EUROPEAN CAR TAXES AND THE CO2 INTENSITY OF NEW CARS.

What is the impact of CO2 based car taxes?

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Abstract:

Since 2000 many European countries have revised their car taxation. Most countries now have a CO_2 component in the tax they levy on acquisition, ownership or both. This thesis analyzes the effect of these changes on the average CO_2 emissions of new cars, with the use of a reduced-form panel regression model including fixed effects and a structural equation model (SEM). In the reduced-form model outcome, acquisition tax is the only tax variable that is significant at 10% and it is also strongest in size. The SEM takes into consideration car characteristics as a mediator. Its results confirm and clarify the previous finding. While all vehicle characteristics have a significant effect on CO_2, only acquisition tax and gasoline price significantly work through the mediating vehicle characteristics. However, they do so through different modes. Acquisition taxes seem to shape the consumer's choice of engine power (kW), while gasoline prices determine the share of diesel cars that are purchased. Ownership taxes based on CO_2 significantly reduce CO_2 intensity, but there is no significant effect that works through the vehicle characteristics. In order to achieve lower average CO_2 emissions of their car fleet, policy makers are advised to implement both CO_2 based ownership and acquisition taxes, which is not currently the case for all European countries.

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1 Introduction

European taxation of cars has changed substantially over the last two decades in Europe. Most countries' main concern was revenue management. With the growing threat of climate change and environmental concerns, the governments have shifted their focus from generating tax revenues to internalizing the social and environmental costs that occur from car use. In the European states that comprise EU15, transportation emissions amount to over 25% of total CO_2 emissions, over 90% of which are attributed to transportation on roads (Kwon, 2006).

The resulting costs are of economic, environmental and social nature. Economic costs consist in the building and maintaining of the roads. Ecological cost are the obstruction of wildlife and increase in greenhouse effect. Social costs consist of reduced air quality and noise. Naturally, these negative impacts should be paid for by those who create them. Given the looming threat of climate change it is important to reduce the negative impact. What are the ways in which we can internalize these costs most effectively?

Before a government can choose the right instruments, it must be understood which options it has. Essentially it must try to make the car user pay for his externalities. At the same time the burden should not overshoot in order to improve overall welfare. For instance, the burden should not be so heavy that using the car is too expensive for effective use. Thus, which ways are there to tax the car user effectively and which of these types of taxes is most helpful to lower the environmental impact of a country's car fleet?

Since the 1990's the European Commission has focused its attention on the levels of CO_2 as the main metric to measure pollution and its progress in its reduction. Since 2002 it aims to reduce these emissions with a set schedule that has gotten extended over time. By 2020 the amount of CO_2 that is emitted on average by new cars should drop to 120g CO_2 /km. In the past two decades the CO_2 emissions have indeed decreased. Previous research indicates that taxes play a substantial role. A mix of different taxes has been implemented however and every European country has their own mix of taxes they levy on the acquisition, ownership and use of the car.

Thus the following is the central research question of this paper:

How do car taxes affect CO_2 emissions of new cars?

Further questions help to understand the dynamic of car taxes: What role do taxes play in the car buying decisions? Can we observe that a certain type of tax (on acquisition, ownership or fuel) has an impact on a certain consumer preference? In conjunction with the reviewed literature, these questions lead the hypotheses that are formulated in chapter 5.1 of this paper.

This study will focus on the correlation of the three main tax types that are levied on car use, namely acquisition taxes, ownership taxes and fuel taxes. It uses time-series data on the CO_2 emissions of new cars in each of the EU15 countries. The study is not directly concerned with the overall level of CO_2 that is emitted but rather it examines the average level of CO_2 that is emitted by new cars. This level is determined for each car and model by a test, called the New European Driving Cycle.

In order to answer the research question within this paper, we will first explores the types of car taxes further in the next chapter. Thereafter, we see the literature in chapter 3 and their theoretical and empirical standpoint on the subject. Subsequently, we will derive the appropriate data and framework in the 4^{th} chapter. We commence to the methodology in chapter 5, which states the hypotheses and puts forth the strategy to investigate them. This is done with two models, of which the results are presented separately. The 6^{th} chapter discusses the results with regards to the hypotheses. Finally, in chapter 7^{th} chapter I conclude the thesis.

2 Car taxation in Europe

The different types of taxes have been used very differently by the individual European Union member states. The European Commission intends to create a homogeneous system of taxes, which it believes to be adequate to deal with the challenge of rising CO_2 emissions from transportation. This chapter goes more in depth to understand the differences in taxes and European situation.

2.1 Types of car taxes

The common taxes can be categorized into acquisition tax, ownership tax and fuel tax.

2.1.1 Acquisition tax

This is a non-recurring charge, to be paid when a new vehicle is purchased and registered. It is commonly referred to as registration tax, registration fee, turnover tax or vehicle sales tax (VST).. Each countries has a different way to calculate the registration tax. The purchase price and the engine characteristics are the most important factors, where diesel and petrol engines are often distinguished. The part based on the engine is calculated by horsepower or kilowatts and/or cubic capacity and increasingly in recent years, partially by ecological characteristics in the form of exhaust emissions or fuel consumption.

Theoretically it is a good tool to use purchasing costs because the it is taken into account immediately when the consumer makes a buying decision. If consumers are near-sighted and do not take into account the accumulating future costs such as ownership taxes and fuel costs, acquisition taxes could be the most important tool to shape buying behavior.

2.1.2 Ownership tax

It is charged periodically, also referred to as annual circulation tax (ACT) vehicle tax or road tax. Countries have different ways to determine the amount that is levied. Often it is based on engine power, cylinder capacity, weight or fuel consumption. Since the above mentioned acquisition tax consists of a large fee up front, it may hamper the purchase of new cars to an extent that is more than desirable. The average renewal time of the car fleet will rise and lead to inefficient technology and lowered amount of car sales. In contrast, the total costs of ownership taxes accumulate over a car’s lifetime. Thus, a near-sided buyer might not take into account the full price at the time of purchase and make an buying decision that costs him more money and potentially produces more emissions over the active life-span (lock-in effect).

2.1.3 Fuel tax

This charge is often categorized as a usage based tax or excise duties. The amount levied is different in each member state and depends on their policy. This also leads to different relative prices, i.e. the end price for gasoline compared to the end price for diesel. Similar to the ownership tax, this cost accumulates over time and may not be sufficiently represented in consumer's decision making at the time of car purchase. Unlike ownership and acquisition taxes however, this tax is levied on actual usage, since it must be paid every time a consumer is paying for gas. Therefore it is crucial for total CO_2 reduction. In this study however, we are interested in the effect these future accumulative costs have on the purchase decision instead of overall CO_2 emissions.

2.2 The European CO_2 objective

Many countries have adjusted their car taxation since the 1990. Before the environmental concerns started to play a role, car taxation was used primarily to generate revenue to the country. The changes mostly focus on taxing CO_2 emissions more directly, however each country did this in a different way, based on different political views, private interests or socio-economic disposition.

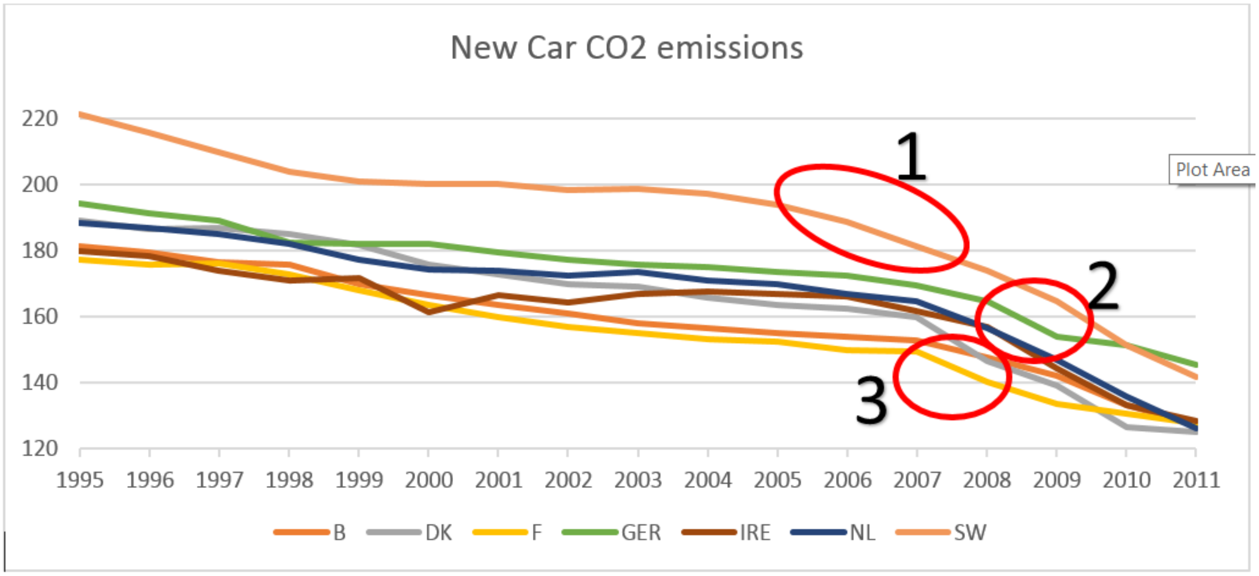
In 1995 The European Commission agreed that there must be a coordinated common target. Specifically the target was, to reduce the CO_2 emissions from an average of over 180 g/km CO_2 in 1995 to 140g/km (39.0 mpg) in 2008 and to 120 g/km (45.5 mpg) by 2012. It was later extended to the limit of 95 g/km (36.0 mpg) by 2020. The first attempt to coordinate this with car manufacturers was in the form of a voluntary agreement that was made with the Association of Automobile Manufacturers in 1998. It contained the following targets:

Information on the CO_2 emissions should be made readily available to consumers. Moreover, taxes should be implemented in a way that buyers are influenced to make more CO_2 conscious decisions. It was not yet stated which of the taxes are considered most favorable or in what form they should be implemented. Also in this agreement, there was no mechanism of sanctions or penalties if the manufacturers did not meet the target. Subsequently, similar agreements were made with the Japanese manufactures that comprise JAMA as well as the Korean association, KAMA. When the progress of new car CO_2 rates was evaluated in 2007, the result was below expectations. It appeared that real sanctions were necessary if the target should be met by 2012.

Up the time of this writing in 2014, each member state has a different system in which it employs its car taxes. The European commission has a set of recommendations on the car taxation of its member states (Proposal for a Council directive on passenger car related taxes). In order to homogenize the states' tax systems it proposes to abandon registration taxes in favor of annual circulation taxes. The aim is also to base taxation on emissions rather than weight, engine size or other car characteristics.

