A Guide Through the Fuel Taxation Jungle

An Analysis of the Differences Between Countries' Fuel Taxation Policies

Bachelor Thesis

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Abstract: The two major theories in the field of optimal taxation are the Ramsey rule of efficient taxation and the Pigouvian tax. As is the case with most economic theories, they are based on stark simplifications. In this thesis I show that, using a multiple regression model with time fixed effects, although merits accrue to both theories, neither one succeeds at properly explain the excise rates that countries charge on both gasoline and diesel. Based on a panel of 20 countries monitored over 29 years, numerous other factors have been found to lead countries to choose a higher or lower excise rate than can be explained by the two theories. The theories may still drive actual taxation policy. However, other variables can cause the observed excise rates to deviate from the optimal level prescribed by either of the two theories, which are thus insufficient to fully explain the taxation policy.

JEL Classification: E62, E64, H21, H23

*Keywords:*Externalities, fuel taxation, optimal taxation, taxation policy

1 Introduction

Taxes can have multiple objectives. The first and foremost reason for governments to impose taxes on goods and services is to finance government activities. As most government services are delivered for free (one seldom has to pay directly for a certain service), governments need alternative channels through which it can obtain its financial means, the most prominent of which is taxation of income, intermediate and final goods, housing and many other products. Taxes, however, can also have other objectives. Many goods that economic agents use or consume impose externalities on other agents. A textbook example is the bugle player, who thoroughly enjoys playing his bugle. His neighbour, on the other hand, dislikes the sound of the bugle. Thus, by playing his bugle, the player imposes a cost on his neighbour. The objective of many taxes is to incorporate this cost to outsiders into the price of the good, via taxation. So in the two person world in the above example, a government could impose a tax on playing the bugle equal to the marginal damage of the neighbour, so as to obtain the socially optimal amount of bugle playing, where the marginal benefits equal the marginal costs. This concepts also translates into another objective, promotion of the use of one good over another, by regulating the price of either one of them (via taxes or subsidies).

So taxation is a tool through which governments can finance their current activities, and it allows governments to alter market outcomes by interfering with the market prices of goods. In this thesis, I shall focus on the taxation of two types of oil based fossil fuels: gasoline and diesel. The tax rates on these fuels differ largely between countries, or geographical areas in general. Looking at the taxations (to be presented at greater length in section 5) one can see that the EU countries charge relatively high excise rates, whereas the non-EU Anglo-Saxon countries (especially Australia, Canada and the USA) charge very low excise rates. More interestingly, when referring to the externality theory of taxation, all EU countries impose an excise rate which is above the marginal social cost of the consumption of either type of fuel (estimated by Parry (in Parry, 2001 and Parry & Small, 2005) to 30 to 40 US-$ cents per litre). The non-EU Anglo-Saxon countries charge excise rates well below this estimated externality cost. It thus is relatively safe to conclude that the incorporation of externalities is not the only driver of the tax rate on gasoline or diesel. Hence, the aim of this thesis is to investigate further what drives the fossil fuel taxation policy of countries, in order to explain countries tax rates. I shall do this based on a panel of 20 OECD countries for which data are available over 29 years (from 1978 until 2006). This research only focuses on household consumption, rather than overall consumption, as tax rates for the different sectors differ. This leads to the following research question, which will be answered by a set of three sub-questions.

Research Question: What are the drivers of the excise rates charged on gasoline and diesel used in household transportation?

- How have the excise rates on the two types of fossil fuels changed over time?

- How has consumption of these fossil fuels evolved over time?

- What are factors that explain this variation in the excise rates?

The first sub-question shows the variation in the excise rates over time. In the absence of any disturbing factors, one should observe a relationship between the consumption of fuel and the excise rates charged. However, in the real world there are disturbing factors, so the variation is most likely to be caused by a set of multiple other factors. This question is the focus of the third sub-question, which aims to explain the observed variation in the excise rates that have been charged on gasoline and diesel over the period from 1978 until 2006. These results will be used to derive a more general answer to the central research question.

The second sub-question is relevant, because the consumption of fossil fuels has an influence on the externalities that are caused by the consumption of fossil fuels (which in turn is important for the Pigouvian tax scheme). Whereas the Greenhouse Gases (GHG) and CO_2 emitted per litre are the same, regardless of how much fuel is consumed, an increase in overall consumption does impose more total externalities. More cars consume more fuel, and thus, on aggregate emit more CO_2 and GHG. Moreover, more cars lead to more congestion problems, and thus impose an externality on other road users. Finally, more congestion leads to less economical driving (the most efficient travelling speed is 50-55 mp/h, or 80-85 km/h (Center for Transportation Analysis, 2010)), thus emissions per kilometre increase with congestion, as well. Hence, an increase in the consumption of fuel should lead to an augmentation of the excise rates, to incorporate the greater externalities. A final aspect to consider is that the emissions per kilometre are lower for diesel powered cars than for gasoline powered cars with similar specifications (Sullivan et al., 2004). This may thus also explain the difference in the excise rates between the two fuel types.

The final sub-question will then investigate other factors and variables that play a role in determining the excise rates countries charge on fossil fuels. Excise rates of the countries in the sample differ largely from each other. While this may in part be due to differences in the externalities of consumption and the price elasticities for demand, it is highly unlikely that all of the variation is caused by these two factors. Moreover, one can also observe fairly large variations in the excise rates within countries, caused by policy changes that are unlikely to be due to a sudden increase in the externalities or a decrease the price elasticity. Hence it is necessary to identify further factors influencing taxation policy.

