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Power of Your Choice

An Empirical Study of Origin-Specified Electricity Contracts in Sweden

Author: Isa Diamant

Supervisor: Håkan Jerker Holm

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Abstract

The purpose of this thesis is to study some aspects of origin-specified electricity contracts in Sweden. Consumers may choose a contract for which the electricity is specified to originate from for example renewable resources, or from one exclusive energy source such as solar, wind, hydroelectric or nuclear power. The study is mainly based on data over supplied electricity contracts for households in January 2020, obtained from Energimarknadsinspektionen. Horizontal product differentiation theory is applied to study the correlation between the market share of a firm and the number of origin-exclusive contracts offered by the firm. A statistically significant, low-to-moderate correlation coefficient of 0.426 is found, meaning that larger firms tend to offer a higher number of origin-exclusive alternatives. Vertical product differentiation theory is applied to study if there is a price difference between contracts with guaranteed renewable electricity and contracts with no such guarantee. This is studied by running an Ordinary Least Squares regression with the control variables market share, bidding area and pricing structure. A significant price difference is found, where contracts with guaranteed renewable electricity are estimated to cost 1.175 öre more per kWh than other contracts. For a typical household, this means that switching to a contract with renewable electricity is estimated to increase the yearly electricity costs by 235 Swedish kronor.

Key words: Renewable electricity, renewable price premium, Swedish electricity market, horizontal product differentiation, vertical product differentiation.

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1. Introduction

1.1. Introducing the Topic

The electricity sector is often described as one of the main players in the global transition towards a sustainable, low-emitting society. Electricity can be produced by combustion of fossil fuels which leads to emissions of greenhouse gases, for example carbon dioxide (CO2). It can also come from nuclear power, or from renewable resources such as solar, wind or hydroelectric (hydro) power. These alternatives are not associated with emissions of CO2 and may be referred to as fossil free. A large part of the emissions reduction work in the electricity sector is done by replacing emitting electricity production with renewables.

The electricity market in Sweden serves around 5.5 million households. A typical Swedish residential house (not an apartment) has a yearly electricity consumption of 20 000 kilowatt hours (kWh) according to Energimarknadsbyrån (2020a) which is an independent consumer advisory bureau. Consumers may choose certain features of their electricity contracts. For example, they can choose to pay a fixed price per kWh, a variable price, or a combination.

Apart from pricing structure, consumers have the option to choose which type of source their electricity originates from. Electricity suppliers may for example offer electricity contracts with only fossil free or renewable electricity. Firms may even offer contracts with electricity exclusively from one type of origin such as wind, solar, hydro, or nuclear power. Consumers are thereby offered a range of contracts to choose from. The price paid may vary across contracts with different pricing structures and power sources. To provide an example, for a household with a yearly consumption of 20 000 kWh, a price increase of 5 Swedish öre per kWh increases the household's costs for electricity by 1000 Swedish kronor per year.

1.2. Purpose and Research Question

The purpose of this thesis is to study some aspects of origin-differentiated varieties of electricity contracts in Sweden. The research question chosen to fulfill this purpose is the following:

How can product differentiation for electricity contracts in Sweden be explained and does it affect prices?

To answer the question, I will apply microeconomic theory of horizontal and vertical product differentiation on the market for electricity contracts. I will then perform an econometric study on cross-sectional data over electricity contracts supplied to households in Sweden in January 2020. The correlation between market share and number of origin-exclusive varieties (with power from exclusively solar, wind, hydro or nuclear, respectively) supplied will be investigated, and an Ordinary Least Squares (OLS) regression will be run to analyze prices for contracts with electricity from guaranteed renewable resources compared to other contracts.

1.3. Delimitations

I have chosen to delimit this study to contracts offered in January 2020, i.e. before the Covid-19 crisis may have affected the market for electricity contracts. Albeit interesting, I believe it is too early to draw any relevant conclusions about the Covid-19 crisis' long-term effects on the studied market. Therefore, I have chosen to delimit my study to January, which is before the crisis started in Europe.

I have also chosen to delimit my study to the two most common pricing structures of electricity contracts: fixed price and variable price contracts. This means that I leave for example combined fixed and variable pricing structures out of the picture. For the fixed and variable price contracts, I have chosen to study one-year fixed price contracts, which is one of the standard lengths for fixed price contracts, and variable price contracts that are running contracts, which is what Energimarknadsbyrån (2021a) recommends to consumers.

1.4. Disposition

In Chapter 2, I present a brief background to the Swedish electricity market, different pricing structures of electricity contracts and examine different electricity origins and their features. In Chapter 3, theories of horizontal and vertical product differentiation are presented and applied. Thereafter, relevant previous research is presented in Chapter 4. In Chapter 5, I present data collection and variable specifications as well as descriptive statistics. In Chapter 6, the empirical approaches to test my hypotheses are presented. In the following chapter, Chapter 7, I present and analyze my results. Thereafter, in Chapter 8, I discuss the results and some assumptions made. In Chapter 9, conclusions are presented.

2. Background

2.1. The Swedish Electricity Market

The Swedish electricity market was deregulated in 1996 (Energimarknadsbyrån, 2020b) and is shared with Norway, Finland, and Denmark (Energimarknadsbyrån, 2020c). About 85% of the electricity sold in Sweden is sold through this shared marketplace called Nord Pool (Energimarknadsinspektionen, 2021a). Market participants include for example electricity producers, electricity suppliers (i.e. the companies from which consumers purchase electricity), network operators and final consumers (Energimarknadsbyrån, 2020c). The main buyers on the Nord Pool market are the electricity suppliers, but some large industry actors may also purchase power directly from Nord Pool (Energiföretagen, 2020). There are currently 151 electricity suppliers in Sweden of which some are regional, and some are national (Elskling, n.d.a).

Nord Pool is a so-called spot market where the price is determined the day before the electricity is delivered. The price is determined hourly, meaning that it varies throughout the day (Energiföretagen, 2020). The price determinants for electricity include both the supply and the demand. For example, if nuclear plants are turned off or water reserves are low, the price may increase. On the demand side, warmer temperatures may decrease prices as the demand for electricity is low. As electricity to some extent is exported and imported, prices on oil may influence the price for electricity in Sweden, too (Energimarknadsbyrån, 2020c).

Although the Scandinavian markets are intertwined, Swedish consumers are obliged to purchase electricity from Swedish electricity suppliers (Energimarknadsbyrån 2020c). The power transmission and distribution networks are operated as natural monopolies (Energimarknadsinspektionen, 2020a). In 2011, Sweden was divided into four different bidding areas, from SE1 in the north to SE4 in the south. Generally, there is a surplus of electricity in the north where more is produced and less is demanded. The deficit in the south generally leads to higher prices (Energimarknadsbyrån, 2020d).

Figure 1. Bidding areas in Sweden. Source: El.se, n.d.

2.2. Pricing Structures of Electricity Contracts

Consumers may choose between various types of electricity contracts. They can for example agree with the electricity supplier to pay a fixed price per kWh for a specified time period (the most common time periods are one, two or three years). The only part of the price that may be subject to change with this pricing structure is a change in taxes but other than that, the fixed price per kWh does not change over the contracted period (Energimarknadsbyrån, 2021b).