Implementation of taxes for CO_2 reduction

As a consequence of the individual interests and challenges of each country, the car taxation reforms come at various times and in different forms. Germany introduced its CO_2 based ownership tax in 2009. Previously, the German tax was determined by the cylinder capacity of the engine. The United Kingdom has increased its fuel tax drastically since 1993 for both diesel and petrol. Germany and the Netherlands tax diesel less than petrol for their energy efficiency or to support commercial vehicles, which usually use diesel engines. Despite efforts to make taxes across countries more similar, the shift towards CO_2 taxation may be analogous in its goal to reduce pollution, but with very diverse underlying tax systems.



For instance, Sweden underwent a tax reform in 2006. Previously, their circulation tax was largely based on vehicle mass. The new circulation tax was based on emissions ratings. In this case it seems that the tax change may have affected new car CO_2 emission substantially enough to be visible on the graph of figure 1 (circle 1). In 2009, Germany moved away from taxing engine capacity and introduced an emission based circulation tax. The drop in emissions seems to be visible in the graph under circle 2. France introduced their bonus-malus program in 2008. It included subsidies of up to 1000 Euros for low emission vehicles and a penalty of up to 2600 Euros for high emission vehicles. For instance, a car that has emissions between 100 and 120 g CO_2/km would give the buyer a subsidy of 700 Euro on the purchase of a new car. According to (D'Haultfoeuille et al., 2010) there was a 285 million deficit resulting from this program because of a response that was much higher than anticipated. We see this response in 2008 where the graph appears to drop faster than previously and most clearly out of the three examples. (cf. circle 3)

3 Factors influencing CO_2 intensity

The objective of this chapter is to understand what key factors of carbon intensity the literature has found. According to Pindyck (1980) the fuel efficiency is the most important factor in determining overall CO_2 emissions. Transportation energy demand is a function of the size and the efficiency of the current automobile stock, and how much this stock is used by consumers. The efficiency of the stock is determined by consumer choice at purchase and can be influenced. The choice of the usage however is often limited. An important reason is that work transit is more or less fixed in the short and medium term and thus the efficiency becomes the most important factor. Therefore, if the energy efficiency of new vehicles increases year after year, the level of car fleet CO_2 intensity will reflect this improvement over time.

We try to get an understanding of the variables that influence CO_2 emissions intensity and its causes. The factors can be divided into several categories which can be divided into macro-economic factors, taxes, vehicle characteristics and producer decisions on the supply side. Subsequently we will group the work of the literature and discuss the contributions in that order.

Macro-economic factors

In order to have a general framework what factors influence energy demand for consumers, we should consider a much cited paper by Ehrlich et al. from 1971. The I=PAT equation is illustrated, which equates the environmental impact of human activity to the factors population, affluence (per-capita income), and technology. While population is particularly determinant of the overall level of CO_2 emissions, population change is also an essential determinant of socio-economic activity. Affluence and technology tell us more about the average choice of cars that consumers make. The latter is what is interesting for us in identifying factors that influence CO_2 intensity of the countries' car fleet. In reference to the IPAT equation, Tae-Hyeong Kwon (2005) notes, "The average fuel efficiency of new cars can change due either to an improvement in fuel technology or to a shift in consumer demand to different vehicle types in terms of fuel efficiency." This demand in turn can be shaped in various ways, some of which are in the realm of public policy such as taxes, as they will be discussed below.

Since the amount of emissions that is being produced is a direct consequence of the combustion of fuel, we need to know which factors reduce and which factors increase it. Placing the focus on fuel demand, there have been a few studies that estimate price elasticities of transport fuel demand using utility models for households' economic decisions. For instance Graham and Glaister (2004) and McCarthy (1996). Based on different results across these studies, I could not make out a consensus about the elasticity of demand for fuel. However, short term elasticity seems to have decreased over the last years, coinciding with rising income (also Goodwin et al., 2004). This means that consumers do not respond as strongly to higher prices for energy intensive products and fuel itself as they used to in the past. These studies usually do not incorporate taxes or other policy changes. However, Johannsson and Schipper (1997) do incorporated tax changes. They find a significant negative correlation between taxes and fuel intensity of the car fleet. A study examining consumer decision by Lehman et al. (2003) identified as the most important factors influencing car buying behavior in the UK, are car price, fuel efficiency, size, reliability and comfort. Relatively unimportant were the factors environmental concern and road tax.

Ryan et al. (2009) did model the elasticity of passenger car demand and CO_2 emissions intensity by estimating the effects of prices, income, tax policy and technical vehicle characteristics on passenger car sales and CO_2 emissions for the years 1995 to 2004. Thus, it is attempted to estimate CO_2 intensity using technical vehicle factors and non-technical factors as explanatory variables. The latter include various taxes levied on cars, allowing the discrimination between them, based on their potential to reduce CO_2 emissions. The distinction of technical characteristics and socio-economic factors will be useful for our model as well.

Small and Van Decker (2007) analyze the rebound effect of increased fuel economy. This effect refers to the increased amount of travel that consumers engage in while total expenditure stays the same as a result of improved fuel efficiency. Despite improved utility for the consumer, the overall emission level remains steady. Small and Van Decker found this rebound effect to be relatively low at 2.2% in the United States. This can be partly attributed to low relative fuel cost, leading to small importance of cost per driven kilometer in general. It is possible however, that this rebound effect plays a role in car acquisition. The interesting question is, if the improved fuel economy and lower emissions allow the purchase of larger engines and heavier cars. Some research has been done to this regard. Kwon (2006) identifies an offset of technology improvements by growing engine size. From the 1990 onward, the growing car size has also offset the slowing of technological improvements in Great Britain.

We can conclude that income seems to be an important factor in determining fuel demand and thus CO_2 intensity, even though the we cannot be sure about the income elasticity of this demand because the effects of costs of cars, taxes and fuel are not exactly known and may be complex.

Taxes

In their 2009 paper, Ryan et al. examined the impact of national fiscal measures in the EU15 and found that taxes have disparate effects on CO_2 emissions intensity. Circulation (or ownership-) taxes appeared to have a more significant effect on CO_2 intensity than did acquisition taxes. The latter became insignificant when country fixed effects were included. While Schipper (2002) found that a higher diesel share of the car fleet does not necessarily translate to lower average CO_2 emissions, the results of Ryan et al do show that when circulation taxes on diesel increased, the share of diesel declines and is related to a rise in CO_2 intensity.

The European Union commissioned a study in 2002 by COWI. It is a comprehensive study, that calculates the potential CO_2 emissions reduction by replacing the flat or car price-based registration and circulation tax, by direct CO_2 based taxes. The report comes to the conclusion that using a combination of acquisition and ownership tax that are each directly calculated by the amount of CO_2 emissions, has the largest CO_2 reduction potential compared to other car taxation schemes. Since the comparative effect of ownership seemed larger than that of acquisition taxes however, the European Commission proposal refers to this paper in recommending abolishment of registration taxes in favor of circulation taxes.

Vance and Mehlin (2009) point out that relying exclusively on technological improvement as it is suggested by some research as a focal point of environmental efforts, and thus focusing on the supply side development, foregoes much of the CO_2 abatement potential. By placing more exclusive focus on just fuel taxes, the overall CO_2 emissions potential could be hampered, if consumers take into account only immediate costs when buying a car. This is due to the consumer being locked in with a fuel inefficient car after purchase, while real costs of emissions are only incurred later. The paper concludes that empirically the thesis holds, that in order to change the composition of the car fleet, circulation tax and fuel taxes are the most important factors. This means that there is evidence that consumers do take into account later costs of usage, i.e. fuel costs and circulation costs adequately. In elasticity calculations to estimate the response to changing fuel costs, the outcomes confirm from a consumer demand analysis that fuel costs are indeed the most important factor in determining car buying decision and thus car demand.

On the other hand, there is also research that suggests that acquisition taxes have the most impact on CO_2 reduction. Using a discrete choice model, Giblin and McNabola (2009) model car buying decisions among which taxes play an important role. Using data from Ireland, the researchers came to the conclusion that vehicle taxes can reduce CO_2 intensity by 3.6-3.8%, if they are carbon emissions-differentiated. In comparison, fuel price or fuel taxes had relatively little impact on the purchase decisions of consumers. Also Rogan et al. (2011) find that registration taxes have a significant effect on CO_2 emissions of 13% in the year of introduction, through a rise in diesel share of cars. Nijland et al. (2012), who use data from 2001 to 2010 find that acquisition taxes contribute a lot to consumers' decision making for or against diesel cars, while fuel taxes and ownership taxes have very little impact. Van Meerkerk et al. (2014) used revealed preference data from 2004-2011 to estimate tax impact on vehicle type choice behavior. The findings are that acquisition taxes that are sufficiently differentiated as in the Dutch case are effective in stimulating sales of low emitting cars, while no significant effect was obtained by the ownership taxes.

Fuel price

Klier and Linn (2010) find a significant effect of fuel prices on the type of car sales in the United States. The change arises from the increased gasoline price in the years leading up to 2007, and explains nearly half of the decline of market share by US car makers which implies a substantial change in consumer demand. However, in order to improve fuel economy, raising taxes on gasoline even further would only have a moderate effect. In particular, levying federal taxes on gasoline to raise the price per gallon by 1 US dollar, would improve the fuel economy by 0.8-1 mpg (equivalent to 4-5 g CO2/km for gasoline), which is considered to be too low and might be due to price elasticities not being uniform for rising income and across the demographics spectrum. For further studies on the details, Klier and Linn suggest using vehicle characteristics as endogenous variables to have a type of dynamic approach that captures long-run effects, which in such a model are not limited to consumer choice but also producer's decisions. This can be realized by the framework we will build in the Approach part of the thesis.

Vehicle characteristics

Giblin and McNabola (2009) use a discrete choice model to model the car buying decision. The factors are grouped into Socio-economic features, car price and operation cost and vehicle characteristics. The socio-economic features are comprised of family structure, income and age. Car price and operation costs are comprised of producer price (before taxes), car taxes, company car taxes and fuel prices. Finally, the vehicle characteristics group is comprised of emissions, size, engine capacity, acceleration and fuel type.

Supply side

The effectiveness of the voluntary agreement (VA) was researched only to a limited extent. Mehlin et al. (2004) found that technological improvements of cars that are geared towards the reduction of CO_2 emissions have had a significant impact on CO_2 intensity, despite overall vehicle characteristics showing an unfavorable trend in the form of increased engine power, higher mass and larger size. This development is believed to be a demand side effect. Mehlin et al. conclude that the overall technological improvements have been spurred by the VA.

The production decisions of the suppliers, the agreements that are made and the technological progress are thus factors determining the vehicle characteristics that are being offered to the consumers. It follows, that it is necessary to model these characteristics to create a model for CO_2 intensity.

