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Effect of fuel tax on carbon dioxide emissions in Sweden

- a panel estimation approach

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Bensinskattens effekt på mängden koldioxid i Sverige

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Abstract

Greenhouse gases are increasingly causing both global climate changes and local health issues. In particular, carbon dioxide emissions represent 81% of total greenhouse gas emissions. There is evidence that fuel taxes can be adopted as a mitigation measure to lower greenhouse gas emissions and contribute to climate change adaptation goals. Using a panel data approach, this study examined the impact of Swedish fuel taxes on carbon dioxide emissions in various municipalities. The empirical model involved a set of explanatory variables, identified based on the relevant literature that are believed to influence the dependent variable (carbon dioxide emissions), namely: fuel taxes (the variable of interest), the number of passenger cars and the population density in a municipality in a given year. Moreover, to capture the spatial effects, the study included the regional classification of each municipality (rural or urban) as an explanatory variable. Overall, the results indicated that fuel tax has a statistically significant negative effect on carbon dioxide emissions. Specifically, a 1% increase in fuel tax in a given municipality would be associated with a reduction of 0.8% in the amount of carbon dioxide emissions. Distinguishably, the results revealed a positive and statistically significant relationship between carbon dioxide emissions and the municipalities being classified as urban. In light of these results, the study concludes that fuel tax could be utilized as a climate policy instrument, but it should be complemented by other socio-economic and environmental policies tailored to each municipality to achieve the intended effect.

Contents

1 Introduction

This chapter begins with a background that overviews the fuel tax in Sweden. Next, the chapter present the research problem, the purpose of the study and its limitations.

1.1 Background

The greenhouse effect is a natural phenomenon, and is the term for the global warming caused by the greenhouse gases. It works like a blanket, without it the temperature on Earth would be about 30 degrees less compared to today. However, when the total amount of greenhouse gases increases it causes the global temperature to increase. With the increased temperature comes consequences, climate changes (World Wide Fund for Nature (WWF), nd). Several studies have shown the importance of a fuel tax to control for emissions caused by greenhouse gases (Sterner 2007; Sterner 2010).

Until the 1980s, the tax was only directed towards gasoline. The revenue was earmarked, for different types of purposes within the traffic industry. In 1990, the value-added tax was introduced, which depends on the production costs and the gross margin. Today, the tax is not intended to be used for one specific purpose, but instead the revenue generated is government revenue (Ekonomifakta 2020).

In 1991, today's fuel tax was introduced in Sweden, which consists of a carbon dioxide tax, an energy tax and a value added tax (Government Offices of Sweden 2020). These three parts accounts for about 60 percent of the retail price (Ekonomifakta 2020).

Since the implementation of the fuel tax, it has been increased several times for a number of reasons. There are many incentives for a constantly increasing fuel tax. The fuel tax was not raised for climate and environmental purposes, but has become a common regulation for that very purpose. The main goal of a fuel tax is achieving sustainable development, where the climate threat is a constant motivation to try to limit the greenhouse gases. In Sweden, the fuel tax is a big part of the climate policy to reduce the amount of air pollution (Ministry of the Environment 2015).

As a part of the European Union, EU, Sweden has climate goals at an EU level to achieve. "In addition, the European Council has endorsed the goal that the EU should reduce greenhouse gas emissions by between 80-95% by 2050, of which at least 80% in the region." according to the Swedish Environmental Protection Agency (EPA 2020). 2017 Sweden committed to national climate goals that consist of a climate law, climate goal and a political advice concerning the climate to be able to achieve the EU's goals for 2050. When achieving the climate goals, Sweden has net-zero greenhouse gases emissions. That is, in 2045 Sweden should have decreased its levels of emissions by 85% compared to the emissions in 1990. (EPA 2019).

Historically, the climate has always changed, slowly, but the average temperature is now increasing faster than before. There are many reasons for that, but mainly because of the use of fossil fuels (Swedish Society for Nature Conservation 2020).

