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Gasoline Demand in the Different Regions of Sweden

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Abstract:

In this thesis, we study the price and income elasticities of gasoline demand in the different regions of Sweden. By collecting data for each region in the period between 2002-2017 we try to derive these elasticities. The purpose of this is to contribute to the understanding of the distributional effect in Sweden when the gasoline price increases. We expected higher price elasticities in absolute values in the more urban regions, and lower price elasticities in the more rural regions. Lower income elasticities were also expected to be found in regions with relatively high income, while higher income elasticities would be found in the regions with relatively low income. The estimates derived for each region do not confirm these patterns. However, when instead estimating the elasticities for groups of regions (according to their population densities), the price elasticities found are in expected ranges. The income elasticities that are found are still partly counterintuitive though. We discuss our results and provide some research avenues for better estimation.

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Acknowledgement: We want to thank our supervisor Marion Dupoux, for her valuable advices and guidance.

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1. Introduction

The transport sector stands for roughly a third of all the emissions of greenhouse gases in Sweden. Of this total, the road traffic stood for around 93% in 2017 (Ekonomifakta, 2019). To reduce this, multiple instruments have been used, with the most acknowledged one perhaps being fuel taxes. One thing that fuel taxes intuitively imply are higher prices on fuel. However, there are other things that follow with fuel taxes that may not be as straight forward. One of these things is the impact higher fuel prices have on the individual's wallet.

While higher fuel taxes are easily motivated by environmental reasons, the implication of higher prices affects people differently. People who are dependent on fuel to get through their everyday life will most likely be more affected than people who are not. People who live in rural areas, who are dependent on their cars to get to work, school or just to buy groceries, will probably have less flexibility if the prices on fuel goes up.

In Sweden, there are huge differences in the rurality of each region. These differences make it hard ignore how increased fuel prices impacts the people in different regions. This thesis focus on gasoline demand and to understand how this demand response in different regions to a price increase. This is essential to understand when discussing higher fuel taxes.

This leads us to our research question, "Does the price and income elasticities of gasoline demand differ between the regions of Sweden?". By deriving price and income elasticities for each region, we can potentially see how sensitive the gasoline demand in each region is to a price increase and an income increase respectively. We remarked that there is a lack of studies on elasticities of gasoline at the regional level in Sweden. This thesis will try to estimate these elasticities, to give a clearer view of how people are affected depending on which region they live in.

By using data from the period 2002-2017, we run several OLS-regressions to derive the elasticities. Our results do not show the expected patterns that we establish according to economic theory and earlier studies. While this could imply that Sweden is an irregularity, we comment throughout the thesis how the study could have been improved.

The thesis will be structured as following: Section 2 will give a quick background on the regions of Sweden. Section 3 is a review of earlier literature relevant to our research question. In section 4, the relevant economic theory will be described, as well as our derived hypotheses. Section 5 is where our data is described. Section 6 describes the method we have used to derive our results. Section 7 shows the results with following discussions and Section 8 states conclusions.

2. Context

Regions

There are 21 regions in Sweden. The division is illustrated in Figure 1. Each region has its own government, which is called "regionfullmäktige". The regions have many responsibilities, though only four that are mandatory. These are healthcare, dentalcare, regional development and public transport (SKL, 2019).

Figure 1. Regions of Sweden

Source: SCB

The 21 regions differ in many ways, from the geographic circumstances (e.g. north or south) to population density. While Stockholm is a rather small region, it had a population density of 353 inhabitants/km^2 (2017 data). This considerably contrasts with the region of Norrbotten, which had a population density of 2.6 inhabitants/km^2. The regions also differ in terms of the average disposable income per household, where Stockholm once again had the highest of 242 000 SEK in the year 2017. By contrast, the regions of Gotland, Blekinge and Örebro had the lowest disposable income per household, with 197 000 SEK in the same year (SCB, 2019).

Another important difference between the regions is public transport. Each region's government chooses the public transport supplier, which they finance with public funds (SKL, 2019). For example, the region of Västra Götaland has Västtrafik for public transport supplier (Västra Götalandsregionen, 2019), while the region of Skåne has Skånetrafik as supplier (Region Skåne, 2019).

These differences might affect the elasticities of gasoline in each region, which would imply that the regions differ in their response to a price change of gasoline. The most important factors according to us, would be population density, income and availability of substitutes to gasoline (e.g. public transport). The fact that it is the region's government that chooses public transport supplier, we can motivate our choice to study regions specifically. How the suppliers handle the public transport in their region, can influence people's decisions when deciding to travel with public transport or not. Important factors when deciding if one will travel public, may be e.g. the price of traveling public compared to taking your own car, how many departures there are per day or simply the quality of the rides.

3. Literature Review

3.1 Elasticities of gasoline

There is plenty of literature on the subject of price elasticities of gasoline. With the large amount of studies, it is not strange that there is also an equally large amount of different results. Several reviews of this body of literature summarize earlier results.

Dahl and Sterner (1991) summarize over a hundred studies' results in a meta-analysis about gasoline demand and comment on the different kinds of methods to estimate gasoline demand elasticities. They find that even though many studies have contradictory results, this would be natural due to e.g. the many different models, types of data, countries, time periods and econometric methods that are used. They make some important distinctions between models. One is that different models capture different elasticities. While dynamic models capture both a short and long run elasticity, static models seem to capture some sort of intermediate run elasticity. Short run elasticities measure adjustments up to a year depending on what data is used, while long run elasticities measure the total adjustment which could take several years. At the end of their meta-analysis they note that the short run price elasticity of gasoline seems to be between -0.22 to -0.31, while the long run price elasticity seems to be between -0.8 to -1.01. They also find that the short run income elasticity appears to be between 0.44 and 0.52, while the long run income elasticity is between 1.10 and 1.31 (Dahl & Sterner, 1991).

In a similar survey, Graham and Glaister (2002) comment on the effect of different kinds of methods and types of data on results. Their meta-analysis show that short run price elasticities of gasoline tend to be around -0.3 and long run elasticities between -0.6 and -0.8. They also find short run income elasticities between 0.35 and 0.55 and long run income elasticities between 1.1 and 1.3. In their conclusions, they point out that higher prices do make a difference in gasoline consumption, especially in the long run, but it is not a proportional effect (Graham & Glaister, 2002).

Sterner (2012) note that there is a consensus in previous literature that the long run price elasticity of fuel tends to be around -0.8 and the long run income elasticity tends to be around unity. The short run equivalents tend to be about a third of the long runs. But Sterner (2012) emphasize that the price elasticities of fuel may differ between countries. While fuel demand is mostly determined by price and income, a country's taxes, fees and other policies that affect the transport sector might play a big role in this difference in elasticities (Sterner, 2012).

3.2 Elasticities of gasoline in specific countries

In this subsection, we provide a short review of earlier estimates of gasoline elasticities. Following papers have studied specific countries, which gives us a better view of how different circumstances can create heterogeneity in elasticities.

As Sterner (2012) noted, the elasticities in different countries vary greatly. For example, Hughes, Knittel and Sperling (2008) derive the short run price elasticity of gasoline in the U.S. They use aggregated monthly data and different models for two periods, 1975-1980 and 2001-2006. They find short run elasticities between -0.21 and -0.34 in the first period and between -0.034 and -0.077 in the second period. With these results, they draw the conclusion that people have become more insensitive to price changes now relative to previous decades. By interpreting this as evidence for structural changes in the U.S market for transportation fuel, they emphasize the implications this could have for policy making in the future (Hughes et al., 2008).

Baranzini and Weber (2012) uses quarterly data to study the price elasticity of gasoline in Switzerland, during the period 1970-2008. They find the price elasticity to be -0.09 in the short run and -0.34 in the long run. The small price elasticities that is found could according to Baranzini and Weber (2012) be explained by high incomes and low gasoline prices. They also find a long run income elasticity at 0.67 and a short run income elasticity at 0.025. (Baranzini & Weber, 2012).

Pyddoke and Swärdh (2015) study how the use of privately-owned cars varies in Sweden during the period 1999-2008 due to multiple factors, including fuel price. Their results show that the car travel elasticity of fuel prices is between -0.2 and -0.4 in the short run and between -0.3 and -0.6 in the long run. Overall, they note that car travel is rather inelastic since it is below unity. Pyddoke and Swärdh (2015), like Baranzini and Weber (2012), explain this low elasticity with the fact that car travel takes up such a small part of one's total income. They also derive income elasticities of car travel, which shows to be fairly lower than other studies' results. The short run income elasticities are reported to be between 0.01 and 0.07, while the long run income elasticities are between 0.15 and 0.2 (Pyddoke & Swärdh, 2015).