Summary

In order to create a model that controls for factors that are not the result of the taxes themselves we find that there is a recurring set of control variables in the literature. These are income, car price, road infrastructure and population. (Eskeland and Feyzioglu, 1997; Johansson and Schipper, 1997; Storchmann, 2005). Some papers include a lag. Ryan et al. (2009) include the CO_2 emissions as a lagged variable with a one period lag, however, the effect of tax changes is found to be largely limited to the year of introduction.

Consequently, the literature suggests the use of the following variables to estimate CO_2 emissions of new cars:

1. **Population**
2. **Affluence (Income, GDP per capita)**
3. **Taxes (ownership taxes, acquisition taxes and fuel taxes)**
4. **Technical vehicle characteristics, engine (engine power, engine size and not available are size or mass)**

5. **Fuel mix (share of diesel engines out of all cars)**
6. **Energy price (gasoline and diesel price for consumers)**
7. **Road network**
8. **Car prices**
9. **Trend (time effect)**
10. **Technology**

4 Approach and data

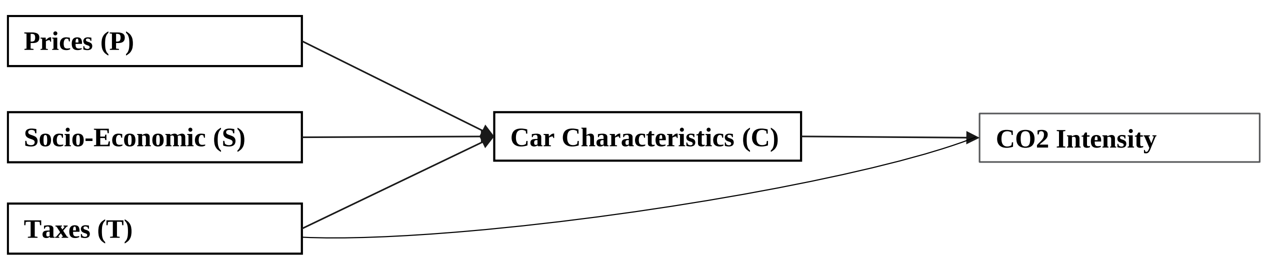
This chapter is concerned with the approach of the research. We will estimate a reduced-form model and a full model to answer the research question. The reduced-form model does not take into account vehicle characteristics, while the full model includes them in the form of structural equations as will be discussed below.

4.1 Approach

This paper examines the effect of tax changes on CO_2, measured as the amount of CO_2 emitted as determined by the European driving cycle. The CO_2 data is available from 1995 to 2012 for the 15 countries of EU15.

As depicted in the figure below, the CO_2 emissions are influenced indirectly by exogenous factors taxes (T) including acquisition taxes and ownership taxes, socio-economic (S), represented by GDP and prices (P), consisting of a car price index. CO_2 intensity is directly influenced by the endogenous factors car characteristics (C) and taxes (T). Car characteristics are comprised of engine size, engine power and fuel mix. Taxes are comprised of the tax dummies for CO2-based acquisition and ownership tax, as well as gasoline price (and by extension, fuel prices).

Figure 1 Theoretical Model



The structural equations do not lend themselves well for the interpretation of coefficients. Furthermore, due to limits in model identification, we cannot add all the dummies for time effects, which a linear OLS model does allow. Therefore, in chapter 5 of this thesis, a fixed effect model will be prepared first, before moving to the Structural equations. In it, the exogenous variables are directly regressed against New Car CO_2 Emissions.

4.2 Panel data

The data that is used is structured as a cross sectional and time-series format.

Econometric models that are based on panel data examine group effects on the one hand and time effects on the other. In our case the groups are the 15 EU countries. The time-series consists of the year 1995 until 2012. Using statistical models that take these dimensions into account we can properly address heterogeneity and observe individual effects which would otherwise go unnoticed. Two of these group specific effects fall into the categories fixed effects and random effects that can be estimated with multiple linear regression and also structural equation models. We will lay out the implication for the study in the remainder of chapter 4.

4.3 Panel dimensions and variables

The data is structured in a group dimension that consists of the country and a time dimension that consists of the year of the observation. Below I will present them and introduce the variables that will make up the data of the model.

Countries

The EU15 countries were chosen because they allowed for a reasonably long observation time for most variables that are commonly used. They consist of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and United Kingdom. However, in the final SEM estimation, Greece is dropped due to some missing data. This leaves us an N of 14 countries.

Years

The times-series aspect of the data consists of the years that new car CO_2 data was available. This was the case from the year 1995 for the dependent variable and the most recent data is from 2012. However the World Bank macroeconomic data is only available until 2011. That gives us 18 time periods, or t=17. The panel has a total of 255 observations, based on 15 cases and 17 years. Most variables below have some missing values however, which will be discussed below.

New Car CO_2

New Car CO_2 refers to the country's average carbon dioxide rating of all new cars sold in a year. The carbon dioxide rating of a car is the amount of CO_2 that is emitted per driven kilometer, as determined by the New European Driving Cycle. The yearly data of the 15 countries provided in two different forms by the European commission statistics office Eurostat. (Until 1999 the data was separated by organization. That means, ACEA (Europe), JAMA (Japan) and KAMA (Korea) had separately accumulated figures for their respective members. I combined these by using the average out of these organizations, weighted by the number of registrations. The data from 1995 is available in PDF file tables on the European Commission site on Climate action.[1]

From the year 2002 onward the data is collected by the European Commission and is based on data delivered by the member stats. This does not involve automobile associations. In total the data is available from the years 1995 to 2012, which provides us with 18 time periods. The data is

[1] Monitoring of CO2 emissions - Decision 1753/2000 (repealed)

available on Eurostat for the years 2002 until 2012 in the form of an updated spreadsheet[2]. According to a disclaimer of Eurostat, combining these figures is not recommended. A warning is offered about possible inconsistency in data collection in 2002[3]. The methodology used for data collection prior to 2002 leads to slightly lower figures then the subsequent periods due to the way different engine sizes of the same model group were merged. The difference for the year 2003 between the different sources was reported to be up to 1g in the average CO_2 figures. This discrepancy, for our purposes, should be acceptable.

Engine Power

Engine Power (in kW) is one of the car characteristics and it is one of the consumer choices that can be influenced measurably by taxes, since it is a simple metric. Some countries have based their taxes directly on engine power in the past (France and Italy for their acquisition tax and Austria, Belgium, Greece, Italy and Spain for ownership tax calculations). The data stems from ACEA.

Engine Size

Engine power is measured in cubic centimeters (ccm) of cylinder capacity. Similar to engine power, engine size is a simple measure to tax and potentially influence. In the past most countries have used this as a tax basis either for acquisition taxes or ownership taxes. (Greece, Ireland, Portugal, Spain for acquisition tax and Belgium, France, Germany, Greece, Ireland, Luxembourg, Portugal and United Kingdom for ownership tax). The data is obtained from ACEA.

Dieselshare

This variable refers to the share of diesel vehicles that were sold out of all vehicles for a particular country. The information is obtained from ACEA[4]. Since the combustion types are largely comprised of petrol and diesel I will refer to this indicator as determining the fuel mix. The percentage of cars equipped with a diesel engine have risen in all countries over time. The variable is important indicator, because diesel engines are more efficient in that they can produce similar power at lower amounts of fuel and thus combust less carbon. As a result, if all thing are held constant, an increase in the diesel share of vehicles will result in lower average CO_2 emissions.

1.1 [2] **[tsdtr450] - Average carbon dioxide emissions per km from new passenger cars - Gram of CO2 per km**
"This indicator is defined as the average emissions of carbon dioxide per kilometre by new passenger cars registered in a given year."

[3] Monitoring of ACEA's Commitment on CO2 Emission Reductions from Passenger Cars (2003).

[4] http://www.acea.be/statistics

Acquisition tax

The acquisition tax data was collected using a variety of sources. The ACEA tax guides and "Overview of CO_2 based motor vehicle taxes in the EU" were helpful for the years 2006 to 2012. To supplement this with more detail and for previous years, other papers and institutional publications were used.

Due to the various ways in which the taxes are calculated it is not possible to make a scale variable out of the entire tax scheme. One way is to choose a representative vehicle model and to use this car's characteristics to compare the levied taxes across time and between countries. The required work of researching the correct tax calculation and producing this variable was beyond the scope of this thesis. Moreover, the mentioned approach can only capture spot checks of the entire car market. As a compromise of the above, the best solution was to make a dummy that is "1" for the year that a significant component of the tax is based on its CO_2 emission level.

In order for there to be a significant CO_2 component in the tax and thus be considered "CO_2 based" or alternatively have an adequate spread in tax burden. The difference between low (<120g/km) and high (>200 g/km) CO_2 emission should be at least proportional to the emission difference or 2000 Euros difference in tax or more. In some cases this is achieved by directly calculating the g/km of CO_2 emission, liter/100km of fuel consumption or may even be based on price primarily with a multiplier for emissions like Finland or Denmark, or a bonus-malus system as it is employed in France and Austria and Belgium. There is no car specific acquisition tax in Germany, Luxembourg, Sweden and UK. In the case of Austria, France, Ireland and Spain, the new tax was directly calculated with CO_2 emissions (or in the case of Austria, fuel consumption) as a basis. For Belgium, Denmark, Finland, Germany, Greece, Netherlands and Portugal the CO_2 component is a part of the equation to calculate the rate, differentiating for the spread in CO_2 intensity.

Demonstration of CO_2 fee differentiation in Denmark

As an example Denmark's acquisition tax in June 2007 is a product of the car price and a factor 180% (for cars over 65,900 DKK). Strictly speaking, the tax is not based on CO_2 primarily but price. However, the CO_2 differentiation is substantial and compares to CO_2 based taxes as the following calculation will show. For fuel efficiency better than 16km per liter of petrol, 4000 DKK is deducted for every extra km. On the other hand, 2000 DKK is added for every km worse in fuel economy. This leaves us with the following table:

Table 1: Danish acquisition tax differentiation

Fuel Economy	Fee/Rebate (EUR)	Effective CO_2 Emission
13km/l	+804.84	184.0g CO_2/km
14km/l	+536.56	170.9g CO_2/km
15km/l	+268.28	159.5g CO_2/km
16km/l	Neutral base	149.5g CO_2/km
17km/l	-536.56	140.7g CO_2/km
18km/l	-1073.12	132.9g CO2/km
19km/l	-1609.68	125.9g CO2/km
20km/l	-2146.24	119.6g CO2/km

The total difference of a car emitting less than 119.6 and more than 184g CO_2 is 2951EUR. A feebate approach like this is also used by France, Austria and Belgium. Rather than an emissions-based tax, this tax is based on vehicle price and includes a correction, based on CO_2. An overview of the countries' acquisition tax basis can be found in the appendix.

