and from this, rendered an average factor for each bidding zone. These factors thus represented how large the electricity price for each bidding bidding zone was relative to the prices in SE3, on average. Finally, to err on the side of caution and avoid biased results, we adjusted the factors to decrease the difference between SE3 and the other bidding zones by 10%. We consequently adjusted the price of SE3 between November 2011 and April 2013 by a factor of approx. 0.9921 for SE1, 0.9914 for SE2, and 1.0209 for SE4. Even if the bidding zone reform was implemented as late as in November, the resulting wholesale price differences between the zones for the last two months of the year were great enough for the average annual wholesale prices to differ at least as much or more between zones in 2011 compared to the upcoming years until 2018. Thus, adjusting the annual retail prices for 2011 to reflect the differences between zones was justified, as the average annual price differences in 2011 was equally large or larger than the price differences for the other years.

Appendix III: Breusch-Pagan and Hausman Tests

Test I: Breusch-Pagan for OLS versus RE (2007-2018)

Table 7: Breusch-Pagan test for OLS versus RE

```
. quietly xtreg Gridtariff EC Tax Municipalityoperation Reinvestment mwh
> Economicassociation Retail Production i.BA

. xttest0

Breusch and Pagan Lagrangian multiplier test for random effects

        Gridtariff[na,t] = Xb + u[na] + e[na,t]

        Estimated results:
                         |       Var     sd = sqrt(Var)
                ---------+-----------------------------
-                Gridtar~f |    2364451       1537.677
e |   531758.6       729.2178                          u
|   696569.5       834.6074

        Test:   Var(u) = 0
                             chibar2(01) =  5172.67
                          Prob > chibar2 =   0.0000
```

Using data from 2007-2018, the Breusch-Pagan test results favored RE over OLS.

Test II: Hausman for FE versus RE (2007-2018)

Table 8: Hausman test I for FE versus RE

	---- Coefficients ----			
	(b) fixed	(B) random	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
EC	.0428902	.0446926	-.0018024	.0007554
Tax	.7561902	.7535347	.0026555	.0011213
Reinvestment	-.7711732	-.7637459	-.0074272	.0222288
mwh	.0012689	-.0000998	.0013687	.0004283

```
                     b = consistent under Ho and Ha; obtained from xtreg
      B = inconsistent under Ha, efficient under Ho; obtained from xtreg
  Test:  Ho:  difference in coefficients not systematic

              chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                      =       17.18
            Prob>chi2 =      0.0018
```

Using data from 2007-2018, the Hausman test displayed a p-value of $0.0018 < 0.05$. The test indicated a correlation between our explanatory variables and unobserved fixed effects. Thus, as the results indicated that the assumption of $Cov(a_i, x_{ijct}) = 0$ was violated, fixed effects regressions were favored over random effects regressions.

Test III: Hausman for FE versus RE with between estimators (2007-2018)

Table 9: Hausman test II for FE versus RE

	(b) fixed	(B) random	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
EC	.0428902	.0428931	-2.84e-06	.0001565
Tax	.7561902	.75608	.0001102	.0006931
Reinvestment	-.7711732	-.766129	-.0050441	.0167868
EC	.0012689	.0012645	4.35e-06	2.99e-06

```
                          b = consistent under Ho and Ha; obtained from xtreg
           B = inconsistent under Ha, efficient under Ho; obtained from xtreg

 Test:  Ho:  difference in coefficients not systematic

                  chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        2.24
                Prob>chi2 =      0.6908
```

In this Hausman test, we tested the fixed effects model against our correlated random effects model. The high p-value showed that the Hausman test favored random effects over fixed effects. This was expected, as we controlled for the between variation of our time-varying variables, in effect controlling for the correlation with unobserved fixed effects.

Appendix IV: Wald Tests of Interaction Effects

Test I: Wald test of interaction effect between profit maximizing companies and retail electricity cost.

Table 10: Wald test I for interaction effects.

```
. quietly xtreg Gridtariff i.Profitmax##(c.EC c.Tax c.mwh c.Reinvestment), fe
robust

. test 1.Profitmax#EC

 ( 1)  1.Profitmax#c.EC = 0

       F(  1,   264) =   15.46
            Prob > F =    0.0001
```

In this Wald test, the hypothesis that the estimated interaction coefficient is equal to zero is rejected on a 0.001 percent level. The test is performed on data between 2011-2018.

Test II: Wald test for interaction effect between vertically integrated companies and retail electricity cost.

Table 11: Wald test II for interaction effects.

```
. quietly xtreg Gridtariff i.VIC##(c.EC c.Tax c.mwh c.Reinvestment), fe robust
. test 1.VIC#EC

 ( 1)  1.VIC#c.EC = 0

       F(  1,   264) =    5.23
            Prob > F =    0.0230
```

In this Wald test, the hypothesis that the estimated interaction coefficient is equal to zero is rejected on a 5 percent level. The test is performed on data between 2011-2018.