The most common pricing structure in Sweden is to pay a variable price per kWh. The price the consumers pay is then determined by the Nord Pool price fluctuations and is thus not known in advance. The consumer pays a weighted average of the Nord Pool market price during each month, plus additional fees to the electricity suppliers, taxes and so on. The variable price contract can be either running or agreed for a specific time period, for example six months or one year. To avoid being locked in with an electricity supplier with unexpectedly high prices, variable price contract consumers are advised by Energimarknadsbyrån to have a running contract, which means that they are free to terminate the contract as they wish (2021a).

It cannot with certainty be said on beforehand which of the pricing structures that is the cheapest over time. For the fixed price contracts, the electricity suppliers charge the consumers for the risk of increasing prices. For the variable price contracts, it is on the other hand the consumers that take this risk for volatile prices themselves. Running contracts may cost more per kWh than one-year contracts because of the consumers' right to terminate the contract.

Over long time horizons, variable price contracts have historically been cheaper (Energimarknadsbyrån 2021c).

Other types of contracts exist, too. For example, consumers may choose to have a combination of a fixed and a variable price per kWh (Energimarknadsinspektionen n.d.). Since 2012 (Elskling, n.d.b), hourly pricing is another possibility for consumers. This means that the consumer may reduce their costs by moving their consumption from a peak hour to an off-peak hour, by for example choosing to charge their electric car in the night instead of in the morning (Energimarknadsinspektionen, n.d.).

If a household does not choose a contract, for example when their previous contract has expired, they are provided a default electricity supplier (Energimarknadsinspektionen, 2013). It is the network operators that assign these consumers a default electricity supplier in case they do not choose one themselves. This type of contract is often substantially more expensive than other types of contracts (Energimarknadsbyrån, 2021d). About 10% of the consumers in Sweden have this type of contract (Energimarknadsinspektionen, 2020b).

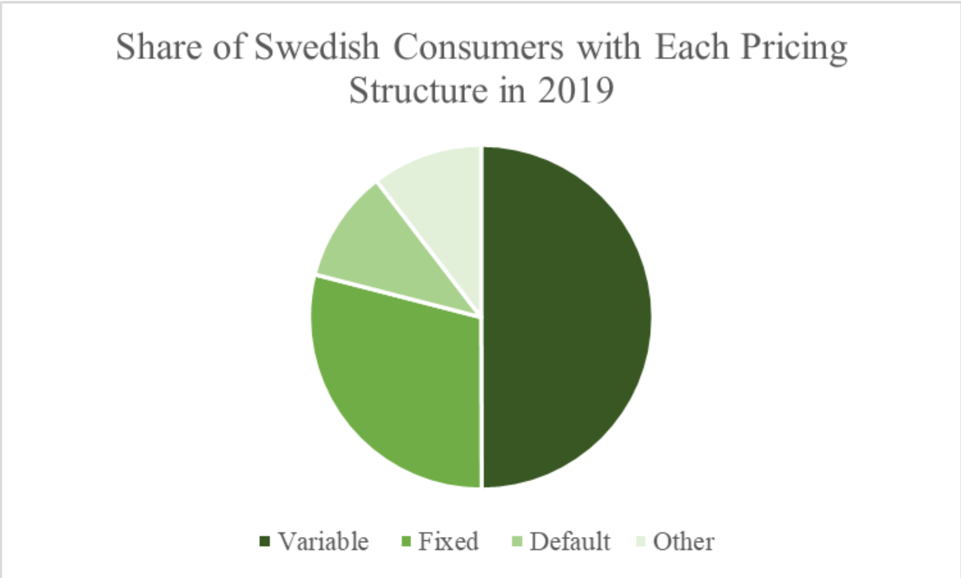

Figure 2. Share of consumers with each pricing structure.

Based on data from Energimarknadsinspektionen, 2020b.

2.3. Electricity, Emissions, and Guarantees of Origin

Apart from choosing pricing structure of a contract, consumers may also have preferences for other features such as environmental performance. Electricity can be produced in several ways, for example from fossil fuels, nuclear power, and renewable resources. Electricity production from fossil fuels such as coal and oil is associated with high emissions of CO2 (Kättström, 2019). These are not considered renewable resources as they take a long time to be produced (Vattenfall, n.d.a).

Electricity can also be produced by nuclear power. This production is not associated with high emissions of CO2 but is not considered renewable as it requires uranium which is a finite resource. Hence, nuclear power can be said to be fossil free but not renewable (Vattenfall, n.d.a). Renewable resources include for example solar, wind, and hydro power. It also includes bioenergy and other resources (European Environment Agency, 2018). These are not associated with high emissions of CO2 (Vattenfall, n.d.a).

In Sweden, water and nuclear together stand for almost 80 % of the electricity production (Energimyndigheten, 2020). Sweden does not generally rely on fossil fuels for electricity production but may produce and import electricity from such resources when the electricity demand is high (Kättström, 2019).

When electricity is produced, it is transmitted to the electricity grid. Here, the electricity is mixed, and it is not possible to separate e.g. electricity generated by wind power from electricity generated by nuclear power (Vattenfall, n.d.a). To make possible for consumers to decide from which type of resource their electricity comes from, a system of *guarantees of origin* (GO) has been invented. The GO system was introduced to the Swedish electricity law in 2005 (Energimarknadsinspektionen, 2020c). The GOs are electronic certificates that serve as proofs of the origin of the electricity and apply to all electricity sold. The system is supervised by authorities such as Energimyndigheten and Energimarknadsinspektionen. As the exact origin of a specific kWh cannot be traced as the electricity is mixed in the grid, the electricity suppliers can use GOs as proof that the same amount of electricity that a consumer uses originates from the indicated source, for example solar power (Vattenfall, n.d.a).

Thanks to the GO system, electricity suppliers may offer contracts with only renewable or fossil free electricity. Some electricity suppliers may even offer contracts with electricity exclusively from one type of source, for example wind power. The origin-specified contracts may come with an additional cost. If a consumer does not have a specified contract with for example fossil free electricity or electricity from wind power, they will receive electricity from the Nordic residual mix. This is the electricity mix that remains when consumers with origin-specified contracts have received their electricity (Energimarknadsinspektionen, 2020d).

3. Theory

Pepall, Richards and Norman (2014) describe the two types of product differentiation theories in their book *Industrial Organization – Contemporary Theory and Empirical Applications.* In this chapter, I will present and apply these theories of product differentiation. Horizontal product differentiation theory is examined in the first section, followed by vertical product differentiation theory in the next section.

3.1. Horizontal Product Differentiation

Horizontal product differentiation is a theory in which consumers are assumed to have different preferences regarding certain features of a given product (Pepall, Richards & Norman, 2014, p. 142). Two examples of horizontally differentiated products can be breakfast cereals, where a high number of different varieties can be found in a grocery store, or the amount of pulp in orange juice which can vary from none to added. The central point is that consumers differ in their preferences – some love pulp in their orange juice while others have strong preferences for no pulp.