CO_2 ownership tax

Ownership tax is a dummy variable for the condition, that ownership tax is either directly based on the amount of CO_2 that a car emits or alternatively, the tax rate must be sufficiently differentiated based on CO_2 intensity. The sources for this data are European Tax overviews, ACEA tax guide and various publications and peer reviewed papers on national tax changes. The countries that base their tax directly on CO_2 are Denmark (fuel consumption), Finland, Greece, Ireland, Luxembourg, Netherlands (2012), Sweden and United Kingdom. Countries that take CO_2 as part of the calculation for their ownership tax are Germany, Ireland and Italy. The other countries, namely Austria, Belgium, France and Spain do not currently have a CO_2 based ownership tax.

Fuel price

Diesel and Petrol price data are taken from International Energy Agency (IEA). The numbers refer to "Energy End-Use Prices (USD/unit, USD/toe, USD PPP/unit)" as denoted by IEA. The Petrol variable refers to Premium Unleaded 95 RON and is the year's average.

Fuel price variance includes the fluctuating import price, based on contracts, cost of import and trading fluctuations on the one hand and taxes on the other hand. In opposition to a fixed percentage rate of VAT, fuel taxes are an absolute amount of money levied per liter of fuel, regardless of the import price of the fuel (e.g. €0.65 per liter of unleaded petrol in Germany, 2011). Thus, effect of fuel price changes on New Car CO_2 emissions can be established, which is crucial knowledge to learn about the effect that levying fuel taxes can have. The fuel tax effect itself however, cannot be isolated by this approach. Since diesel and petrol prices are highly correlated, both should not be included. I choose to include gasoline due to the larger share of petrol cars.

Income

The data for income is provided by Eurostat and is measured in euros per inhabitant in current prices. It is an exogenous variable and captures the economic condition and disposable income. This variable captures fluctuation in welfare. Generally, larger welfare is expected to raise the demand for larger car sizes and likewise increase engine capacity and power. It is important to control for income as a main socio-economic indicator as we expect demand of certain car characteristics to be partly based on the average economic situation of the buyers.

Road density or road network

Road density refers to the amount of kilometers of road divided by the land area. After first differencing, the density does not play a role as the land areas stay constant in the time of observation so we are rather isolating the change in road network. The data is provided by the World Bank. The variable is included due to the theoretical expectation that private car demand is influenced by the availability and extensiveness of car infrastructure. Better car infrastructure may thus lead to more potential car use and make a larger investment more worthwhile.

Car registrations per capita

This variable captures the annual amount of car registrations per capita. It is derived from the ACEA's total annual registration figures, divided by the country's population. The population data is provided by the World Bank.

Time trend and car price

The time trend can absorb effect of CO_2 reduction that that occurs constantly over time, beyond the variables that we control for. This could be due to technological advancements from car manufacturers. Ryan et al (2009) include a time trend that is significant in their energy demand model. In the fixed effects model I chose to use time-specific fixed effects instead of a time trend. For the SEM model it is not possible to create a model that is identified.

The car price variable is the nominal price for an Opel Astra 1.4L without taxes. It is the only car model that existed over the range of time periods. The data is available in separate tables from the European Commission. In the SEM model it serves as a trend variable.

5 Methodology

This chapter presents the hypotheses, the strategy to test them and the analysis.

5.1 Research hypotheses

The problem of interest lies in limiting the CO_2 reduction. Most European countries have changed their taxes to new CO_2 based car taxes. Controlling for a trends in time and Socio-economic conditions, we wonder if the taxes had an effect on the CO_2 intensity of new cars. Thus I propose the hypothesis:

Hypothesis 1: Changing acquisition and ownership taxes to be based on CO2 leads to a significant reduction in CO2 emissions.

Most countries previous taxes were based on a combination of price and car characteristics. We are interested in how the taxes have affected the demand for these car characteristics and if they can be differentiated. Hence, the following hypothesis:

Hypothesis 2: The taxes affect CO_2 intensity indirectly, through car demand, measured by the average engine characteristics and the share of diesel vehicles.

5.2 Strategy

The first model will be a reduced-form model that uses exogenous variables of socio-economic nature to assess the effect of tax changes directly on CO_2 emissions of new cars.

Transformation of variables and model specifications

Large positive numbers were transformed to their natural logarithm, which applied to nine variables as shown in the table 2. For time series analysis it is advised to use stationary variables. This is in order to avoid covariance that is based on trends instead of the non-trend variation that we need to estimate accurate covariance between variables. Thus, in order to derive stationary variables I tested which variables had a unit root and are thus non-stationary. I tested for stationarity using the "unit root test in panel data" based on the augmented Dicky and Fuller test with two lags (Dicky & Fuller, 1979), where the null hypothesis is that the variable contain a unit root. This was the case for nine variables (table 2). As a result, these were transformed to be first differences. For the SEM model all variables including the dummies were transformed using a within transformation to estimate the model with a fixed effects, grouped by countries.

Table 2: Variable Transformation

Variable	No Transformation	Ln	First Difference
New Car CO_2 (g/km)		x	x
CO_2 Acquisition Tax	x		
CO_2 Ownership Tax	x		
Engine Power (kW)		x	x
Engine Size (ccm)		x	x
Dieselshare (decimal)			x
Gasoline Price (USD/unit)		x	x
Income (USD/capita)		x	x
Car Price (EUR)		x	x
Population		x	x
Registrations per capita		x	
Road Density		x	x

Estimating technical characteristics

Using two models allows us to first have a view on the general trends that macroeconomic factors have on CO_2 intensity, without trying to decompose the mechanism by which it is affected. Socio-economic factors such as income and prices play an important role for the type of cars that are purchased. Income determines what size and motorization is affordable on average so we expect there to be a significant relationship with CO_2. Transport infrastructure can determine if owning a car brings the desired ease of transport or if viable alternatives compete with the use of a car. These assumptions should be tested with the reduced model and the estimated parameters will tell us the size of the coefficients.

In order to make better policies, we want to know by which mechanism the macroeconomic factors and taxes influence CO_2 emissions. If we can understand which factors influence a consumer's buying decision, we can levy better taxes. Thus we define the car choice by measurable characteristics that we believe have an impact on CO_2. As derived from the literature, we have engine characteristics, in kW and ccm, and fuel type. According to theory, these characteristics determine CO_2 intensity and are determined by the same macroeconomic factors that I use in the reduced-form model.

Estimating CO_2 intensity

It is tempting to estimate CO_2 by treating all our explanatory variables as exogenous. However, this is not possible, since from theory we know that technical characteristics (engine power, engine size and fuel type) are determined by the social-, price- and tax- variables as well as cultural variables. Some of these are observed, others are not. In any case, we must treat the technical characteristics of cars as endogenous variables.

Since engine size and power are closely related to CO_2 intensity, they should be used in a model with multiple levels to estimate their effect on CO_2 intensity. Similarly, the percentage of diesel vehicles has a direct impact on CO_2 levels. Average CO_2 emissions for a given car tends to be lower than a gasoline counterpart of the same characteristics and performance. The size of this effect is limited, since this is only a switch to the other fuel type rather than a continuous trend. Nevertheless, some countries' percentage of diesel car sales have increased by over 25 percent points which results in a substantial change in CO_2 intensity. Hence, CO_2 is explained by taxes (T), prices (P), socio-economic factors (S).

5.3 Fixed effects model for panel data

In order to control for influences that are specific to a country, but that I do not have in the model as a variables that I use, it is helpful to apply a fixed- or random effects approach. These allow to control for all time-invariant influences that we cannot observe. We are aware of some, such as the status value of cars in a culture or the importance of car transportation relative to public transport. However, many others are unknown. We can control for all these factors as long as they do not change over the period we observe, which in this case is 1995 to 2012.

An important distinction between random effects and fixed effects is that using a random effects model, these time-invariant variables are thought to be uncorrelated with the explanatory variables. Given that the model relies on socio-economic variables such as income and population density, we should assume that the omitted variable is likely to be correlated. Testing the data in this regard by applying different models to the data, including several country specific variables and using the Hausman test showed that omitted variables were correlated with the model to a significant degree.

We are interested in the variation of the variables over time. It is common to use a fixed effects approach in order to capture those effects. For instance, each of the 15 countries have different characteristics that may have their own factors that influence CO_2 levels. The demography of a country may have an impact on car choice or the density may have an impact on the size of the cars. In our case, the parameters of interest describe the effect of taxes on the New Car CO_2 emission within the same country, over time ("within variation"). In order to isolate this relationship from unobserved variables we can single out the fixed effect. We assume that there are factors within each country that influences both the independent variables and the CO_2 emissions and control for those factors. The covariance between the error term and the independent variables is the technical result of the above assumption. The country specific, time-invariant factors should not be correlated with other countries.

The model equation is:

$$Y_{it} = X_{it}\beta + \alpha_i + u_{it} \qquad \text{for } t = 1, \ldots, T \quad \text{and} \quad i = 1, \ldots, N$$

where
– Y_{it} is the dependent variable where i = country and t = time (year)
– X_{it} stands for one independent variable
– β is the coefficient for the independent variable
– α_i (i=1….n) is the intercept for each country
– u_{it} is the error term.

5.3.1 Time-specific fixed effects

With the Stata test “testparm” I test if we need to include time-specific fixed effects. The performed test is a modified Wald test. The null hyphothesis is that all time dummies from the regression are equal to zero. Given that the test score is significant at 1%, we reject the hypothesis that the coefficients of the time dummies are zero. Therefore we know that we need to include time-fixed effects.

The first model is a fixed effects model using “xtreg, fe” in Stata. It is the straight-forward approach to assess the effects from a bird’s eye view or Macroeconomic view, the impact of socio-economic variables directly on CO_2 intensity of new cars. Therefore the intermediate steps that influence CO_2, such as car demand, car characteristics and fuel mix are not individually dissected, but rather absorbed in the coefficients of the socio-economic variables.
The variables in the model are:

- Acquisition tax based on CO_2 emissions (dummy variable)
- Ownership tax based on CO_2 emissions (dummy variable)
- Road density (as first-difference of the natural logarithm)
- Registrations per capita (as natural logarithm)
- Gasoline price (as first differenced natural logarithm)
- Income (as first differenced natural logarithm)

Testing for serial correlation

I tested for serial correlation using Wooldridge’s test. The test statistic found no autocorrelation. This should be expected, after the variables were transformed.

5.3.2 Fixed effects model results

In this chapter I will present the outcome of the FE model. There are two different models. I adjusted the model based on test statistics on model fit. The first model is a fixed effects model with time-dummies for time-fixed effects. The second one has adjusted standard errors to correct for heterogeneity and yield robust results. This model will be used to draw our reduced-form conclusions from.