Aklilu (2016) notes in a working paper that studies about different countries may not be comparable due to their differences in methods and data. He instead, study the elasticities of both gasoline and total fuel in the EU-28 countries at once. The data is collected from the period 1978-2013, but not all countries had data available from these years, so for these countries the period is shorter. Aklilu (2016) finds that both the short run and the long run price elasticity of gasoline varies in the EU. The short run elasticity varies between -0.005 in Spain to -0.58 in Romania, while the long run price elasticity varies between -0.04 in Malta to -1.96 in Sweden. On average, the short run price elasticity in the EU-28 countries are found to be -0.17 and in the long run -0.72. Aklilu (2016) also finds a great variation of the income elasticities in the EU-28. The lowest short run income elasticity is found in Spain, which is estimated at 0.018. This is while the highest is estimated to be 1.32 in Lithuania. The lowest long run income elasticity is -0.12 in Belgium, while the highest is found in Germany at 6.49. The average short run income elasticity is 0.45 and the average in the long run is 1.44 (Aklilu, 2016).

3.3 Distributional effects of a higher gasoline price

The objective of this thesis is to try to find elasticities of the different regions of Sweden. If the elasticities of the different regions vary from one another, there could be serious policy implications. As the literature shows, we have reason to believe that these differences exist.

Larsson and Sandin (2018) study the effects of a tax raise on emissions from gasoline and diesel in Sweden. While they find that a tax raise reduces emissions, which gives significant environmental gains, the increase in the societal welfare is limited. They find negative distributional effects, which is partly due to the fact that rural areas are more affected than urban areas by a tax increase. Further, they also find that the social welfare gains of a tax increase are larger in cities than in rural areas. These results make fuel taxes challenging to implement. In their recommendations, they call for more studies on other policies than taxes that affects traffic more specifically in cities, policies like parking fees e.g. (Larsson & Sandin, 2018).

Sterner (2012) agrees with the statement that fuel taxes reduce emissions. He even goes as far as saying that it is one of the most efficient tools to achieve a lower level of emissions. Although fuel taxes may have been implemented mostly for fiscal reasons and less for environmental ones, the effect surely is both. A common argument against fuel taxes that Sterner (2012) mentions is that they tend to be regressive. While taxing a good that is mainly used by the wealthier would be progressive, taxing a good that is mainly used by the poor is regressive. In this question, Sterner (2012) makes the conclusion that fuel taxes tend to be progressive in low income countries and regressive in high income countries (Sterner, 2012).

Sterner (2007) makes an interesting point. If a fuel tax is such a great instrument, why is it not used more universally? It may be because policy makers and politicians do not believe in climate change or simply because of lobbying. Policies are not always adopted to maximize welfare or to favour the environment, and here the difference of short and long run price elasticities is of great significance. The inelastic properties of the short run elasticity might frighten politicians while it is only in the long run that the environmental effects show up (Sterner, 2007).

As Larsson and Sandin (2018) mentioned, a big part of the distributional factor is the geographical difference in price sensitivity of fuel. Nicol (2003) studies price elasticities of gasoline in different regions in both Canada and the U.S. Except from the finding that the regions in Canada seems to be more sensitive than the regions in the U.S, he also finds that there are differences between regions in the same country. Though, he emphasizes on the fact that the regional differences are small compared to the different household characteristics. Due to this, policy making should not only be based on the average elasticities of households (Nicol, 2003).

An important finding in the literature about regional differences of price elasticities, is that rural areas seem to be more sensitive to an increase in the price than urban areas. Bureau (2011) studies the effects of a fuel tax increase in France. Amongst the findings, richer households seem to be less sensitive than poorer households and rural households seem to get more affected than urban households. With no surprise, the worse-off seem to be the poorer rural households (Bureau, 2011). Blow and Crawford (1997) make a similar study on a tax increase but in the U.K. They also find that there are differences in how a higher cost of private transport affects different regions. Like other studies, they find that it is the poorer households, especially in rural areas, that are affected the most (Blow & Crawford, 1997).

Pyddoke and Swärdh (2015), as mentioned before, study how the use of privately-owned cars varies in Sweden due to multiple factors, including fuel price. They also check the effect of living in an urban or rural area and finds that the lowest sensitivity is found in rural areas close to urban areas. This may be explained by people living in the rural area and working in the urban area. Individuals with lower income also seem to be more sensitive towards price, this might depend on the fact that transport takes up a bigger part of their total income compared to higher income individuals. Conclusively, car travel elasticity of fuel prices seems to decrease with income and is the lowest in rural areas close to urban areas (Pyddoke & Swärdh, 2015).

Eliasson, Pyddoke and Swärdh (2016) study the distributional effects of different tax instruments on car-use in Sweden. While these instruments usually are fiscally motivated, they are becoming increasingly motivated by environmental reasons. As many others, they note that there are widespread concerns of both regressivity and unevenly distributed damage towards rural areas when discussing fuel taxes. They calculate welfare losses by simulating different tax raises and implementations and they find that, while these instruments are on average progressive, they hurt the poor and rural residents disproportionately. They point out the finding that the geographical location of the area seemingly does not matter, but it is the type and function of the area that determines the sensitivity. In other words, it is the distinction between urban vs rural and not north vs south that is of importance. Another important finding is that the different household characteristics seem to be of big importance in determining the effects of a tax raise (Eliasson, Pyddoke & Swärdh, 2016). This is in line with what Nicol (2003) found in his study that was mentioned earlier.

3.4 Price elasticities of gasoline in different regions of Sweden

Studies on gasoline demand and its elasticities in Sweden are relatively scarce. SIKA (2008), which stands for The Swedish Institute for Communication Analysis, noted in 2008 that studies on price elasticities of gasoline on regional level in Sweden is missing, but is needed (SIKA, 2008).

Due to its closeness to our thesis, Dahlkvist's (2016) master thesis must be mentioned. By dividing Sweden into six different regions, she succeeds in finding different "intermediate" price elasticities for all of them. Dahlkvist (2016) reports the following results of -0.63 for average of Sweden, -0.72 for major towns, -1.05 for Stockholm, -0.63 for southern areas, -0.38 for urban north, 0.01 for rural north and -1.01 for Malmö/Göteborg. She concludes that rural areas seem to be more inelastic than urban areas which agrees with earlier literature (Dahlkvist, 2016).

4. Theoretical Framework & Hypotheses

In this section, the economic theory relevant for our research question and the hypotheses we derive will be described.

4.1 Consumer theory

Consumers are assumed to receive utility from consumption of goods. The consumers are considered to be rational, maximising their utility given their respective preferences and budget constraints. This can be described by a utility function (U), which is dependent on a basket of different goods, x_n. This can be described by Equation (1):

Equation (1). $$U = u(x_1, x_2, \dots, x_n) = u(x)$$

When a rational consumer decides how much of a certain good to buy, there are different factors that their decisions are based on. With preferences and the consumers budget constraint (income) already mentioned, price might be the most important factor left. Intuitively, higher prices will most often result in a decreased consumer demand. This is in economics called *the law of demand* (Perloff, 2014).

The budget constraint represents what the consumer can afford. You can describe the budget constraint with Equation (2):

Equation (2). $$Y = p_1 x_1 + p_2 x_2 + \dots + p_n x_n$$

Y is the consumers income while P_n is the price of the good x_n. The consumers cannot consume more than their income, which means that income restrains consumers from increasing its consumption and therefore reaching a higher utility (U). In other words, the consumer's objective is to maximize their utility, subject to their budget constraint (Perloff, 2014). The consumer problem is shown in Equation (3):

Equation (3). $$\max U(x_1, x_2, \dots, x_n)$$
$$s.t.\ Y = p_1 x_1 + p_2 x_2 + \dots + p_n x_n$$

A price increase of a good in the consumer's basket means that the consumer, if choosing to keep the same type of goods in the basket, will have to reduce their total amount of goods consumed. The consumers could instead choose to change the composition of their basket of goods, buying more of the goods that are cheaper. This willingness to trade a certain good x_1, for another good x_2, is called the marginal rate of substitution (Perloff, 2014). Simply said, it measures the rate at which the consumer is willing to trade x_1 for x_2. This relationship is explained in Equation (4), where U_1 is the utility the consumer gains from the good x_1, while U_2 is the utility gained from good x_2:

Equation (4). $$MRS = -U_1/U_2$$

When a consumer can substitute a certain good for another, the goods are called *substitutes* (Perloff, 2014). In the context of our thesis, the best example for substitute goods are if you are going to use your car or instead use other transports, such as public transports. If the price of gasoline increases considerable under a longer period, you might decide to take the bus e.g., instead of travel by car. This is of course provided that the prices for public transport does not increase, or at least not in the same extent.

4.2 Price elasticities

How a price change of a certain good affects the demand of that good can be explained by the *price elasticities* of demand. Price elasticities are explained by the percentage change in the quantity demanded, in response to a given percentage change in the price (Perloff, 2014). This is shown in Equation (5):

Equation (5). $$\varepsilon = \frac{percent\ change\ in\ quantity\ demand}{percent\ change\ in\ price} = \frac{\frac{\Delta Q}{Q}}{\frac{\Delta P}{P}} = \frac{\delta Q}{\delta P}\frac{P}{Q}$$

Here ε is the price elasticity, *Q* the quantity demanded and *P* the given price. The price elasticity answers the question "How much does the quantity demanded of a product change, in a response to a 1% increase in its price?". That is, if the price goes by 1%, the quantity changes with ε%. In this thesis, it is the quantities and prices of gasoline that are of interest.