The greenhouse gases are a collection name for the gases underlying the greenhouse effect. Many of the greenhouse gases occur naturally in the atmosphere such as the most important greenhouse gas water steam. Some other gases that occur naturally in the atmosphere are carbon dioxide, nitrogen oxide and methane. A gas that is not naturally present in the atmosphere, that occurs due to human influence, is Freon (WWF nd). Carbon dioxide is the primary cause of the increased greenhouse effect and the biggest source of carbon dioxide emission is combustion of fossil fuels, but also when harvesting forests, stands for about 67% of the total amount of greenhouse gases (Swedish Society for Nature Conservation nd). The share of carbon dioxide has increased by over 35 percent since the middle of the 1800's century (Environmental Protection Agency (EPA) 2008).

An important perspective in the study is the urbanization happening in Sweden. According to Statistics Sweden 85 percent of the Swedish population live in urban areas. Looking back 200 years in time, it was the opposite, 90 percent of the Swedish population lived in the countryside. There are two ways to interpret urbanization, the first one is that urbanization describes a movement of population from rural to urban areas. The other way of looking at urbanization is that it represents a ratio between the population in urban and rural areas, also called degree of urbanization (Statistics Sweden 2015).

1.2 Problem

The Swedish Environmental Protection Agency, EPA, published statistics of Sweden's emissions of greenhouse gases from domestic transport in 2019. The statistics shows that the greenhouse gas emissions are decreasing, but also that the greatest source of CO_2 emissions are passenger cars (EPA 2019). David & Kilian (2009) is a study that in many ways can be compared with this study. David & Kilian (2009) is a study with the purpose of estimating the effect of a gasoline tax on carbon dioxide emissions in the USA. Their paper will be beneficial for this study, which is applied to the case of Sweden. This study attempts to fill voids in the existing the literature in this field of research. It does so by using new data published in 2019 at a municipal level in Sweden (SMHI 2019).

There are two aspects regarding the consequences of carbon dioxide emissions. The global average temperature is increasing and that causes climate changes that are almost impossible to overestimate. Today's society is facing a big challenge to mitigate the negative climate- and environmental changes. The consequences of the elevated global temperature are both numerous and devastating. A few examples are melting glaciers, increased water levels and extreme temperatures causes metrological changes which in turn causes unstable food production among others. The changing climate affects the conditions for species, habitats and entire ecosystems to the extent that they are threatened. The increased levels of greenhouse gases, with focus on carbon dioxide, does not only result in elevated global temperature, but also consequences such as acidification and eutrophication. (World Wide Fund for Nature (WWF nd).

Another important perspective is human health. Individuals are on a daily basis being exposed to great amounts of air pollution, greenhouse gases. This pollution can have a negative effect on the health, in forms of example heart- and lung diseases. The air pollutants that are most dangerous for the human to be exposed to are inhalable particles, such as nitrogen dioxide and ground level ozone gases. Among the biggest sources of air pollution is vehicles, road transportation. In particular, fumes of vehicles, as an externality, but also the particles that occur as an externality of wear of stud tires (EPA 2019). Sweden has introduced a number of different local and regional policy measurements in order to reduce the local health issues, arising from increased amounts of Greenhouse gases, and to be able to reach the Swedish environmental goal “Fresh air”. Some examples of local and regional incentives are congestion tax, in Stockholm and Gothenburg, reduced speed in some streets, and several incentives to change the individual's behavior, which includes increased number of individuals to use a bike cycle, and use carpool, etc. and reduced amount of parking lots (EPA 2019).

When focusing on Sweden, the expected consequences are milder winters and an increased number of storms, with increased intensity. In general, Sweden will have a warmer climate, with both advantages and disadvantages, especially with respect to the agricultural perspective. Where the advantages lay in the warmer climate which will lead to improved cultivation conditions (EPA 2008). The warmer climate also contributes to an increased risk of periods of drought (WWF nd).

Air pollution has come to be a big problem for a sustainable future. Reduced climate impact and fresh air, are two of Sweden’s environmental goals (Environmental goals of Sweden 2018). One of the governmental incentives to achieve those two goals is an increased fuel tax.

Many studies have been done analyzing the fuel prices elasticity, Sterner (2007) among others, with results that shows how the fuel taxes are distributed unevenly between socioeconomic categories in society. That is, fuel taxes are strongly regressive and therefore have the greatest effect on the poor in society.