Outline: The remainder of the thesis will be as follows. Section 2 will present the findings of prior research done in this field, and defines the concepts used throughout the thesis. Section 3 will discuss the scientific and social relevance of this thesis. Section 4 will present the data and methodology used to answer the research question and the corresponding sub-questions. Section 5 and 6 will deal with answering the first and second sub-question, respectively. Section 7 presents the analysis and the results. Based on this, I will evaluate each of the factors that are believed to have an influence on the excise rates, in terms of their observed effects. The conclusions will be given in section 8. The thesis will be concluded with the discussion of the limitations of the thesis and the possibilities for further research in section 9.

2 Literature Review

Much literature has looked at aspects that may affect the taxation policy of countries. When looking at the current excise rates on fossil fuels throughout EU countries, then the proportion of taxes of the final sales price is striking. In 2007, the average price of a litre of standard unleaded fuel in the UK was 95.1 pence. Of this, 63.7 pence (66.7%) were taxes (petrolprices.com). This is equivalent to a tax rate of 102.9%. In contrast, the VAT rate in the UK currently is 20% (direct.gov.uk). These figures are largely consistent with observations from other EU members. The tax rates in the US, on the other hand, are considerably lower. The average total tax rate on gasoline in 2011 is 49.5 cent per gallon, or 13.08 cent per litre (api.org), equivalent to a tax rate of 12.5% [1]. This thesis will focus on explaining the differences in tax rates on fossil fuels in different countries. For this, I shall analyse the factors that may influence countries decisions on the tax rate for fossil fuels. As the data suggest,

[1]Note that this figure is the US average tax rate on gasoline; Tax rates differ per state

excise rates differ due to more than can be explained using the two major taxation theories. Also, more variables are necessary to fully grasp the essence of each of the two concepts. These variables will be derived from the literature of (fuel) taxation, upon which a number of hypotheses will be based that will be tested in the analysis. The hypotheses are listed below.

These two major economic theories that prescribe an optimal tax structure are the Ramsey rule of taxation and the Pigouvian tax. The Ramsey rule of efficient taxation says that goods whose demands are inelastic should be taxed at a relatively high rate in order to minimise the distortionary effect of government taxation as a whole, the deadweight loss of the tax. A tax causes both production and consumption of a certain good to fall short of its privately optimal amount (neglecting externalities), and thus leads to a sub-optimal outcome (Ramsey, 1927).

The Pigouvian tax, on the other hand, prescribes that a tax should incorporate all the externalities that are caused by the consumption of a good, in order to reduce the consumption of that good to its socially optimal point. In the case of either fossil fuel, consumption has a number of negative externalities. First of all, combusting both diesel and gasoline leads to the emission of CO_2 and other GHG that harm both the environment as well as human health. Secondly, combustion leads to the emission of toxic gases that further harm human health. Finally, consumption of fossil fuels by cars and other road vehicles leads to significant congestion problems. Each of these externalities incurs a certain social costs, which is not incorporated in the net (tax-free) prices of gasoline and diesel. Hence, a tax may be needed to reduce the demand to a level which is socially optimal, i.e. a level of consumption where the marginal benefits of consumption equal the marginal social cost (Perman et al., 2003).

In the analysis, I will thus include two variables, each describing one of the two streams of taxation theory. For the Ramsey rule, I shall compute the price elasticities of demand for each country and each type of fuel. According to the Ramsey rule, countries with a less elastic demand should then charge higher excise rates. The computation will be done on basis of OECD and World Bank data on consumption, prices, population, income and the exchange and inflation rates (in order to be able to express rates of different countries in one common unit). Moreover, other variables will be included, as the data suggests that neither of the two taxation concepts fully explain the variance in the excise rates charged on gasoline and diesel.

Hypothesis 1: A less elastic demand for fossil fuels will lead to higher tax rates on these fuels.

Whereas the Ramsey rule of taxation primarily focuses on the relative tax rates on goods, it is also important to note that the overall tax rate is expected to be influenced by the fiscal position of a country. The problem with a government deficit and taxation is that it is hard to distinguish the causal order. On the one hand one could argue that a government deficit causes countries to install higher tax rates, in order to increase government tax revenue. Moreover, this policy may be very effective in terms of the generation of tax revenues when the demand for fossil fuels is inelastic. Hence, the combination of two factors, the public balance and the price elasticity, may drive countries to charge higher excise rates. Another view, proposed by Milton Friedman, is that high tax rates increase the government revenue, which leads to increased government spending and eventually to a government deficit. Anderson, Wallace and Warner (in Anderson et al., 1986), however, have tested this hypothesis and concluded that in all cases but one, the government deficit is caused by external factors, after which the tax rates on commodities are often raised to close the government deficit. Thus, while according to the Ramsey rule, a less elastic demand should lead to a higher tax rate of that particular good, the magnitude (and direction) of the public balance is expected to increase the overall tax rate of all goods. Hence, the public balance can be used to explain the excise rates on gasoline and diesel.

Hypothesis 2: The public balance has an influence on the taxation policy of a country. The larger the public deficit, the higher the tax rate on goods, and thus fossil fuels, will be.

Combining the first two hypotheses, leads to another hypothesis. If it is efficient to tax inelastic goods at a higher rate, and a public deficit is expected to increase the overall tax level, then it is also efficient to raise the tax rate on the inelastic goods by more than that on elastic goods, in case of a public deficit. Also, it is to be expected that when the elasticity for fossil fuels is lower, then the increase in the excise rate caused by the public deficit will become larger.