The magnitude of the price elasticity decides whether the demand of the good is unitary, elastic or inelastic. The interpretations of these is shown in Equations (6), (7) and (8):

Equation (6): $$\varepsilon = -1 = unitary\ elastic$$

Equation (7): $$\varepsilon < -1 = elastic$$

Equation (8): $$0 > \varepsilon > -1 = inelastic$$

A *unitary* elastic demand implies that if the price increases by 1%, the quantity demanded decreases with -1%. *Elastic* demand implies that if the price increases by 1%, the quantity demanded decreases with more than -1%. If the demand is relatively *inelastic,* it implies that if the price increases with 1%, the demand decreases by less than -1% (Perloff, 2014).

There is also a difference between elasticities in the short and long run, especially in the context of gasoline demand. In the short run, consumers might only be able to choose not to consume as much of a good. Meanwhile, on the long run the consumer has more time to adjust, maybe by finding a substitute good or in some other way (Perloff, 2014). In the context of our thesis, in the short run consumers might be forced to simply drive less to consume less gasoline in case of a price increase. While in the long run they might be able to buy a less thirsty car, change to a diesel car or even to move closer to work. The duration of the short run depends on the scenario, i.e. how long it takes for consumers to adjust their demand for a certain good. In this thesis however, we will not derive short and long run elasticities. We will instead derive *intermediate* run elasticities, which earlier mentioned is something in between a short and a long run elasticity.

We hypothesize that the demand for gasoline in Sweden is relatively inelastic to prices. As mentioned above, this means that a price increase of 1% would imply a demand decrease of less than -1%. This inelastic demand is assumed to exist because of a lack of substitutes and the relatively high income in Sweden. Regarding the difference across regions however, we also expect a certain pattern in the price elasticities, where the more rural regions have more inelastic demand than their more urban counterparts. As mentioned in section 2, the most important factors causing these differences according to us, would be population density, income and availability of substitutes of gasoline. While the more urban areas have a higher population density, this would imply shorter distances to travel and more options of transport modes. This could itself reduce the usage of gasoline. The much higher access to substitutes (e.g. better public transports and better infrastructure) in the more urban areas are also one potential reason for a higher price elasticity.

4.3 Income elasticities

As mentioned before, the consumers income act as a constraint on their consumption. We can measure how the quantity demanded gets affected by an increase in a consumer's income, with the so-called *income elasticity.* Income elasticities are explained as the percentage change in the quantity demanded at a given price, in response to a given percentage change in income (Perloff, 2014). This is explained by Equation (9):

Equation (9).

$$\xi = \frac{percent\ change\ in\ quantity\ demand}{percent\ change\ in\ income} = \frac{\frac{\Delta Q}{Q}}{\frac{\Delta Y}{Y}} = \frac{\delta Q}{\delta Y}\ \frac{Y}{Q}$$

ξ is the income elasticity, Q is once more the quantity demanded and Y stands for income. Income elasticities answers how much does the quantity demanded of a product change, in a response to a 1% change in the consumers income. So, if income increases by 1%, the demand changes by ξ%.

Depending on what value the income elasticities takes for the demand for a certain good, we can define the good as e.g. normal or inferior. The income elasticity of demand for a normal good is positive, which means that if the income increases, the demand also increases. There are also different normal goods. There are necessity goods, which have an income elasticity between 0-1 and there are luxury goods, which have income elasticities ξ>1. As opposite to normal goods, there are the inferior ones. For these, the income elasticities take a value of ξ<0, i.e. negative. This means that for inferior goods, the demand decreases if the consumer's income increases (Perloff, 2014).

As with price elasticities, there are a difference between the short run income elasticities and the long run income elasticities. Though, as earlier mentioned, we will derive intermediate run elasticities, for both price and income elasticities.

The income elasticities' values are equally as hard as the price elasticities to hypothesize. We do however hypothesize that gasoline is a normal, necessity good, with an income elasticity between 0-1. This is based on several studies that have long run estimates around 1 and the short run estimates around one third of the long run. Pyddoke and Swärdh (2015) and Baranzini and Weber (2012) however, finds lower values for their income elasticities.

We expect a pattern of the income elasticities, as with the price elasticities. Though, we now assume a pattern where the regions with higher income have lower income elasticities in absolute values. This hypothesis has it grounds in earlier literature. Pyddoke and Swärdh (2015) e.g. notes that individuals with lower income seems to be more sensitive towards price changes of gasoline. The reason for this is supposedly that gasoline expenses takes up a higher share of the budget for an individual with low income, than what it would to an individual with high income.

5. Data

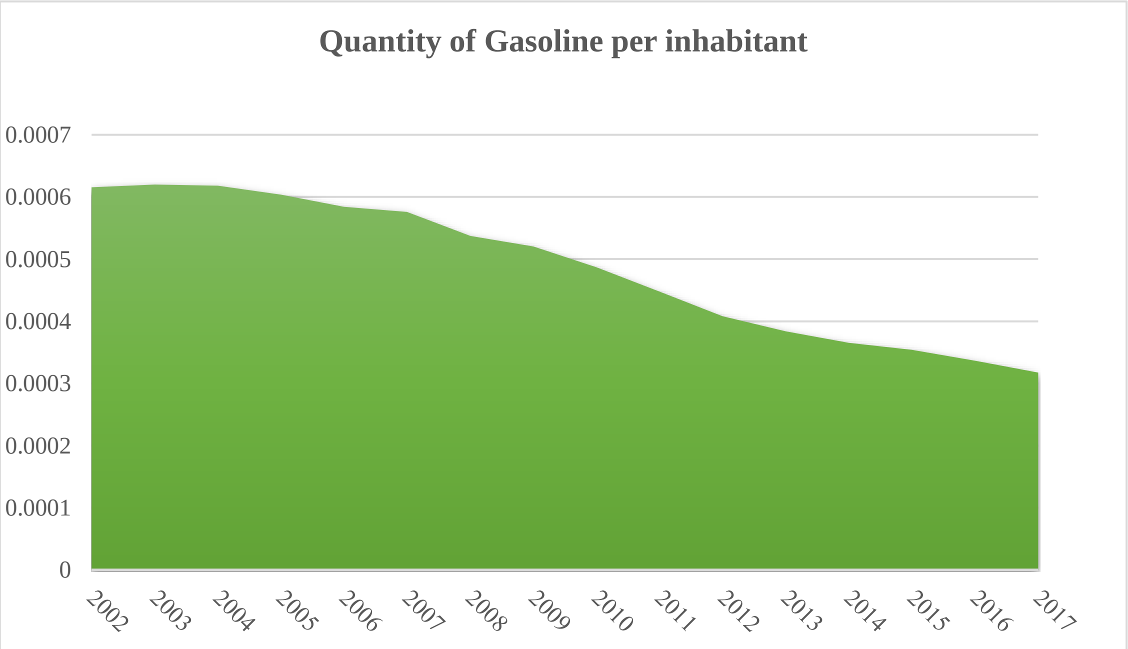
The data that is used in this thesis has been collected from three different sources. Prices come from SPBI (Swedish Petroleum and Biofuel Institute), the GDP-deflator comes from The World Bank and finally, gasoline supplied, income and inhabitants stem from SCB (Statistics Sweden). Ideally, a longer time period would have been studied, but due to limitations in the data, we had to confine to the period 2002-2017. Table 1 (p.16) presents all the summary statistics.

5.1 Dependent Variable – Quantity of Gasoline per Inhabitant

In this thesis, we are interested in the quantity of gasoline supplied to the final consumer, measured in thousands m^3. The data is provided by SCB (2019) and is measured and therefore updated yearly at a regional level in Sweden. One variable that surely affects the quantity of gasoline in a specific region is the number of inhabitants. To remove the population-difference between the regions, the quantity of gasoline supplied is divided by the number of inhabitants in each region. This gives us our dependent variable, quantity of gasoline supplied per inhabitant, denoted by *q*.

Overall, in the period 2002-2017, the gasoline supplied per inhabitant has steadily decreased in Sweden, as one can observe in Graph 1. This trend can also be observed at the regional level, but no region stands out from the pattern observed in Graph 1.

Graph 1: Quantity of gasoline supplied per inhabitant, 1000m^3 - Sweden



Source: SCB (2019)

5.2 Independent Variables

Price and tax

The price data are collected from SPBI (2019) and represent the yearly average price for gasoline in Sweden. It is measured in SEK/litre. SPBI (2019) has divided the price into four different parts; product cost, tax, value added tax and gross margin. Fuel taxes in Sweden is divided into two parts; energy and carbon dioxide tax. Further, there is also a value added tax that is added to the price. This means that there is a total of three taxes that directly influence the gasoline price. We will add SPBI's tax and value added tax together and just call this the tax component.

