Geographical distribution of the Swedish gasoline tax

A panel estimation of price elasticities and consumer surplus loss using cointegration techniques

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Abstract

This study examines if inhabitants of different municipalities in Sweden are more harshly affected given an increase in gasoline tax. This is done by examining the demand elasticities and consumer surplus loss using a panel Error Correction Model. The results show that inhabitants of rural municipalities are more unresponsive and lose out more consumer surplus from a hypothetical increase in the tax. The loss is however so small that the tax can be considered basically proportional. The policy implication is that compensation for the benefit of rural inhabitants is unmotivated.

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1. Introduction

One of the greatest challenges of this generation is the question of how to tackle global climate change. Many different tools have been proposed and criticized for their effectiveness and harming side effects. This thesis aims to explore one the side effects of a common emissions curbing tool. The geographical burden on consumers from the Swedish carbon tax on gasoline.

The question is interesting from three interconnected point of views. The first perspective is to evaluate if the Swedish carbon tax is politically and popularly sustainable, based on just gasoline consumption. The second perspective is from that of the Swedish countryside, which have seen a wedge driven between them and the cities in terms of economic ability, demographics and average income. The third point of view is from the French protest movement "Les gilets jaunes" who in 2018 started protesting against the increase in fuel taxation and the perceived wedge driven between the rural inhabitants and the urban elite (https://www.theguardian.com/world/2018/nov/16/gilet-jaunes-yellow-jackets-protesters-france-standstill, 2020). These problems form the basis for why this topic is interesting and why it needs to be investigated.

The main question is "What are the regional distribution effects of the carbon tax on gasoline?" Sub questions relating to this is if different areas of Sweden display different gasoline price elasticities compared to each other and how this affects consumer surplus.

The restrictions made in this thesis concern mainly the fuel that is being investigated. Gasoline is the only fuel considered as it makes up big part of the transportation fuels in Sweden. In addition, gasoline is the main fuel of study in most of the previous empirical research. To enhance comparability between this thesis and previous research and to narrow down the focus, gasoline is the fuel of main interest.

The study is carried out by using panel data on municipality level for the income and quantity of gasoline consumed as well as the price of fuel. Price elasticities are estimated and compared with the other regions and to previous studies using a cointegration approach. The price- and income elasticities form the basis of, if and how much, each region is disproportionally affected in their expenditure on gasoline and how this translate into real terms of consumer surplus change given a tax increase. Income elasticities are estimated as it is something included in previous research which enhances comparability.

The main findings of this thesis are that rural municipalities are more harshly affected than urban municipalities even though the price elasticities do not differ. This is due to the already high consumption of fuels for rural municipalities. The harsher effect is however small in absolute monetary terms and when compared to the greatest and lowest change in consumer surplus. The conclusion is therefore that the tax can be seen as basically proportional. Based on this conclusion, policies aimed at alleviating the effects of the carbon tax is not well founded and may be better spent elsewhere.

The thesis has the following disposition: This first section introducing the subject is followed by the second section which discusses discuss theory and why we would believe that rural municipalities have a different response to price changes than their urban counterparts. The third section summarizes previous research from international and national research on differing price elasticities as well as to how put it into a broader perspective. The fourth section covers the data being used. The fifth section covers the methods used and the assumptions made. The sixth section goes through the results and is followed by a discussion of the results in the seventh section and a conclusion in the eight section.

2. Theory

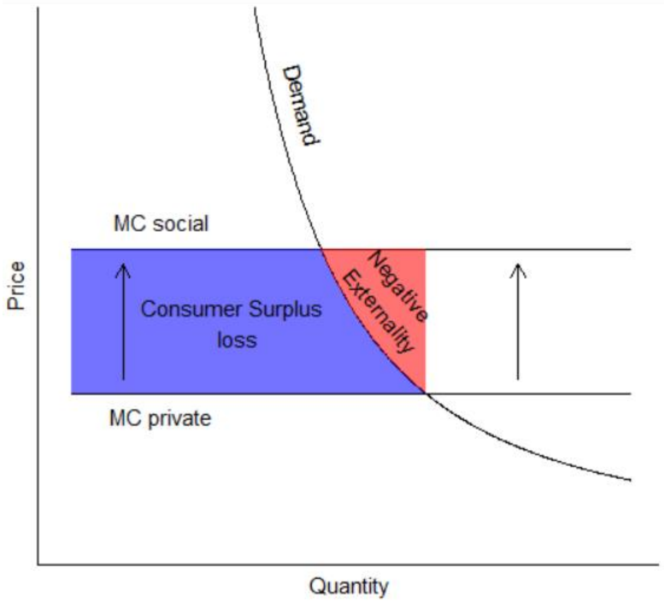
The purpose of this chapter is to provide a theoretical overview of how a tax affect consumers and why different groups of consumers would be differently affected by a tax. In addition, this chapter discuss ways in which to measure the effect on equity that the tax has and why the tax is implemented in the first place.

2. 1 Negative externalities

The reason for implementing the carbon tax can be explained through the theory of negative externalities. Gasoline consumption is considered as one of the most typical examples of negative externalities as private consumption incurs a cost to the utility of some third part that is neither the consumer, nor the producer. The negative externality is therefore experienced outside of the market and create a socially inefficient outcome, not considered in the market price. What the aim of a CO_2 tax, gasoline tax or other emissions reducing measure, is to align the socially efficient quantity with that of the private quantity. The environmental tax is an example of a Pigouvian tax (Hindriks & Myles, 2013) since it attempts to control quantity consumed by increasing the marginal cost. This is demonstrated in figure 1 which displays that the supply curve faced by an individual in a non interfered market (MC private) is below that of the socially efficient supply curve (MC social). The negative externality that is created is a measurement of how inefficient the non interfered market is. Through a Pigouvian tax, the government attempts to increase the marginal private cost so that it matches that of the social marginal cost (MC social). In figure 1 the Pigouvian tax is shown with the upwards pointing arrows which increase the private marginal cost to the marginal social cost.

The Swedish government have had a desire to reduce the quantity of gasoline consumed and the emissions that it produces through different initiatives. One of these initiatives is to increase fuel prices by increasing fuel taxation, which as explained previously would reduce the negative externalities associated with emissions and climate change. An optimal tax increases the marginal cost of the producer so that the new marginal cost matches the social marginal cost.

Figure 1 – Negative externalities & its correction



2. 2 Tax incidence

When a tax is introduced per unit sold on a market, the market price increases. This causes consumers and producers to revaluate the quantity they desire to purchase. However, because of the tax, a wedge between what the consumer pays, and the producer receives is established as some of the price that the consumer pays goes to the government extracting the tax. Who pays the lion´s share of the tax depends on the relative size of the participants price elasticities and this is what determines the tax incidence (Maron & Muehlegger, 2001). A relatively higher price elasticity of supply means that the consumer pays more of the tax than if their elasticities would have been equal. Consumers´ tax incidence is therefore greater than the incidence for suppliers.

$$\frac{dp}{dt} = \frac{\eta}{\eta - \epsilon} \qquad (1)$$

The incidence can be measured as the supply elasticity divided by the difference between the elasticity of supply and of demand, η and ϵ. dp and dt are the changes in price and taxes respectively. The left-hand side of Equation 1 shows how much the post-tax price change, when a tax increases by 1 unit. A tax incidence value of 1 therefore means that any increase in taxes are reflected by an equally large increase in consumer prices. In that case, dp and dt mirror each other one to one. There are two cases when the pass through rate is 1, and the tax is born completely by the consumer. This happens when demand is perfectly inelastic or when supply is perfectly elastic. The consumers pays for the entire tax burden when the tax incidence is 100%.

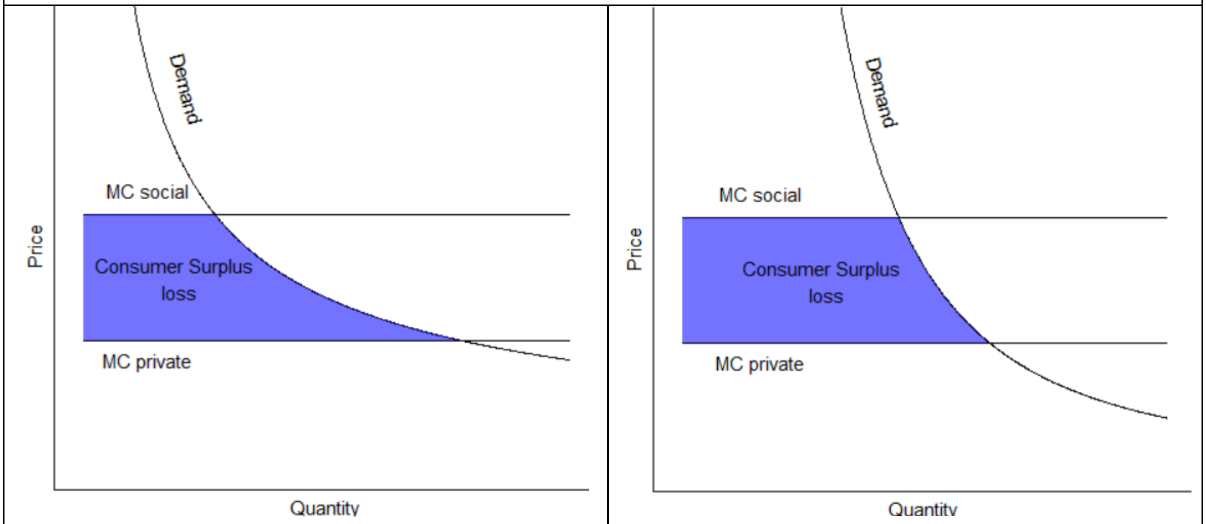
$$\Delta CS = \frac{1}{2} * (Q_0 + Q_1) * (P_0 - P_1) \qquad (2)$$

One way to measure the real effects of a tax is to examine how consumer surplus change. Assuming a linear demand curve one may use Equation 2. The change in consumer surplus (ΔCS) on the left hand size is a function of the pre and post tax quantities, Q_0 and Q_1 and their respective prices, P_0 and P_1. One may broadly say that the change in consumer surplus depends on 2 interconnected variables. The ability to change the quantity consumed as a response to price increases, and the initial quantity consumed. If on the other hand, one assumes that demand is non-linear, the regular calculation of consumer surplus according to the "rule of a half", which assumes linear demand, will be biased upwards (Tag unit A1.3 – User and provider impacts, 2017). This biasedness is, however, less pronounced when small changes in the tax are considered as then the linear and non-linear curves will be closer to each other. The demand curves of one type of consumer may differ from another depending on different characteristics of their environment. One of these environmental factors may be geographical, such as having further to drive to work or spend leisure time.