Table 3: Fixed Effect Model Results
Dependent Variable: Ln CO2 of New Cars

		FE Xtreg, fe		FE robust Xtreg,vce(robust)	
Type	**Variable**	**Coefficient**	**p-value**	**Coefficient**	**p-value**
Dummy	Acquisition Tax	-0.01	0.04	-0.01	0.12
		(0.01)		(0.01)	
Dummy	Ownership Tax	-0.01	0.02	-0.01	0.07
		(0.01)		(0.01)	
Ln	Road Network	-0.04	0.07	-0.04	0.37
		(0.02)		(0.04)	
Ln	Registration per Capita	-0.00	0.69	-0.00	0.66
		(0.01)		(0.01)	
Ln	Gasoline Price	-0.02	0.67	-0.02	0.69
		(0.04)		(0.04)	
Ln	Income	0.02	0.61	0.02	0.69
		(0.04)		(0.05)	
	Constant	-0.04	0.16	-0.03	0.34
		(0.03)		(0.03)	

(Standard deviation in parentheses)

Table 4 FE model measures

	FE	FE (cluster country)
Observations	225	240
F-statistic	6.22	n/a
Degrees of freedom	(35, 189)	(14, 14)
p-value	0.00	n/a
R-square (overall)	0.45(adj.)	0.49
(within)	n/a	0.52
(between)	n/a	0.36

Since the fixed-effects regression used in my model relies on the assumptions that the errors are independently and identically distributed, we need to make sure that they are not violated within-sections (countries) nor across countries (groupwise heteroskedasticity). In order to test the residuals of model 1 (simple FE) I derived a modified Wald-statistic for groupwise heteroskedasticity (cf. Greene, 2000). The test result (xttest3 in Stata) is significant, telling us to reject the hypothesis that the error variances of each group are equal to the error variance across all groups. Thus, it detects heteroskedasticity, which means the standard error that the model calculated could be too small. The second model uses robust standard errors, which are based on the Huber/White/sandwich VCE estimator (Wooldridge, 2013; Stock and Watson, 2008).

As we can see from the robust results in table 3, none of the coefficients are significant. The dummy for CO_2-based ownership tax is close, and is significant at 10%, while the CO_2-based acquisition tax dummy has even lower significance. The rest of the variables cannot be considered to be considered close to a level of significance and are not reliable. However, all the signs of the variables are as expected. Both tax dummies and gasoline price are negatively correlated. Considering their size, the model estimates that with the introduction of CO_2 based acquisition taxes, the CO_2 intensity of new cars dropped by 1 percent. Ownership tax has a very similar size, corresponding to a drop of 1 percent as well. Gasoline price is also negative, indicating that higher prices for fuel lead to the acquisition of more efficient cars. Income is positive, suggesting that the theory of larger average car purchases holds true. Registrations and Income are significant predictors of CO_2 intensity. The variable for registrations per capita fluctuates only little. As the amount of cars per 100 inhabitants increases by 1, CO_2 decreases by 0.4 percent. An increase in income of one percent leads to a 0.02 percent increase in CO2 output.

5.4 Structural Equation Model

Structural Equation modeling allows us to investigate more complex relationships between CO_2 intensity and the independent variables. It serves our purpose well as a combination of an analysis of variance (regular regression) and a factor analysis. It is way to perform a multilevel regression and allows testing the proposed relationships between variables. We use the proposed relationships from theory to build a model and test if we can confirm this relationship. In case the model does not fit the data, we reject it. Hence, we take a confirmatory approach.

We need to define the terms exogenous and endogenous variables, as they can mean different things in different contexts. The variables that we assume not to be influenced by other variables, will be referred to as exogenous. In our model, income, gas price, population, registrations per capita, road density, car price and acquisition and ownership taxes are exogenous. Arguably, income, gasoline price and car price do influence registrations per capita, however, the level of covariance is acceptably and the factors can be treated as exogenous. Registrations is thus determined by other factors, which lie outside the model. Endogenous variables are those that are determined by other factors within the model. CO_2 intensity is endogenous and so are the car characteristics that we will use, which are fuel type, average power and average engine capacity. The role that these endogenous variables play is discussed below.

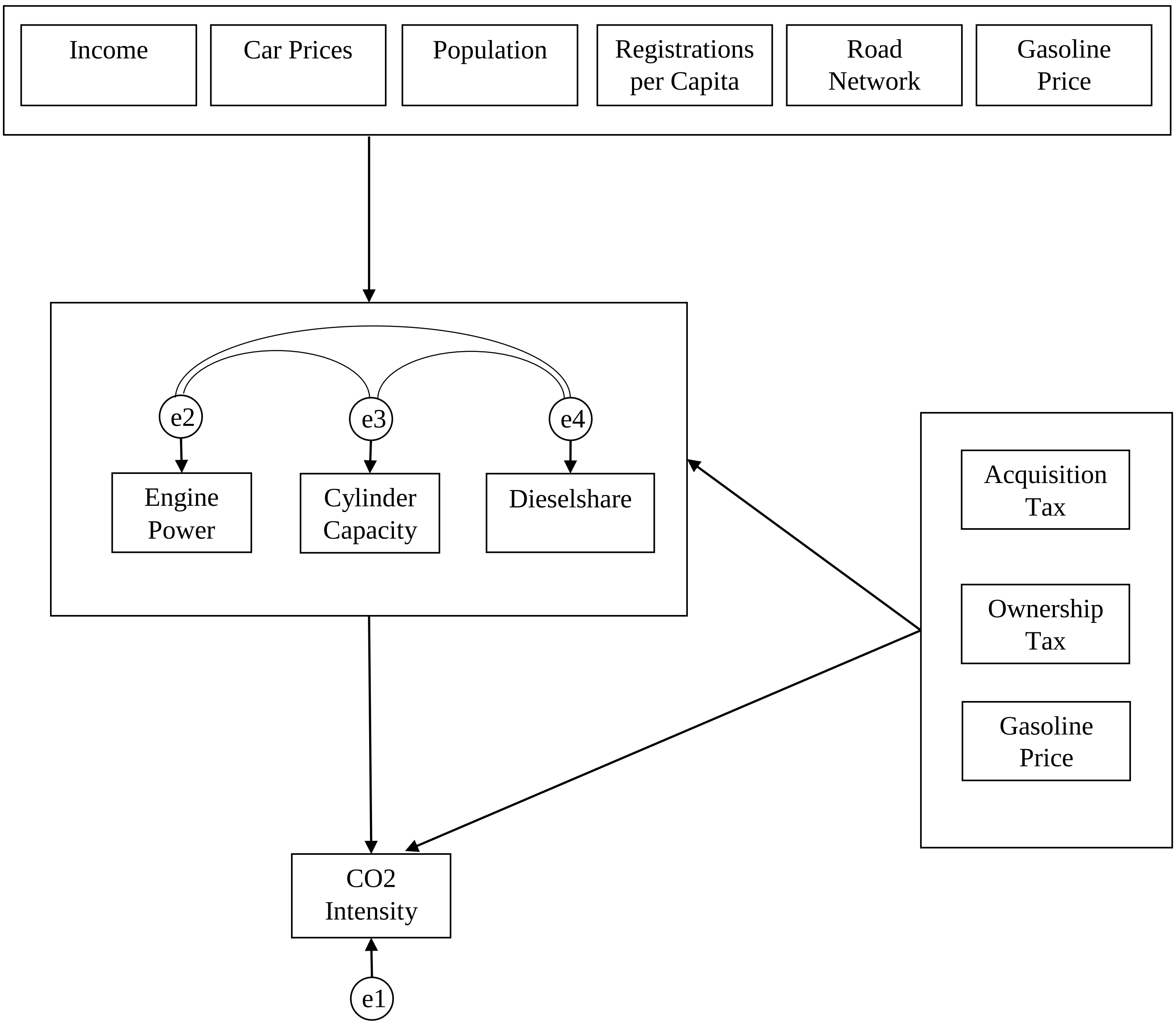
Use of Car characteristics

The shortcoming of with the Fixed Effects model is that we cannot include the most meaningful predictors for CO_2 output that are available, which are the car characteristics. They are engine capacity (ccm) and engine power (kW) and the fuel type. These are endogenous characteristics that are assumed to be functions of socio-economic conditions. Since we cannot treat these variables as if they were on the same level as household income and therefore we cannot use them in a linear regression fixed effects model.

We believe that car taxes, income, gasoline price, population growth, registrations per capita and road density determine the development which type of car is demanded in a given country. An example of this is, that we assume higher income to result in larger cars on average. Thus, the car demand changes based on the economic conditions. In order to capture this effect we use engine characteristics, which in turn are closely related to the size of a car and altogether determine the CO_2 emissions. The car characteristics act as so-called mediators. According to theory, these variables govern the effect that the endogenous variables have on CO_2 intensity. By having three endogenous variables the effect of that socio-economic conditions have on car demand can be decomposed further. Most importantly, we hope to understand better if a certain tax has a propensity to affect a certain car characteristic more than another and if this effect is significant for CO CO_2 2 intensity.

The full model is specified by the following system of paths:

Figure 2: Conceptual Structural Equation Model
(Path diagram. For better overview, double boxed variables indicate that the path connected to the outer box goes to each of the contained variables)



Taxes as direct predictor

The theory suggests, that rather than the tax exclusively having an effect on car buyers through prices (i.e. car choices being subject to more differentiated prices from CO_2 based taxes), the existence of the tax also has a direct effect on the CO_2 emission. For instance, with the present of sufficiently CO2-differentiated taxes, the buyer is aware of the fuel consumption or the corresponding emissions of a car, or even the price penalties that await him in the future, which makes buyers look for CO_2 efficient cars directly, rather than choosing more efficient and less costly engine characteristics. Vance and Mehlin (2009) find that car buyer are not myopic and take into account future costs as a buying criterion. A similar effect is to be expected from gasoline prices, a factor that buyers are very aware of, since we are reminded of fuel prices every time we fill up a tank at the gas station.

Focus on within effects

Due to the nature of the data, there are distinct between and within effects in our variables. Bartels et al. refer to this as cluster confounding. For instance, changes in income within a country have an impact on average disposable income and thus the car choices that are made based on this change in this country, potentially driving up CO_2. To avoid this, we take the safe route and focus purely on within effect. Comparing GDP to a different country might have the opposite effect, for instance if countries with higher GDP tend to have more resources for developed green policies. If these effects are simply combined, it is referred to as cluster confounding and needs to be avoided. (Skrondal and Rabe-Hesketh 2004). In order to stay consistency and avoid this difficulty, I believe that it is best to focus exclusively on the within effects, as we have done before in the fixed effects model.

Within transformation

In order to implement within effects into SEM, all variables are entity-demeaned to account for the country-specific intercepts. By taking the country average over all years and subtracting this from the each value we eliminate the time-invariant unobserved effect.

Time-fixed effects limitation

In contrast to the fixed-effects model, the structural equation model (SEM) does not allow to control for time-fixed effects. This is due to the limitation on the number of paths that can be estimated with a given set of relationships. The inclusion of time-fixed effects in the linear fixed effects model did not result in interpretation changes, which suggest that we may use a trend instead. There were no substantial changes in coefficients, change of direction or substantial change in significance of the variables in the regression outcome. I thus believe that foregoing the fixed effect is not ideal but acceptable given the benefits that the SEM approach has and replacing it with the car price variable.