To get a good measure of demand, we have adjusted these values for inflation to get real values. This is done by dividing the values with a GDP-deflator collected from The World Bank (2019), with the base year 2010. By doing this, we have created the independent price variable, denoted by *p*, and tax variable, denoted by *tax*.

In Graph 2, one can observe the evolution of both real prices and real taxes over time. As you can see, in real value, the tax has been quite steady compared to the price between 2002 and 2017. The total real price has varied from the lowest value of 10.7 SEK in 2003, to the highest value of 14.64 SEK in 2012. At the same time, the tax has stayed between the remained values of 7.48 SEK and 8.18 SEK.

Graph 2: Real prices and taxes in SEK, base year 2010 - Sweden

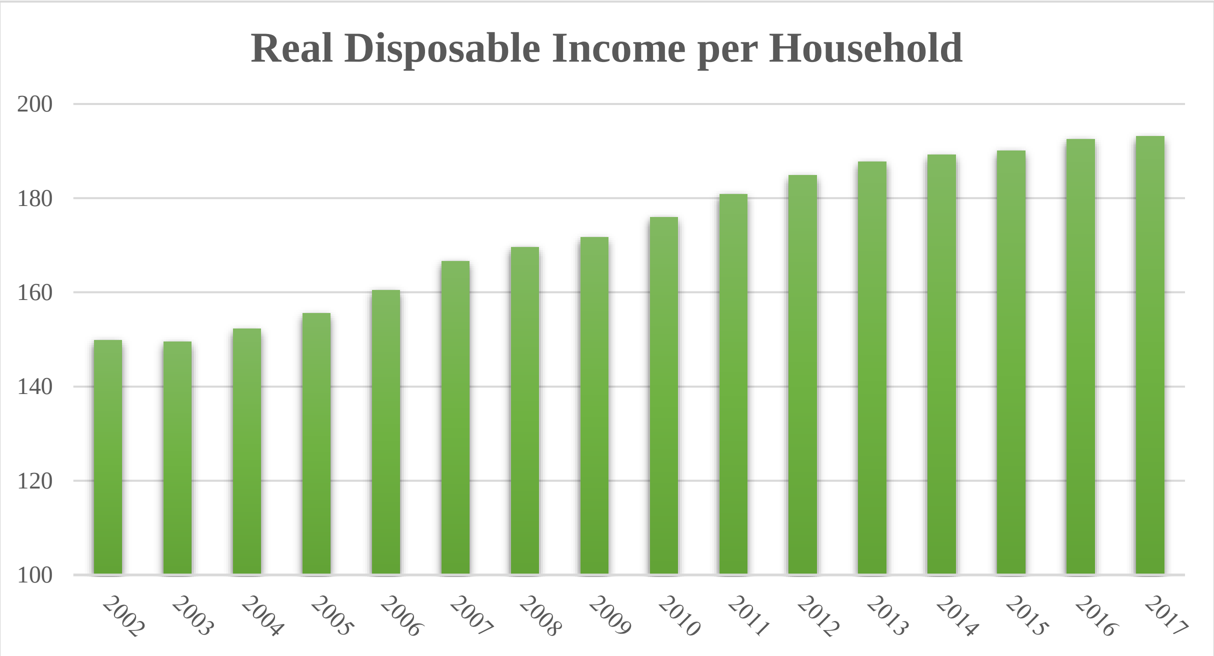
Source: SPBI (2019)

Income

The data for income is collected from SCB and represent the disposable income of households per inhabitant. It is the yearly average income, measured in thousands Swedish crowns. Here we have, as before, divided the values with the GDP-deflator to obtain the real values. This gives us the independent variable income, denoted by *y*.

In Sweden, the real disposable income per household has increased steadily over the years, as can be observed in Graph 3 for the years 2002-2017. Income increased from 150 thousand SEK in the year 2002, to 193 thousand SEK in the year 2017. The time evolution of income for the different regions is similar to the entire country's and no specific region stands out.

Graph 3: Real disposable income per household, in thousands SEK, base year 2010 - Sweden



Source: SCB (2019)

5.3 Descriptive statistics

The summary statistics in Table 1 display that the mean of gasoline supplied per inhabitant ranges between 0.00038 in Stockholm to 0.00062 in Jämtland. The region with the highest variation during the time period is Stockholm, which decreased the gasoline consumption per inhabitant from 0.00051 to 0.00021. This can be compared to Gävleborg which is the region with the lowest variation going from 0.00066 to 0.00042. In percentage, Stockholm is the region with the biggest decrease in their consumption, with 59%. Compared, Gävleborg is the region with the smallest decrease, with 36.4%.

The highest mean of disposable real income per inhabitant is found in Stockholm at 1.9661. The lowest mean is reported in Gotland at 1.587. Halland had the largest income increase going from 1.4988 to 2.012, i.e. an increase by 34 percent. Södermanland has the smallest increase in income during the time, starting at 1.4411 and ends at 1.8064, i.e. about a 25% increase.

Gasoline prices and taxes are the same for all regions in Sweden. While prices are determined on the market, fuel taxes in Sweden is determined on a national level (Law (1994:1776)).

Table 1. Summary stastistics

		Gasoline supplied per inhabitant				Real prices				Real taxes				Real income			
Region	**N**	**mean**	**sd**	**min**	**max**	**mean**	**sd**	**min**	**max**	**mean**	**sd**	**min**	**max**	**mean**	**sd**	**min**	**max**
Stockholm	16	0.000377	0.00011	0.00021	0.00051	0.12628	0.01103	0.10718	0.14649	0.0782	0.0021	0.07478	0.08185	1.96614	0.17268	1.71083	2.18235
Uppsala	16	0.000475	0.00012	0.00031	0.00063	0.12628	0.01103	0.10718	0.14649	0.0782	0.0021	0.07478	0.08185	1.7066	0.14942	1.48726	1.88893
Södermanland	16	0.000536	0.00011	0.00036	0.00068	0.12628	0.01103	0.10718	0.14649	0.0782	0.0021	0.07478	0.08185	1.64402	0.12843	1.44115	1.8064
Östergötland	16	0.000477	9.7E-05	0.00034	0.00061	0.12628	0.01103	0.10718	0.14649	0.0782	0.0021	0.07478	0.08185	1.63685	0.14628	1.41809	1.82474
Jönköping	16	0.000549	0.00011	0.00038	0.00068	0.12628	0.01103	0.10718	0.14649	0.0782	0.0021	0.07478	0.08185	1.64946	0.15724	1.40656	1.85225
Kronoberg	16	0.000543	0.00013	0.00036	0.00071	0.12628	0.01103	0.10718	0.14649	0.0782	0.0021	0.07478	0.08185	1.64979	0.13642	1.42758	1.81557
Kalmar	16	0.000554	0.0001	0.00039	0.00068	0.12628	0.01103	0.10718	0.14649	0.0782	0.0021	0.07478	0.08185	1.60716	0.1529	1.37197	1.79641
Gotlands län	16	0.000601	0.00012	0.00043	0.00075	0.12628	0.01103	0.10718	0.14649	0.0782	0.0021	0.07478	0.08185	1.58699	0.15924	1.34891	1.79723
Blekinge	16	0.00055	9.8E-05	0.0004	0.00068	0.12628	0.01103	0.10718	0.14649	0.0782	0.0021	0.07478	0.08185	1.59017	0.13287	1.3835	1.76947
Skåne	16	0.000474	0.0001	0.00032	0.00059	0.12628	0.01103	0.10718	0.14649	0.0782	0.0021	0.07478	0.08185	1.70616	0.14676	1.48423	1.87976
Halland	16	0.000566	0.00014	0.00038	0.00075	0.12628	0.01103	0.10718	0.14649	0.0782	0.0021	0.07478	0.08185	1.78281	0.18394	1.49879	2.01198
Västra götaland	16	0.000489	0.00012	0.00031	0.00064	0.12628	0.01103	0.10718	0.14649	0.0782	0.0021	0.07478	0.08185	1.7075	0.16242	1.45268	1.91643
Värmland	16	0.00056	0.00012	0.00038	0.00072	0.12628	0.01103	0.10718	0.14649	0.0782	0.0021	0.07478	0.08185	1.61174	0.151	1.37137	1.81438
Örebro	16	0.000498	0.00011	0.00033	0.00064	0.12628	0.01103	0.10718	0.14649	0.0782	0.0021	0.07478	0.08185	1.60219	0.13391	1.39503	1.76972
Västmanland	16	0.000509	9.9E-05	0.00034	0.00064	0.12628	0.01103	0.10718	0.14649	0.0782	0.0021	0.07478	0.08185	1.66413	0.14766	1.44115	1.8503
Dalarna	16	0.000595	0.00012	0.00041	0.00076	0.12628	0.01103	0.10718	0.14649	0.0782	0.0021	0.07478	0.08185	1.62198	0.1496	1.39503	1.82336
Gävleborg	16	0.000554	8.4E-05	0.00042	0.00066	0.12628	0.01103	0.10718	0.14649	0.0782	0.0021	0.07478	0.08185	1.60646	0.13665	1.3835	1.78743
Västernorrland	16	0.000564	0.00012	0.00038	0.0007	0.12628	0.01103	0.10718	0.14649	0.0782	0.0021	0.07478	0.08185	1.62931	0.14571	1.40656	1.81438
Jämtland	16	0.000619	0.00014	0.00041	0.0008	0.12628	0.01103	0.10718	0.14649	0.0782	0.0021	0.07478	0.08185	1.60121	0.14802	1.37197	1.80539
Västerbotten	16	0.000485	9.8E-05	0.00034	0.00062	0.12628	0.01103	0.10718	0.14649	0.0782	0.0021	0.07478	0.08185	1.5896	0.14942	1.34891	1.78743
Norrbotten	16	0.000526	9.3E-05	0.00038	0.00066	0.12628	0.01103	0.10718	0.14649	0.0782	0.0021	0.07478	0.08185	1.65607	0.17087	1.39503	1.88623

6. Methodology

In this section, we will describe and justify the models we have chosen and the econometric approaches we have taken.