Hypothesis 3: A public deficit will increase the excise rates on fossil fuels by more, the lower the price elasticity is.

The variable for the Pigouvian tax is based on findings of Parry (in Parry, 2001 and Parry & Small, 2005), who has estimated the monetary value of the sum of the externalities that are caused by the consumption and combustion of fossil fuels. In this, Parry finds that the total external cost of consuming one litre of gasoline is between 15 and 20 pence (in 2001), which corresponds to about 30 to 40 US-$ cents (in 2006). This transformation is needed, as I will express all prices and tax rates in constant 2006 US-$ throughout the remainder of this thesis. Parry also finds that the tax rate charged in the United Kingdom is well above the estimated marginal external cost of consumption, whereas the excise rate in the US is considerably lower than the estimated marginal external cost.

When countries adhere to the Pigouvian taxation scheme, it is to be expected that an increase in the externalities of the consumption of fossil fuels will also lead to an increase in the excise rates, to internalise the externalities into the price. The externalities are influenced by multiple factors, such as the car density (higher car density leads to more congestion, also impairing the fuel economy), the total distance driven and the aggregate amount of fuel consumed.

Hypothesis 4: The larger the externalities of the consumption of fossil fuels, the higher the excise rate charged on fossil fuels.

As said before, the car density in a country, measured as the number of cars per 1000 inhabitants, affects the externalities of fuel consumption and thus should lead to a higher tax rate on fossil fuels, as shown by Rietveld and van Woudenberg (in Rietveld & van Woudenberg, 2005). More cars consume more fuel, and the congestion problems will also be larger, given a certain road infrastructure. Moreover, fuel taxation is also a more viable policy tool (regardless of the aims of the tax) when consumption is larger, as tax revenue is also increasing with consumption. Hence, it is to be expected that a higher car density will induce countries to charge a higher excise rate, assuming that the aim of the policy is to (partially) internalise the externalities in the sales price of gasoline.

Hypothesis 5: A higher car density will increase the externalities from the consumption of fossil fuels and thus increase the excise rates on these fuels.

Also the composition of the vehicle fleet in a country may influence the excise rates charged by countries. More specifically, it may affect the relative excise rates charged for gasoline and diesel, respectively. On the one hand, having a relatively large share of gasoline cars implies that the majority of externalities caused by car traffic are caused by gasoline fuelled cars, which could result in a higher excise rate for gasoline. On the other hand, governments may choose to impose a lower excise rate on gasoline, to minimise the distortionary effect of the tax, and offset the loss in tax revenue by increasing the tax rate in diesel, in order to maintain a comparable level of tax revenue (and vice versa). Hence, the effect of the composition of the vehicle fleet largely depends on the relative weights assigned to either the distortionary effects of a tax and the externalities caused by consumption. The externalities per litre of diesel consumed are significantly higher than they are for gasoline, as especially the emission of particulate matter is far larger (Delucchi, 2000). Hence, from a Pigouvian standpoint, the excise rates on diesel should be higher, too. A greater share of diesel cars should thus further encourage countries to charge higher excise rates, leading to hypothesis 6. The composition of the vehicle fleet will be measured by the percentage of diesel cars in a country.

Hypothesis 6: The composition of the vehicle fleet in a country will have a significant effect on the taxation policy of a country. A greater share of diesel cars should lead to higher excise rates on diesel.

The existence of an oil industry in a country may induce the country to tax fossil fuels differently from countries that do not extract crude oil. As both diesel and gasoline are derivatives of crude oil, changing the excise rates on fossil fuels indirectly influences the production of crude oil or the refining of crude oil to diesel or gasoline. Also, large industries tend to have a relatively larger influence on policy decisions than smaller industries and firms, because of the importance of the industry to the countrys economy. Moreover, large industries have larger financial resources which can be used to influence policy than smaller industries, via lobbying activities (Salamon & Siegfried, 1977). This can thus lead to policies that favour these industries, such as low excise rates on oil based car fuels.

Hypothesis 7: The larger the oil industry in a country, the lower the excise rate on oil based fuels will be.

The presence of an automotive industry is expected to show similar effects as the presence of an oil industry (ibid.). Countries may be inclined to charge relatively low excise rates, as low excise rates lead to an increase in the usage of cars. This will also cause an increase in the number of cars sold. Often, inhabitants of a country have a domestic bias towards cars (i.e. people tend to prefer cars of domestic manufacturers, all else equal), so that the domestic car manufacturers benefit more than other car manufacturers. This, in turn, increases the profits for the domestic manufacturers (and thus their tax liability), and creates extra jobs, so that the foregone income from the excise rate may well be smaller than the overall benefits that are associated with the lower excise rate.

Hypothesis 8: The presence of a domestic automotive industry will lead lower excise rates on fuels.

The penultimate factor of importance is tax competition. Tax competition describes the phenomenon that countries tax certain goods or types of income at a low rate in order to attract multinational companies to settle in that particular country, or to instigate inhabitants of neighbouring countries to buy their goods in the low tax country. Thus, by charging relatively low tax rates, the demand for the goods will increase, as foreigners have an incentive to buy those goods abroad, where the tax rate is lower. In general, we see that large economies tend to adhere to higher tax rates than smaller ones. According to Slemrod (in Slemrod 2003), this is due to the fact that large economies tend to be more attractive for large corporations than smaller economies, as the knowledge base and the infrastructure are superior, and the scope for synergies is larger. Hence, the larger economies offer a superior value proposition, which should induce multinational companies to settle in the large economies, despite the possible cost savings that could be incurred by settling in smaller economies with lower tax rates.