An intuitive model for understanding the theory of horizontal product differentiation is the *spatial model of product differentiation*, invented by Harold Hotelling in 1929. The model can be viewed as a street on which a single monopolist supplier decides to open a shop. The number of consumers N live evenly distributed along the street. The length of the street is 1 mile and is denoted z. Each consumer lives on a distance x_i from the shop, where i denotes each consumer.

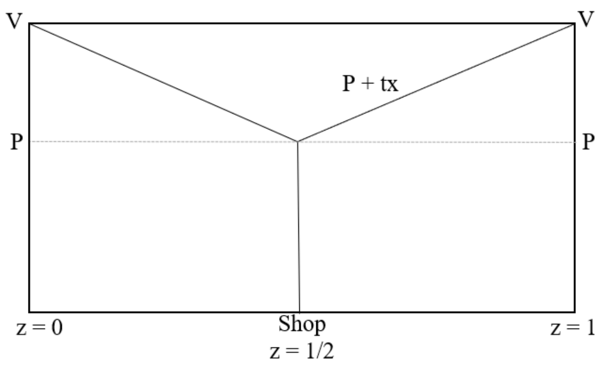

Figure 3. The full-price line for consumers if the monopoly opens one shop in the middle of the street and supplies the entire market. Based on Pepall, Richards & Norman, 2014, p. 145.

In the spatial model, every consumer is assumed to have the same reservation price V. As long as the full price does not exceed V, a consumer is willing to buy the product. What is meant by the full price is the price charged by the supplier, plus the transportation costs t (there-and-back) times the distance x the consumer travels to the shop. All consumers face the same price, but different transportation costs due to their varying distances from the shop, and therefore different full prices (Pepall, Richards & Norman, 2014, pp. 144-146).

The consumer who lives furthest away from the shop but still buys the product is called the marginal consumer. This person faces the highest full price of the purchasing consumers. This applies both left and right of the shop, as the shop attracts consumers from both directions. This explains the Y-shape of the full price line. Assuming that the entire market is served, the monopolist will want to locate their shop in the middle of the street, at ½. This allows the supplier to reach the largest possible number of consumers while charging a price as high as possible (Pepall, Richards & Norman, 2014, pp. 146-147).

The monopolist may consider opening more than one shop. As stated above, the shorter the consumers travel to the shop, the higher price the monopolist can charge. By opening more than one shop, the monopolist decreases the maximum travel distance for the consumers. The price the monopolist can charge as a function of number of shops is $P(n) = V - \frac{t}{2n}$ given that the entire market is served and that the shops are distributed symmetrically along the street. As the number of shops increases, the subtraction term decreases and thus increases the price that the monopolist may charge (Pepall, Richards & Norman, 2014, pp.146-148).

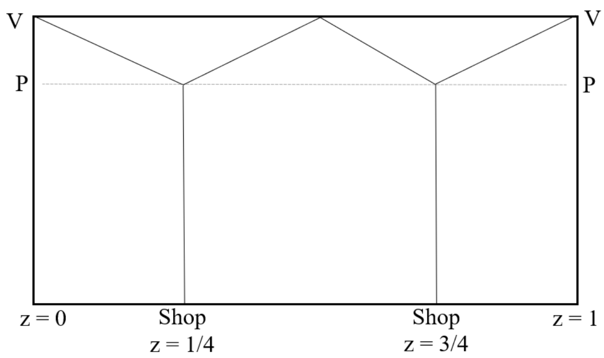

Figure 4. A monopolist with two shops.
The maximum distance for a consumer to travel to the shop is shorter compared to Figure 3 where there is only one shop. The monopolist is therefore able to charge a higher price.
Based on Pepall, Richards & Norman, 2014, p. 147.

The monopolist's profit function looks as follows:

$$\pi(n) = N\left(V - \frac{t}{2n} - c\right) - nF$$

Here, n is the number of shops the monopolist opens. $V - \frac{t}{2n}$ is the price the monopolist can charge while supplying the entire market, where V is the consumers' reservation price and t their transportation costs. c denotes the (constant) marginal cost of producing each good and F is the setup cost associated with opening one new shop (Pepall, Richards & Norman, 2014, pp. 148-149).

The optimal number of shops is $n^* = \sqrt{\frac{Nt}{2F}}$. We can see that the optimal number of shops increases as the market size, i.e. the number of consumers N, increases. If there are high transportation costs t, the optimal number of shops is likely to be high. If setup costs F are high, however, the optimal choice of shops decreases (Pepall, Richards & Norman, 2014, pp.148-150).

Note that the model explains monopolist behavior. On a market with more than one firm, a firm's actions are based on other firms' behavior, too. However, it may be expected that a firm with a larger market share acts more monopoly-like than a firm with less market power. The number of consumers N can be seen as the number of consumers that each firm serves. Hence, a larger market share may be expected to increase the number of different shops that a firm opens.

Now, it is time to apply horizontal product differentiation theory on the market for electricity contracts. For simplicity, let us for this purpose consider a market within the market, with only consumers that have preferences for electricity contracts with one exclusive origin that is either solar, wind, hydro, or nuclear power. Which origin that is preferred is here assumed to vary among consumers – some prefer wind power while others want hydro, and so on. An electricity supplier may choose to offer a minimum of zero and a maximum of four origin-exclusive contract varieties with electricity from either solar, wind, hydro or nuclear power. Note that if zero origin-exclusive alternatives are offered, it does not necessarily mean that the firm offers no contracts at all. If this is the case, the firm may offer an unspecified contract, or a contract that is specified to be renewable or fossil free, or both, but they offer no origin-exclusive contract. The contracts that are not origin-exclusive are used for the vertical product differentiation analysis but are left out of this horizontal product differentiation analysis for simplicity. The number of origin-exclusive varieties n offered is expected to increase as the consumers N served by the electricity supplier increases.

Again, the discrepancy between theory and reality is strongly present when applying theory on cases from the real world. The geographical conceptualization from Hotelling gets more abstract as consumers do not live on a street but instead have different preferences for different electricity origins. Also, the theoretical assumption that the consumers are evenly distributed along this "street" of preferences is strong and not realistic. Despite unrealistic, this even distribution is assumed for the purpose of making this application possible. The transportation cost in the model can, when applied, be viewed as a form of inconvenience cost for not obtaining a contract with the consumer's perfect preference for a specific origin. The cost of opening a new shop F may include administration and planning of GOs.

The horizontal product differentiation theory thus suggests that the larger the electricity supplier, the higher number of different origin-exclusive alternatives will be offered. This makes me express the following hypothesis:

H1: *Market share and the number of origin-exclusive varieties supplied by a firm are positively correlated.*

3.2. Vertical Product Differentiation

Moving on to vertical product differentiation theory, a key distinction from the horizontal theory is that all consumers are assumed to share the same preferences; everyone prefers a product of higher quality and everyone agrees to what defines this quality. What varies among consumers is instead their willingness to pay (WTP) for a given level of quality. The WTP can be determined by income levels, attitudes, and more (Pepall, Richards & Norman, 2014, p.157). For example, flying business class would be preferred over economy class by most people, but not everyone is willing to pay the extra price for this quality increase.