6.1 Models

We have chosen static log linear equation models to derive the elasticities. These models are chosen due to their simplicity. There are of course drawbacks of simplicity, one is that static models do not derive both short and long run elasticities. For this, one would need a dynamic model. Instead, static models derive something close to intermediate run elasticities (Dahl & Sterner, 1991). Even if an intermediate run is not optimal to see how elasticities will change over time, it will give us the opportunity to compare the differences in income and price elasticities between the different regions of Sweden. Therefore, the static model will help us understand the potential heterogeneity across regions.

By running an ordinary least squares (OLS) regression with logged variables on both sides, we obtain the elasticities in the coefficients in a straightforward way. The first model, Model (1) is described below.

(1) $$lnq = \beta_0 + \beta_1 lnp + \beta_2 lny + U$$

On the left-hand side, we have the logged value of our dependent variable, quantity of gasoline supplied per inhabitant (*q*). On the right-hand side, we have a constant β_0, our logged values of our independent variables, real price (*p*), real income (*y*) and our unobserved component (*U*). The unobserved component (*U)* contains all the other factors that influence our dependent variable, and that is not included as independent variables in our equation. We are interested in the price elasticity (β_1) and the income elasticity (β_2) of the demand for gasoline.

Model (2) is described below and includes the tax variable.

(2) $$lnq = \beta_0 + \beta_1 lnp + \beta_2 lntax + \beta_3 lny + U$$

On the left-hand side, we again have the logged value of our dependent variable, quantity of gasoline supplied per inhabitant (*q*). On the right-hand side, we have a constant β_0, our logged values of our independent variables, the real price (*p*), the real tax (*tax*), real income (*y*) and finally the unobserved component (*U*). Model (2) will help us disentangle the effect of the price from the effect of the tax on quantities, the price and the tax do not evolve in the same manner over time (refer to Graph 2). $\beta_1$represents price elasticity, β_2 represents the tax elasticity and β_3 represents the income elasticity of demand for gasoline.

To derive the results of an OLS-regression, there are certain assumptions that must be met. After some investigation, we concluded that precautions had to be taken with our variables to avoid violating some OLS-related assumptions.

6.2 Multicollinearity

We have reason to believe that we have a multicollinearity problem in our regression described in Model (2). This will violate the OLS assumption that independent variables should have no linear relationship. In Model (2), we have both the price *p* and the tax. Since prices include the tax, the information on the tax is stored twice, in two different variables. In order to solve this, we create the variable "price without tax". We now use price without tax (*pwt*) and tax (*tax*) as variables instead. This will give us a better estimation on how the variables affect the quantity.

This leads to the Model (3) described below with the same notations as before.

$$(3) \qquad lnq = \beta_0 + \beta_1 lnpwt + \beta_2 lntax + \beta_3 lny + U$$

6.3 Stationarity

Since we run regressions for each region, our data is in a time series format. A basic assumption about time series data is that it needs to be stationary. Time series are often non-stationary. It is indeed often the case that series, such as income, have a linear or exponential time trend. This will cause the mean, variance and autocorrelation to change over time. To control that our variables are stationary, we use the augmented Dickey-Fuller (ADF) test. But, before the ADF test can be run, we need to choose which lags to include in the test. A lag is a past value of the variable in question and is used to take historical factors that may cause present differences in the endogenous variable, into account (Mehmetoglu & Jakobsen, 2016). According to Wooldridge (2012), there are no hard rules to follow when choosing lags for the ADF test. When using annual data one or two lags should suffice, Woolridge (2012) states. For every lag you include, one observation is lost.

Complementary to Wooldridge's (2012) notion to use one or two lags when using annual data, we have used the STATA command *varsoc*. This gives us information on which optimal lag orders to put in the ADF test (STATA, 2019).

When the ADF test does not reject the null hypothesis that our series is non-stationary, which we will often observe in our results, we differentiate our non-stationary variables and run the ADF test again. When the test rejects the null hypothesis of non-stationarity, then we keep the level of differentiation and use it for our regressions. Differentiating allows us to remove the time trends or large variability, at the expense of the loss of one observation. In some cases, a second differentiation was needed, which means two observations were lost. More information about the ADF-tests can be found in Appendix, where the steps of differentiation is shown.

Model-wise, this means that we now have the differentiated version of some variables, which leads to new versions of both Model (1) and Model (3):

(1) $$lnq = \beta_0 + \beta_1 d_i lnp + \beta_2 d_i lny + U$$

(3) $$lnq = \beta_0 + \beta_1 d_i lnpwt + \beta_2 d_i lntax + \beta_3 d_i lny + U$$

Where d means differentiation and i gives the level of differentiation. The furthest differentiation that was made were to the second stage, which means that *i* only takes the value of 0, 1 or 2. All the ADF results with lag orders and chosen differentiations are shown in Table 2.

Models (1) and (3) will be performed for each of our 21 regions. The results will then be compared, and we will see if there is heterogeneity between the different regions.

6.4 Pooled Time Series Data

Because of the small number of observations that we have, pooling our time series data might give better results due to an increased number of observations. The cost of pooling our time series data is that now, we do not check elasticities for each region, but for groups of regions.

The formation of the groups is based on population density. This is heavily influenced by the rural vs urban aspect of regions. We mean that the higher the population density, the more urban the regions are and the lower the population density, the more rural the regions are. The 6 groups we constructed are illustrated in Table 3. The same models, (1) and (3), that were used for each region are applied to the 6 groups of regions.

One problem arose when grouping the regions together. Some regions had the same variables, stationary at *different* stages of differentiations. This meant that we had to differentiate the variables to the same stage, as to get homogenized results. In order to do this, we looked at the region in each group with the highest differentiation stage of the variable and converted the other regions' variables to the same stage. When this was done, we verified that all variables were still stationary. In Table 4, the different differentiation stages of each variable for each group are showed.

Table 2. Results of ADF tests.

Results ADF															
	lnq			lny			lnp			lntax			lnpwt		
Region	**Diff**	**Stationary**	**Lags**	**Diff**	**Stationary**	**Lags**	**Diff**	**Stationary**	**Lags**	**Diff**	**Stationary**	**Lags**	**Diff**	**Stationary**	**Lags**
Stockholm	1st	5%	0	1st	10%	0	1st	10%	0	0	5%	1	2nd	1%	0
Uppsala	0	1%	1	2nd	-	3	1st	10%	0	0	5%	1	2nd	1%	0
Södermanland	0	5%	0	2nd	5%	3	1st	10%	0	0	5%	1	2nd	1%	0
Östergötland	0	10%	1	2nd	10%	2	1st	10%	0	0	5%	1	2nd	1%	0
Jönköping	1st	1%	0	1st	10%	0	1st	10%	0	0	5%	1	2nd	1%	0
Kronoberg	1st	1%	0	2nd	10%	3	1st	10%	0	0	5%	1	2nd	1%	0
Kalmar	1st	1%	0	2nd	1%	0	1st	10%	0	0	5%	1	2nd	1%	0
Gotland	1st	1%	0	2nd	-	2	1st	10%	0	0	5%	1	2nd	1%	0
Blekinge	1st	1%	0	1st	1%	0	1st	10%	0	0	5%	1	2nd	1%	0
Skåne	1st	5%	0	2nd	-	0	1st	10%	0	0	5%	1	2nd	1%	0
Halland	1st	1%	0	2nd	5%	2	1st	10%	0	0	5%	1	2nd	1%	0
Västra Götaland	2nd	-	2	1st	10%	0	1st	10%	0	0	5%	1	2nd	1%	0
Värmland	1st	1%	0	2nd	1%	0	1st	10%	0	0	5%	1	2nd	1%	0
Örebro	1st	10%	0	1st	1%	0	1st	10%	0	0	5%	1	2nd	1%	0
Västmanland	1st	1%	0	2nd	1%	0	1st	10%	0	0	5%	1	2nd	1%	0
Dalarna	1st	1%	0	2nd	5%	0	1st	10%	0	0	5%	1	2nd	1%	0
Gävleborg	1st	1%	0	2nd	1%	0	1st	10%	0	0	5%	1	2nd	1%	0
Västernorrland	2nd	10%	1	1st	10%	0	1st	10%	0	0	5%	1	2nd	1%	0
Jämtland	0	5%	2	1st	5%	1	1st	10%	0	0	5%	1	2nd	1%	0
Västerbotten	0	10%	0	1st	10%	0	1st	10%	0	0	5%	1	2nd	1%	0
Norrbotten	1st	1%	0	2nd	-	3	1st	10%	0	0	5%	1	2nd	1%	0

Table 3. Population density.