In Sweden, the situation is different; it is a matter of rural and urban differences concerning the fuel tax. The Swedish government strives towards development of the whole Sweden, where the countryside and urban cities are in balance and the standard for living and working in Sweden should be raised (Swedish Television 2018). However, the rapid increase of the fuel tax in Sweden continues, and the consequences of that is a deteriorating economic seat for many, especially in the rural areas. In urban municipalities, there is access to public transport that can work as a substitute for the car. In these regions, there are also often smaller distances and therefore the bicycle can substitute to use a car. Sweden is an elongated country and for many people the use of a car is not a choice. When looking at rural municipalities the car is in many cases mandatory, to make everyday life work (Skattebetalarna 2019).

1.3 Aim and delimitations

The aim of this study is to investigate the effect that the fuel tax has on carbon emissions in Sweden. That includes to look at if there are any differences between rural and urban municipalities in Sweden. Two research questions will be answered in this study:

1. *How does fuel tax affect carbon dioxide emissions in Swedish municipalities?*
2. *How does the effect of fuel taxes spatially differ between rural and urban municipalities?*

When analyzing the effects of fuel tax, this is a study limited to Sweden. As a result of that the fuel tax differs between different types of fuel, this study aims to examine the fuel tax directed towards gasoline. The reason the study chose gasoline instead of diesel is because of that the majority of private cars are driven on gasoline.

This study contributes to the existing literature because it approaches the spatial differences in a new way. That is, the study aims to examine if rural and urban municipalities affect the CO_2 emissions differently.

The study has, due to the time frame for this bachelor thesis, limitations. First is that the study will focus on the emissions from private cars, even though there exists data from the whole transport category. The limitation was made to cars only due to that data from SCB shows that the majority of domestic emission comes from cars in Sweden (EPA 2019). Another limitation of the study is that it only considers the carbon dioxide emissions caused by passenger cars. The choice was made with respect to that the greatest amount of greenhouse gases in the atmosphere is carbon dioxide (EPA 2008).

2 Theoretical framework and literature

There are papers that have done similar studies, a big part of them focus on the elasticity of different types of fuel, but the majority of the papers are aimed toward gasoline. Sterner has done many studies in this area where he focuses on the importance of fuel taxes as an instrument for reducing air pollution. Sterner (2007), has many perspectives in the article as to be able to give a broad picture of the problem concerning fuel taxes as an important instrument for climate policy. The results show that the increased demand for fuel would be much larger in the absence of a fuel tax. The article also wants to highlight the price elasticity as elastic in the long run, which can be of use for policy makers. Another angle of this topic is examined in the study *Distributional effects of taxing transport fuel*, (Sterner 2010). The paper aims to highlight that there is a negative view of fuel tax that is shared by many in the community. These people, who are against fuel taxes, often suggest that it is strongly regressive. That is, that the fuel taxes for example mainly hurt the poor in society. With that in mind, the study wants to show the importance of fuel taxes, because of it being an important instrument regarding the climate changes. The papers results indicate that the consequences of a fuel tax are strongly influenced by the choice of country and methodology. Smith (2000) examined the distributional effects of increases in price, in the United Kingdom. One subgroup that is of interest in this study is the rural category. Their results show that an increased fuel tax caused individuals, living in rural regions, an increased economic burden. Eliasson, Pyddoke & Swärdh (2016), Sterner (2010) and Smith (2000) analyzed the distributional effects of a fuel tax. The results show that the two most important geographical factors when looking at the distributional effects of a fuel tax are rural and urban areas and central cities and suburbs. This paper wants to highlight that the purpose of the tax, corrective or fiscal tax, determines if distributional effects should be taken into account or not regarding the level of the taxation. However, rural regions in comparison with large cities, suffer proportionally higher from welfare losses.