In the theory of vertical product differentiation, price P is determined by quantity Q and quality z. The inverse demand function is thereby written as $P = P(Q, z)$. The price is expected to decrease as the quantity Q increases and increase as quality z is increases (Pepall, Richards & Norman, 2014, p.158).

Applied on the case of electricity contracts, we may assume that all consumers agree that renewable electricity is of higher quality than non-renewable electricity. However, everyone may not be willing to pay a price premium for this extra quality. Note that the assumption of consumer preferences is different from the horizontal model where each consumer was assumed to have their own preference for electricity origin. Here, it is instead assumed that everyone agrees that renewable electricity is of higher quality than non-renewable electricity.

Remember again the distinction between theory and reality. In the real world, consumers *do not* agree that renewable electricity is preferred over non-renewable electricity. For example, solar panels may be considered ugly (Vattenfall, n.d.b), wind power is sometimes criticized for creating noise (Sveriges Television, 2021) and hydro power may have a negative impact on ecosystems (Naturskyddsföreningen, n.d.). Despite these debates, I consider it realistic enough to view these renewable electricity origins as being agreed to be of higher quality due to their environmental performance and renewability.

Nuclear is however not included in the renewable electricity and is thus not viewed as being generally agreed to be of higher quality than other origins of electricity. Arguments in favor of nuclear power may bring up their low emissions of CO_2, but arguments against it include the safety risks and the fact that the nuclear waste must be stored for thousands of years until it is not dangerous anymore (Loth, 2020). Also, nuclear is not renewable as it uses uranium which is a finite resource. Because of the historical and vivid nuclear debate, I will not consider nuclear as part of the electricity of higher quality from the consumers’ view.

Assuming that renewable electricity is seen as being of higher quality than non-renewable electricity, vertical product differentiation theory suggests that this high-quality product will be priced higher. Note that some of the non-renewable contracts may still include renewable electricity but are not guaranteed to do so – their electricity originates from nuclear power, unspecified fossil free sources, or the residual mix. The following hypothesis is expressed:

H2: *The price per kWh for contracts with guaranteed renewable electricity is higher than for contracts with no such guarantee.*

4. Previous research

4.1. Product Differentiation of Electricity

In the article "A Review of Electricity Product Differentiation", Woo et al. (2014) study product differentiation of electricity. As means to differentiate the product electricity, the authors list attributes such as "power quality, level of reliability, time of use (TOU), volume of usage (kWh), maximum demand (kW), and level of environmental impact" (Woo et al, 2014, p. 263). The authors begin by stating some of the features of electricity as a product. For example, they emphasize the important role that electricity has for economic growth and the damages that power outages may have. They also point out the difficulties with the lack of close substitutes to electricity, and the limited storage possibilities which implies that electricity must be produced and consumed in the same moment.

Over time, the authors have seen developments in the electricity market. For example, government subsidies have driven development of renewable energy. Also, the so-called "advanced metering infrastructures (AMI)" (Woo et al. 2014, p. 263) have been developed. These AMI improvements have made for example real-time pricing and two-way communications between producers and consumers possible and are, according to the authors, a main driver of product differentiation in electricity.

The authors state several "Criteria for a useful differentiated product" (Woo et al. 2014, p. 264) for example financial aspects, customer acceptance and engagement, and environmental aspects such as greenhouse gas emissions reductions et cetera. They focus on how consumers can get more active in their electricity consumption thanks to AMI, and how to incentivize them to use electricity during off-peak hours. They also suggest a “cut-off ladder” (Woo et al. 2014, p. 269) meaning that in case a supplier faces a higher demand than they can meet, the consumers will be cut-off (in other words, have a power outage). The order for the consumers to be turned off will be determined by the price they have been willing to pay for their place in the ladder. Woo et al. conclude that this type of differentiation in electricity may be useful and decrease costs for the electricity delivery.

Woo and Zarnikau (2019) examine the price premium of renewable energy in Texas in their article “Renewable Energy’s Vanishing Premium in Texas’s Retail Electricity Pricing Plans”. Their aim is to study a potential a price premium on renewable energy and find that there in fact is no statistical evidence that such premium exists anymore. Surprisingly, they find indications (but no statistical evidence) for a discount on renewable energy and conclude that the price premium has vanished. The authors explain this result with the decreasing costs for renewable energy and conclude that continuing the development of renewable energy will not negatively impact Texas residents. They also conclude that with a vanished price premium, the need to find consumers’ WTP for renewable electricity is less relevant.

4.2. Consumer Preferences for Electricity

Studies in behavioral economics have been conducted by several researchers. In the article “Psychological Determinants of Attitude Towards and Willingness to Pay for Green Electricity” Hansla et al. (2008) perform a mail survey study to find out what determines customers’ WTP for green electricity. The authors find that the WTP for green electricity is positively correlated with a positive attitude towards it, and negatively correlated with electricity costs. They do not find evidence of income influencing WTP for green electricity. Hansla et al. also investigate what determines the positive attitude towards green electricity and conclude that this attitude is related to altruistic values, awareness of consequences beliefs and concerns about environmental problems.

Krishnamurthy and Kriström (2015) study households’ preferences for green electricity in 11 OECD countries in their article “Determinants of the Price-Premium for Green Energy: Evidence from an OECD Cross-Section”. The study is performed as a survey study and is, according to the authors, the first study of its kind making possible comparisons across countries. The authors do not find income as a main determinant for WTP of green electricity, but rather that environmental attitudes expressed as for example being part of an environmental organization has a positive effect on WTP for green electricity.

Tabi et al. (2014) point out an important problem for studies of WTP for green electricity – there may be a difference between stated and revealed WTP where survey respondents tend to overstate their WTP compared to their actual consumer patterns. The authors list methods, for example certain interview-techniques, to overcome this problem, but state that it is important to keep this potential divergence in mind. In their article “What Makes People Seal the Green Power Deal? – Customer Segmentation Based on Choice Experiment in Germany”, the authors aim to find a market size estimation for potential consumers of green electricity. They also aim to identify the differences between the customers that already have a green electricity contract and the customers that express strong preferences towards green electricity but have not signed such contract.

In accordance with other research results, Tabi et al. find that “perceived consumer effectiveness” (Tabi et al. 2014, p. 211), in other words how much the consumers believe that their own behavior affect the environment, is significantly different between people who have a green electricity contract and people who express environmental concerns but have no such contract. They also find that the different groups have varying perceptions of the price level of green electricity contracts. The group with a green electricity contract generally believed that the price of green electricity was lower than the group that had not yet sealed the contract but was positive towards green electricity believed. The authors also find other psychographic attributes having an effect on whether or not the green electricity contract is signed; adopters trust science to a larger extent, they have a higher WTP for eco-friendly products in general and have also changed electricity contract more recently than non-adopters in general. Interestingly, the authors find more of these psychosocial determinants than socio-demographic determinants. They do not find age, gender, household income or size of household to affect whether or not a green electricity contract is sealed. The only socio-demographic determinant they find is that the adopters have higher education.