	Inhabitants/km^2	Group
Stockholm	353	1
Skåne	122	1
Västa götaland	71	1
Halland	60	2
Blekinge	54	2
Västmanland	53	2
Södermanland	58	2
Uppsala	45	3
Östergötland	43	3
Örebro	35	3
Jönköping	34	3
Kronoberg	23	4
Kalmar	22	4
Gotland	19	4
Gävleborg	16	5
Värmland	16	5
Västernorrland	11	5
Dalarna	10	5
Västerbotten	5	6
Jämtland	3	6
Norrbotten	3	6

Table 4. Differentiations of each group.

Group	Differentiering				
	lnq	lny	lntax	lnp	lnpwt
Stockholn	2	2	0	1	2
Skåne	2	2	0	1	2
Västa göta	2	2	0	1	2
Halland	1	2	0	1	2
Blekinge	1	2	0	1	2
Västmanla	1	2	0	1	2
Södermar	1	2	0	1	2
Uppsala	1	2	0	1	2
Östergötla	1	2	0	1	2
Örebro	1	2	0	1	2
Jönköping	1	2	0	1	2
Kronober	1	2	0	1	2
Kalmar	1	2	0	1	2
Gotland	1	2	0	1	2
Gävlebor	2	2	0	1	2
Värmland	2	2	0	1	2
Västernor	2	2	0	1	2
Dalarna	2	2	0	1	2
Västerbot	1	2	0	1	2
Jämtland	1	2	0	1	2
Norrbotte	1	2	0	1	2

7. Results and discussion

*7.*1 *Model (1)*

The results of Model (1) for each region are shown in Table 5. The price elasticities are as explained before, the coefficient β_1, while the income elasticities are the coefficient β_2. Most of our results are not significant, which may be because regions are to small subjects to study, or simply because we have got too few observations.

Table 5. Estimated elasticites - Model 1.

Elasticities - Model 1		
Region	**Price elasticity**	**Income elasticity**
Stockholm	0.002584	-0.9913629
Uppsala	1.041702	9.562373
Södermanland	0.7748551	0.476398
Östergötland	0.8351482*	8.031755
Jönköping	-0.1467519	-0.0708345
Kronoberg	0.1912416	-0.755609
Kalmar	-0.0561964	-0.0396488
Gotland	-0.5070495	-0.2861385
Blekinge	-0.7407742**	2.325772***
Skåne	-0.3459789**	2.604584**
Halland	-0.0037245	-1.17155
Västra Götaland	-0.1272212	0.2327262
Värmland	-0.2438915*	0.0222004
Örebro	-0.11985	1.147617**
Västmanland	0.0175092	-3.376763***
Dalarna	0.0817219	0.2943194
Gävleborg	0.0454181	0.0079265
Västernorrland	0.0606878	-0.0432455
Jämtland	5.505792	2.76962
Västerbotten	0.3288413	8.32108
Norrbotten	-0.5192107**	1.50649

*** p<0.01
** p<0.05
* p<0.1

Expected results were that price elasticities would have negative signs and that income elasticities would have positive signs. This model gave us 11 (out of 21) regions with the opposite of the expected sign on price elasticities, which is more than half of our regions. It also gave us 8 regions with the opposite of the expected sign on income elasticities.

At first, we thought that the few regions with variables that never became stationary, i.e. the variables *lnq* or *lny*, possibly could give us counterintuitive results. Shown in Table 5, there were also counterintuitive results for regions that had all the variables stationary though.

Our expectations were also that the more rural regions would have lower price elasticities in absolute value, while the more urban regions would have higher price elasticities. This would be due to e.g. better public transport and a higher population density in urban regions. Following these expectations, the region of Norrbotten, which had a population density of 3 inhabitants/km^2 in the year of 2017, would have one of the lowest price elasticities. This is while the region of

Stockholm, which had a population density of 353 inhabitants/km^2 would have one of the highest price elasticities. As seen in Table 5, this pattern cannot be observed.

With the price elasticities ranging from -0.7407742 in Blekinge to 5.505792 in Jämtland, these results indicate that a price change could have either a positive or negative effect on gasoline demand. The results also indicate that there would be big differences between regions. A total of 11 regions goes against our assumption that gasoline demand would decrease when the price increases.

Magnitude-wise, some price elasticities stand out. Not only did we get some regions with unexpected signs of elasticities, but for Jämtland we even obtained a price elasticity as large as 5.505792. Every region that has the expected negative sign, are found to have an elasticity with a magnitude that is closer to earlier studies.

Our expectations about the income elasticities were that the higher the region's income, the lower in absolute value the income elasticity would be. This pattern is not observable either, which can be seen if compared to the summary statistics in Table 1.

The income elasticities stretch from -3.376763 in Västmanland, to 9.562373 in Uppsala. These results indicate that an income change could have either a positive or negative effect on the quantity of gasoline demanded. As well as the price elasticities, these results indicate huge differences between regions, with 8 of them going against our normal good assumption.

With earlier studies reporting long run income elasticities around 1 and short run around a third of the long run, our results are hard to grasp. There is only a handful of regions reporting an income elasticity close to this magnitude.

7.*2 *Model (3)

This time we used Model (3), which meant we removed the variable *p* and instead included the variables *tax* and *pwt.* Table 6 shows the results of Model (3) on each region.

The price elasticity, which now is calculated with *pwt* instead of *p*, gave us fewer regions with positive signs. Remember that negative price elasticities were expected. This time, there were 8 regions that had positive price elasticities, instead of Model (1)'s 11 regions. This is in terms of our expectations, better results. But 8 regions with positive signs still seems like a problem.

The price elasticities stretch from -0.6067756 in Gotland, to 0.3091678 in Kronoberg. As with Model (1), we get both positive and negative price elasticities. Both models now show that price could have either a positive or negative effect on gasoline demand.

Our expectations regarding the degree of urbanism are not confirmed by this model either. A pattern where the more rural regions have lower price elasticities is not observable. The magnitude of the price elasticities has changed though. With Model (3) implemented, the magnitude of elasticities has decreased, which can be considered as a progress. We now have no region that stands out, as we had with Model (1). This may be due to the variable *pwt*, which is described earlier.

We also still obtain 8 regions with a negative sign on the income elasticity, which goes against our expectations. The expected pattern that regions with higher income would have lower income elasticities, cannot be observed with Model (3) either.

The income elasticities now stretch from -2.54083 in Västmanland, to 16.04312 in Uppsala. As with Model (1), Model (3) also implies that an income change could have either a positive or negative effect on gasoline demand. The magnitude of the income elasticities is particularly large even with Model (3). With Uppsala as the region that stands out the most with an estimate of 16.04312, many of the results depart strongly from earlier studies.

The biggest change from Model (1) to (3) though, is the inclusion of the new variable *lntax*. The estimated coefficient for this variable is called tax elasticity, which would explain how gasoline demand respond to a tax change on gasoline. This elasticity has the expected sign on all, except 3 regions. The lowest tax elasticity is -5.141532, found in Uppsala, and the highest 0.5354161 is found in Jönköping. These results indicate that a tax increase has a negative effect on the gasoline demand.

It is hard to say what magnitude we expected on the tax elasticities, given the lack of literature on this concept. Due to the correlation between tax and price, and the fact that tax regularly is included in the price, our initial thought was that the tax elasticities would be a lower version of the price elasticity. This is not what is observed in the results though. The tax elasticities became much larger than the price elasticities. This might imply that the tax has a stronger effect on the gasoline demand than what the price without tax has.

Both Models (1) and (3) gave us contradictory results, to both our expectations and earlier studies. This makes it hard to say if Model (1) or Model (3) is better. Model (3) gives steady expected signs on tax elasticities and fewer positive signs on price elasticities though.

Table 6. Estimated elasticites - Model 3.