2. 3 The distributional effects of environmental taxes

When the price of a good increases, consumers usually react by decreasing their consumption of that particular good. Why consumers react in different ways may come down to individual preferences but also restraints placed on them by their environment. In the context of fuel prices, this may be due to the fact that some consumers have to transport themselves across longer distances than others for work or for leisure. An increase in gasoline price may therefore cause consumers to switch to public transport when available, although this luxury may not exist for ruralities in, usually, poorer communities. The lower amount of people, tax revenue and the lesser population density in rural municipalities may make communities reluctant to invest in public transport, leaving inhabitants to rely on their fuel consuming vehicles.

Figure 2 – difference in consumer surplus loss



Panel A – Elastic demand

Panel B – Inelastic demand

The basic insight can be exemplified as in figure 2 in which panel A shows the consumer surplus loss for an elastic consumer and panel B for an inelastic consumer. The elastic consumer loses consumer surplus, but the loss is less than that of the inelastic consumer. This is because of the elastic consumer´s greater ability to react to price changes. The inelastic and possibly rural consumer is harder hit by the tax than their elastic counterpart.

For the last couple of years, the Swedish countryside have faced challenges due to changes in demographics, rates of urbanisation and economic conditions (Starkare kommuner - med kapacitet att klara välfärdsuppdraget, 2020). One other distinguishing characteristic of rural areas is their reliance on fuel for cars and other personal transports which would make their demand less elastic than their urban counterparts. The Swedish government have realised the division and tried to compensate and equalize between municipalities (Det kommunala utjämningssystemet - behov av mer utjämning och bättre förvaltning, 2019) but the wedge still persists.

Whether more rural consumers are harder affected by increases in fuel taxes depends on the price elasticities of the municipalities and their initial consumption of the quantities. Previous research appears to support the reasoning laid out in this theoretical chapter.

3. Previous Empirical Research

The purpose of this chapter is to summarize the previous research that have been done on the estimated division between the urban and rural consumers and the methods they used.

3. 1 Elasticity of demand

Previous research on the geographical difference in price elasticity of demand for Sweden show that it is usually inelastic for both the short and the long run. Dahlkvist (2016), which uses a househould budget survey, find that the more inelastic areas are in the rural north with elasticities of -0.38 and Stockholm with -1.05. Using a fixed effects model, Bastian & Börjesson (2015) finds that the short run price elasticities on kilometres driven vary between -0.36 and -0.63 for urban municipalities. Comparing to the rest of Sweden which has elasticises between -0.10 and -0.64, they also conclude that rural municipalities are less elastic. Pyddoke & Swärdh (2015) examine kilometers travelled using a panel, instrumental variables approach using lagged variables as instruments. They divide their sample into 4 income classes and on gender. They find that urban municipalities and men are more elastic across almost all income classes. They also find that long run elasticities for Sweden follow a similar pattern where the rural areas are on average less elastic than urban or suburban areas yet they are all more elastic in the long run compared with the short run.

The magnitude of the Swedish income elasticity vary between the studies found. Dahlkvist (2016) find an average elasticity of 0.46, ranging from 0.37 to 0.58, where the most inelastic value belongs to the urban north. Income does not vary as much as the study's price elasticities. The income elasticities of Pyddokke & Swärd (2015) are substantially lower at roughly 0.1 with some big outliers and it does not vary much either. Both authors conclude that the price elasticity of demand exhibit variation between rural and urban areas, whilst income show smaller variance. Brännlund & Nordström (2012) find however no difference in price elasticities according to income or geographical divisions.

Studies for other countries reach the same conclusion. Rural areas and higher income subsets are more inelastic, ranging from -0.17 for the most inelastic group, to -0.3 for the most elastic group for France (Bureau, 2011). The estimates from other countries agree with the previous research on Sweden, in that the short run price elasticities are on average -0.3 and the long run price elasticity is on average -0.8 (Brons, Nijkamp, Pels & Rietveld, 2008).

Studies using a cointegration approach to estimate long and short run price and income elasticities find most of the estimates to be inelastic. Rodrigues & Bacchi (2017) tabulates previous cointegration studies which shows that price elasticities are of small magnitude. The short run price elasticity ranges from -0.32 to -0.04 and the long run price elasticities ranges from -0.63 to -0.06. The income elasticity of theses studies ranges from 0.03 to 1.64 for the short run and 0.36 to 2.68 for the long run. Income have therefore a greater impact on gasoline consumption than price with the long run being of greater magnitude than the short run estimates. Zeleke (2016) uses a cointegration approach for each EU-28 countries and finds that the average gas price elasticity is -0.17 in the short run and -0.72 in the long run. For the income elasticity the short run is estimated to be 0.45 in the short run and 1.44 in the long run. Few studies have however used a cointegration approach to estimate the geographical variation of price and income elasticities, within a country. One exception is the study by Freitas & Kaneko(2011), which examines ethanol consumption. The more developed Center-south regions were found to have more elastic long run price estimates at -1.658 compared with the developing North-northeast regions which had an elasticity of -1.408.

These elasticities give hints on how taxes produce an impact on the welfare of different municipalities but is not all encompassing. Looking at the impact from a different viewpoint than elasticities may reveal how much a tax actually affects consumers. Other viewpoints used by previous research are discussed in the next section.

3. 2 The geographical equity of environmental taxes

Previous research on the distributional effect have mostly looked at the difference between income groups such as Sterner (2012) and Nikodinoska & Schröder (2015) and Mathur & Morris (2014), who find the tax to be regressive. Sterner finds that the regressivity was "however so small that the tax can for practical purposes be considered broadly proportional or neutral" (Sterner, 2012, p.81).

The geographical difference have not gained as much attention, however it is present in the Swedish case as well, as more rural areas are subject to higher welfare losses compared to their urban counterparts. Eliasson, Pyddoke & Swärdh (2016) estimate the welfare loss of rural areas to be 50 to 70% higher than those in urban areas. They also find that the role and central function of the city is more important than the size or location of it within Sweden. “central cities” are the cities with a central function in its surrounding area. The groups of municipalities are ranked according to the difference in impact on the municipality groupings. The biggest difference in distribution is between rural and urban areas, the 2nd biggest difference is between the central cities and the respective suburbs and the smallest difference is between central cities of different sizes.

Brännlund & Nordström (2012) find a regional distributional effect where sparsely populated rural areas, carry a larger share of the tax burden, despite no difference in price elasticities. The magnitude of the regressivity is not commented on. Edwards(2004) uses previous studies´ elasticities to estimate the change in cost when the goal is to reach the emissions level of 1990 through a tax increase of 3kr. The increase in costs for the average consumer does not surpass 4000kr and the difference between lowest and highest cost increase is 1000kr. Unsurprisingly this follows the narrative of the highest cost increase is seen in rural areas. There is evidence of regressivity but this is very small in practical terms and can be regarded as basically proportional.

Studies examining the geographical distribution in other countries also find regressivity arising from a special tax on fuels or a general carbon tax (Wang, Hubacek, Feng, Guo, Zhang, Xue & Liang, 2019; Liang, Wang & Wei, 2013; Spiller, Stephens & Chen, 2012)

Based on previous literature, the elasticity between urban and rural municipalities should differ in terms of the rural areas being more inelastic. Income elasticities may also differ but the difference is not as big as with the price elasticities. Most of the previous literature find that increases in fuel prices has redistributive effects, where rural areas are hit the hardest in nominal terms and as a share of income. There is interestingly enough, very little distinction found between southern and northern municipalities. The regressivity of fuel taxes is however very small, irrespective of the measurement.

3. 3 Measurements of equity

In the literature found, the progressivity or regressivity of a tax is usually measured in 3 ways. Calculating the difference in consumer surplus, of an index or compensated variation.

Studies estimating the effect on consumer surplus using the "rule of one half" include; Eliasson, Pyddoke & Swärdh (2016) who study Sweden and Bureau (2011) who assumes a linear demand function for French Household data. Brännlund & Nordström (2002) uses a Quadratic Almost Ideal Demand System to estimate the compensated variation, that is how much money the average consumer would need in order to restore their utility level to the pre-policy level. Other studies use indexes based on a measurement similar to the Gini-coefficient.

Eliasson, Pyddoke & Swärdh (2016) who looks at the Swedish welfare loss from a carbon tax found that the "triangle" that is subject to bias makes up only 1-2% of the total welfare loss. The "triangle" is the non-square area of the consumer surplus as seen in Figure 2. Any bias induced by approximating a non-linear demand with a linear one is therefore very small if my results are similar to previous research. If the potential bias is still of concern, one may apply an integral to the demand function in order to gain the value of consumer surplus. This approach introduces additional uncertainty into the estimation of consumer surplus since its reliant on the intercept being close to the true values. Due to the uncertainty and the Fixed effects method used, the "rule of one half" will instead be used.

The Suits index is used by Sterner (2012) and Wang, Hubacek, Feng, Guo, Zhang, Xue & Liang, (2019). Cornwell & Creedy (1996) use the similar Kakwanis measure while Liang, Wang & Wei (2013) simulate the distribution of income and then compare the respective gini-coefficents to evaluate the progressiveness of the tax. Disadvantages of the compensating variation and the indices in regard to this study are the requirement for micro-level data.

4. Data

The data used for this study consist of macro level national price data and more micro level municipal data for Sweden. Sweden is the geographical limitation of this thesis since data on municipal gasoline consumption was easily available. Price were gathered from the Swedish petroleum and biofuel institute and gives information on a national level. Litres of yearly gasoline consumed, average income in thousands of kronor and the other covariates were collected from the Swedish Bureau of Statistics (SCB). The covariates are the percentage of men in the municipality and the population density of the municipality. The covariates also include commuting patterns of how relatively many commuters go into, out from and commute within the municipality for work. The measurement of gasoline is the BF95 fuel type, that is 95-octane gasoline, and population density is measured as the number of inhabitants per square kilometre for each year. Quantity of gasoline consumed is divided by the population of each municipality in order to gain the average inhabitant´s consumption of gasoline. The entire data set spans yearly from 2001 to 2017 with the gasoline price going even further back. The covariates related to commuting span from 2004 to 2017.

Table 1 – Summary statistics

	N	Mean	St. Dev.	Min	Max
Real mean income (thousands)	4,913	238.597	35.335	175.233	510.092
Gas per capita	4,913	546.062	202.778	0.00001	2,673.310
Percent men	4,913	0.503	0.008	0.476	0.536
Percent in	4,046	0.114	0.079	0.015	1.002
Percent out	4,046	0.169	0.091	0.019	0.458
Percent within	4,046	0.296	0.084	0.093	0.519
Population density	4,913	136.514	474.060	0.200	5,689.100
Real gas price	17	13.234	1.341	10.957	15.357

The statistics software used in this thesis were R and Stata. Most of the work was done through R whilst Stata was used to conduct panel unit root tests and cointegration tests. The code for R as well as the data used can be accessed at Supersoppan/Master-Thesis-Spring-2020 (2020). Some quantities of fuel consumed were registered as zero and were replaced by 1e-5 in order to avoid taking the natural log of zero.