Addition of correlation between endogenous variables

By default, all variable's error terms are assumed to be uncorrelated in the structural equation model. In this model, all exogenous and endogenous variables are observed. By theory it is acceptable for the error to correlate because these three variables are the result of the same purchase decisions accumulated by thousands of car purchases in each country, meaning that the origin of the data are the same buying decisions and the variables are related. So by nature of these indicators, the errors will be unavoidably correlated. In that case is common to allow correlation of errors. Landis, et al. (2008) argue that estimation of errors in a confirmatory SEM setting should be acceptable if "correlations among measurement errors are unavoidable" (Landis et al., 2008). "Such situations include when multiple measures of the same construct are used in longitudinal research, or when indicator variables share components". In our case the endogenous variables ccm, kW and Dieselshare are allowed to have correlating residuals, which is depicted by the connected error terms in the path diagram above.

Robust standard errors for intragroup correlation

We specify standard errors that are based on intragroup correlation, with which the requirement for observations to be independent is relaxed. Observations are independent across the different groups, but not within groups. The coefficients remain the same with the model that we use to assess model fit.

5.4.1 SEM results

In this chapter the results of the Structural Equation model will be presented. Subsequently I will describe the effect and the correlation matrix that is the outcome of this model, where covariances between the endogenous variables are allowed to correlate. The full output is presented in Appendix B. The taxes' impact on car characteristics will be discussed first, followed by the combined impact they have on new car's CO_2 intensity. This analysis is based on the model that considers two levels of variables, assuming CO_2 emissions to be based on car characteristics, which are in turn explained by taxes, prices and socio-economics condition. Thus it tests hypothesis 2 as mentioned in Chapter 4. The variable structure is as follows:

Table 5: Summary of Explanatory Variables

Dependent Variable	**Endogenous Explanatory Variables**	**Exogenous Explanatory Variables**
CO2 Intensity	Engine Power	Acquisition Tax
	Engine Capacity	Ownership Tax
	Dieselshare	Income
		Fuel Price
		Road Network
		Population
		Car Price
		Registrations

The model calculates 41 parameters. They are comprised of 34 structural coefficients, of which six direct coefficients and one intercept, 27 indirect variable and three intercept for the three endogenous equation, four variances for the dependent variables and three covariances between the endogenous variables.

CO_2 intensity is dependent on engine power in kilowatts, cylinder capacity in cubic centimeters, share of diesel vehicles out of all sold cars, taxes on acquisition, taxes on ownership, and gasoline price. The latter two are the tax dummies. They are also dependent variables for the former 3 variables which describe the car characteristics. The reason for this is, that consumers take into consideration not only the price and car characteristics when choosing a car, but take into account the taxation on CO_2 emissions, which then has an impact on car buying decision.

Table 6: Structural Equation Model Results
Coefficients (standard errors) with option *vce (cluster country)* for adjusted standard errors
$\chi 2$ (5, N=191) 10.14, p = 0.07

Independent	**Dependent**			
	CO_2	kW	ccm	Dieselshare
Engine power (kW)	**0.24** (0.07)			
Engine size (ccm)	**0.24** (0.12)			
Dieselshare	**-0.15** (0.03)			
Acquisition tax	**-0.02** (0.00)	**-0.03** (0.00)	**-0.02** (0.00)	-0.02 (0.01)
Ownership tax	**-0.02** (0.00)	-0.00 (0.01)	0.00 (0.01)	0.02 (0.02)
Gasoline price	**0.04** (0.01)	-0.00 (0.01)	-0.01 (0.01)	-0.10 (0.02)
Income		**-0.18** (0.07)	**-0.15** (0.06)	0.06 (0.11)
Population		0.23 (0.42)	0.47 (0.58)	-0.76 (1.20)
Registrations		**-.07** (0.02)	**-0.06** (0.01)	**-0.06** (0.03)
Road density		0.05 (.05)	0.03 (0.03)	-0.05 (0.05)
Car Price		**0.01** (0.00)	0.00 (0.00)	0.01 (0.00)

Standard errors in parentheses. Bold coefficients are significant at 5%

The model is specified with the option to allow for intragroup correlation of the covariance ("vce (cluster country)" in Stata). The fit statistics are based on the general model without the cluster specification. The magnitude of the coefficients should not be interpreted since they are no reliable measures.

Direct, Indirect and Total Effect

The direct effect is the influence of a variable on another, represented by a path. The indirect effect, as it will be discussed below, consists of the impact that one variable has on another as that variable's influence carries through another intervening variables (Hoyle & Kenny, 1999). The total effect that a variable has on CO_2 intensity is the sum of the direct effects on it and additionally, the effect it has by working through the intervening variables.

Direct Effect

Engine characteristics

Considering the equation of engine power (kW) and its independent variables, we see that there are four significant dependent variables. Car price and income are positively correlated, whereas CO_2 based acquisition tax and registrations per capita are negatively correlated with CO_2 intensity. Acquisition seem to lower the engine power considerably. According to the coefficient, having CO2 based taxes in place on average lowered the engine power by 2.6 percent, ceteris paribus. However, it should be noted that the accuracy of SEM coefficients overall are debatable, but since this is the direct relationship of an exogenous variable on an endogenous variable it arguably is a relevant result. The car price index captures the variation of the "price tag" on cars, thus it seems counterintuitive that consumers are able to afford higher powered cars. A possible interpretation is, that higher prices in the segment that the index is comprised of (1.4 liter Opel Astra, C-segment) leads to fewer secondary cars being purchased. Furthermore, the pricing strategy of car makers, in this case Opel, is complex and endogenous to economic forecasting. Conversely, increasing registrations per capita could be due to a larger share secondary or tertiary cars being bought, which in turn reduces engine power in those years.

For engine capacity (ccm), the same variables are significant except car price, which is not significant. An interesting observation is that, contrary to the coefficient direction of engine power, ownership tax coefficient has a positive sign. On the other hand, gasoline price and population have negative signs. Despite their similarities and correlation, these engine characteristics be influenced by slightly different factors. However, the coefficients do not have a significant p-value and interpretation of these differences is merely speculation.

Regarding the Dieselshare equation, only two variables have significant coefficients. As expected, a rise in gasoline price leads consumers to opt for more diesel cars. The negative relation in registration taxes could be attributed to the second car effect. The idea is, as more cars are being registered per capita, the share of second or third household cars is higher in these years. It is not common for these smaller cars to be equipped with a relatively heavy diesel engine. This is analogous to the negative correlation of registrations with engine size and capacity, where the same reason may apply. It is interesting that Dieselshare seems to rise with ownership tax (not significant, however) and fall with acquisition tax. This can be attributed the specifications of the tax differentiation for fuel type in the countries, where diesel is sometimes taxed heavier for acquisition taxes but less heavy in ownership taxes.

Tax variables

The factors that are directly regressed on CO_2 intensity all are significant. The positive sign of the gasoline price coefficient is surprising. The coefficient tells us that a rise in gasoline price results in the purchase of a less efficient car on average, even though the size of the parameter is relatively small compared to the other log-transformed variables, the high z-score indicates that this coefficient is prioritized in this correlation matrix. It may be a case of a spurious relationship. For instance, cold winters could drive up energy prices on the one hand and also shift people's car buying decisions towards heavier or safer cars. Unfortunately, we do not have car mass available as a variable. The remaining coefficients' signs are as expected from the literature and economic theory. Average engine size and capacity are positively correlated with CO_2 emissions. The share of diesel cars is negatively correlated with CO_2 emissions, which is expected since diesel engines emit less CO_2 for an equivalent production of force. Both, the CO_2 -based ownership and acquisition tax dummies are negatively correlated with CO_2 intensity.

<u>Specific Indirect Effects</u>

In order to assess mediation in SEM, the most important effect to help understand the paths is the specific indirect effect (Brown, 1997). It is the portion of total indirect effect that works through a single intervening variable (Fox, 1980). Specifically, we want to determine the indirect effect of acquisition tax and ownership tax on CO_2 intensity through the mediating variables engine power (kW), engine capacity (ccm) and Dieselshare. The specific indirect effects were calculated with the Stata nlcom command (for non-linear combinations) that computes combinations of non-linear parameter estimate after a Stata estimation. The standard errors of the specific indirect effects are computed using the delta method, which assumes the estimate of the indirect effect to be normally distributed. This assumption is generally accepted in order to obtain the variance of product of these coefficient estimates in specific indirect effect calculation (Sobel, 1982; Bollen, 1987).

Table 7: Indirect effects of Tax forms based on CO_2 coefficients (standard errors in parentheses) based on full SEM

	Specific indirect effect on CO_2 through mediators			Total Indirect Effect	Direct Effect	Total Effect
Variable	kW	ccm	Dieselshare	CO_2	CO_2	CO_2
CO_2 based acquisition tax	**-0.01** **(0.00)**	-0.00 (0.00)	0.00 (0.00)	**-0.01** **(.00)**	**-0.02** **(0.00)**	**-0.03** **(0.01)**
CO_2 based ownership tax	-0.00 (0.00)	0.00 (0.00)	-0.00 (0.00)	-0.00 (0.00)	**-0.02** **(0.00)**	**-0.02** **(0.01)**
Gasoline price	0.00 (0.00)	-0.00 (0.00)	**-0.02** (0.01)	**-0.02** (0.01)	**0.04** (0.01)	**0.03** (0.01)

Bold coefficients are significant at 5%

In Table 7 we see that there are only two significant specific indirect effects. The one of acquisition tax that works through engine power is a significant predictor of CO_2 emissions. The other being the indirect effect of gasoline price on CO_2, which works through Dieselshare. This proves that there is an observed effect of CO_2 based acquisition taxes on CO_2 intensity. Comparing the total indirect effects of the two tax dummies and gasoline price, acquisition tax has the most significant coefficient with the largest size. This suggest that acquisition tax is the most reliable in influencing CO_2 intensity through the relationships of factors that is proposed in our hypothesis.

It is important to take into consideration, that the tax dummies as well as gasoline price were also used as direct predictors of CO_2 intensity, which means that part of their overall effect is absorbed by the direct path. When the coefficients of the specific indirect effects of all mediators (of kW, ccm and Dieselshare) are combined, we arrive at the total indirect effect. Total indirect effect of acquisition tax on CO_2 is significant. This effect is not significant for the ownership dummy and nor does it have a significant effect through any of its mediators alone.