Kanbur and Keen (in Kanbur and Keen, 1993) analyse tax competition from a game-theoretical perspective, and come to the same conclusion as Slemrod, namely that large countries charge higher tax rates than small countries. However, Kanbur and Keen focus on commodity goods (such as fuel), rather than foreign capital in the form of foreign companies settling in the domestic economy. Their argument is as follows. Assuming a world with two countries, a large one and a small one. The population size is proportional to the country size, i.e., the large country has more inhabitants than the small one. Moreover, they assume that the tax difference outweighs the travel costs, so that consumers of each country are willing to travel to the other to buy commodities. In this setting, the smaller country has a greater incentive to undercut the large countrys tax rate, because the potential market growth for the small country is far greater than it would have been if the large country had undercut the small countrys tax rate. Hence, we expect small countries to have a lower tax rate, also on gasoline.

Hypothesis 9: Due to tax competition, large countries will tend to adhere to higher fuel tax rates than smaller countries.

Finally, I shall use a dummy variable for a green government to incorporate the different policy choices that different governments make. In general, left-winged and green parties tend to increase tax rates on goods in general, and thus also on fossil fuels, as their expenditure to social welfare programmes in general is higher than that of right-winged governments. More liberal governments, on the other hand, tend to adhere to low tax rates in order to allow the economy to flourish and to minimise the excess burden of taxation (Summers, Gruber & Vergara, 1992). The dummy variable does not make a distinction between left-winged parties and green parties, as green parties often are left-winged, as well. Moreover, the taxation policies of either parties are expected to be indistinguishable. This leads to my final hypothesis.

Hypothesis 10: Left-winged governments will impose a higher excise rate than right-winged governments.

3 Social and Scientific Relevance

The scientific relevance of this research is that it presents a general insight in the factors that influence the fossil fuel taxation decision of countries. The present literature mainly focuses on assessing the adequacy of taxes from a Pigouvian taxation point of view (most prominently Parry), whereas a lot of the macroeconomic literature also focuses on the evaluation of the efficiency of taxes (the Ramseyan viewpoint). Moreover, most literature focuses on a small set of countries, often just one or two. In this thesis, however, I aim to make general statements on relevant economic drivers for the excise rates charged by countries on gasoline and diesel. For this I will use a panel of 20 OECD countries that have been monitored on multiple aspects over a period of nearly 30 years. This allows the use of far more information, which is expected to lead to more reliable and conclusive results. Also, the use of a panel allows controlling for unobserved heterogeneity between countries and between time periods, further increasing the reliability of results.

The social relevance lies in the contribution to a better understanding of governments fiscal actions that I hope this thesis will deliver. Often, citizens are opposed to taxation, and tend to be weary of policy changes in this field. However, I presume that there is some rationale behind the tax rates charged, which I hope to shed light on through this thesis.

4 Data and Methodology

In answering the research question, I will make use of both quantitative as well as qualitative data. Data on fuel taxes for different types of fossil fuels (and their net prices) have been obtained from the OECD for the period ranging from 1978 until 2006. Data on fuel consumption for different types of fossil fuels come from the OECD, as well. Consumption data for individual member states range from 1960 until 2006. Hence the relevant period used in this thesis will be limited to the years between 1978 and 2006. In the coming subsections, I will describe the transformation made to data used in the analysis. The data on net prices and the excise rates have been used in answering the first sub-question. The consumption data are relevant for the second sub-question. Other variables were used in answering the final sub-question.

4.1 Net Prices

The net fuel prices have been obtained from the statistics database of the OECD. The problem with these data is that the net prices are expressed in local currencies, and have not been adjusted for inflation. However, in order to be able to compare figures from different countries and different years, these adjustments have to be made. For this, I have also obtained data on the CPI for each country over the period from 1978 and 2006 from the OECD, as well as the average annual exchange rates between each of the countries in the sample over the period described above. The first step then was to adjust each of the net prices for inflation, using the CPI data (the net prices are effectively "translated" into 2006 values). The adjustment is done for each year, by multiplying the net price of a year by the CPI index of 2006, and dividing it by the CPI index of the base year (i.e. the year from which the value stems).

After expressing all values in the respective 2006 currencies, they could still not be compared between countries. So, using the 2006 exchange rate, I transformed the net prices into one common currency, being 2006 US-$. Only one exchange rate is necessary in this case, as all the net prices were already expressed in their respective 2006 local currencies. Now that all the prices are in the same unit, they can be used for comparisons over time and between countries.

4.2 Excise Rates

Also the excise rates had to be expressed in a common unit for them to be compared. The methodology and data used are the same as for the net prices. So I first transformed each of the excise rates into the 2006 local currencies, and then translated them into 2006 US-$, in order to be able to compare the excise rates in the different countries over time, and across countries.

4.3 Absolute Consumption Data for the OECD Countries

For the description of the consumption data I shall first look at the aggregate consumption of all OECD countries over the period, as well as in three other OECD regions. The same could be done for every country in the dataset separately, but the extra insights gained from this would be limited. The data on the consumption of both gasoline and diesel stem from the OECD Statistics database. In this dataset, the consumption is measures in million tonnes per year over the period between 1960 and 2008. I have limited myself to the period between 1978 and 2006, as data on excise rates are only available over this period, so that only the analysis of the data in that period makes sense. The absolute gasoline consumption is expressed in thousand metric tonnes. By definition, the absolute values have not been adjusted for population changes. The figures are aggregates of the countries in that respective OECD region. However, countries for which no data on the excise rates were present have been omitted (yet again, because analysis is only sensible if data on both consumption and the corresponding excise rate are available).