Elasticities - Model 3			
Region	**Income elasticity**	**Tax elasticity**	**Price elasticity**
Stockholm	0.0816453	-2.346097**	0.2243475**
Uppsala	16.04312**	-5.141532**	-0.1970074
Södermanland	1.71098	-4.349394	-0.0015529
Östergötland	-2.499722	-2.499722	0.0997871
Jönköping	-0.3300677	0.5354161	-0.196339**
Kronoberg	-2.173745**	-1.152625*	0.3091678**
Kalmar	-0.2157386	-0.3805515	-0.0224812
Gotland	-1.498875	0.0290468	-0.6067756
Blekinge	0.6152392	-0.3690684	-0.2333655***
Skåne	1.666132	-0.5408015	-0.0865576
Halland	-1.164026	-0.3538413	0.0106351
Västra Götaland	-0.1023808	0.4607007*	-0.1108302***
Värmland	0.422727	-0.8597898	-0.1246954
Örebro	0.5650455	-0.6875701***	0.0104612
Västmanland	-2.54083**	-0.2740908	-0.1042736
Dalarna	0.0817219	-0.810582**	-0.1257407*
Gävleborg	0.1319643	-0.1607166	0.0013814
Västernorrland	0.1563135	-0.0660199	0.0497372
Jämtland	5.505792	-4.365875	0.174873
Västerbotten	8.737743*	-3.768944*	-0.048872
Norrbotten	2.147552***	-0.7483606**	-0.2184947***

*** p<0.01
** p<0.05
* p<0.1

*7.*3 ***Model (1) – Groups***

Model (1), with the variables *p* and *y*, was now implemented on the groups mentioned in Section 6.4. The results are shown in Table 7.

With our data set now being pooled time series data, the results changed. The price elasticity estimates all became as expected, negative. Already, these results fit in better with both earlier literature and our assumptions. With the highest (in absolute value) price elasticity being -0.3461439 in Group 1 and the lowest being -0.0016796 in Group 4, these results fit in quite good with earlier literature in *other* countries. However, Dahlkvist (2016) seems to be one of the few reporting intermediate run elasticities of gasoline in Sweden. As stated in section 4.4, she reports an average intermediate run price elasticity in Sweden of -0.63. Compared to this value, our numbers are lower.

When looking for our expected pattern of lower (in absolute values) price elasticities in more rural areas, our expectations are not all fulfilled. The groups are as mentioned in section 7.4, characterized by their population density. The higher population density, the more of an urban region it would be according to us. This implies that Group 1 would have the highest price elasticity, while the elasticity would get lower and lower the further down the list. The pattern holds until Group 4, with Group 5 having almost as high an estimate as Group 1.

Table 7. Estimated elasticites - Model 1 - Groups.

	Elasticities - Model 1 - Groups	
	Income elasticity	**Price elasticity**
Group 1 (Stockholm, Västra götaland, Skåne)	0.11914	-0.3461439**
Group 2 (Blekinge, Halland, Västmanland, Södermanland)	-0.8409661**	-0.0737853
Group 3 (Örebro, Jönköping, Östergötland, Uppsala)	0.6248687*	-0.0332402
Group 4 (Kronoberg, Gotland, Kalmar)	-0.1979684	-0.0016796
Group 5 (Dalarna, Värmland, Gävleborg, Västernorrland)	0.8197569	-0.3227058**
Group 6 (Norrbotten, Jämtland, Västerbotten)	0.6737366**	-0.116183

*** p<0.01
** p<0.05
* p<0.1

While the price elasticity now seemed to give more expected results, the income elasticity is still negative for some groups. This time there are two out of the six groups. With Group 2 having the lowest income elasticity of -0.8409661, Group 5 has the highest at 0.8197569. When looking at the groups with the expected positive signs, we can see that their value is more in line with earlier studies. Recall that long run income elasticities are estimated to be around 1, while the short run elasticities are usually a third of the long run. These results, excluding the negative estimates for Group 2 and 4, are right in that area.

The expectation of lower income elasticities in regions with higher income is hard to trace when having grouped the regions together. This is due to the grouping being made by their population density. To get a clearer picture of the income’s effect on the elasticities, the groups could be sorted by income.

The results derived with Model (1) on our groups seems more justifiable than the results derived from implementing both models on each region, at least when checking with earlier literature. The lack of the expected pattern of more rural areas having higher price elasticities, is still there though.

*7.*4 *Model (3) – Groups*

Table 8 shows the results of Model (3) for the different groups. Recall that Model (3) includes the variables *pwt* and *tax*, instead of the variable *p.*

The price elasticities, which refer to the variable *pwt* instead of *p*, are all with the expected negative sign. The lowest price elasticity is found in Group 3, with -0.0126448 and the highest is found in Group 5, with -0.161306. These results, as with Model (1) on groups, fit better with earlier literature in *other* countries than when the models were implemented on each region. These estimates are even smaller than with Model (1) though, which already had quite low estimates for being intermediate run elasticities. As before, the pattern of lower price elasticities in more rural regions is not found.

The income elasticities are different, but there are still two regions that have unexpected negative signs. This time it is Group 1 and 2, instead of Group 2 and 4 as with Model (1). Group 2 reports the lowest income elasticity at -0.7106874 and Group 5 reports the highest one at 0.9894844. Except for the two negative income elasticities, these estimated values are also in the expected area according to earlier studies. Note that all regions have different estimates with Model (3) than they had with Model (1).

As with Model (1), the pattern of lower income elasticity with higher income, is hard to trace when having grouped the regions. Recall our notation from section 8.3, that the groups would be needed to be sorted by income instead of population density to be able to see this pattern.

Table 8. Estimated elasticites - Model 3 - Groups.

	Elasticities - Model 3 - Groups		
	Income elasticity	**Tax elasticity**	**Price elasticity**
Group 1 (Stockholm, Västra götaland, Skåne)	-0.2273376	-0.237981	-0.0801511
Group 2 (Blekinge, Halland, Västmanland, Södermanland)	-0.7106874**	-0.4588179*	-0.0702937**
Group 3 (Örebro, Jönköping, Östergötland, Uppsala)	0.5118527	-0.2686416	-0.0126448
Group 4 (Kronoberg, Gotland, Kalmar)	0.0362138	-0.2559053	-0.1528992
Group 5 (Dalarna, Värmland, Gävleborg, Västernorrland)	0.9894844**	-0.0872338	-0.161306***
Group 6 (Norrbotten, Jämtland, Västerbotten)	0.6866843**	-0.2650658	-0.0518564

*** p<0.01
** p<0.05
* p<0.1

The tax elasticities when estimated for groups, continued to be consistent with our expectations, i.e., negative signs. The lowest tax elasticity is -0.0872338 in Group 5, while the highest is found to be -0.4588179 in Group 2. These tax elasticities are not as high as when estimated for each region. Instead, these elasticities are quite close to expected values, if we look at the tax elasticity as a part of the total price elasticity.

It is worth noting that, with both regions and groups of regions, the tax elasticity is higher than the price elasticity. This implies, as noted in section 8.2, a strong negative relationship between the tax and quantity of gasoline.

When the regions are grouped together, the models are still hard to compare. The expected patterns are not observable with either models, which would imply that they do not exist. With both models, the results show price and income elasticities that are in line with earlier studies.

7.*5 *Further discussion

Many of our results are counterintuitive, both against our hypotheses and earlier literature. Following will be a discussion of things that could have been made different, which might have given us more intuitive results.

One thing that Dahlkvist (2016) does different from us, is that she uses expenditure data for income, where we instead use disposable income. According to Dahlkvist (2016), the expenditure data is a better predictor for consumption than what annual income is. This is intuitive, as income might be saved or invested.

We have also divided the quantity of gasoline supplied with inhabitants. A more fitting denominator instead of inhabitants might be *drivers*. This would give quantity of gasoline supplied per *driver*, instead of per inhabitant. We also use annual data for the quantity of gasoline, which only gave us 16 observations for each region. More observed years, or even monthly data, to get more observations might be to prefer.[1]

Following this thread, more information about household characteristics might be good to include in the models when deriving elasticities. Both Nicol (2003) and Eliasson, Pyddoke & Swärdh (2016) finds big differences in gasoline elasticities between different household characteristics. In our models, the only household factor that is shown is their income. Most likely, characteristics like e.g. number of children, number of cars per household and number of drivers per household, would have been relevant variables to include in our models.

[1] We contacted SCB to see if there was monthly data available for the quantity of gasoline supplied in each region, but they answered that they did not collect this data on a monthly basis.

8. Conclusions

In this thesis we tried to find the intermediate run elasticities of gasoline in each region of Sweden. We also attempted to find the elasticities for groups of regions in Sweden. This was made by running OLS-regressions with two different models.

When estimating the elasticities for each region with either model, it is hard to find any specific patterns. Both the price and income elasticity estimates became counterintuitive for many of the regions. This meant that when using regions, none of the hypotheses could be confirmed. The most intuitive results were the tax elasticities derived with Model (3). These were almost exclusively negative.

When using groups of regions, the results became more intuitive. The price elasticities all became negative, all in a range that are acceptable according to earlier literature. This meant that one of our hypotheses about the price elasticities could be confirmed. The expected pattern of more rural areas having lower price elasticities were not observed, which meant that this hypothesis was not confirmed.