Total effect

The total effect of a variable consists of both the sum of the indirect effects combined with the effect in their direct prediction on CO_2. Acquisition tax as well as ownership tax are significant predictors of CO_2 intensity. This means that in the years with the new CO_2 based taxes, the CO_2 emissions decreased, taking all other things fixed. With total effects we combine the indirect effects and direct effects of each variable. In the case of gasoline price we saw opposing effect, being partially mediated through the engine characteristics in the direct and indirect effects section above. The total effect of the gasoline price variable on CO_2 is significant and positive. This means that the direct effect is substantially stronger than the indirect effect that works through the vehicle characteristics.

5.4.2 Model fit

Table 8: SEM fit statistics

Model measures	
N, observations	191
Chi-square	10.14
degrees of freedom	5
p-value	.07
Absolute fit indices	
SRMR	.016
RMSEA	.073
Incremental fit indices	
CFI	.99
TLI	.92

In order to determine whether a SEM model is acceptable fit indices are used. Subsequently it should be established if the paths that are specified are acceptable. The Chi-square statistic is $\chi 2$ =

10.14 with a model fit p-value of 0.07 (significant chi-square indicates lack of a satisfactory model fit) for five degrees of freedom and a sample size of N = 191. The baseline comparison indices return values for Tucker-Lewis (TLI) = 0.92, and Comparative Fit (CFI) = 0.99. A commonly used fit statistic is RMSE, which is the square root of the mean of the covariance residuals. An RMSE of zero would refer to a perfect fit. At a value of .08 many researchers consider the model to be an "adequate fit" (Browne & Cudeck, 1993) and below 0.05 is a good fit (Stieger, 1990). More recently, a cutoff point for a "good fit" of 0.06 is suggested (Hu & Bentler, 1999). The model fit statistic returns an RMSEA of 0.07 and falls in the region of this suggestion. The pclose statistic shows the probability that the RMSEA is smaller or equal to 0.05, which is 0.228. This fit is considered "adequate", with a "reasonable error of approximation". Another way of measuring the fit is by measuring the relative improvement compared to the baseline model. The Comparative Fit Index (CFI) does that and is considered to indicate good fit at above .95 (Hu & Bentler, 1999). We can conclude that the model is reasonably congruent with the underlying data. The paths and the covariance specification in this model explains the data in an "adequate" way, based on model fit statistics.

5.5 Summary of results

In the methodology, a simple reduced-form model as well as a final model using structural equations were established. In the previous section we estimated the two models. The first is a reduced-form model, which includes exogenous variables, including the tax dummies that are regressed on CO_2 emissions. The second one is a structural equation model that uses exogenous variables to explain car characteristics (endogenous), which in turn explain CO_2 intensity. The engine characteristics are not part of the reduced-form model, as endogenous variables cannot be included in a fixed effects model. However, we can draw conclusions from the exogenous variables that we have and compare the result with the suggestions of the literature.

The p-values and coefficients of the variables differ substantially between the different versions of the model. In the relatively small sample size, the meaning of individual data point in the dummy variables becomes very big and the coefficient's p-value hinges on them (see chapter 6, limitations) and changes with slight amendments of variance estimators (clustered by group and autocorrelation in our case). The results of the two models coincide in the sense that acquisition taxes come forth as the most relevant predictors in both models, while this is not the case with ownership taxes or gasoline price. The gasoline price coefficients show contradicting signs depending if the gasoline price is mediated through Dieselshare (negative effect on CO_2) or directly (positive effect on CO_2). Finally, in their direct effect all three tax related variables have as significant effect on CO_2 intensity.

6 Discussion and Limitations

First I will discuss the hypotheses and then I will discuss their meaning about taxes for the abatement of CO_2 levels in new cars. I will also take into account the role of gasoline prices.

6.1 Hypotheses

6.1.1 Hypothesis 1:

The results of both the reduced-form model gives limited evidence of a significant impact of the CO2 based tax changes in Europe. The robust model does not return significant coefficients for the tax variables. Thus, only a tendency, that the acquisition tax dummy is an important factor can be observed. Sind it is not conclusive, we must consult the finding from the full model. The SEM gives evidence of a significant impact of the tax changes. Both taxes prove significant in their overall effect on CO_2. In the SEM the time-fixed effects could not be included but were replaced by a price trend in the form of car prices as is also performed by Ryan et al. (2009). This change effectively leaves more variation to be attributed to the tax variables. Furthermore, we included direct predictors in the form of car characteristics, which mediate the exogenous factors and therefore they do not directly compete for covariance with the tax variables. Analyzing the paths more closely, we find that that acquisition tax is significant both in its direct and indirect effect and we can conclude that acquisition tax based on CO_2 is significantly and negatively correlated with CO_2 intensity. Hence, changing the acquisition tax that was previously not based on CO_2, to a tax based on CO_2 significantly reduces CO_2 intensity of new cars.

Concerning ownership tax, the direct effect is significant which qualifies for the tax to be considered a significant predictor of CO_2 intensity and we do not reject the hypothesis. However, the fixed effect result attributed little importance to the variable, while in the SEM the exogenous control variables are reduced to indirect factors. It is thus important to take another look at the role of ownership tax, which is a subject in the discussion of hypothesis 2.

6.1.2 Hypothesis 2:

The estimation of paths allows us to distinguish the effects between factors so that we can answer if the taxes and socio-economic factors effect CO_2 intensity through the demand of certain car characteristics as the theory in the literature proposes. All three technical vehicle characteristics, namely Engine Power (kW), Engine Size and Dieselshare had a significant effect on CO_2 intensity, which confirms an important part of the theory on which basis the paths were specified. In what way taxes have an effect on CO2 is the issue will be discussed below.

Acquisition tax

The SEM results showed that Acquisition Tax has a significant indirect effect through the factors engine size and engine power. In the years that the tax was based on CO_2 emissions, car buyers chose vehicles with lower engine power on average, ceteris paribus. Engines with smaller power prove to have significantly lower CO_2 emissions. In combination with economic theory we will assume causality for this effect. This finding proves that acquisition tax can shape car buying behavior, with respect to engine power and engine size. As a consequence, this affects CO_2

emissions. Despite the specific individual effect through engine size not being significant, the specific indirect effect through engine power is strong enough for acquisition tax to have a significant indirect effect on CO_2 intensity. Thus, basing acquisition taxes directly on CO_2 can be expected to reduce CO2 emissions of new cars, because consumers purchase vehicles with less powerful engines on average.

Ownership tax

In the full model, ownership tax has a significant negative relationship with CO_2 intensity. This is based on the direct and total effect. Ownership is not significant in its indirect effect through the car characteristics. It does not have any significant relationship to any of the engine characteristics. This suggests that there are other mechanisms at play that lie outside of the vehicle characteristics that make up this model. A possibility is the average size and mass of cars. Consumers may choose relatively bigger cars as the ownership tax is not based on mass (to be precise, not anymore in Denmark, Finland, Netherlands, Sweden) and instead have less powerful engines relative to before the tax was introduced. This would increase the average CO_2 intensity (which is the average of all cars' European CO_2 emissions rating, as determined by a standardized driving cycle).

Influence on buying decision

When we compare the two types of taxes, a plausible economic interpretation is, that people's buying decisions are directly influenced by acquisition taxes, a tax that is encountered immediately when the car is bought. In contrast, ownership taxes occur over a vehicles lifespa and are taken into account as much for the choice of the car. This finding stands somewhat in contrast with results from studies that attribute acquisition taxes merely a supporting role in the abatement of CO2 emissions. (COWI report, 2002; Ryan et al.,2009; Giblin & McNabola, 2009; Birkeland & Jordal-Jorgensen, 2001; and Hayashi et al., 2001). All the above studies conclude that more emphasis should be placed on ownership taxes. For New Car CO2 levels in the European case, those results cannot be confirmed by this study. Rather, the opposite is the case, since the size of coefficients is consistently higher for Acquisition Tax than it was for Ownership Tax in both the reduced-form model as well as the full model. However, none of the above papers has used empirical model that include the tax reforms from 2008 onward, which were plenty (eight ownership tax reforms and four acquisition tax reforms).

6.1.3 Gasoline price and fuel tax

Gasoline prices have a significant effect on CO_2. In the case of the SEM model, it is important to take a closer look at this finding. We can see that gasoline price has a significant positive relationship with both engine power (not significant) and CO_2, which is not expected. However, there is a significant positive relationship with Dieselshare, which we expect. This effect works is calculated to be a significant specific indirect effect with a negative sign. This proves that gasoline prices influence CO_2 intensity by shifting consumer's decisions to buy a diesel vehicle, rather than alter the size or power of the engine. It seems evident from this finding, that fuel taxes provide an important tool for shaping car buying behavior, but must be used in combination with

CO_2 based acquisition taxes and a lesser degree ownership taxes to be successful in influencing the composition of the car fleet and reduce CO_2 intensity.

6.1.4 Limitations

It should be clear that the dependent metric of interest is CO_2 intensity. It refers to the average amount of a number of g/km that a car emits established on the basis of a driving test. So final usage and final emissions is a different subject. Thus, the result give have no direct implication on amount of usage (e.g. total km driven), even though it is a closely linked subject. Thus, for effective policy decisions, both aspects, the car fleet CO_2 intensity as well as the usage must be considered.

The tax dummy variables were created for this research and are based on many different publications to find out historical taxes and changes of the countries. Subsequently, I had to find a measure by which to decide what qualified as a CO_2 based tax. This was done with a high standard of accuracy, however since the tax models are so different, some educated but subjective judgment is inevitable. Another point of ambiguity is to choose the cut off line for what counted as "based on CO_2". Given the vastly different ways to calculate the taxes, this line comes down to judgment once more. One example is the Dutch acquisition tax. It had a CO_2 component from 2006, but the differentiation between low and high emitting vehicles was too little to qualify as being CO_2 -based. The differentiation became sufficient in 2008, when it more than doubled.

The model estimates the effect of a tax change within the same year and there are no lags included for any of the factors. Some countries introduced their new taxes in the middle of the year. A robustness check for these countries proved difficult since it was challenging to retrieve this level of tax information for all countries.

A shortcoming of the result and any research in this field is, that all results are based on the standard European driving cycle, which has been criticized as imprecise. Moreover, it is not a complete measure of efficient energy use. Traffic management through smart navigation, or driving behavior assistants, or any technology that produces efficiency gains in a holistic sense driving environment, rather than just the emissions from driving a set distance, cannot be taken into account nor will is it incentivized.

Some researchers argue that the effectiveness of the recent registration tax changes was very costly to the country's budgets. The feebate registration tax system in France made substantial loss in revenues of 285 million Euros (D'Haultfoeuille et al., 2010) and Ireland incurred losses of an estimated 166 million Euros (Rogan et al. 2011) after its simultaneous registration and ownership tax change in 2008. It is arguable that the successful greening of the roads through CO_2 differentiated taxes, turned out in reality to be heavily subsidized by these tax changes. The reasonable response is to adjust the pivot point of the tax differentiation to be set lower, now that policy makes have had time to learn more about the strong response to these incentives.