5. Data

5.1. Data Collection

To collect data and create variables, have used Excel and partly Python (Jupyter Notebooks). Some variables are used at contract-level, and other variables are used at firm-level.

5.1.1. Contract Information

The main source of data is a spreadsheet with electricity contracts obtained from Energimarknadsinspektionen (2021b). The spreadsheet includes information about every contract that is offered to Swedish households with a yearly consumption of 20 000 kWh, which is a typical consumption of a residential house (not an apartment) (Energimarknadsbyrån, 2020a). The information provided in the data contains the name of the electricity supplier, the contract pricing structure and length (for example one-year fixed price or running variable price contract), the name of the contract, which bidding area the contract is offered in (SE1-SE4) and the price per kWh including fees, taxes et cetera. The information is based on what is reported to Energimarknadsinspektionen’s independently run electricity contract price comparison website elpriskollen.se, from which data is gathered on the 15th of every month. For the variable price contracts, the price reported is the price from the month before. The dataset includes a total of 20 924 observations from January 2020 to September 2020. As stated in section 1.3, I have chosen to delimit my study to contracts offered in January 2020 and the pricing structures one-year fixed price and running variable price. I have also excluded the few observations where the bidding area is unknown. After these delimitations, I proceed with 994 contract observations.

5.1.2. Market Share

Information about the electricity suppliers’ market shares is obtained from Stattin at VA Insights, which is a website offering news about for example the Swedish and European energy markets. Stattin (2020) lists the number of consumers supplied by each of the 30 largest firms in Sweden in 2020. To find the market share, the number of consumers for each firm is divided by 5 504 947, which is the number of low-voltage sockets in Sweden in 2018 (Statistiska Centralbyrån, 2019). This number is used as an approximate number of total electricity consumers in Sweden.

Largest Electricity Suppliers in Sweden 2020

Rank	Supplier	Customers	Market share in %
1	Fortum	900 000	16.4
2	Vattenfall	874 000	15.9
3	Eon	700 000	12.7
4	Jämtkraft	285 000	5.2
5	Göteborg Energi	280 000	5.1
6	Bixia	215 000	3.9
7	Skellefteå Kraft	181 000	3.3
8	Telge energi	179 000	3.3
9	GodEl	130 000	2.4
10	Mälarenergi	127 000	2.3
11	Kraftringen	120 000	2.2
12	Öresundskraft	100 000	1.8
13	Mölndal Energi	93 000	1.7
14	Varberg Energi/Viva	72 000	1.3
15	Nordic Green Energy	67 000	1.2
16	Energi Försäljning Sverige	63 000	1.1
17	Stockholms Elbolag	60 000	1.1
18	Borås Elhandel	55 000	1
19	Jönköping Energi	50 000	0.9
20	Storuman Energi	46 000	0.8
20	ESEM	46 000	0.8
22	Umeå Energi	44 000	0.8
23	Karlstads Energi	42 000	0.8
23	Gävle Energi	42 000	0.8
25	Luleå Energi	41 000	0.7
26	Fyrfasen Energi	40 000	0.7
27	Gotlands Energi	33 000	0.6
28	Halmstads Energi och Miljö	28 000	0.5
29	Kalmar Energi	25 000	0.5
30	Affärsverken Karlskrona	24 000	0.4

Table 1. Number of customers and market shares for the 30 largest electricity suppliers in Sweden. Sources: Stattin, 2020, Statistiska Centralbyrån, 2019, own calculations.

Together, the 30 largest firms supply around 90 % of the market. To estimate the market shares for the 121 small firms that are not on the list, the remaining 10% of the market is divided by 121. These are thereby estimated to have a market share of 0.08% each. Note that these market shares refer to the entire electricity market, including e.g. businesses and apartment households, and not only the market for 20 000 kWh consumption households which is studied in this thesis. However, the estimated market shares are considered relevant to use for this study.

Out of the 151 electricity suppliers in Sweden, 113 are found in the data I have chosen to study. The reasons why not every supplier is represented vary. For example, the firm Energi Försäljning Sverige does not supply private consumers but only companies (Energi Försäljning Sverige, n.d.) which explains why the firm is not found in Energimarknadsinspektionen's data over contracts offered to households. Other firms, such as for example Affärsverken Karlskrona, are represented in the full dataset from Energimarknadsinspektionen but not in the chosen subset of the data. These electricity suppliers do not appear in the chosen data simply because they do not offer any of the contract types one-year fixed price or running variable price contracts in January 2020. Out of the 30 largest firms in Sweden, 26 are represented in the data. The non-appearing large firms are Affärsverken Karlskrona, Borås Elhandel, Energi Försäljning Sverige and Skellefteå Kraft. Of the 121 small firms in Sweden, 87 are represented in the data with contracts offered to households in January 2020. The number of observations on firm-level is thereby 113 of which 87 small firms' sizes are estimated and 26 large firms' sizes are based on the numbers from Stattin (2020).

5.2. Variables

5.2.1. Dummy Variables

Prior to presenting the variables used, I will give a brief introduction to dummy variables. Dougherty (2016) explains in his book *Introduction to Econometrics* that dummy variables are useful when comparing groups of observations to each other. For example, I may suspect that there is a price difference between the fixed and variable price contracts and choose to create a dummy variable for this. All contracts with a fixed price are then assigned a 1, and the variable price a 0. The variable price group is then used as a reference group. This allows for interpreting these two categories with different intercepts (Dougherty, 2016, pp. 230-232).

Dummy variables can also be used for more than two categories (Dougherty, 2016, p. 237), for example the four bidding areas SE1, SE2, SE3 and SE4. The dummy variables are created in the same manner as in the case with only two categories, still excluding one reference group which I have chosen to be SE1. Dummy variables can run in several dimensions simultaneously; a contract is offered in one of the four bidding areas while also having a fixed or variable price. Other dummy variables are added, too.

5.2.2. Variable Specification

Market share refers to the market share in % held by each firm. See 5.1.2. for details. On the contract-level, market share refers to the market share held by the firm supplying the contract.

Number of varieties is the number of origin-exclusive varieties offered by a firm. Origin-exclusive means that the electricity originates from one exclusive resource which can be solar, wind, hydro or nuclear. A firm is seen as providing a given variety if the firm offers an origin-exclusive contract from this variety in one or several of the bidding areas. The number of differentiated varieties can take the numbers 0, 1, 2, 3 and 4.

Price is the price per kWh in Swedish öre.

SE1 contracts refer to the contracts offered in bidding area 1.

SE2 contracts refer to the contracts offered in bidding area 2.

SE3 contracts refer to the contracts offered in bidding area 3.

SE4 contracts refer to the contracts offered in bidding area 4.

Fixed price are the contracts with a price that is fixed for one year.

Variable price are the contracts with a running variable price.

Renewable are the contracts with guaranteed renewable electricity. This includes origin-exclusive contracts with wind, solar or hydro power as well as contracts whose names include any of the words “green”, “environment” or “renewable” [1].