Another change to the data were made by removing the municipality "Knivsta" which was formed in 2003, 2 years after the samples started being collected. The variable "gaspercapita" is the litres of gasoline consumed per municipality divided by the total population at each year. The variables "percentmen", "percentin", "percentout" and "percentwithin" were constructed by taking the number of men, commuters in, out and within the municipality and dividing by the population. The monetary variables, income and price were normalized by 2017 CPI gathered from the Federal Reserve Bank of St. Louis.

The data is divided into municipalities but are also associated with different municipality groupings as defined by Swedish Association of Local Authorities and Regions (SALAR). These groupings are based on "structural parameters such as population and commuting patterns" (Classification of Swedish municipalities 2017) and are good for distinguishing between different types of municipalities. Commuting patterns are interesting as they indicate whether a population is dependent on another city, such as a central city as suggested by Eliasson, Pyddoke & Swärdh (2016). The population aspect is good for showing how the population, and thereby size, affects gasoline expenditure. Previous research found for example that the size of a municipality is affecting expenditure, to some degree. A distinction between north and south is not present due to being outside the scope of this thesis and since previous research little difference between those groups.

The municipality groupings are divided into 3 groups of 2, 3 and 4 subgroups. The main groups are distinguished between each other based on how large the city or municipality is. The subgroups within them are then further divided into central cities and the surrounding municipalities. These are in some cases further distinguished into low-commuting municipalities, those reliant on visitor industry and those who are considered more rural than the other subgroups. The municipality groupings can be further read in Appendix 1 but their names are quite telling of what kind of municipality they are trying to capture.

5. Method

This study differs from previous research in terms of the data and method being used for Sweden. While previous research have used micro level individual data over a short time horizon, this thesis goes in a different direction and uses regional aggregated data intermixed with one national variable, gas price. This increases the amount of time periods available which enables techniques which look at long term effects, such as the Error Correction Model (ECM). The downside of this method is that the aggregated data may hide certain nuisances that are present at the micro level. This thesis is therefore novel in 3 different ways. It uses data with a longer regional time period for Sweden, a ECM to estimate the elasticities and confidence intervals of the estimates are examined.

5. 1 Pass through rate

For the duration of this study, I will assume that the pass through rate is 100% due to perfect elasticity of supply. Recall from Equation 1 that this means that producers increase the price by the same amount as the tax increase. Only the consumers bear the burden of the tax. The supply curves will therefore look like those in figures 1 and 2, completely horizontal. The same assumption about the pass through rate is used in many other studies concerning tax incidence (Wang, Hubacek, Feng, Guo, Zhang, Xue & Liang, 2019; Mathur & Morris, 2014; Zeleke, 2016; Dahlkvist, 2016; Fullerton, Salazar & Elizalde, 2015; Brannan, 2012; Hughes, Knittel & Sperling, 2008; Freitas & Kaneko, 2011; Sterner, 2012; Bureau, 2011; Yousef, 2013; Rodrigues, Bacchi, 2017; Park & Zhao, 2010; Crôtte, Noland & Graham, 2010)

The assumption of 100% pass through may at first glance not seem entirely plausible since we usually assume that producers have increasing marginal costs. Previous studies show however that it is a reasonable assumption. Maron & Muehlegger (2001) find that the pass-through rate in the US gasoline market was around 100% and sometimes even more, depending on the refinery capacity utilization. Alm, Senoga & Skidmore (2009) found similar results of 100% pass through, since the gasoline markets are close to perfect competition, especially for urban US states. Rural states had a lower pass though rate.

5. 2 Comparing estimates

As mentioned previously, this thesis explores another way of finding different responses to a treatment. Previous studies have estimated coefficients for each region or grouping of regions and examined the point estimates. This thesis goes a step further and examines the confidence intervals of each of the point estimates of interest which has the benefit of including the uncertainty, standard errors, of the estimates into the analysis as well as showing graphically and more pedagogically the uncertainty connected to the estimates. Not taking into account the uncertainty connected to an estimate may cause one to conclude that there are differences when in fact there is none. Regular standard errors were used and the robustness of the results were checked by including covariates and checking how, or if, the estimates change.

In order to compare confidence intervals (CI) between each other, one might think that comparing the CIs of two estimates at significance of 95% is enough. This, however, increases the probability of type 1 errors, false positive, as demonstrated in Payton, Greenstone & Schenker (2003) and Goldstein & Healy (1995). They argue that using confidence intervals of 84% results in type 1 errors 5% of the times. This is similar to testing the null hypothesis of an estimated coefficient with significance level 5%, which is standard in econometrics.

As the aim of this thesis is to study the distributional effects of the carbon tax, demand responsiveness to price and income changes is needed to see if there is a difference in response and in turn if there is a difference in impact on expenditures. The income elasticities were considered as to increase comparability to previous research which always look at income and price elasticities. The responses will be used to examine the expenditure that the average citizen of the municipalities have.

The elasticities are estimated based on their belonging to a certain municipality grouping defined by the SALAR since it captures urbanization, dependence on other cities and other useful characteristics. The divisions allow one to explore the differences between central cities and their surrounding municipalities as suggested by Eliasson, Pyddoke & Swärdh (2016). Central cities fill a functional role in the region as a hub for work and as being relied upon by the surrounding municipalities.

I will use national price of fuel because getting data on municipal level is very difficult and any differences in price between regions and gas stations can be assumed to be arbitraged away due to the homogeneity of the product. The distributional effect will therefore be fully attributed to different characteristics of the municipalities.

5. 3 Distributional effect

The distributional effect can be assessed in two different ways, which the data allows for. One of these is to examine the elasticity of demand for fuel which exemplifies how different inhabitants are affected by the tax change. The other value is the change in consumer surplus as seen in equation 2. The estimation of the change in consumer surplus is needed to put taxes´ effect into real value. If the consumption of fuels is very low, then an increase in price will barely make a dent in the wallet of the average consumer, at which point the price increase does not reflect the real blow that consumers face. This will be demonstrated by calculating the change in consumer surplus given an increase in the tax as recommended by practitioners such as Transport Analysis Guidance (Tag unit A1.3 – User and provider impacts, 2017).

When using income, one may worry about the validity of the results according to the lifetime income hypothesis in that annual income is a bad proxy for the true expected income throughout life. Any annual deviation from one period to another may not reflect a change in expected lifetime income but may instead be random. Since the data is aggregated on municipality level, the effect of a single individual´s deviation from their "true" income is diminished and any individual's deviation from their permanent income is greatly reduced as the effect cancel each other out.

5. 4 Error Correction Model

To examine the distributional effect, a ECM was chosen in order to make use of the super consistency coming from nonstationary variables and to estimate long run coefficients. The super consistency is useful since consistent estimates are reached faster which is advantageous due to the short time frame of only 16 to 13 years worth of data. Additionally, the use of panel data compensates for the small time frame due to a large amount of individuals. If there is cointegration between the variables, then subsamples based on the municipality grouping will be used to estimate each municipality groups' price and income elasticity.

$$q_{t,i} = \alpha_1 * p_{t,i} + \alpha_2 * i_{t,i} + \eta_i + \epsilon_{t,i} \qquad (3)$$

The process of using an ECM starts by testing whether the variables of interest are nonstationary. The variables of interest are price, quantity and income as seen in Equation 3. Equation 3 represent the cointegrating relationship where q, p and i are the natural log of gasoline per capita, national gasoline price and the income per capita respectively. α_1 and α_2 are the long run coefficients of price and average income, respectively. η_i is the individual fixed effects. While nonstationary variables may seem to have an effect on each other this may be spurious when in effect they are not related at all. In order to test if the model is spurious or not, one may test if the residuals, $\epsilon_{t,i}$, of equation 3 are stationary. This thesis uses a panel cointegration test for simplicity. If the test indicate that the variables are cointegrated then the coefficients in equation 3 can be interpreted as the long run change of the dependent variable when the independent variables change. Based on previous research we would expect that price of gasoline, income and gasoline consumption are cointegrated. The assumption rests on that previous research have found that income, consumption and the price of a particular fuel are cointegrated such as in Fullerton, Salazar & Elizalde (2015), Zeleke (2016) and Rodrigues & Bacchi (2017),

Since a fixed effects approach is being used, equation 3 needs to be rewritten as to capture deviations from the individual specific mean and thus remove the unobserved intercept, η_i. The deviation from the individual specific mean is represented by the accent "$\tilde{}$". The addition of the accent slightly changes equation 3 to look like the one in equation 4 where the coefficients represent deviation from the individual specific mean.

$$\tilde{q}_{t,i} = \alpha_1 * \tilde{p}_{t,i} + \alpha_2 * \tilde{i}_{t,i} + \epsilon_{t,i} \qquad (4)$$

If the cointegration test indicate that there is cointegration present, we know that the error terms of the cointegrated equation, $\epsilon_{t,i}$, are stationary. As $\epsilon_{t,i}$ can be seen as deviation from the long run equilibrium found in equation 4, one may include the lagged and estimated residuals, $\hat{\epsilon}_{t-,i}$ into the short run regression of equation 5. This captures how the short run quantity per capita responds to the previous deviation from the equilibrium found in the long run. The short run regression coupled with the long run error term finally forms the ECM, as seen in Equation 5.

$$\Delta\tilde{q}_{t,i} = \gamma_1 * \hat{\epsilon}_{t-1,i} + \beta_1 * \Delta\tilde{p}_{t,i} + \beta_2 * \Delta\tilde{i}_{t,i} + \beta_3 * \tilde{X}_{t,i} + \mu_{t,i} \qquad (5)$$

Δ is the difference operator and the subscripts t, t-1 and i are the current, past and individual observations. $\mu_{t,i}$ is the error term for the Error correction model and $\hat{\epsilon}$ is the error term for the long run relationship as well as estimated the error correction term (ECT) in the error correction model. X is a set of covariates included in previous studies and for which there is data available as mentioned in the section on data. The covariates will be used as a robustness check by seeing if the results change when including variables which should affect gasoline consumption. One disadvantage of including the covariates is that they span 3 years less, than in the no covariates case. There will therefore be fewer observations which increases the uncertainty of those results.

One requirement for the ECM to hold is that the value of γ_1, which is the speed of adjustment parameter, is between -1 and 0. The speed of adjustment parameter gains its name due to representing how fast any error in the long run is corrected for in the short run. The requirement on γ_1 being between greater than -1 is to eliminate oscillation of the error term, as any values below the limit results in overcorrection in the short run. On the other side, γ_1 can not be positive since that would mean that any positive deviation would lead to even higher values of the dependent variable in the error correction model.