4.4 Per Capita Consumption in OECD Regions

The insights to be gained from looking at the per capita consumption, however, are far more significant, as the developments shown above may be influenced by multiple factors other than a behavioural change of consumers. A very prominent suspect is population growth. *Ceteris paribus*, a larger number of people implies a larger number of road going vehicles in circulation, and thus to a greater consumption of fuel (both fossil and non-fossil). Hence, the data displayed in this section are the per capita consumption data for the countries included in the sample. The population data have been obtained from the database of the World Bank Group (data were unavailable at the OECD). The per capita consumption is calculated by dividing the absolute consumption by the total population in a country. For the purpose of clarity, I have yet again clustered part of the data into two specific regions, the EU and the OECD as a whole. The USA are also included separately, due to the fact that it is comparable to the EU in terms of size and population.

Other factors that will be included in the analysis are the price elasticities for each country and fuel, the volume of crude oil extracted in each country, the existence of a domestic automotive industry, the car density, the composition of the vehicle fleet (in terms of fuel type), the countrys public balance, its size (for tax competition purposes) and the political orientation of the government. Full details on the sources and measurement of these variables is given in table 1 below.

Table 1: Variable Specification

Code	Description	Measurement Base	Source
PRICE ELASTICITY	Price elasticity of demand per fuel type	No data available; computed using income and per capita consumption	Price: OECD Consumption: OECD Population: World Bank
PUBBAL	Public balance	Deficit/surplus as	OECD
PE*PUBBAL	Interaction variable between the price elasticity and public balance	Computed using the above two variables	OECD & World Bank
CARDENS	Car density in a country	Cars per 1000 inhabitants	International Transportation Forum
DIESEL	Share of diesel cars in vehicle fleet	% of diesel cars out of total cars	EU: Eurostat Other: national statistical bureaus
OIL	Amount of crude oil extracted	Million tonnes/year	OECD
AUTOINDUSTRY	Existence of domestic car industry	Dummy variable; 0 = no, 1 = yes	Ultimatecarpage
SIZE	Size of a country (GDP and population)	Dummy variable; 0 = small, 1 = large	G20
GREENGOV	Political orientation of government	Dummy variable; 0 = no, 1 = yes	The Random House Encyclopedia

The price elasticity for the demand of both types of fuel was not readily available for all countries. Hence, in order to be able to include it in the model, it is necessary to compute the price elasticities. The standard formula for calculating price elasticities of demand is shown in equation 1 below.

$$E = \frac{\Delta Q/Q}{\Delta P/P} \tag{1}$$

Where Q is the quantity of fuel demanded, and P is the price per litre of fuel. The price consists of two elements: the price of raw fuel in a country (this figure includes import taxes and other taxes levied on fuel), and the excise rate charged on that fuel.

A major drawback of this formula is that it neglects increases in income, which in principle should influence the quantity consumed. Hence the price elasticity could well turn out to be positive, because the income rose more than the excise rate. However, Coloma (in Coloma, 1999) found that fossil fuels are normal goods, so that an increase in the price (be it through the excise rate, be it via the price of crude oil) should lead to a decrease in the consumption. Following the methodology of Huges, Knittel and Sperling (in Hughes et al., 2006) I will estimate the elasticities using a logistic regression model including the natural logarithms of consumption, price and income (approximated by GDP per capita), rather than using the textbook formula in equation 1. The logistic regression will use separate time-series for each country, in order to obtain distinct price elasticities for each country. This is sensible, because incomes in countries differ, and income has an effect on the price elasticity. The regression equation is presented in equation 2.

$$ln(Cons_t) = \beta_1 + \beta_2 \times ln(P_t) + \beta_3 \times ln(Y_t) + \varepsilon \tag{2}$$

The convenience of this model is that the coefficient of the natural logarithm of the price of a fuel is also the price elasticity of the demand for that fuel. The elasticity estimated via this regression is the long-run elasticity in a country. The natural logarithm of the per capita income is included, to dissect the income elasticity of demand from the price elasticity. The explanatory variables of the excise rates will be estimated by means of a regression model. The model used at first instance will be the Ordinary Least Squares regression model without fixed effects as given by the below formula.

The determining factors of the excise rates will be estimated by means of a regression model. The model used at first instance will be the Ordinary Least Squares regression model without fixed effects as given by equation 4.

$$Y_{jt} = \beta_1 + \beta_2 X_{1jt} + \beta_3 X_{2jt} + \ldots + \beta_{11} X_{10jt} + \varepsilon_{jt} \tag{3}$$

The dependent variable is Y, the explanatory variables are the X variables with their corresponding β coefficients. As usual, the intercept is given by β_1, the error term by ε.

However, given that the data used in the model are panel data, an ordinary least squares regression may not be accurate, as this method does not control for unobserved heterogeneity between cross-sections and time periods (Hill, Griffith & Lim, 2008:385). Thus, by including fixed effects, the reliability of the model will increase, and it will better make use of the large amount of information included in the panel.