Non-renewable are the contracts that are not guaranteed to be renewable. This includes origin-exclusive contracts with electricity from nuclear power, contracts whose names include “fossil free” (as these are not guaranteed to be renewable), and contracts with electricity from an unspecified origin, i.e. from the residual mix.

[1] In Swedish: Grön, miljö, förnybar.

5.2.3. Descriptive Statistics

Descriptive statistics

Firm-level

Variable	*Mean*	*Median*	*S.D.*	*Min*	*Max*	*Number of observations*
Nofvarieties	0.460	0.000	0.866	0.000	4.000	113
Marketshare	0.809	0.081	2.533	0.081	16.352	113

Contract-level

Variable	*Mean*	*Median*	*S.D.*	*Min*	*Max*	*Number of observations*
Price	58.806	58.431	5.061	45.462	119.180	994
Marketshare	2.377	0.081	4.720	0.081	16.352	994
SE1	0.253	0.000		0.000	1.00	251
SE2	0.256	0.000		0.000	1.00	254
SE3	0.278	0.000		0.000	1.00	276
SE4	0.214	0.000		0.000	1.00	213
Fixed Price	0.487	0.000		0.000	1.00	484
Variable Price	0.513	1.000		0.000	1.00	510
Renewable	0.515	1.000		0.000	1.00	512
Non-Renewable	0.485	0.000		0.000	1.00	482

Table 2. Descriptive statistics. Standard deviations are not displayed for dummy variables. Note that the Market share mean is higher on the contract-level compared to the firm-level as larger firms offer more contracts.

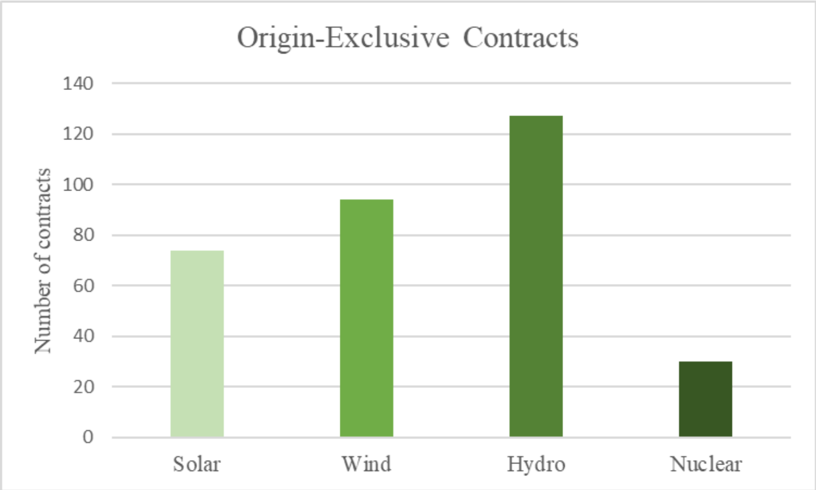

Figure 5. Number of origin-exclusive contracts from each origin out of 994 studied contracts. Based on data from Energimarknadsinspektionen, 2021b.

6. Empirical Approach

In this section, I will present the empirical approaches chosen to test my hypotheses. One correlation and one regression will be described. Thereafter, I will perform a few tests on the regression.

6.1. Market Share and Number of Origin-Exclusive Varieties

As described in section 3.1, horizontal product differentiation theory suggests that the larger the company, the higher number of varieties is offered. Remember that number of varieties refers to the origin-exclusive varieties in this context. I want to study the correlation between market share and number of varieties offered by a company. To do this, I use data on firm-level.

Before proceeding, the meaning of correlation should be clarified. Dougherty (2016, p. 22) explains it as a measure of association between two variables and that it is independent of which units the two variables are measured in. Lind et al. (2018) state in their book *Statistical Techniques in Business and Economics* that the correlation coefficient origins back to Karl Pearson around 1900. The correlation coefficient for two variables is positive if the increase in one variable is associated with an increase in the other variable, and negative if an increase in one variable comes with a decrease of the other variable. The correlation coefficient can take values from -1 to 1. If there is no relationship between the variables, their correlation is zero (Lind et al. 2018, pp. 440-441).

I will study the correlation coefficient for market share and number of origin-exclusive varieties offered by a firm and see if this is positive as the horizontal product differentiation theory suggests. If I can reject non-positivity at the 5 % significance level, which is chosen as the level of significance in this thesis, I can conclude that the correlation coefficient is positive.

6.2. Price for Renewable Electricity

For the application of the vertical product differentiation theory, all consumers are instead assumed to have the same preferences for different varieties of a product. As specified in section 3.2, we have for this theoretical application made the assumption that contracts with electricity from renewable resources are considered to be of higher quality than contracts with electricity from non-renewable resources. Remember that contracts with electricity from non-renewable resources include contracts with electricity from nuclear power, fossil free electricity and unspecified electricity from the residual mix and may thereby include renewable electricity but are not guaranteed to do so.

For this model, data on contract-level is used. I will run the following OLS regression:

$$Price_i = \beta_1 + \beta_2 \times Marketshare_i + \gamma_1 \times SE2_i + \gamma_2 \times SE3_i + \gamma_3 \times SE4_i + \lambda \times Fixedprice_i + \theta \times Renewable_i + \varepsilon_i$$

Explained with words, I aim to study if contracts with renewable electricity as a group has a higher price per kWh than contracts with non-renewable electricity. β_1 is the constant of the regression. As the market share (in %) held by the firm offering the contract may have an effect on the price, this is used as a control variable with the coefficient β_2. I also find it interesting to study if there are any differences in price per kWh for contracts offered in different bidding areas and have therefore added a dummy variable for bidding area. The γ coefficients will tell us about such potential differences. The pricing structure of a contract may also affect prices and a dummy variable with the coefficient λ is created to separate the fixed price contracts from the variable price contracts. Lastly, the contracts with electricity from renewable resources are separated from non-renewable electricity by a dummy variable with the coefficient θ. The multidimensional reference dummy variable group is SE1, variable price and contracts with non-renewable electricity.

All coefficients but θ are tested with a null hypothesis of being equal to zero. As theory suggests that renewable electricity should be priced higher than other electricity sources, I test this with a null hypothesis of θ being non-positive. If I can reject non-positivity at the 5 % level, I can conclude that θ is positive.

6.3. Tests

To test whether I have specified the OLS regression in 6.2 correctly, I will perform a few tests. First, I will perform a Variance Inflation Factor (VIF) test to check for multicollinearity. Then I will see if the residuals are normally distributed, and thereafter check for heteroscedasticity in the error terms by performing a Breusch-Pagan test. To perform the tests, I have used the econometrics software Gretl.

6.3.1. Multicollinearity

Multicollinearity may have severe consequences to a model. Dougherty explains that multicollinearity is the correlation between the explanatory variables. If this is too high, it may cause wrong estimations of the coefficients in the model (Dougherty, 2016, p. 171). Lind et al. state that if the model suffers from multicollinearity, it will not give relevant information about the relationship between the independent variables and the dependent variable (Lind et al. 2018, pp. 509-510). Both Dougherty and Lind et al. emphasize that it is very unusual to *not* see any correlation between the explanatory variables, and thus that the existence of correlation does not mean that the model is wrongly specified. However, if the degree of correlation is too high, it may generate problems and the model may give better estimations of the coefficients if one or more variables are left out of the model (Dougherty, 2016, p. 171) (Lind et al. 2018, pp. 509).