Furthermore, another category of studies in this field of research, that are very similar to this study, where focus is on looking at different determinants and examine their effect on carbon dioxide emissions. Davis & Kilian (2009) wanted to estimate the effect of a gasoline tax on carbon dioxide emissions. They examine that by estimating the effect of an increase in gasoline tax on the gasoline consumption. The estimates where further on used to examine the change of carbon dioxide emissions, which resulted in a change by -0.48%, when increasing the tax by ten cents. The importance of their study, they say, is because they take into account things such as endogeneity of the price of gasoline. They believe that it is well known that increased demand for gasoline is causing the gasoline price to rise. The consequence is an incorrect correlation between the price and the regression error. Which causes the estimates of the price elasticity to be biased towards zero. Lin & Li (2011) estimated the effect of a carbon tax on carbon emissions, in the four countries Denmark, Finland, Sweden, Netherlands and Norway by using the method difference-in-difference, DID, a type of panel regression. Their results indicate that the effect of the carbon tax differentiate depending on the country. In Denmark, Finland, Sweden and Netherlands the introduction of a carbon tax resulted in a negative impact on the growth of its emissions of CO_2 per capita. However, Finland was the only country with significant and negative results. Norway, got the opposite result of a carbon tax. That is, despite of a carbon tax the CO_2 emissions increased. Li & Zhao (2017) examined the environmental effects of a carbon tax in a case study applied on Sidney, by using Transportation and Environment Strategy Impact Simulator (TRESIS), where focus is on car use. As the other studies mentioned the results of the paper shows that a carbon tax will have a negative effect on the carbon emissions, by 3.7 percent in Sidney's metropolitan area and reduce car kilometers driven by 3.5 percent in 2017.

Baiocchi, Minx & Hubacek (2010) analyzed the importance of sociodemographic variables and consumer behavior regarding the greenhouse gas, carbon dioxide, emissions in the United Kingdom. The study finds support of the hypothesis that sociodemographic variables are important in explaining carbon dioxide emissions. They found that emissions are increasing with income and decreasing with the amount of education. Fan et al. (2006) examined the determinants of carbon dioxide emissions. Results showed that GDP per capita, population, energy intensity and population age 15–64, affected the total CO_2 emissions of countries with a high income level. Shi (2003) results, like Fan et al. (2006), found that population growth has a great impact on CO_2 emissions, but also that the impact is greater in developing countries compared to develop countries. Lin & Li (2011) results show that the GDP per capita is positively correlated with the growth rate of per capita CO_2 emissions.

3 Methodology

3.1 Model specification

Two common econometric models, when having panel data, are the Fixed effects model and Random effects model. For this study, the random-effects model will be used. It is called the Random effects model, due to that the variation across entities is assumed to be random and uncorrelated with the other independent variables in the model. The Random effects model is used in this study, due to two main reasons. Firstly, unlike the fixed effects model, the random-effects model varies across entities. Which means that the model captures any spatial differences that can influence the dependent variable. Secondly, the model makes it possible to include time invariant variables, such as urban and rural municipalities in this study, and that is not possible when using Fixed-effects model (Torres-Reyna 2007).

The Random effects model has a major issue, which is important to be aware of, the potential bias, that occurs from omitting fixed effects. The omitted variables bias can lead to wrong estimations. To test for such bias, the Hausman test can be applied. The Hausman test examines if the residuals of the model are correlated with the estimated regressors. The null hypothesis of the test says that they are not correlated, that is random effects (Torres-Reyna 2007). The test was not done in this study which remains a limitation of this study.

The regression follows the structure:

$$y_{it} = \beta_0 + \beta_1 \log Cars_{it} + \beta_1 logPopdens_{it} + \beta_2 logFueltax_{it} + \beta_3 Urban + (\alpha_i + e_{it})$$

(1)

As shown in table 1, the explanatory variables include amount of passenger cars in use, population density, the Swedish fuel tax directed towards gasoline and a dummy variable for urban municipality. The panel data means that the variables are divided into municipalities and years, in model (1) the entity, municipality, are denoted as *i* and the time, years, are denoted as *t*. In model (1), β_0 is the model's constant and β_{1-3} are the variables respectively coefficients. Furthermore, α_i is the individual-specific effects and is included in the error term, $(\alpha_i + e_{it})$. In the econometric estimation, this study used logged variables, because of different units and large coefficients. Logging the variables in this study would likely improve the explanatory variables estimations.

Table 1. *Explanation of variables*

Variable name	Label and unit
CO_2	The amount of CO_2 emissions in municipality, tonnes per year
Cars	Number of passenger cars in use in municipality, number of cars
Population density	How densely populated a geographical area is, inhabitants per km^2
Fuel tax	The taxation on gasoline, SEK per litre
Urban	Urban municipality, dummy variable

3.2 Data and data sources

The dependent variable is carbon dioxide emissions in Sweden, counted in tonnes per year. The national emission data is presented at both county and municipal level, in a grid. The grid, consists of squares corresponding to $1km^2$. The distribution is an estimation based on relevant statistics and geographic data, that is things like road network, car types, cold start share, traffic flows and population data. With respect to that, the finer distribution of total national emissions, the more uncertain the quality of distribution is (RUS nd).