Unfortunately, however, by using fixed cross-section effect, it is not possible to include the variable for the price elasticity, the automotive industry and the country size, as their values are constants. As mentioned before, the price elasticity computed is the long run price elasticity, which is constant throughout the period, by definition. Also, all automotive industries were established well before 1978, and neither has seized to exist. Finally, the classification of the countries size in the sample is constant. The inclusion of fixed cross-section effects also leads to the exclusion of Denmark, Norway and Sweden, as these countries did not have a change of government throughout the period. So an obvious trade-off between the inclusion of more variables and the inclusion of fixed cross-section effects occurred. As a robustness test, I have run three types of regressions: the first is a model that uses neither fixed time effects, nor fixed cross-section effects. Secondly, I have run regressions using the same variables as in the previous model, but with fixed time effects. The third and last model is the model with full fixed effects, but without the above mentioned variables and countries.

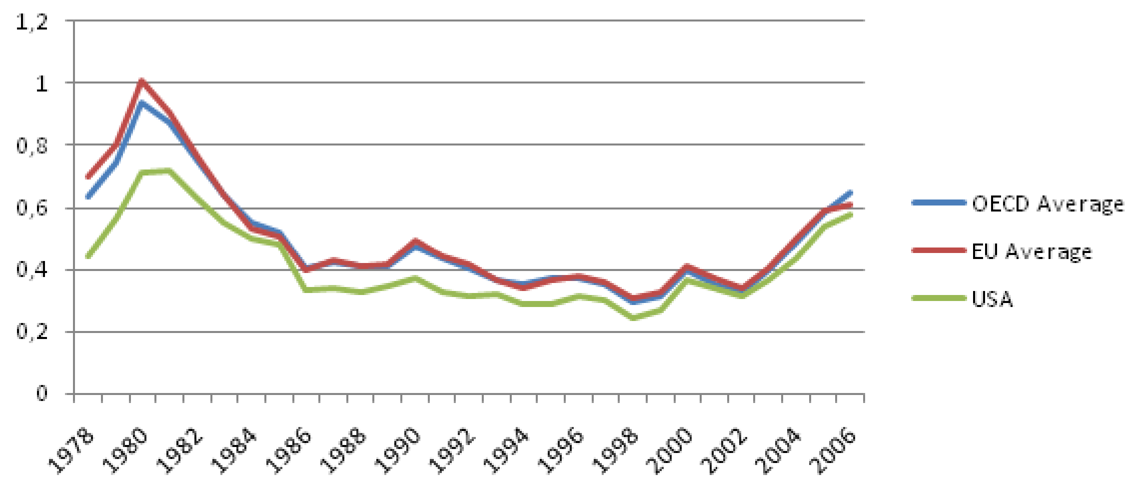
5 Development of the Net Prices and Excise Rates

In order to make inferences on the change of the prices of gasoline and diesel, it is important to describe both the changes in the net prices of either fuel type, as well as the excise rates, given that the final sales price consists of the net price plus the excise rate (plus a profit margin, which will be neglected here). As will be case throughout the remainder of this thesis, I will analyse each fuel type separately for each of three regions: the OECD as a whole [2], the EU countries in the OECD [3] and the USA.

5.1 Net Gasoline Prices

The overall changes in the nominal prices are shown in figure 1. As is to be expected, the movements are highly symmetric for all three selected regions. The differences between the three lines are the import taxes on crude oil or on refined oil in the different regions. The peak for all three regions is in 1980, in the heyday of the second oil crisis. Interesting is the sharp increase in the net prices since 2003.

Figure 1: Net Gasoline Prices between 1978 and 2006



The mean of the average net gasoline price in the OECD is 49.1 US-$ cents. As can clearly be seen from figure 1, it reaches its maximum 94.1 US-$ cents in 1980. Its lowest

[2]This group does not include all OECD countries, as no data were available on some member states. The countries included are: Australia, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Luxemburg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the UK and the USA.

[3]This group does not include all EU countries, merely the EU countries in the sample that were part of the OECD over the full length of the period 1978-2006. The countries included are: Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, the Netherlands, Portugal, Spain, Sweden and the UK.

Table 2: Descriptive Statistics Net Gasoline Price

	OECD Average	EU Average	USA
Mean	0.491	0.501	0.411
Standard Error	0.032	0.034	0.025
Median	0.410	0.418	0.344
Standard Deviation	0.171	0.182	0.134
Variance	0.029	0.033	0.018
Range	0.647	0.703	0.477
Minimum	0.295	0.308	0.242
Maximum	0.941	1.011	0.718
Observations	29	29	29