While the different β coefficients are the short run interpretation of the model, the α coefficients are the long run interpretation. Individual fixed effects where used in order to capture the unobserved effect that each municipality have on gasoline consumption. Time fixed effects where, however, not chosen since gasoline price is time variant but individually invariant. Including time dummies would therefore cause problems with multicollinearity.

One concern when regressing quantity on price is the issue of simultaneity which arises when quantity and price are jointly determined. This causes the estimate to become biased and would lead to wrongful inferrence. The most common way to correct for simultaneity bias is by using an Instrumental Variables approach of which one of the requirements is that the instrument and the endogenous variable are highly correlated. No strong insturments were however found for price in the long aswell as in the short run. The ECM solves this issue as well when the variables are integrated and cointegrated with each other (Ng & Perrion, 1997). The estimates will still be consistent when two variables, such as price an quantity, are cointegrated and are jointly determined,

The model is estimated twice in order to check for robustness and to account for the variables highlighted by previous research as affecting gasoline consumption and for which data was found. The models were chosen based on the mean and median score of the Bayesian Information Criteria (BIC) of each regression based on the municipality grouping. The BIC was chosen instead of the Akaike Information Criteria (AIC) as the BIC avoids overfitting and the model selected based on AIC did not provide sufficiently significant coefficients which is the interest of this thesis.

6. Result

6. 1 Tests

In order to determine whether the ECM is a reasonable approach, one first needs to investigate if the suggested cointegrating variables have a unit root. This is presented in Table 2 where the variables of interest are all integrated of order 1. Since they are integrated of order 1, it is valid to apply a cointegration test.

Table 2 – Unit root tests

	Level		Differenced		Order of integration
	t-statistic	p-value	t-statistic	p-value	
log gaspercapita	7.25	1.00	-32.27	0.00	I(1)
log real price*	-1.07	0.75	-4.04	0.0012	I(1)
log income mean	6.24	1.00	-18.81	0.00	I(1)
log pop_dens	12.82	1.00	-9.15	0.00	I(1)
percentmen	8.26	1.00	-19.22	0.00	I(1)
percentin	-12.98	0.00	-30.03	0.00	I(0)
percentout	-13.46	0.00	-35.90	0.00	I(0)
percentwithin	-17.06	0.00	-47.37	0.00	I(0)

The unit root tests were Levin-Lin-Chu
*unit root test on log real price were conducted using a Dickey Fuller test with no panels

Table 3 contains the cointegration tests which show that the variables of interest are all indeed cointegrated. We can therefore move on to the results and interpret the short and long run coefficients from the following estimation.

Table 3 – Cointegration tests

	test statistic	p value
Pedroni´s cointegration test*		
Modified Phillips-Perron	6.71	0.00
Phillips-Perron	-10.70	0.00
Augmented Dickey-Fuller	-10.53	0.00
Westerlund´s cointegration test**		
Variance ratio	-8.97	0.00

H0 is that there exists no cointegration in the panels between real gas price, real mean income and gas per capita. All variables were logged.
*Ha is that all panels are cointegrated
**Ha is that some panels are cointegrated

6.2 No covariates

Table 4 – The ECM with no covariates

	Commuting municipalities near large cities	Commuting municipalities near small towns	Rural municipalities with a visitor industry	Commuting municipalities near medium-sized towns	Commuting municipalities with a low commuting rate near medium-sized town	Rural municipalities	Small towns	Medium-sized towns	Large Cities
$\hat{\epsilon}_{t-1,i}$	-0.432 * * *	-0.349 * * *	-0.473 * * *	-0.408 * * *	-0.487 * * *	-1.048 * * *	-0.303 * * *	-0.133 * * *	-0.305 * *
$P_{t,i}$	-0.258 *	-0.199 *	-0.054	-0.422 * * *	0.018	-1.403 *	-0.116	-0.403 * * *	-0.581 *
$I_{t,i}$	-2.83 * * *	-2.259 * * *	-2.221 * * *	-1.888 * * *	-2.638 * * *	-1.405	-2.26 * * *	-2.224 * * *	-3.222 * * *
$\Delta P_{t,i}$	-0.121	0.003	0.305	-0.054	0.583 * * *	0.395	0.018	-0.169 *	-0.232
$\Delta I_{t,i}$	-1.476 *	-0.47	1.031	-0.726	0.15	-4.942	-0.301	0.576	-0.282
AIC	-596.50	-892.83	-255.58	-714.91	-461.18	1780.28	-1101.28	-1041.49	-84.39
BIC	-582.90	-878.66	-245.14	-700.79	-448.20	1793.67	-1088.86	-1030.03	-78.78
Adjusted R2	0.15	0.13	0.20	0.16	0.20	0.49	0.10	0.06	0.08
N	688	832	240	816	560	640	464	336	48

*, ** and *** indicates significance at respective significance level. 5%, 1% and 0.1%
Regular standard errors were used

In the case of no covariates, AIC and BIC indicated that a zero lag model was preferred. The estimates can be seen in table 4 and the associated standard errors and confidence intervals are in the appendix. For the baseline model, the Error Correction Term is significant in all regressions and have a very low standard error. Looking at figure 3 we see the difference in how quickly the disequilibrium gap closes. ”Large cities”, with its large confidence interval encompasses almost all of the other estimates with a point estimate of -0.305. This means that for every year, the disequilibrium closes by roughly 30%. The standard errors for Large cities are probably so large due to the small amount of individual observations for that category. Small towns and their surrounding municipalities are also insignificantly different from each other. Medium-sized towns have in contrast a very small speed of adjustment and is significantly different from its municipalities. “Commuting municipalities near medium-sized towns” have a speed of adjustment at -0.408 which is insignificantly different from “Commuting municipalities with a low commuting rate near medium-sized towns”.

Figure 3 – Confidence Interval of Error Correction Term with no covariates

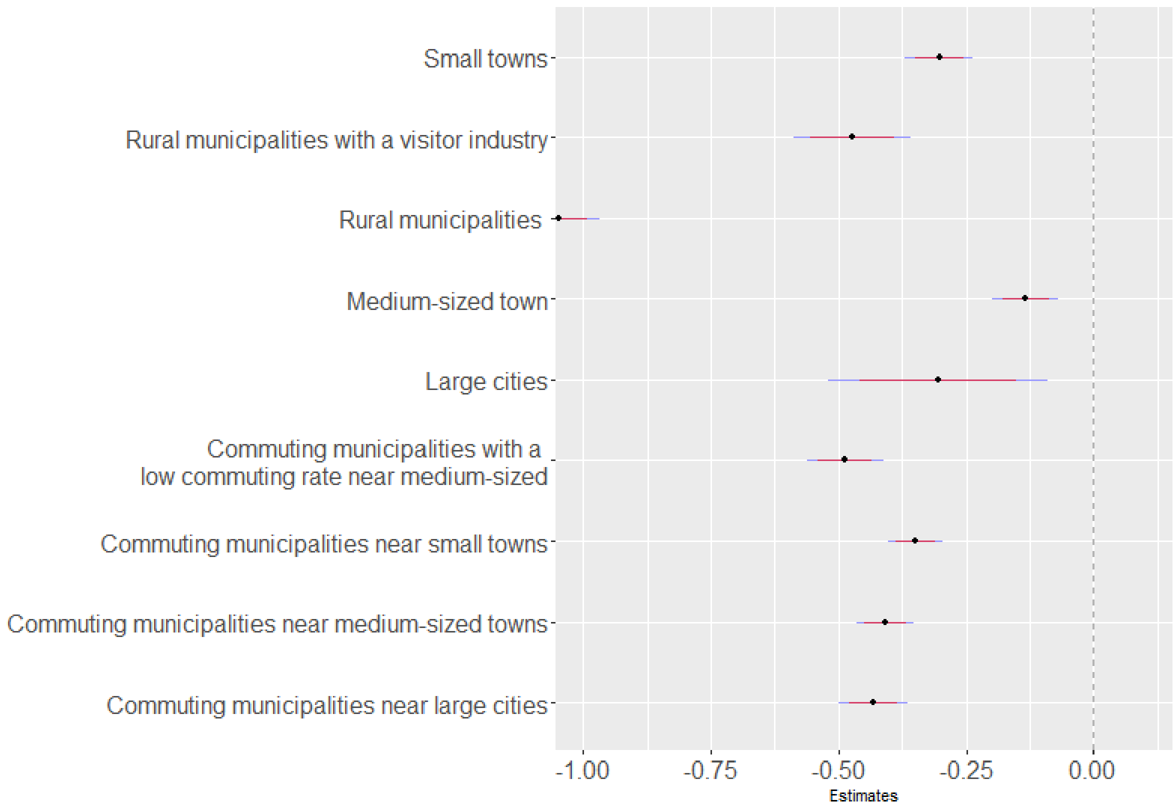


Figure 3 shows point estimates with a dot and confidence intervals of 84% and 95% coloured in red and blue respectively. Horizontal axis indicates which municipality grouping the estimates and their confidence interval relate to.

“Rural municipalities” have a speed of adjustment lower than -1, which is strange for multiple reasons. One would expect that their ability to adjust is hindered by their rural location which in turn inhibits their ability to ditch the car in favour of more public or cheaper transport. The second reason that the estimate is strange is because of the econometric interpretation. With a speed of adjustment coefficient below -1, any deviation from the long run equilibrium results in an overcorrection so that an impulse on the error correction term results in an even larger error in the next period and oscillation of the error term. The confidence interval of “Rural municipalities” does however include estimates which are less than -1 but should be still regarded with caution.

These estimates of the speed of adjustments are far greater than those found in previous research with only “Medium sized town” being close to previous research examining Sweden Zeleke (2020) or the US (Eleftheriou, Nijkamp & Polemis, 2019). The estimates speed of adjustments estimated here are however more similar to the average of all EU-28 countries (Zeleke 2020)

In general, there seems to be no trend of bigger cities being quicker in their response to a disequilibrium although surrounding municipalities give indications of such a trend. The more rural a municipality is, the quicker their adjustment is. The speed of adjustment of surrounding municipalities may be dependent on how big their connected city is although this is not statistically significant. The most interesting differences are between “Small towns” and “medium-sized towns” as well as between “medium-sized towns” and its surrounding municipalities, regular and low commuting.

The long run gas price elasticities seen in Table A.3 and Figure 4 have far greater standard errors than the speed of adjustment coefficient. As seen from the figure, the Confidence interval of “Large cities” encompass its own municipalities as well as the other cities. “Medium-sized town” are insignificantly different from their municipality except for the municipalities with low commuting rate. The point estimates of Large and Medium sized towns are consistent with those of Bastian & Börjesson (2015) whose estimates range from -0.36 to -0.63 for urban municipalities. The estimates found in Table 4 are however inconsistent with those of Dahlkvist (2016) whose point estimates are of greater magnitude.