The independent variables are: cars, average income, population density, fuel tax, GDP per capita and a dummy variable for rural and urban municipalities (see Table 1). The study is based on panel data, divided in municipalities and years. The data is balanced and consists of the total number of municipalities in Sweden, which corresponds to 290, that runs between the years 2010 and 2017 (see Table 2).

The chosen data set were gathered because the variables are described as important determinants of CO_2 emissions in the literature review. The data are mainly collected form Statistics Sweden, but also from the Swedish Petroleum and Biofuels Institute (SPBI) and RUS, The County Administrative Boards in cooperation.

Table 2. *Descriptive statistics*

Variable		**Mean**	**Std. Dev.**	**Min**	**Max**	**Observ.**
CO_2	overall	10.14	0.85	7.89	13.19	N = 2 320
	between		0.85	8.12	13.09	n = 290
	within		0.05	9.76	10.64	T = 8
Cars	overall	9.20	0.88	7.17	12.78	N = 2 320
	between		0.88	7.23	12.70	n = 290
	within		0.04	8.89	9.45	T = 8
Average income	overall	5.57	0.13	5.27	6.32	N = 2 320
	between		0.12	5.37	6.24	n = 290
	within		0.06	5.46	5.69	T = 8
Population density	overall	3.35	1.68	-1.61	8.65	N = 2 320
	between		1.68	-1.61	8.51	n = 290
	within		0.02	2.99	3.53	T = 8
Fuel tax	overall	1.71	0.06	1.65	1.82	N = 2 320
	between		0	1.71	1.71	n = 290
	within		0.06	1.65	1.82	T = 8
GDP per capita	overall	6.02	0.06	5.94	6.13	N = 2 320
	between		0	6.02	6.02	n = 290
	within		0.06	5.94	6.13	T = 8
Urban	overall	0.53	0.50	0	1	N = 2 320
	between		0.50	0	1	n = 290
	within		0	0.53	0.53	T = 8

Notes: *All variables are logged variables, except Urban. The variable Urban is a dummy, that is not logged.*

The variables Average income and GDP per capita are both related to income and that makes them correlated. Due to that reason, Average income is dropped as an independent variable in the study.
The variables Cars, consists of the total number of passenger cars in use at the turn of the year. Average income, is the average income per year with respect to the earned income and from the age of twenty and higher. In Sweden, you have the right to drive a car from the age of eighteen, if you have a driver's license. When gathering the data, there was no option that was perfect, that is from eighteen and older. So, in order to exclude that the variable was overestimated, data were collected from the age twenty instead of sixteen. Population density is measured in inhabitants per square kilometer. Since the fuel tax and the VAT is differently calculated, with different units, this study chose to only account for the fuel tax that has its foundation in environmental issues, in the regression. With that in mind, this study is focusing on the environmental impacts of a fuel tax. Fuel tax, including the carbon tax but also an energy tax, is measured in SEK per litre. Table 2 shows that the variables Fuel tax and GDP per capita, do not vary between municipalities, only over time. That is because these two variables are determined on a national level.

Table 3. *Correlation*

	CO_2	**Cars**	**Average inc.**	**Pop. dens.**	**Fuel tax**	**GDP**
CO_2	1.00					
Cars	0.94	1.00				
Average inc.	0.19	0.23	1.00			
Pop. dens.	0.45	0.56	0.37	1.00		
Fuel tax	-0.03	0.02	0.38	0.01	1.00	
GDP	-0.03	0.02	0.40	0.01	0.94	1.00
Urban	0.24	0.21	0.35	0.22	-0.00	-0.03

Notes: All variables are logged variables, except Urban.