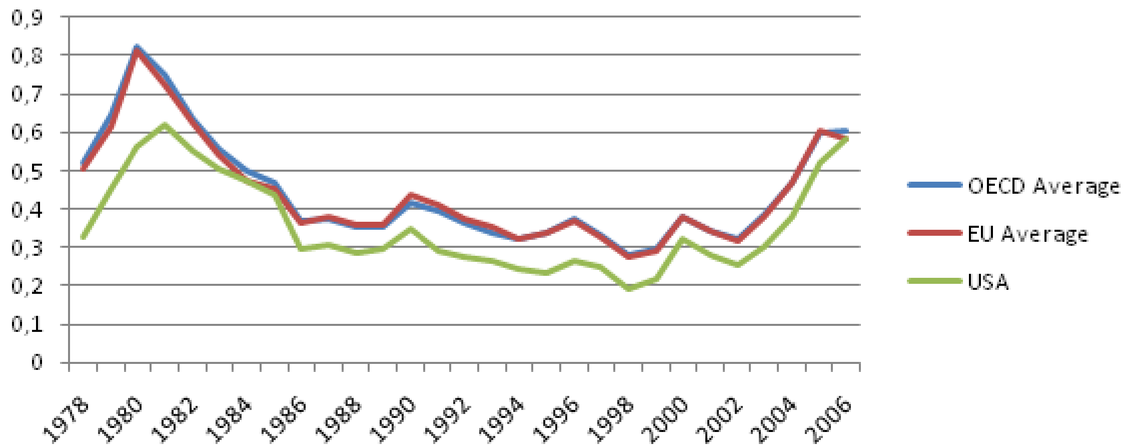
point is reached in 1998, where the net price was just 24.9 US-$ cents. The figures for the EU average net gasoline prices are very similar. Its mean is just 1 cent higher than the OECD mean. Also the EU average peaks in 1980, where the net price was 1.01 US-$, and the lowest net price occurred in 1998, too, when it read a mere 30.8 cents. Finally, the net prices in the USA are slightly below those of the EU and OECD, but they exhibit the same pattern. The mean is equal to 41.1 cents, the maximum 71.8 cents (in 1981) and the minimum equalled 24.1 cents in 1998. The descriptive statistics are given by table 2.

5.2 Net Diesel Prices

As both diesel and gasoline are derived from crude oil, and their net prices are largely driven by the price of crude oil, one would expect a very similar pattern for both types of fuel. The changes are depicted by figure 2. The figure is very similar to that of gasoline.

As the lines for the OECD and the EU are almost identical, it seems that the countries do not charge significantly different pre-sales taxes on diesel. Also, it appears to be the case that no other possible cost drivers, such as transportation and refinement costs, do not play a significant role on the net price of diesel. The mean of the average net OECD diesel price is 44.5 cents, just 4 cents below its gasoline counterpart. The price peaks in 1980, where it read 82.5 cents. The lowest price was 27.9 cents, reached in 1998. The mean EU average price was 44.1 cents, 0.4 cents below the OECD mean. Also the EU price peaked in 1980, with 81.3 cents, its minimum of 27.5 cents occurred in 1998. Finally, the average price in the

Figure 2: Net Diesel Prices between 1978 and 2006



USA over the period was 35.7 cents. The maximum price was 62.1 cents in 1981, and the price reached its lowest point in 1998, where the net price was 19.4 cents. The full descriptive statistics on the net prices of diesel are given by table 3.

Table 3: Descriptive Statisctics Net Diesel Prices

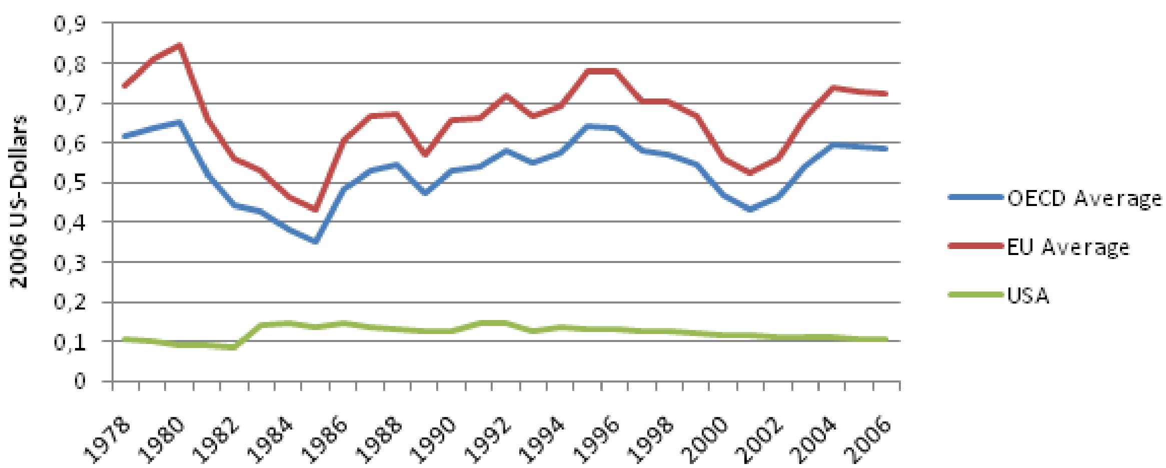
	OECD Average	EU Average	USA
Mean	0.445	0.441	0.357
Standard Error	0.026	0.025	0.023
Median	0.377	0.380	0.302
Standard Deviation	0.142	0.134	0.124
Variance	0.020	0.018	0.015
Range	0.546	0.538	0.427
Minimum	0.279	0.275	0.194
Maximum	0.825	0.813	0.621
Observations	29	29	29

5.3 Gasoline Excise Rates

Figure 3 below shows the evolution of the excise rate on gasoline in selected regions taken from the sample of OECD countries. As can clearly be seen, the average excise rates charged in the EU countries and the OECD countries move very similarly. At all times the excise rates in the EU were higher, but in no period did the excise rates in the two regions change in an opposite direction. A possible explanation for this phenomenon is that the majority of countries included in the sample are EU countries, 14 out of 22 countries, to be precise.

The evolution of the excise rates on gasoline in the USA strongly differs from the evolution of the average excise rates in the OECD and the EU. First of all, the excise rates charged are significantly lower, sometimes as little as one tenth of the rate charged in the EU. Secondly, the smaller changes in the rates yield a more stable rate. The real excise rate has steadily declined from its 1984 maximum before reaching its 1978 level in 2006.