The long run gas price elasticity of “Commuting municipalities with a low commuting rate near medium-sized towns” is completely insignificant. The Confidence intervals of “Small towns” encompass its own municipalities so the difference between the smallest urban centres and their rural satellites are not at all significant. The difference between cities is however interesting. “Medium-sized towns” are significantly more elastic than “Small towns”, although the same can´t be said about the estimate of “Large cities”. No distinction between the different surrounding municipalities can be made according to how big their respective city is. The distinction here seems to be more about the size or role of the central city. Eliasson, Pyddoke & Swärdh (2016) points to the distinction between urban and rural as having the greatest difference and the size of the city as being of less importance. This stand in contrast to my estimates.

Figure 4 – Confidence Interval of Long run gas price elasticity with no covariates

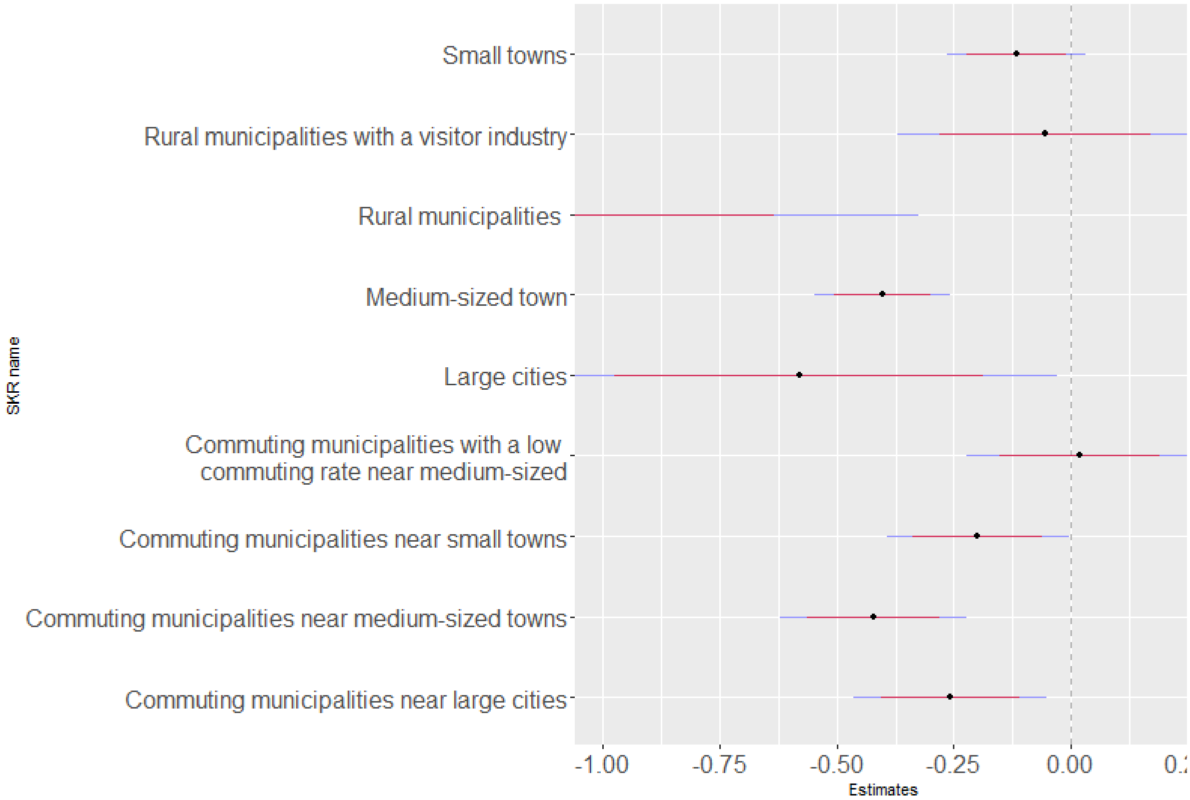


Figure shows point estimates with a dot and confidence intervals of 84% and 95% coloured in red and blue respectively. Horizontal axis indicates which municipality grouping the estimates and their confidence interval relate to

Given that, some rural areas such as “Rural municipalities with a visitor industry” and “Commuting municipalities with a low commuting rate near medium-sized towns” are not significantly different from zero. This may be because of visitors not being that affected by the increase in price as driving and consuming gasoline is a small fraction of holiday and tourist expenses. In the municipalities with low commuting rate, there may be a self-sustained society which does not have that great of a need to commute or seek travels outside of their municipality to bigger towns. The estimate for “Rural municipalities “is again very strange, with a very elastic estimate. This may be because of the above unity speed of adjustment coefficient.

There may be a relation where the bigger a city is, the more price elastic it becomes. Small towns are inelastic with a point estimate that is not statistically significant different from zero. Medium-sized towns are in turn more elastic and so is the point estimate of Large cities although it´s not statistically different from medium-sized towns. Another interesting distinction also concerns medium sized towns and its relationship with its low commuting municipalities. The low commuting municipalities are quicker to respond, based on their speed of adjustment coefficient, but the response is very limited as seen from the insignificant point estimate.

Examining the income elasticities in Figure 5, one can see that the estimates are very elastic compared to the price estimates, previous research and that they are all negative or insignificant from zero. The negativity may arise as a result of higher income leading to more tax revenue and therefore more investments in public transport. Another channel through this may work is that higher incomes are correlated with a greater ability to work from home. Working from home eliminates the need to commute and consume gasoline. In addition, income may also lead to the purchase of more fuel-efficient cars.

Figure 5 – Confidence Interval of Long run income elasticity with no covariates

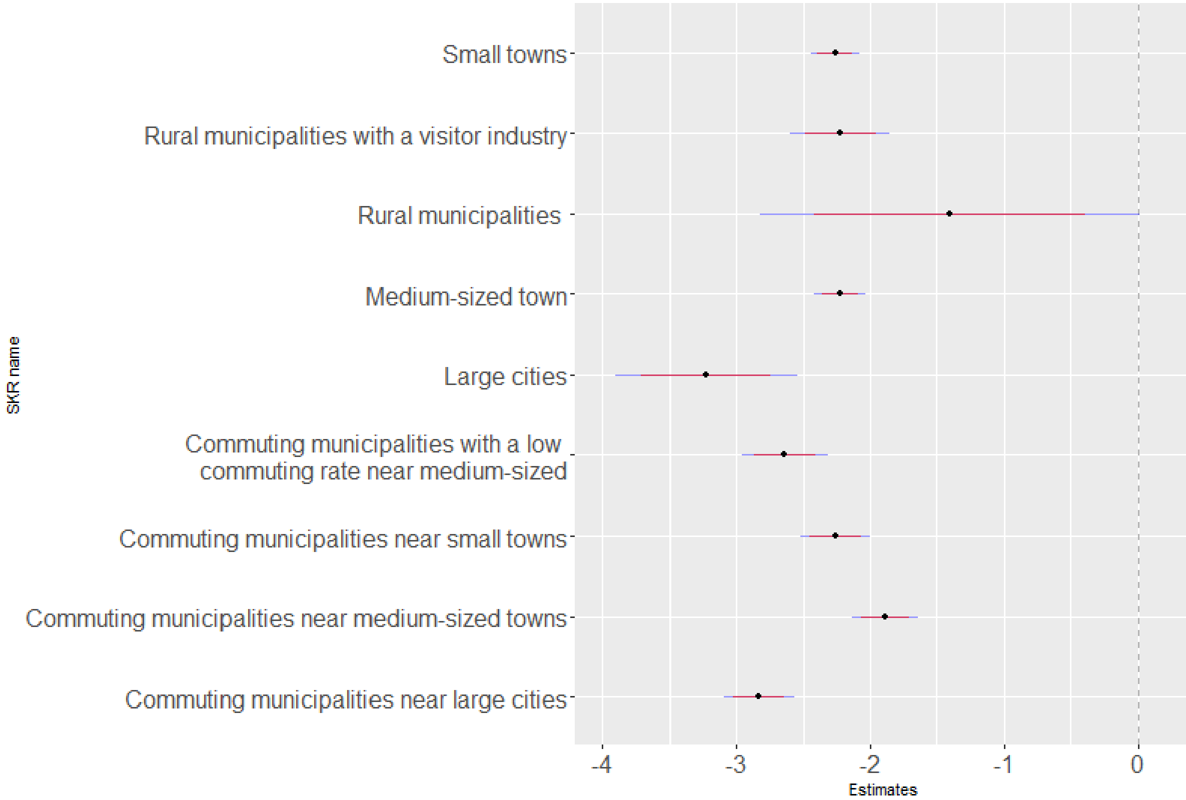


Figure shows point estimates with a dot and confidence intervals of 84% and 95% coloured in red and blue respectively. Horizontal axis indicates which municipality grouping the estimates and their confidence interval relate to

“Large cities” display the same pattern of being insignificantly different from its surrounding municipality. “Medium-sized towns” are barely significantly higher than its surrounding municipality groupings. It is interesting however that the surrounding municipalities go into different directions. The low-commuting municipalities have more elastic long run income estimates than their regular commuting counterpart. The more rural and visitor-dependent municipalities such as “small towns” and “Commuting municipalities near small towns” are very similar in their point estimates as well as the estimate of “Medium-sized towns”

Both Dahlkvist (2016) and Pyddokke & Swärd (2015) use microeconomics individual data for shorter time periods and do not use a cointegration approach. Their estimates are fairly low and have very small variation between municipality groups, in contrast to the negative coeffients and greater variation presented here.

The short run price elasticities as seen in Table 4 are in general insignificant. The only two estimates are the “Medium-sized towns” and their low-commuting surrounding municipality.

What is strange is that the surrounding municipality have a positive estimate. This effect might be caused as a precautionary measure, where drivers buy more fuel in anticipation for even higher gas prices. This seems however unlikely as high consuming drivers should have difficulty storing the gasoline or go through before the next price hike. The insignificant elasticities indicate that consumers have a difficult time reacting to gas price increases.

The estimates are inconsistent with previous research as they find short run price elasticities of around -0.3 or insignificantly from zero for the upper quartile (Pyddokke & Swärd, 2015)

The short run income elasticities are much like the short run price elasticity mostly insignificant. The only significance coming from "Commuting municipalities near large cities" and in turn being negative. The estimates seem reasonable given that it is unlikely that a sudden increase in income would result in higher public transport spending and changed driving habits in the short run, according to the reasoning laid out previously in the section on long run income elasticity. That the estimates are insignificantly different from zero is therefore not that surprising. Previous research such as Pyddokke & Swärd (2015) would agree with the very low short run price elasticities, not surpassing a values of 0.1. They do however find them to be significantly positive. Dahlkvist (2015) on the other hand finds that the magnitude is greater, surpassing a income elasticity of 0.38.