There are two high correlation values (see Table 3). The correlation coefficient between GDP per capita and Fuel tax is 0.94. The correlation coefficient between CO_2 and Cars, 0,94, but do not indicate multicollinearity because it is a correlation between the dependent variable and an independent variable. The correlation between GDP per capita and Fuel tax, is however between two independent variables, and that is not desirable. When reading the results of a regression, you hold all of the other independent variables constant. The correlation between GDP per capita and Fuel tax, means that you cannot make the assumption. So, a high correlation between independent variables, multicollinearity, can cause great problems when later analyzing the independents effect on the dependent variable. The multicollinearity reduces the reliability of the estimated coefficients, and therefore also the mode itself. With respect to that, the regression will not include GDP per capita, due to that the variable of interest is Fuel tax.

A main part of this study is to examine if there are any differences between rural and urban municipalities. Sweden's classification of municipalities 2017 was the foundation for the study's categories rural and urban municipalities. The data was originally divided into three groups: major cities and metropolitan municipalities (A), larger cities and municipalities close to larger cities (B) and smaller cities/suburban and rural municipalities (C). Simplified urban, peri-urban and rural. But this study is not interested in the size of a municipality. It is interested in examining the differences between urban and rural municipalities. To be able to do that, category A and B was merged into urban and C rural municipalities. When making the regression in the econometric program, Stata 16.1, the categories were transformed into a dummy variable, called Urban, where urban = 1 means it is an urban municipality and urban = 0 indicates it is a rural municipality.

The final independent variables in the regression are: passenger cars, population density, urban and fuel tax (see Table 1).

4 Results and discussion

Several regression models were estimated to examine the relationship between the carbon dioxide emissions and fuel tax. Estimating the regression, the study obtains the following results with logarithm variables, except from Urban, due to that it is a dummy variable (see Table 4). Logged variables mean that the coefficients of the regression are interpreted as elasticities, which is changes in percentage. Robust standard errors are used in the regression to address possible heteroscedasticity (See Table 4).

Table 4. *Random effects GLS regression.*

Variables	**Coefficient**	**Robust Std. Err.**
lgCars	0.609***	0.049
lgPopdens	-0.012	0.025
lgFueltax	-0.844***	0.032
Urban	0.137*	0.053
_cons	5.945***	0.381
R-sq	within	0.22
	between	0.83
	overall	0.83
Rho	0.98	

Notes: **** denotes $P \leq 0.001$. * denotes $P \leq 0.05$.*

As shown in table 4, all the independent variables are significant, except for the variable Population density, but since these variables were chosen with respect to existing literatures results it indicates that the model is reliable.

When looking at how well the regression is adjusted it is also important to look at R^2 and rho. The R^2 describes what proportion of the variation in the dependent variable that is explained by the independent variables. The R^2, for a random-effects model is divided into three values: within, between and overall. The within R^2 measure the degree of explanation within entities and the between R^2 measure the proportion of variance in the dependent variable caused by variation between entities. The overall R^2 takes into account both time and entities. So, R^2 is a measure of how well the independent variables explain the variation in the dependent variable. Looking at the R^2 values we can see that most of the variation is explained by between entities and not so much by within entities. The R^2 value 0,83 is a good value, but could have been higher (see Table 4).

Rho is the fraction of the variance in the error due to the individual specific effects. The value is high, 98%, which indicates that the individual effects dominate the unobserved factors that impact the dependent variable (see Table 4). So, when combining these two, R^2 and rho, and taking into consideration that all except one independent variable was statistically significant, we can say that this is a reliable model.

Now looking at the coefficients of the variables, the results are in many ways in agreement with existing literature. Population density has a negative impact on the CO_2 emissions in Sweden, Fan et al. (2006) also determined this relationship. Important to have in mind is that the coefficient of the variable Population density is insignificant for this study, but since Fan et al. (2006) obtained similar results, the question is why Population density has a negative effect on CO_2 emissions (see Table 4), instead of a positive effect. Population density and Urban are related, in that way a high population density indicates an urban municipality. But important to have in mind is that this study only wanted to examine the CO_2 emissions caused by passenger cars in a municipality, and then use the independent variables trying to explain it. So, population density is based on the registered persons in a municipality and a high population density indicates an urban municipality. It could be that the more inhabitants per km^2, the more likely it is an increased number of job opportunities that do not require a car as transport. Where the size of the city is associated with better public transport and the possibility of bicycles or other substitutes. In that way of reasoning a valid explanation for the relationship between CO_2 emissions and population density can be job opportunities and commuting distance. Where job opportunities cause individuals from other municipalities to commute there, which leads to increased emissions in the municipality, which is not explained by population density. The commuting distance decreases with increased population density, as increased population density indicates large cities. With decreased commuting distances, the need of a car likely decreases and therefor also the CO_2 emissions caused by passenger cars. With that in mind an improvement of the study could be to take such factors into consideration, for example number of people commuting.