Although I do not see any obvious multicollinearity problems with the regression, I decide to perform a test for multicollinearity. We could for example imagine the possibility of a high correlation between pricing structure and if the contract guarantees renewable electricity or not, if for example renewable electricity were to be only offered in combination with a fixed price. Hence, I find it relevant to test for multicollinearity.

To test for multicollinearity, a VIF can be used. This is specified as

$$VIF = \frac{1}{1 - R_j^2}$$

where R_j^2 is the coefficient of determination of one independent variable j being treated as a dependent variable and explained by the remaining independent variables. If VIF > 10, the model is said to suffer from multicollinearity and the variable j should be excluded from the model (Lind et al. 2018, p. 510).

I do not find a multicollinearity problem in my OLS regression. All VIF range between 1 and 1.6, which is well below 10. Therefore, I proceed with all variables included in the OLS regression. The VIF test is found in Appendix.

6.3.2. Normality of Residuals

For the interpretations of a regression to be valid, the residuals should ideally follow a normal distribution (Lind et al. 2018, p. 509). If the residuals are not normally distributed, we may be careful with the inference of our results. However, if the number of observations is large, the residuals can be assumed to be approximately normally distributed. I test for normality of the residuals and find that normal distribution is rejected. As the histogram of the residuals looks somewhat normally distributed and the number of observations is large (994), I approximate the residuals to be normally distributed although I keep this in mind when interpreting my results. The test is found in Appendix.

6.3.3. Heteroscedasticity

A correctly specified OLS regression is assumed to have homoscedastic error terms. This means that the probability of the error term taking a specific number is equal among the observations i. If the error terms are heteroscedastic, on the other hand, its variance depends on the observation i. For example, a larger value of the observation i may have a higher variance in its error term than a smaller value of the observation. If homoscedasticity is assumed although heteroscedasticity is the case, the estimations of the OLS will be wrong. One solution to heteroscedasticity is to use robust standard errors (Dougherty, 2016, pp. 291-293, 305).

To test for heteroscedasticity, we test if the variance in the error terms can be explained by the independent variables. If so, the model suffers from heteroscedasticity. I perform a Breusch-Pagan test to test for heteroscedasticity and find that the null hypothesis of homoscedasticity is rejected. Therefore, I choose to use robust standard errors in my OLS regression. The test can be found in Appendix.

7. Results and Analysis

7.1. Market Share and Number of Origin-Exclusive Varieties

Correlation Matrix

Marketshare	Nofvarieties	
1.000	0.426***	Marketshare
	1.000	Nofvarieties

Under null hypothesis of non-positive correlation: p-value < 0.0001

Observations: 113

**p<0.05, the coefficient is significant at a 5% level*
***p<0.01, the coefficient is significant at a 1% level*
****p<0.001, the coefficient is significant at a 0.1% level*

Table 3. Correlation matrix.

The correlation coefficient for Market share and Number of origin-exclusive varieties offered by a firm is significantly positive. For the t-value of the test (4.96), the p-value was found to be <0.0001, which is well below 0.05. Therefore, I reject the null hypothesis of a non-positive correlation and conclude that there is a significant positive correlation between the two variables.

The correlation coefficient is estimated to be 0.426, which can be considered between weak and moderate. This result, that there is a positive correlation coefficient, is in line with the horizontal product differentiation theory which suggested that larger firms would offer a higher number of different origin-exclusive alternatives.

7.2. Price for Renewable Electricity

OLS Regression Results

Dependent variable: Price

Heteroskedasticity-robust standard errors

	Coefficient	**Std. Error**	**p-value**[2]
const	57.952***	0.349	<0.0001
Marketshare	0.059*	0.026	0.0223
SE2	−0.010	0.411	0.9801
SE3	1.235**	0.388	0.0015
SE4	3.229***	0.495	<0.0001
FixedPrice	−1.897***	0.300	<0.0001
Renewable	1.175***	0.305	<0.0001

Adjusted R-squared: 0.108

Observations: 994

**p<0.05, the coefficient is significant at a 5% level*

***p<0.01, the coefficient is significant at a 1% level*

****p<0.001, the coefficient is significant at a 0.1% level*

2. Note that all variables but Renewable are tested with the null hypothesis of having no effect on price. Renewable is tested with the null hypothesis of having a non-positive effect on price.

Table 4. OLS Regression Results.

From the OLS regression, we can conclude that there are several variables that significantly affect the price. Prior to exploring these, however, I will briefly comment on the adjusted coefficient of determination, the adjusted R^2. R^2 can be said to measure to which extent the studied independent variables explain the dependent variable. If $R^2 = 1$, the dependent variable is completely explained by the independent variables, and if $R^2 = 0$, the independent variables do not explain the dependent variable at all (Dougherty, 2016, pp. 108-109). R^2 increases as more explanatory variables are added to a model, regardless of these variables' explanatory effect on the dependent variable. Adjusted R^2 is used to adjust for this (Dougherty, 2016, pp. 188-189) and is presented below the coefficients in Table 4. In the regression, the adjusted R^2 is 0.108 which indicates that the price is determined by variables not included in the model, too. Acknowledging this, we may move on to interpreting the coefficients.

For the reference group which is variable price contracts offered in SE1 with non-renewable electricity, the estimated intercept is 57.952 öre per kWh.

Market share is estimated to have a small but significant effect on the price. An increase of one percentage point of market share held by a firm is estimated to increase the price by 0.059 öre per kWh.

There is no significant difference in price between the reference bidding area SE1 and the bidding area SE2. For bidding areas SE3 and SE4, however, we see significant price differences compared to SE1. Contracts in SE3 are estimated to cost 1.235 öre more per kWh than contracts in SE1. Contracts in SE4 are estimated to cost 3.229 öre more per kWh than contracts in SE1. These results are interesting but not surprising. The electricity surplus in the north and the deficit in the south described in section 2.1 may be probable explanations to this.

The fixed price contracts are estimated to cost 1.897 öre less per kWh than variable price contracts. When interpreting this result, it is important to remember that the studied month is January. Variable price changes over the year and the studied month is a winter month when the variable price tends to be higher. Also, the variable price is a running contract while the fixed price contract is agreed for one year, which may also explain the difference between fixed price and variable price contracts. In other words, this result should not be simply interpreted as fixed price being cheaper than variable price but must consider these potential explanations, too. Therefore, I will not draw strong or general conclusions from this result.

The contracts with electricity from renewable resources have a significant effect on prices and are estimated to cost 1.175 öre more than contracts with electricity from non-guaranteed renewable resources. This is in line with the theory of vertical product differentiation and the assumption that renewable electricity is considered to be of higher quality than non-renewable electricity by all consumers. For a household with a yearly electricity consumption of 20 000 kWh, the yearly price increase of switching to renewable electricity is estimated to be 235 Swedish kronor.