6.3 Covariates

When introducing covariates, the BIC and AIC does not agree on the optimal model. BIC indicates a lag selection of 0 while AIC indicates a lag selection of 2. The 0 lag model was chosen as per the reasons outlined in the method, to avoid overfitting and since the 2 lag model did not produce different results.

As can be seen from figure 5, the non-covariate case for speed of adjustment looks very similar to when no covariates are included. The only difference is higher standard errors and larger point estimates for all municipality grouping. Due to the estimation procedure of the long run coefficients, these are the same irrespective of if covariates are included or not and will therefore not be commented on. The short run estimates with covariates are pretty much the same in terms of significance, sign and magnitude and does not add to the result.

Figure 5 – Confidence Interval of Error Correction Term with covariates

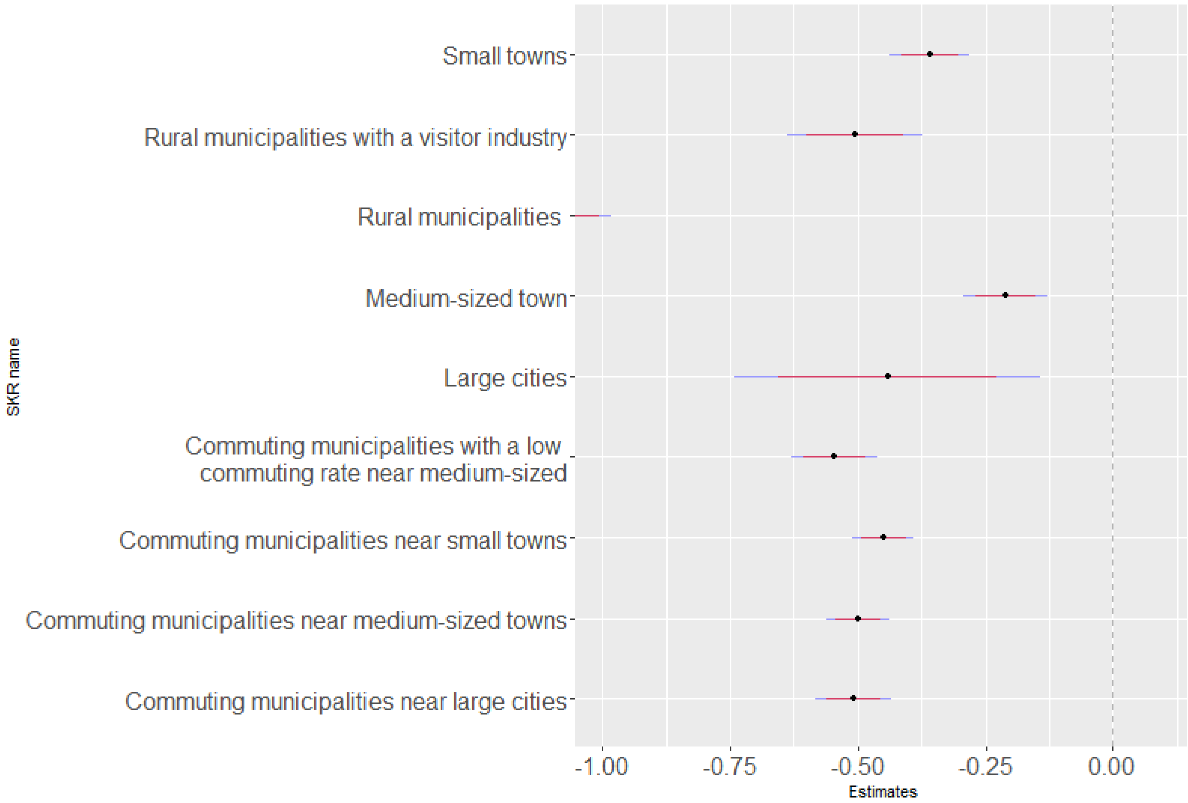


Figure shows point estimates with a dot and confidence intervals of 84% and 95% coloured in red and blue respectively. Horizontal axis indicates which municipality grouping the estimates and their confidence interval relate to

7. Discussion

Based on the results, the notion of the central city and the satellites as being polar opposite, in their response to gasoline price, is challenged. The confidence intervals of gasoline price responses overlap and the null that they are different is rarely rejected. Medium sized towns are in general more elastic and less swift in their response, as indicated by a low speed of adjustment coefficient. Small towns and low commuting municipalities close to the medium-sized towns are less elastic but they reach their long term equilibrium faster. Those municipalities with low commuting rates are either very dependent on their car and are not able to respond to a price change. It might also mean that they are self-sufficient within their community and do not have a need for limiting their consumption. The first explanation seems more reasonable as otherwise bigger communities such as those grouped into "Large cities" would also have an elasticity closer to zero.

The confidence interval of "Large cities" encompass the other two cities which makes rejecting the null hypothesis of same elasticities difficult. Based on the elasticities of "Medium-sized towns" and "Small towns", there does seem to be evidence of bigger cities having more elastic demand. This should however be taken with a grain of salt as they only consist of two estimates, but this is something that we would expect based on theory and previous research. The estimates of the normal-commuting municipalities surrounding each central city are very similar to each other which suggest that all commuting municipalities are similarly affected, irrespective of their associated city. That the coefficients for the speed of adjustment is similar amongst them further supports this thought. "Rural Municipalities" should be briefly touched upon as being very strange, as according to theory and previous research it should be far more inelastic.

Based on the results and a ranking similar to that made by Eliasson, Pyddoke & Swärdh (2016) a generalization can be made of what groupings affect price elasticities. The size of central cities is the greatest decider of price elasticity differences as these are consistently different except for bigger cities. The second most important distinction is between cities and their surrounding municipalities since these are less often significantly different except for the low commuting municipality. The third and last division are those between municipalities that surround central cities. This difference is the least important, since the very similar elasticities can be regarded as being insignificant from each other.

The long run income elasticity is expected to be positive, according to previous research, but from the regression they are clearly negative. This can be for a number of reasons, such as the previously mentioned effect of higher income indicating greater ability to work from home, more public transport spending or the ability to purchase more fuel-efficient cars. The clash with previous research may be cause for concern but may also introduce nuance and reflect the long run relationship as well as the longer time period being used in this thesis. The strange estimates might be because of the previously mentioned hypothesis, that income increases public expenditure on public transport or a greater ability to work from home or buy more fuel efficient cars.

The error correction terms are the only estimates indicating different responses. The surrounding municipalities of cities have a higher point estimate of the error correction term, indicating that they are quicker to react to changes in price or income. The reason for this may be because of already high gasoline consumption on non essential transport which are more easily cut.

7. 1 Change in Consumer surplus

To explore further if and how rural areas are more affected by a hypothetical tax increase, table 4 was used to compute the difference in consumer surplus after a 3kr increase in tax in 2017 which gets passed on to the consumers. The effect of a tax increase of 3kr has been considered by other researchers such as Flood & Manuchery (2015), Edwards(2004) and Larsson & Sandin (2018). First the individual change in consumer surplus on each municipality was calculated from the results with no covariates, and then the mean was taken on each municipality group.

As can be seen from Table 6, there is not much difference between municipalities. The largest difference is between Large Cities and “Rural municipalities with a visitor industry” at 1073 kr. Unsurprisingly the more rural a municipality becomes, the more they lose as found by previous research. The findings and patter presented by Eliasson, Pyddoke & Swärdh (2016) is partly seen here. The greatest difference is between those of diverging urbanization, such as” Large Cities” and “Rural municipalities with a visitor industry” which is what they found as well. The two contrasting areas with the second biggest difference is those of different sizes of urban areas. The difference between “Large Cities”, “Medium-sized towns” and “Small towns”, ie central cities of different sizes, are less than those of urban versus rural areas. This is in contrast to Eliasson, Pyddoke &Swärdh (2016) who find urban against rural areas to have the smallest difference and exhibits the least amount of regressivity. The third most amount of regressivity is found between municipalities that surround a central city. The least amount of regressivity found in my estimations are those of central cities compared to their suburbs. They differ at most 300kr and interestingly enough, the difference is reduced as the comparisons are made mode rural. “Large Cities” and its suburbs have a larger difference than those of “Small towns” and its suburbs. The strange coefficient estimated for “Rural municipalities” does not produce an equally strange value of consumer surplus change. Despite the very elastic estimate, they still rank nr 2 in terms of how affected they are. Third affected is “Rural municipalities with a visitor industry” which has the disadvantage of being both rural and inelastic.

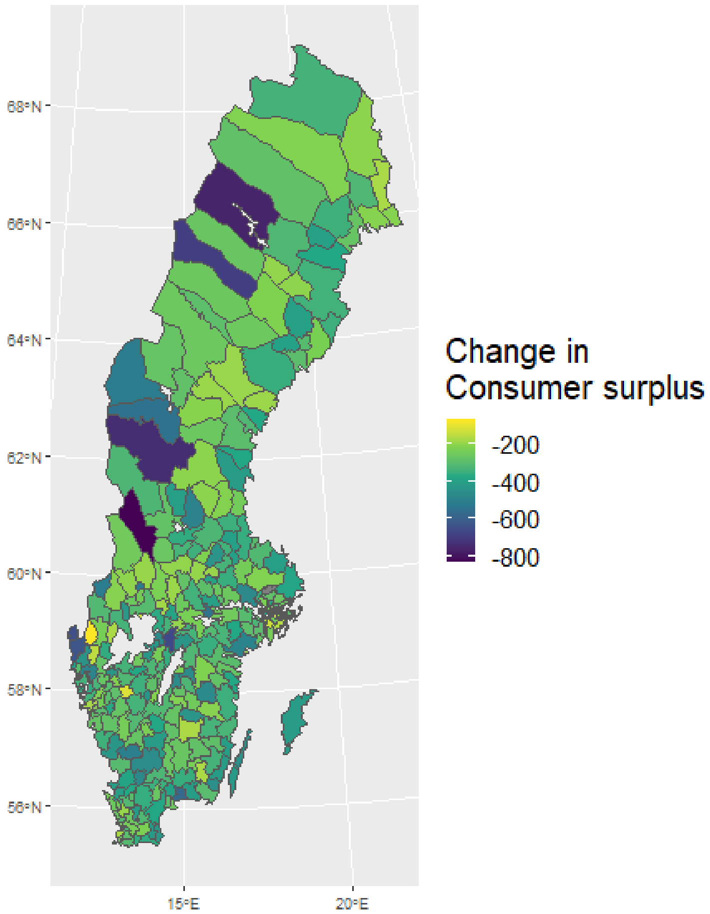
Table 6 – Consumer surplus change given a 3kr increase in taxes