The coefficient of Cars is positive, which mean that an increasing number of passenger cars in a municipality is followed by an increased amount of CO_2 emissions. According to EPA passenger cars were the greatest source of CO_2 emissions in Sweden 2019 (EPA 2019), and with respect to that it was an expected result, that Cars should have a positive effect on CO_2 emissions (see Table 4).

In accordance with other studies, this study shows that a fuel tax has a negative effect on CO_2 emissions (see Table 4). When holding the other independent variables constant, an increase in Fuel tax by one unit, SEK per litre, decreases the CO_2 emissions by 0.84% in a municipality. With these results in mind the Swedish fuel tax is a good climate policy instrument. The question, is really a constant increase of the fuel tax, the best option from a social perspective? The results of Eliasson, Pyddoke & Swärdh (2016) and Smith (2000) as this study, indicates that the objectives of the fuel tax are conflicting, that is if the intentions of the fuel tax are fiscal or corrective. In reality, the reason for a fuel tax is both fiscal and corrective. When setting the level of fuel tax, that perspective must be considered. The variable Urban, when classified as an urban municipality has a positive effect on the CO_2 emissions, with 0.137% in a municipality (see Table 4). The variable is associated with increased emissions, which indicates that Sweden has spatial differences regarding rural and urban municipalities and their different effects on the CO_2 emissions. The urbanization will continue (National Geographic nd) and the variable shows that urban municipalities has greater CO_2 emissions compared to rural municipalities. Further development should be focused to give inhabitants in rural municipalities incentives to stay.

The study faces some strong limitations. There could be drivers of CO_2 emissions omitted in the model, e.g., economic growth. If fuel taxes increase over time, any other variable with a positive time trend could also drive the results (a spurious correlation problem). In addition, there is very little variation in the tax variable. As a national tax, it does not vary across regions, and the changes over time in the study period are also small and few. An alternative approach would have been to study fuel prices rather than taxes which would have allowed for a more efficient estimation. Consumers are probably more concerned with the retail price than with the tax. Unfortunately, the data of different fuel price indices for the various regions were not readily available. Using the random effects model might also have led to biased estimates.

5 Conclusions

The objectives of the study were to examine the effect of the Swedish fuel tax on CO_2 emissions. Another objective was to see if there are any spatial differences regarding rural and urban municipalities in Sweden. The method for this study was random-effects model, because of two reasons. Firstly, the model varies across entities, which in this study was necessary to be able to spot any spatial differences. Secondly, the model makes it possible to include time invariant variables, that is the dummy variable for urban municipalities. The main results from the study are the statistically significant coefficient of fuel tax, which shows that the Swedish fuel tax has a negative impact on CO_2 emissions, -0.844. When holding the other independent variables constant, a one unit change in Fuel tax decreases the CO_2 emissions with 0.84%. However, this comes at the risk of obtaining biased estimates. The variable Urban, show that an urban municipality has a greater impact on the environment compared to a rural municipality. That is, an urban municipality has a negative effect on the CO_2 emissions caused by passenger cars, that a rural municipality does not have.

Urbanization is continuing and by 2050 it is said that two-thirds of the global population will live in urban areas (National Geographic nd). The urban variable highlights the problem of urbanization, because of that it shows that urban municipalities has a greater negative climate impact, compared to rural municipalities. This study's contribution to future policy making is to raise awareness of the consequences of urbanization. That is, an important part of Sweden's climate measures should be to make the countryside attractive, so people who live in the countryside have an incentive to stay and that people want to move there. The Swedish fuel tax is an important climate policy, but it is also important to care about the Swedish countryside.

Raising the fuel tax may not be the only solution for a sustainable future. Since the variable Urban shows that urban municipalities are causing greater amount of greenhouse gas emissions compared to rural municipalities. Combining the fuel tax with policies such as increased parking fees and give individuals incentive to use the bicycle or carpool should be in focus.

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