8. Discussion

8.1. Discussion

Considering a normal budget of a household with a yearly electricity consumption of 20 000 kWh, the estimated price increase of 235 Swedish kronor per year for switching to electricity of higher quality can be seen as relatively low. The number of consumers with each contract is unknown since this data is not public and we can therefore not know exactly how many consumers that have chosen to pay a price premium for renewable electricity. However, relating back to previous research such as the results from Tabi et al. (2014), the price of renewable electricity may not always be known by the consumers. This lack of information about the price may prevent consumers, who in fact have a high WTP, from signing a contract with renewable electricity. Consider for example the fact that around 10 % of the Swedish consumers have a default supplier, which indicates that they are not active in their choice of electricity contract. With this in mind, we may view the estimated yearly price increase of 235 Swedish kronor for switching to renewable electricity as small, but this does not immediately mean that consumers are informed about it.

The assumptions made about consumer preferences may also be discussed. For the application of the horizontal product differentiation theory, consumers were assumed to have different preferences for origin-exclusive electricity. Their preferences were assumed to be evenly distributed between exclusively solar, wind, hydro and nuclear power. Also, the costs for the firm were assumed to be equal for the different power sources. All these assumptions are strong and not exactly in accordance with the real world. However, they are considered relevant for the application of horizontal product differentiation theory. The reader should note that other assumptions may be made instead and that these could affect the results.

For the vertical product differentiation theory, other assumptions were made about consumer preferences. Here, renewable electricity was treated as a high-quality product which every consumer would prefer over other electricity given the same price. The fact that some firms offer contracts with electricity exclusively from nuclear power is an indication of the distinction between this assumption and the real world. As stated in section 3.2, the assumption was made based on some features of renewable electricity and the debate about nuclear power. However, other assumptions on what is defined as high-quality electricity may be made. For example, if only the CO_2 emissions were to be considered, fossil free electricity including nuclear power could be seen as high-quality electricity compared to unspecified electricity. This could potentially generate other results than the results I obtained.

8.2. Suggestions for Further Research

It would be interesting to compare the price premium on renewable electricity found in this study with future similar studies of the Swedish electricity market. As Woo and Zarnikau (2019) found that the renewable price premium had vanished in Texas thanks to lower costs of renewable electricity production, it would be interesting to see if Sweden is moving in the same direction or if the price premium will remain.

9. Conclusions

In this thesis, some aspects of product differentiation of electricity contracts have been studied. Horizontal product differentiation theory is applied to study the correlation between firms' market shares and the number of origin-exclusive varieties that they offer. This correlation is studied on firm-level, where each firm serves as one observation. For the application of the horizontal product differentiation theory, consumers have been assumed to have varying preferences – some prefer solar, and others want nuclear, et cetera. The consumers are here assumed to be evenly distributed along the line of preferences for solar, wind, hydro and nuclear power – an assumption that is not necessarily realistic but is made for the application of the theory. The other contracts in the data (i.e. the contracts that are not specified to deliver electricity from one exclusive origin) have been excluded from this analysis for simplicity and saved for the vertical product differentiation analysis.

The correlation coefficient found between market share and number of origin-exclusive varieties offered is significantly positive, which is what the horizontal product differentiation theory suggested. It is estimated to be 0.426, which can be considered a low to moderate correlation. In other words, we can say that larger electricity suppliers tend to offer a higher number of different origin-exclusive alternatives. This goes in line with the horizontal product differentiation theory which proposed that a larger market leads to a higher number of optimal "shops". A consumer with preferences for electricity from one specific origin may thereby be recommended to start looking for such contract at the larger firms, as chances are higher that these firms offer a contract with electricity from their preferred origin.

Vertical product differentiation is applied to study whether there is a difference in price between high-quality contracts and low-quality contracts. Here, all consumers are assumed to agree that renewable electricity is of higher quality than electricity that is not specified to be renewable. This assumption can be criticized, but was made based on environmental performance, renewability, and the controversy surrounding nuclear power.

An OLS regression was run with the control variables market share held by the firm offering the contract, which bidding area the contract was offered in and if the contract was a one-year agreed fixed price or a running variable price contract. Market share was found to have a significant but small positive effect on the price, where larger firms tend to charge slightly higher prices. Contracts offered in SE3 and SE4 were found to be significantly more expensive than contracts offered in SE1. This result was not surprising considering the electricity surplus in the north of Sweden and the deficit in the south. No significant difference in price was found between contracts offered in SE2 compared to SE1. Contracts with a fixed price agreed for one year were found to cost significantly less per kWh than running variable price contracts but note that this should be interpreted carefully as the month January may not be representative for a year. Also, the varying lengths (one-year agreements and running contracts, respectively) of the contracts may explain some of this price difference.

The results from the OLS regression show that contracts with guaranteed renewable electricity cost significantly more than contracts with no such guarantee and that the price difference is estimated to be 1.175 öre per kWh. This is in line with the vertical product differentiation theory and the assumptions made about renewable electricity being considered to be of higher quality than non-renewable electricity. For a household with a yearly consumption of 20 000 kWh, switching to electricity from renewable resources is thus estimated to increase the household’s electricity costs by 235 Swedish kronor per year.

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11. Appendix

11.1. Normality Test of Residuals

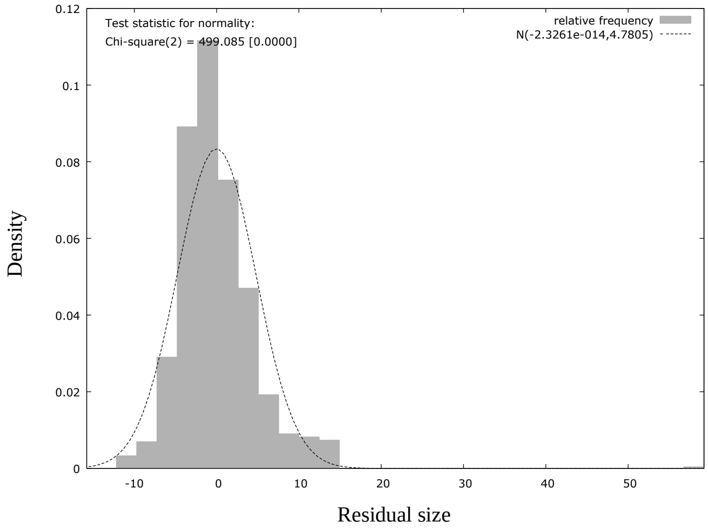

Figure 6. Normality test of residuals.

11.2. Variance Inflation Factors

Variance Inflation Factors

Minimum possible value = 1.0
Values > 10.0 may indicate a collinearity problem

Marketshare	1.026
SE2	1.498
SE3	1.518
SE4	1.454
FixedPrice	1.011
Renewable	1.029

Table 5. Variance inflation factors.

11.3. Breusch-Pagan Test

Breusch-Pagan Test for Heteroscedasticity

H0: Homoscedastic error terms
Test statistic: 84.89
P(Chi-square(6)>84.89)=0.0000

Table 6. Breusch-Pagan test for heteroscedasticity.