Municipality grouping	Mean	Biggest loser
Commuting municipalities with a low commuting rate near medium-sized	-1,095	4
Rural municipalities	-1,269	2
Rural municipalities with a visitor industry	-1,663	1
Small towns	-1,184	3
Commuting municipalities near small towns	-1,069	6
Commuting municipalities near medium-sized towns	-1,077	5
Commuting municipalities near large cities	-860	8
Medium-sized towns	-994	7
Large Cities	-590	9

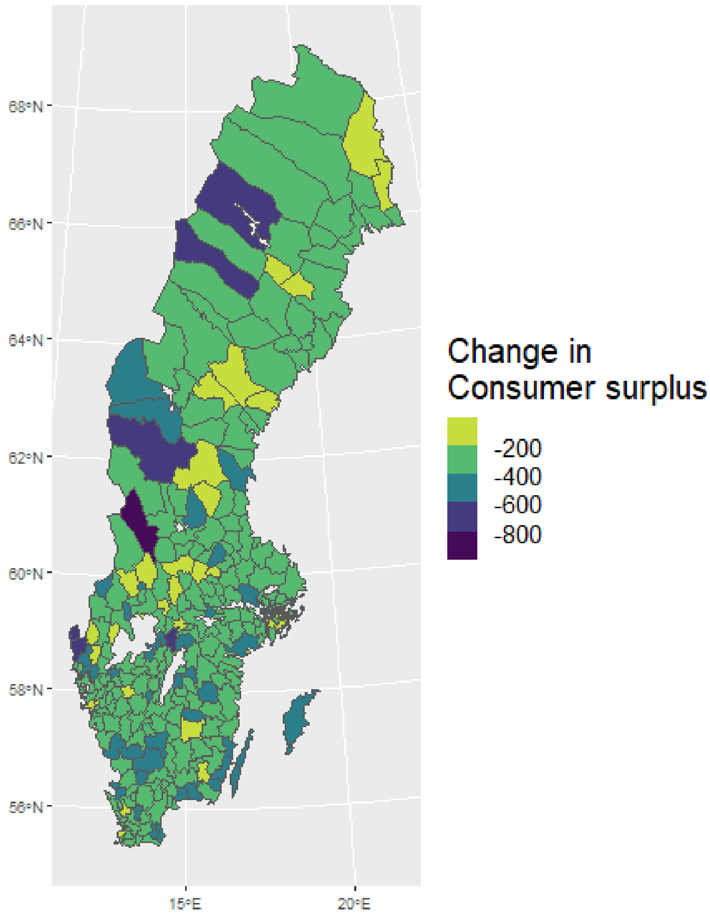
The difference in consumer surplus produced by the tax is found to be regressive but in terms of real value, the regressivity is very small. More rural areas are harder affected but there is a small change in consumer surplus. In addition, the long run demand elasticity does not affect consumer surplus very much, as found by previous research. “Rural municipalities” with its higher elasticity is still hard hit in comparisons to other more inelastic municipality groupings. The claim by Eliasson, Pyddoke & Swärdh (2016) that the consumer response constitutes a small part of consumer surplus loss is confirmed here.

Based on this estimation of consumer surplus the greatest difference is in descending order: urban versus rural municipalities, urban municipalities of different sizes, surrounding municipalities surrounding different cities and lastly, urban versus surrounding municipalities. This is partly in contrast to the ranking of price elasticities which saw the distinction between cities as being most important followed by cities versus surrounding municipalities and finally between surrounding municipalities. The difference may arise because of all municipality groupings´ inelastic demand which increases the importance of the initial quantity consumed, rather than how they react.

Figure 6 – Map of change in Consumer surplus given a 3kr increase in taxes



Panel A - Continous range



Panel B – Discrete ranges

The maps in panel A and B show the municipality level change in consumer surplus with the values being mapped continuously to each colour for a more detailed overview as in panel A, or where each value is categorized to a colour for ease of use as in panel B. As can be seen from the map figure, the more rural a municipality becomes, the more they lose from a hypothetical tax increase. The analysis is based on Panel B due to the ease of use. Some areas in the north western part of Sweden are the hardest hit, although this is contrasted by municipalities which are the least severely hit. The northern part of Sweden is therefore not uniformly affected in contrast to southern or in the middle of Sweden. The areas surrounding the 3 big cities, Malmö, Gothenburg, and Stockholm exhibit a layering effect where the further out a municipality gets, the harder affected they are.

8. Conclusion

Are rural municipalities disproportionately affected by increases in the tax on gasoline? Yes, although with several caveats. Firstly, the real economic effect for all types of municipalities is not that great when considering the big increase in the tax. Secondly, the difference between the hardest and lightest hit municipalities, very rural and very urban respectively, is not big. The difference amounts to less than 1100kr. Thirdly, the elasticities are mostly not statistically different from each other and there is not trend of rural areas having smaller elasticities.

This thesis contributes to the existing body of knowledge by supporting the most common findings. These are that rural areas are more seriously affected in terms of actual impact measured in terms of change in consumer surplus although with above mentioned caveats. The results of this thesis diverge from previous research when it comes to the difference in price elasticities, the effect of income on gasoline consumption and what traits are associated with differing gas price elasticities. Income has previously found to be positive when using micro-level data, compared to my negative estimate when using more aggregated data. The results on income should therefore be taken with a grain of salt. The municipality traits found by Eliasson, Pyddoke & Swärdh (2016) are not found to correlate with differing responses, or at the very least their ranking of traits does not match the ones from my results.

The implications of this thesis are that the debate around the countryside´s resistance to carbon taxes are not based in economic findings. Policies aimed at easing the burden of the carbon tax may therefore not be well targeted, given a broader goal of reducing greenhouse gas emissions and halting climate change. Further care should be taken at exploring other ways in which the emissions-connected tax on gasoline affect the inhabitants of the Swedish municipalities, such as through industries, public transport or other fuel types.

Further research should aim at exploring the effect on diesel and other fuels used for transport. Other divisions and groupings of municipalities could also be explored to gain nuance which may reveal a difference in price elasticities. Given more detailed data on price and gasoline consumption on a monthly basis allows one to explore the more immediate response to changes in gasoline prices.

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Appendix

Table A.1 – Definitions of Municipality groupings
A. Large cities and municipalities near large cities
1. Large cities - municipalities with a population of at least 200 000 inhabitants with at least 200 000 inhabitants in the largest urban area.
2. Commuting municipalities near large cities – municipalities where more than 40 % of the working population commute to work in a large city or municipality near a large city.
B. Medium-sized towns and municipalities near medium-sized towns
3. Medium-sized towns – municipalities with a population of at least 50 000 inhabitants with at least 40 000 inhabitants in the largest urban area.
4. Commuting municipalities near medium-sized towns - municipalities where more than 40 % of the working population commute to work in a medium-sized town.
5. Commuting municipalities with a low commuting rate near medium-sized towns - municipalities where less than 40 % of the working population commute to work in a medium-sized town.
C. Smaller towns/urban areas and rural municipalities
6. Small towns - municipalities with a population of at least 15 000 inhabitants in the largest urban area.
7. Commuting municipalities near small towns - municipalities where more than 30 % of the working population commute to work in a small town/ urban area or more than 30 % of the employed day population lives in another municipality.
8. Rural municipalities - municipalities with a population of less than 15 000 inhabitants in the largest urban area, very low commuting rate (less than 30 %)
9. Rural municipalities with a visitor industry – municipalities in rural area that fulfil at least two criteria for visitor industry, i.e. number of overnight stays, retail-, restaurant- or hotel turnover per head of population.

Table A.2 – Error correction term in the no covariates case						
	Estimates	Std Errors	Lower CI 84%	Upper CI 84%	Lower CI 95%	Upper CI 95%
Commuting municipalities near large cities	-0.432	0.034	-0.4796	-0.3844	-0.49864	-0.36536
Commuting municipalities near small towns	-0.349	0.027	-0.3868	-0.3112	-0.40192	-0.29608
Rural municipalities with a visitor industry	-0.473	0.059	-0.5556	-0.3904	-0.58864	-0.35736
Commuting municipalities near medium-sized towns	-0.408	0.029	-0.4486	-0.3674	-0.46484	-0.35116
Commuting municipalities with a low commuting rate near medium-sized towns towns	-0.487	0.038	-0.5402	-0.4338	-0.56148	-0.41252
Rural municipalities	-1.048	0.041	-1.1054	-0.9906	-1.12836	-0.96764
Small towns	-0.303	0.034	-0.3506	-0.2554	-0.36964	-0.23636
Medium-sized town	-0.133	0.033	-0.1792	-0.0868	-0.19768	-0.06832
Large cities	-0.305	0.11	-0.459	-0.151	-0.5206	-0.0894

Table A.3 – Long run price coefficient in the no covariates case						
	Estimates	Std Errors	Lower CI 84%	Upper CI 84%	Lower CI 95%	Upper CI 95%
Commuting municipalities near large cities	-0.258	0.105	-0.405	-0.111	-0.4638	-0.0522
Commuting municipalities near small towns	-0.199	0.099	-0.3376	-0.0604	-0.39304	-0.00495
Rural municipalities with a visitor industry	-0.054	0.161	-0.2794	0.1714	-0.36956	0.26156
Commuting municipalities near medium-sized towns	-0.422	0.101	-0.5634	-0.2806	-0.61996	-0.22404
Commuting municipalities with a low commuting rate near medium-sized towns	0.018	0.122	-0.1528	0.1888	-0.22112	0.25712
Rural municipalities	-1.403	0.55	-2.173	-0.633	-2.481	-0.325
Small towns	-0.116	0.075	-0.221	-0.011	-0.263	0.031
Medium-sized town	-0.403	0.074	-0.5066	-0.2994	-0.54804	-0.25796
Large cities	-0.581	0.282	-0.9758	-0.1862	-1.13372	-0.02828

Table A.4 – Long run income coefficient in the no covariates case						
	Estimates	Std Errors	Lower CI 84%	Upper CI 84%	Lower CI 95%	Upper CI 95%
Commuting municipalities near large cities	-2.83	0.135	-3.019	-2.641	-3.0946	-2.5654
Commuting municipalities near small towns	-2.259	0.134	-2.4466	-2.0714	-2.52164	-1.99636
Rural municipalities with a visitor industry	-2.221	0.189	-2.4856	-1.9564	-2.59144	-1.85056
Commuting municipalities near medium-sized towns	-1.888	0.128	-2.0672	-1.7088	-2.13888	-1.63712
Commuting municipalities with a low commuting rate near medium-sized towns	-2.638	0.163	-2.8662	-2.4098	-2.95748	-2.31852
Rural municipalities	-1.405	0.724	-2.4186	-0.3914	-2.82404	0.014039
Small towns	-2.26	0.093	-2.3902	-2.1298	-2.44228	-2.07772
Medium-sized town	-2.224	0.098	-2.3612	-2.0868	-2.41608	-2.03192
Large cities	-3.222	0.346	-3.7064	-2.7376	-3.90016	-2.54384