Data Limitations

This research ignored all-electric cars, which were a small share or the European car fleet up to 2011 (below 0.6% in the Netherlands, which had the largest share).

Stata produces modification indices with the "estat mindices" command (and "reports modification indices for omitted paths in the fitted model"[5]). The result can help researchers explore paths that give a better fit for the model, albeit it an easy way to be misled by chance and spurious relationships. In the case of our SEM model it suggests including income as a direct explanatory variable for CO_2 in addition to income already being an exogenous explanatory variable for car characteristics. It seems counterintuitive that higher income leads to higher CO_2 emissions beyond engine characteristics. It means that there is a mechanism that makes the average consumer choose cars that are more CO_2 intensive, without them having stronger or larger engines. The choice of larger and heavier cars (engine taking constant) would explain why there would be a potential direct effect on CO_2 intensity in the data. For instance, a Mercedes E250 has ca. 10g/km higher CO_2 emissions than the C250 with the same engine. Thus, a variable on average car mass is necessary to decompose this field of research further. It is available from 2001 onwards. Since for our time period we do not have the variable on car size or weight available however, we could not explore this path. Nijland et al. (2013) confirm that income is closely related to car mass and through it with CO_2 intensity.

The CO_2 data is possibly subject to inconsistency in 2002, which could lead to a bias in that year. To be precise, the CO_2 figures might have shifted up slightly (up to 2% according to Eurostat) due to the change in data source, meaning the significance of a policy effect could be undervalued for that year. That year did not contain tax changes, however. Overall, I believe the difference to be acceptable.

[5] From Stata help manual of estat mindices "Modification indices are score tests (Lagrange multiplier tests) for the statistical significance of the omitted paths". See Sorbom (1989) and Wooldridge (2010, 421–428) for the application of the test.

7 Conclusion

In this thesis I aimed at gaining a better understanding of the effect of car taxes on the average CO_2 emissions of new cars. Specifically I tested two hypotheses. The first poses that the introduction of CO_2 based acquisition and circulation taxes leads to significantly reduced CO_2 intensity. The second hypothesis poses that the variation in New Car CO_2 emissions can be explained through car characteristics, namely average engine size (ccm), average engine power (kW), and the share of diesel cars. The thesis poses that these factors represent the consumer's buying decision. It is therefore tested if CO_2 intensity could be influenced by shaping these endogenous factors through the use of taxes. I used a reduced-form model and a full model to test these two hypotheses. The outcome suggests that hypothesis one holds true for our data which refers to the EU15 states and the acquisition and ownership tax changes in these states reduced the CO_2 intensity significantly. Hypothesis 2 proved more complicated to prove or disprove. The model was able to confirm the relationships that were suggested by the literature, by creating representative paths between the independent and dependent variables. The structural equation model returned statistics of good fit and explains the underlying data well. The directions of the coefficients are as expected, with the exception of gasoline price, which in its direct effect is significantly and positively correlated with CO_2. With regard to the taxes, the tax on acquisition proved to be a stronger predictor of CO_2 emissions both in significance and size than ownership tax. The latter is significant only in its direct effect on CO_2 emission, but was not significant indirectly, through the car characteristics.

These findings suggest that acquisition taxes are a very important tool in shaping CO_2 intensity of the car fleet. Out of 15 countries that were examined in this study, four currently do not levy acquisition taxes. They are Luxembourg, Germany, Sweden and United Kingdom. These four are also in the top 5 countries with the highest average engine power and in top 6 of highest average CO_2 emissions (2012). The findings in this paper tell us that there is a substantial unrealized potential for carbon emission abatement in these countries. Concerning the proposal from 2005 that proposes for European countries to abolish acquisition taxes by the year 2020, the finding suggest that this policy may be counterproductive. Conversely, France currently levies no ownership tax, though it can reduce the car fleets' CO_2 intensity by doing so.

8 References

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9 Appendix

Table 9: Acquisition tax calculation basis
(no changes were found before 1992)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Austria	Ccm, kg	Fuel cons.	Fuel cons.	Fuel cons.	Fuel cons.	Fuel cons.	Fuel cons.	Fuel cons.	Fuel cons.	Fuel cons.	Fuel cons.	Fuel cons.	Fuel cons.	Price, Fuel cons.	Price, Fuel cons.	Price, Fuel cons.	Price, Fuel cons. Bonus/ malus	Price, Fuel cons. Bonus/ malus	Price, Fuel cons. Bonus/ malus	Price, Fuel cons. Bonus/ malus	Price, Fuel cons. Bonus/ malus
Belgium	-	-	-	-	-	-	-	-	ccm	ccm	ccm	ccm	ccm	ccm	ccm age	ccm age	ccm, age, CO2	ccm, age, CO2	ccm, age, CO2	ccm, age, CO2	ccm, age, CO2
Denmark	-	-	-	-	-	price	price	price	price	price	price	price	price	price	price	price CO2	price CO2	price CO2	price CO2	price CO2	price CO2
Finland	-	-	-	-	-	-	price	price	price	price	price	price	price	price	price	price	price CO2	price CO2	price CO2	price CO2	price CO2
France	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	CO2 Bonus/ malus	CO2 Bonus/ malus	CO2 Bonus/ malus	CO2 Bonus/ malus	CO2 Bonus/ malus
Germany	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Greece	-	-	-	-	-	price ccm	price ccm	price ccm	price ccm	price ccm	price ccm	price ccm	price ccm	price ccm	price ccm	Price Ccm, Emis-sions	Price Ccm, Emis-sions	Price Ccm, Emis-sions	Price, cm, Emis-sions	Price Ccm, Emis-sions	Price Ccm, Emis-sions
Ireland	-	-	-	-	-	Price ccm	Price ccm	Price ccm	Price ccm	Price ccm	Price ccm	Price ccm	Price ccm	Price ccm	Price ccm	Price ccm	CO2	CO2	CO2	CO2	CO2
Italy	-	-	-	-	-	hp	hp	hp	hp	hp	hp	hp	fee	fee	fee	fee	fee	fee	kW, weight seats	kW, weight seats	kW, weight seats
Luxembourg	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Netherlands	-	-	-	-	-	Price, fuel type	Price, fuel type	Price, fuel type	Price, Effici-ency rating	Price, Effici-ency rating	Price, Effici-ency rating	Price, Effici-ency rating	Price, Effici-ency rating	Price, Effici-ency rating	Price, CO2 Fuel type	Price, CO2 Fuel type	Price, CO2 Fuel type	Price, CO2 Fuel type	Price, CO2 Fuel type	Price, CO2 Fuel type	Price, CO2 Fuel type
Portugal	-	-	-	-	-	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm, CO2	ccm, CO2	ccm, CO2	ccm, CO2	ccm, CO2	ccm, CO2	ccm, CO2
Spain	-	-	-	-	-	Price, ccm, fuel	Price, ccm, fuel	Price, ccm, fuel	Price, ccm, fuel	Price, ccm, fuel	Price, ccm, fuel	Price, ccm, fuel	Price, ccm, fuel	Price, ccm, fuel	Price, ccm, fuel	Price, ccm, fuel	CO2	CO2	CO2	CO2	CO2
Sweden	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
UK	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none

"-" indicates that no information was found. Blue shaded cells indicate CO_2 based taxes

Table 10: Ownership tax calculation basis
(no changes were found before 1997)

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Austria	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW
Belgium	Engine rating	Engine rating	Engine rating	Engine rating	Engine rating	Engine rating	Engine rating	Engine rating	Engine rating	ccm	ccm	ccm	ccm	ccm	ccm	ccm
Denmark	kg, fuel cons.	kg, fuel cons.	kg, fuel cons.	kg, fuel cons.	kg, fuel cons.	kg, fuel cons.	kg, fuel cons.	kg, fuel cons.	kg, fuel cons.	kg, fuel cons.	kg, fuel cons.	kg, fuel cons.	kg, fuel cons.	kg, fuel cons.	kg, fuel cons.	kg, fuel cons.
Finland	Kg, Fuel type	Kg, Fuel type	Kg, Fuel type	Kg, Fuel type	Kg, Fuel type	Kg, Fuel type	Kg, Fuel type	Kg, Fuel type	Kg, Fuel type	Kg, Fuel type	Kg, Fuel type	Kg, Fuel type	Kg, Fuel type	CO2, Kg	CO2, Kg	CO2, Kg
France	kW, age, fuel	kW, age, fuel	kW, age, fuel	Ccm, age	Ccm, age	Ccm, age	Ccm, age	Ccm, age	Ccm, age	none	none	none	none	none	none	none
Germany	Ccm, Emmis-Sions rating	Ccm, Emmis-Sions rating	Ccm, Emmis-Sions rating	Ccm, Emmis-Sions rating	Ccm, Emmis-Sions rating	Ccm, Emmis-Sions rating	Ccm, Emmis-Sions rating	Ccm, Emmis-Sions rating	Ccm, Emmis-Sions rating	Ccm, Emmis-Sions rating	Ccm, Emmis-Sions rating	Ccm, Emmis-Sions rating	Ccm, CO2	Ccm, CO2	Ccm, CO2	Ccm, CO2
Greece	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm	CO2	CO2
Ireland	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm	CO2	CO2	CO2	CO2	CO2
Italy	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW, emis-sions	kW, emis-sions	kW, emis-sions	kW, emis-sions	kW, emis-sions
Luxembourg	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm	CO2	CO2	CO2	CO2	CO2
Netherlands	Weight, Fuel type	Weight, Fuel type	Weight, Fuel type	Weight, Fuel type	Weight, Fuel type	Weight, Fuel type	Weight, Fuel type	Weight, Fuel type	Weight, Fuel type	Weight, Fuel type	Weight, Fuel type	Weight, Fuel type	Weight, Fuel type	Weight, Fuel type	Weight, Fuel type	CO2, weight
Portugal	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm	ccm, CO2	ccm, CO2	ccm, CO2	ccm, CO2
Spain	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	hp	hp	hp	hp	hp	hp	hp	hp
Sweden	Weight, fuel type	Weight, fuel type	Weight, fuel type	Weight, fuel type	Weight, fuel type	Weight, fuel type	Weight, fuel type	Weight, fuel type	Weight, fuel type	CO2, weight	CO2, weight	CO2, weight	CO2, weight	CO2, weight	CO2, weight	CO2, weight
UK	Lump sum	Lump Sum, ccm	Lump Sum, ccm	Lump Sum, ccm	CO2, ccm, fuel type	CO2, ccm, fuel type	CO2, ccm, fuel type	CO2, ccm, fuel type	CO2, ccm, fuel type	CO2, ccm, fuel type	CO2, ccm, fuel type	CO2, ccm, fuel type	CO2, ccm, fuel type	CO2, ccm, fuel type	CO2, ccm, fuel type	CO2, ccm, fuel type

Blue shaded cells indicate CO_2 based taxes