The income elasticities also became more intuitive when using groups instead of regions. However, there were still two of six groups still being counterintuitive with both models. This meant our hypothesis about positive income elasticities was not confirmed. The ones that are with the expected signs are though in an acceptable range according to earlier literature. The expected pattern of regions with higher income having a lower income elasticity were not found, which meant that this hypothesis could not be confirmed either.

We ask for more studies on the gasoline demand in the different regions of Sweden, due to this being such a current topic. With the current debate about whether gasoline usage should be decreased by an increased price, the expected effects and implications must be studied.

9. Appendix

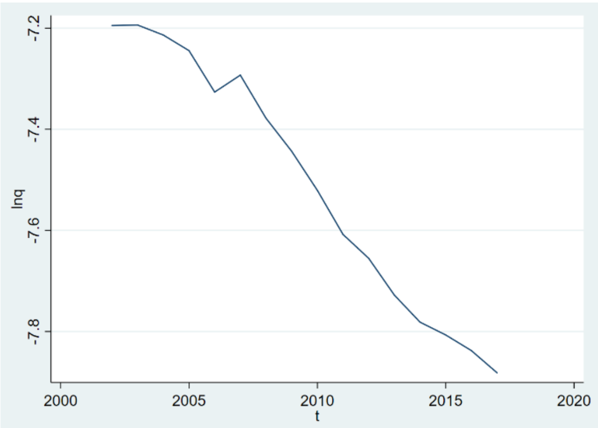
Stationarity and ADF-test

To test if our variables for the regions are stationary, we used the ADF-test as mentioned in Section 6.3. Here we will more elaborately show the results when the variables became stationary by being differentiated. To do this we will show the steps taken for one region, Halland.

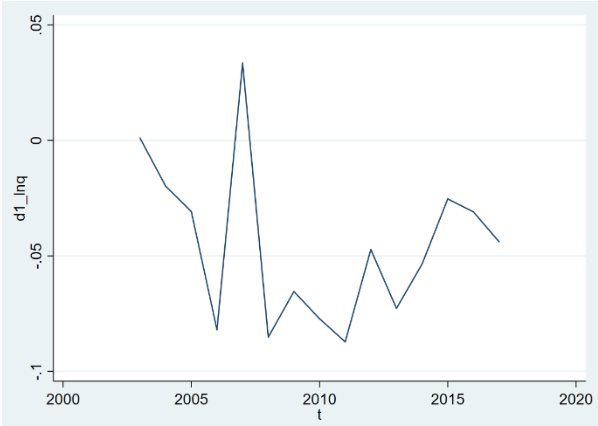
As we can see in Graph 4, there is a clear negative time trend in the logged quantity of gasoline, *lnq* in Halland. This trend will show a false correlation between our dependent variable *lnq* and our independent variables. The ADF-test requires trends to be acknowledged when running the test, this is done by including *trend* in the STATA-command. When running the test, if the null hypothesis that states that the variable is non-stationary gets rejected, we can conclude that the variable is stationary. If the null hypothesis cannot be rejected, we are not able to exclude that the variable is non-stationary. This is also explained in section 6.3.

With variables that we could not reject the null hypothesis, differentiation was needed. In Graph 5, the same variable *lnq* for Halland that is shown in Graph 4, is shown at its first differentiation stage. The negative trend that can be seen in Graph 4 is not present in Graph 5.

Graph 4. Trend of lnq for the region Halland.



Graph 5. First level of differentiation of lnq.



When running the ADF-test on the first level of differentiation of *lnq*, we would now not include the *trend*-option. The ADF-test now gave us a p-value below 0.05, which meant we were able to reject the null hypothesis of a non-stationary variable. These steps were as mentioned earlier, taken for all the variables to rule out the problems of non-stationarity.

10. References

Aklilu, AZ. 2016. Gasoline and diesel demand elasticities: A consistent estimate across the EU-28. Working Paper Series 2016:12, Swedish University of Agricultural Sciences.

Baranzini, A., Weber, S. 2012. Elasticities of Gasoline Demand in Switzerland. *Energy Policy*, 63, pp. 674-680.

Blow, L., Crawford, I. 1997. The distributional effects of taxes on private motoring. Commentary No. 65. London:*The Institute for Fiscal Studies*

Bureau, B. 2011. Distributional effects of a carbon tax on car fuels in France. *Energy Economics*, 33(1), pp. 121-130.

Dahl CA., Sterner T. 1991. Analyzing gasoline demand elasticities: a survey. *Energy Economics*, 13, pp. 203–210.

Dahlkvist, E. 2016. *Elasticity of demand for gasoline in Sweden*. Bachelor thesis, Swedish University of Agricultural Sciences.

Eliasson, J., Pyddoke, R., Swärdh, J.-E., et al. 2016. Distributional effects of taxes on car fuel, use, ownership and purchases. Tech. rep., *CTS-Centre for Transport Studies Stockholm* (KTH and VTI).

Graham, D., Glaister, S. 2002. The demand for automobile fuel: a survey of elasticities. *Journal of Transport Economics and Policy*, 36(1), pp. 1–26.

Hughes, J., Knittel, C., & Sperling, D. 2008. Evidence of a shift in the short-run price elasticity of gasoline demand. *The Energy Journal, International Association for Energy Economics*, 29(1), pp. 113-134.

Mehmetoglu, M., Jakobsen, T.G. 2016. *Applied statistics using stata - a guide for the social sciences*. Sage Publications Ltd.

Larsson, M., Sandin G. 2018. Effekter av en skattehöjning på bensin och diesel. *Ekonomisk Debatt*, 46(2), pp. 28–39.

Nicol, C. 2003. "Elasticities of demand for gasoline in Canada and the United States", *Energy Economics*, 25, pp. 201-214.

Perloff, Jeffrey M. 2014. *Microeconomics with calculus*. Fourth edition, Global edition. Boston: Pearson.

Pyddoke, R., Swärdh, J.E., 2015. Differences in the Effects of Fuel Price and Income on Private Car Use in Sweden 1999-2008. CTS Working Paper 2015:1. *Centre for Transport Studies*, Stockholm.

Sterner, T. 2012. Distributional effects of taxing transport fuel. *Energy Policy*, 41, pp. 75-83.

Sterner, T. 2007. Fuel taxes: an important instrument for climate policy. *Energy Policy,* 35, pp. 3194–3202.

Wooldridge, Jeffrey M. 2012. *Introductory econometrics: a modern approach*. 6th ed. Boston: Cengage Learning.

11. Data References

Ekonomifakta, 2018. *Greenhouse gas*
Available at: https://www.ekonomifakta.se/Fakta/Miljo/Utslapp-i-Sverige/Vaxthusgaser/, [2019-05-23]

Region Skåne, 2019. *Public transport*
Available at: https://www.skane.se/organisation-politik/Vart-uppdrag-inom-kollektivtrafik/[2019-05-07]

State institute for communication analysis, 2008. *Acceptable distribution effects of increased fuel tax?*
Available at: https://www.trafa.se/globalassets/sika/sika-rapport/sr_2008_11_lowres.pdf, [2019-05-03]

StataCorp LLC, 2019. *Manual varsoc*.
Available at: https://www.stata.com/manuals13/tsvarsoc.pdf [2019-04-30]

Statistics of Sweden, 2019.*Oil deliveries – presented by municipalities*
Available at: https://www.scb.se/hitta-statistik/statistik-efter-amne/energi/tillforsel-och-anvandning-av-energi/oljeleveranser--kommunvis-redovisning/, [2019-04-24]

Statistics of Sweden, 2019. *Disposable income of households by region.*
Available at:
http://www.statistikdatabasen.scb.se/pxweb/en/ssd/START__NR__NR0105__NR0105A/NR0105ENS2010T02A/?rxid=f6409081-a6ac-4ff3-bd99-a1eccdeb4f2a, [2019-04-24]

Statistics of Sweden, 2019. *Population density per sq. km, population and land area by region*
Available at:
http://www.statistikdatabasen.scb.se/pxweb/en/ssd/START__BE__BE0101__BE0101C/BefArealTathetKon/?rxid=84810b56-684c-46fc-bca0-0ade02d4c8fd[2019-04-24]

Sveriges Riksdag, 2019. *Law (1994:1776).*
Available at: https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/lag-19941776-om-skatt-pa-energi_sfs-1994-1776 [2019-05-13]

Swedish petroleum and biofuels institute, 2019. *Sales price at pump of gasoline in Sweden*.
Available at: https://spbi.se/statistik/priser/bensin/ [2019-04-24]

Swedish Association of Local Authorities and Regions, 2019. *Municipalities and region*
Available at: https://skl.se/tjanster/englishpages/municipalitiesandregions.1088.html [2019-05-09]

The World Bank, 2019. *GDP deflator*
Available at:
https://data.worldbank.org/indicator/NY.GDP.DEFL.ZS?end=2017&locations=SE&start=2002 [2019-04-24]

Västra götalandsregionen, 2019. *Public transport*
Available at: https://www.vgregion.se/kollektivtrafik/vasttrafik--en-del-av-vastra-gotalandsregionen/ [2019-05-07]