Table A.5 – Short run price coefficient in the no covariates case						
	Estimates	Std Errors	Lower CI 84%	Upper CI 84%	Lower CI 95%	Upper CI 95%
Commuting municipalities near large cities	-0.121	0.141	-0.3184	0.0764	-0.39736	0.15536
Commuting municipalities near small towns	0.003	0.119	-0.1636	0.1696	-0.23024	0.23624
Rural municipalities with a visitor industry	0.305	0.238	-0.028199	0.6382	-0.16148	0.77148
Commuting municipalities near medium-sized towns	-0.054	0.136	-0.2444	0.1364	-0.32056	0.21256
Commuting municipalities with a low commuting rate near medium-sized towns	0.583	0.16	0.359	0.807	0.2694	0.8966
Rural municipalities	0.395	0.915	-0.886	1.676	-1.3984	2.1884
Small towns	0.018	0.084	-0.0996	0.1356	-0.14664	0.18264
Medium-sized town	-0.169	0.07	-0.267	-0.071	-0.3062	-0.0318
Large cities	-0.232	0.341	-0.7094	0.2454	-0.90036	0.43636

Table A.6 – Short run income coefficient in the no covariates case						
	Estimates	Std Errors	Lower CI 84%	Upper CI 84%	Lower CI 95%	Upper CI 95%
Commuting municipalities near large cities	-1.476	0.595	-2.309	-0.643	-2.6422	-0.3098
Commuting municipalities near small towns	-0.47	0.513	-1.1882	0.2482	-1.47548	0.53548
Rural municipalities with a visitor industry	1.031	0.838	-0.1422	2.2042	-0.61148	2.67348
Commuting municipalities near medium-sized towns	-0.726	0.587	-1.5478	0.09579	-1.87652	0.42452
Commuting municipalities with a low commuting rate near medium-sized towns	0.15	0.703	-0.8342	1.1342	-1.22788	1.52788
Rural municipalities	-4.942	3.494	-9.8336	-0.050399	-11.79024	1.90624
Small towns	-0.301	0.408	-0.8722	0.2702	-1.10068	0.49868
Medium-sized town	0.576	0.346	0.0916	1.0604	-0.10216	1.25416
Large cities	-0.282	1.431	-2.2854	1.7214	-3.08676	2.52276

Table A.7 – Error Correction term with covariates						
	Estimates	Std Errors	Lower CI 84%	Upper CI 84%	Lower CI 95%	Upper CI 95%
Commuting municipalities near large cities	-0.509	0.038	-0.5622	-0.4558	-0.58348	-0.43452
Commuting municipalities near small towns	-0.45	0.031	-0.4934	-0.4066	-0.51076	-0.38924
Rural municipalities with a visitor industry	-0.505	0.068	-0.6002	-0.4098	-0.63828	-0.37172
Commuting municipalities near medium-sized towns	-0.5	0.032	-0.5448	-0.4552	-0.56272	-0.43728
Commuting municipalities with a low commuting rate near medium-sized towns	-0.546	0.043	-0.6062	-0.4858	-0.63028	-0.46172
Rural municipalities	-1.069	0.044	-1.1306	-1.0074	-1.15524	-0.98276
Small towns	-0.359	0.04	-0.415	-0.303	-0.4374	-0.2806
Medium-sized town	-0.211	0.042	-0.2698	-0.1522	-0.29332	-0.12868
Large cities	-0.442	0.153	-0.6562	-0.2278	-0.74188	-0.14212

Table A.8 – Long run price coefficient with covariates						
	Estimates	Std Errors	Lower CI 84%	Upper CI 84%	Lower CI 95%	Upper CI 95%
Commuting municipalities near large cities	-0.258	0.105	-0.405	-0.111	-0.4638	-0.0522
Commuting municipalities near small towns	-0.199	0.099	-0.3376	-0.0604	-0.39304	-0.004959
Rural municipalities with a visitor industry	-0.054	0.161	-0.2794	0.1714	-0.36956	0.26156
Commuting municipalities near medium-sized towns	-0.422	0.101	-0.5634	-0.2806	-0.61996	-0.22404
Commuting municipalities with a low commuting rate near medium-sized towns	0.018	0.122	-0.1528	0.1888	-0.22112	0.25712
Rural municipalities	-1.403	0.55	-2.173	-0.633	-2.481	-0.325
Small towns	-0.116	0.075	-0.221	-0.011	-0.263	0.031
Medium-sized town	-0.403	0.074	-0.5066	-0.2994	-0.54804	-0.25796
Large cities	-0.581	0.282	-0.9758	-0.1862	-1.13372	-0.02828

Table A.9 – Long run income coefficient with covariates						
	Estimates	Std Errors	Lower CI 84%	Upper CI 84%	Lower CI 95%	Upper CI 95%
Commuting municipalities near large cities	-2.83	0.135	-3.019	-2.641	-3.0946	-2.5654
Commuting municipalities near small towns	-2.259	0.134	-2.4466	-2.0714	-2.52164	-1.99636
Rural municipalities with a visitor industry	-2.221	0.189	-2.4856	-1.9564	-2.59144	-1.85056
Commuting municipalities near medium-sized towns	-1.888	0.128	-2.0672	-1.7088	-2.13888	-1.63712
Commuting municipalities with a low commuting rate near medium-sized towns	-2.638	0.163	-2.8662	-2.4098	-2.95748	-2.31852
Rural municipalities	-1.405	0.724	-2.4186	-0.3914	-2.82404	0.014039
Small towns	-2.26	0.093	-2.3902	-2.1298	-2.44228	-2.07772
Medium-sized town	-2.224	0.098	-2.3612	-2.0868	-2.41608	-2.03192
Large cities	-3.222	0.346	-3.7064	-2.7376	-3.90016	-2.54384

Table A.10 – Short run price coefficient with covariates						
	Estimates	Std Errors	Lower CI 84%	Upper CI 84%	Lower CI 95%	Upper CI 95%
Commuting municipalities near large cities	-0.362	0.179	-0.6126	-0.1114	-0.71284	-0.01116
Commuting municipalities near small towns	-0.263	0.141	-0.4604	-0.0656	-0.53936	0.01336
Rural municipalities with a visitor industry	0.198	0.283	-0.1982	0.5942	-0.35668	0.75268
Commuting municipalities near medium-sized towns	-0.113	0.16	-0.337	0.111	-0.4266	0.2006
Commuting municipalities with a low commuting rate near medium-sized towns	0.515	0.196	0.2406	0.7894	0.13084	0.89916
Rural municipalities	0.511	1.119	-1.0556	2.0776	-1.68224	2.70424
Small towns	-0.147	0.102	-0.2898	-0.00420	-0.34692	0.05292
Medium-sized town	-0.343	0.084	-0.4606	-0.2254	-0.50764	-0.17836
Large cities	-0.377	0.467	-1.0308	0.2768	-1.29232	0.53832

Table A.11 – Short run income coefficient with covariates						
	Estimates	Std Errors	Lower CI 84%	Upper CI 84%	Lower CI 95%	Upper CI 95%
Commuting municipalities near large cities	-2.042	0.75	-3.092	-0.992	-3.512	-0.572
Commuting municipalities near small towns	-0.926	0.541	-1.6834	-0.1686	-1.98636	0.13436
Rural municipalities with a visitor industry	0.727	0.977	-0.6408	2.0948	-1.18792	2.64192
Commuting municipalities near medium-sized towns	-0.978	0.634	-1.8656	-0.0904	-2.22064	0.26464
Commuting municipalities with a low commuting rate near medium-sized towns	0.025	0.768	-1.0502	1.1002	-1.48028	1.53028
Rural municipalities	-5.617	3.95	-11.147	-0.08699	-13.359	2.125
Small towns	-0.56	0.437	-1.1718	0.0518	-1.41652	0.29652
Medium-sized town	0.209	0.399	-0.3496	0.7676	-0.57304	0.99104
Large cities	0.992	2.312	-2.2448	4.2288	-3.53952	5.52352

Table A.12 - The ECM with covariates									
	Commuting municipalities near large cities	Commuting municipalities near small towns	Rural municipalities with a visitor industry	Commuting municipalities near medium-sized towns	Commuting municipalities with a low commuting rate near medium-sized towns	Rural municipalities	Small towns	Medium-sized towns	Large Cities
$\hat{\epsilon}_{t-1,i}$	-0.509 * * *	-0.45 * * *	-0.505 * * *	-0.5 * * *	-0.546 * * *	-1.069 * * *	-0.359 * * *	-0.211 * * *	-0.442 * *
$P_{t,i}$	-0.258 *	-0.199 *	-0.054	-0.422 * * *	0.018	-1.403 *	-0.116	-0.403 * * *	-0.581 *
$I_{t,i}$	-2.83 * * *	-2.259 * * *	-2.221 * * *	-1.888 * * *	-2.638 * * *	-1.405	-2.26* * *	-2.224 * * *	-3.222 * * *
$\Delta P_{t,i}$	-0.362 *	-0.263	0.198	-0.113	0.515 * *	0.511	-0.147	-0.343 * * *	-0.377
$\Delta I_{t,i}$	-2.042 * *	-0.926	0.727	-0.978	0.025	-5.617	-0.56	0.209	0.992
$Pop - Density_{t,}$	-0.254	-1.863 * *	0.033	0.464	1.163	-0.282	0.242	-1.462	-4.96
$Percent - Men_{t,i}$	0.835	-0.842	5.004	-1.536	-0.76	14.704	1.254	2.193	40.803
$Percent - In_{t,i}$	-0.018	-0.058	-0.056	0.193 *	-0.131	0.91 *	-0.162 *	-0.192 *	2.089
$Percent - Out_{t,i}$	-0.433	-0.388 * *	-0.256	-0.569 * * *	-0.183	-0.401	-0.147 *	-0.134 *	-0.022
$Percent - Within_{t,i}$	0.521 *	-0.07	0.295	-0.01	0.167	-2.167	0.363	0.383 * *	-2.595
AIC	-477.69	-777.12	-200.65	-607.83	-368.38	1626.16	-947.83	-924.24	-68.73
BIC	-442.49	-740.40	-173.87	-571.26	-334.83	1660.79	-915.78	-894.77	-54.83
Adjusted R2	0.18	0.19	0.20	0.20	0.22	0.50	0.13	0.16	0.12
N	602	728	210	714	490	560	406	294	42
*, ** and *** indicates significance at respective significance level. 5%, 1% and 0.1% Regular standard errors were used									