Figure 3: Gasoline Excise Rates between 1978 and 2006



When looking at the descriptive statistics of the average excise rate on gasoline in the selected OECD countries over the period of 1978 until 2006, we see that the mean average gasoline excise rate is roughly 0.53 US-$. More interestingly, however, is that the minimum of 0.35 US-$ is reached in 1985, and the maximum of 0.65 US-$ in 1980. Hence there is no clear trend in the evolution of the excise rates, much in contrast to what was observed with the consumption of gasoline.

Table 4: Descriptive Statisctics Gasoline Excise Rates

	OECD Average	**EU Average**	**USA**
Mean	0.534	0.658	0.122
Standard Error	0.015	0.019	0.003
Median	0.545	0.667	0.126
Standard Deviation	0.079	0.101	0.018
Variance	0.006	0.010	0.000
Range	0.305	0.413	0.062
Minimum	0.35	0.433	0.086
Maximum	0.654	0.846	0.147
Observations	29	29	29

The mean of the average excise rate on gasoline in the selected EU countries is 0.66 US-$, so roughly 13 cents more per litre of gasoline than the OECD average. However, also in the EU countries, the minimum excise rate of 0.43 US-$ is reached in 1985, and the maximum of 0.85 US-$ in 1980. This may well be explained by the large share of EU countries in the OECD, as stated above.

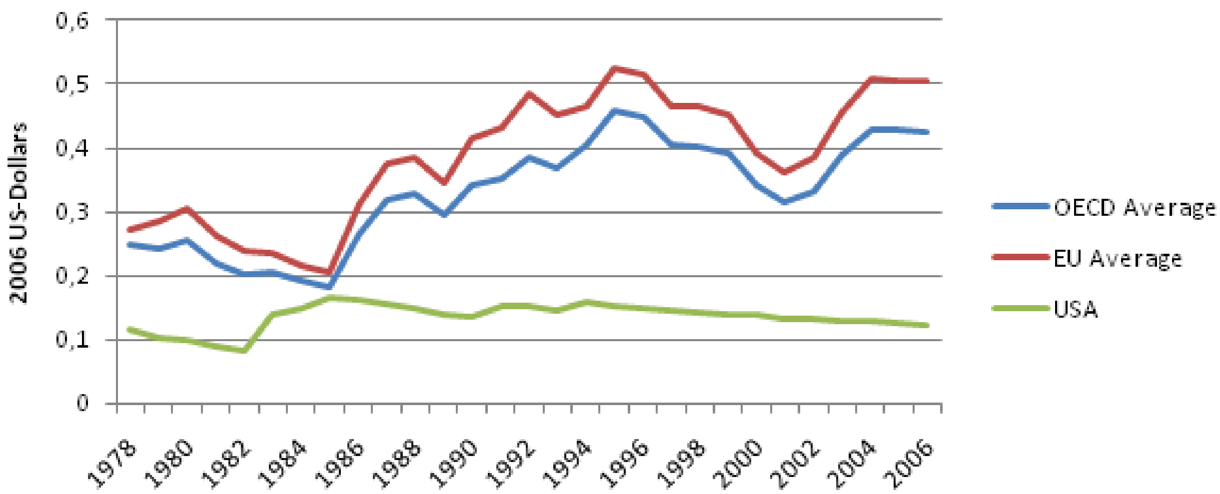
The statistics for the USA show a completely different picture. Unsurprisingly, the mean excise rate over the period is significantly lower, namely 0.12 US-$, about one fifth of the mean excise rate charged in the EU countries. The lowest excise rate of 0.09 US-$ is charged in 1982, the excise rate peaks with 0.15 US-$ in 1984. This also shows that the range of the excise rates charged is far smaller than in the OECD and EU countries. The more detailed descriptive statistics can be found in table 4.

5.4 Diesel Excise Rates

The evolution of the excise rates on diesel fuels in the selected regions is very similar to the evolution of the excise rates on gasoline. For the OECD as a whole, we see a sharp increase in the average excise rate after 1985, a trend which persists throughout the next decade. Between 1995 and 2000, the average excise rate fell sharply, before increasing again strongly after 2001. The same holds true for the average excise rate charged on diesel fuels in the EU countries included in the sample. Yet again, these similarities are likely to be due to the large share of EU countries in the sample.

The excise rate in the USA follows a different pattern. Up until 1982, the rates charged in real terms fell slightly, as the nominal rate stayed constant. Between 1983 and 1986, the excise rate increased rapidly, to almost twice the rate charged in 1982. After 1986, the excise rate on diesel fuels in the USA has been slowly decreasing in real terms. The above can be seen in figure 4 below.

Figure 4: Diesel Excise Rates between 1978 and 2006



Looking at the descriptive statistics yields a much clearer view of how the excise rates charged have evolved over the given period. The mean of the average excise rate charged in the OECD countries is 0.33 US-$, with a minimum of 0.18 US-$ in 1985, and a maximum of 0.47 US-$ in 1995. This implies a range of 0.28 US-$. The figures for the EU are again very similar, yet strictly larger than the respective figures for the OECD countries. The mean EU average excise rate is 0.39 US-$, a mere 0.06 US-$ above the mean of the OECD average. The minimum rate levied is 0.21 US-$ and the maximum rate 0.53 US-$, again in 1985 and 1995, respectively. The figures for the USA, on the other hand, differ largely from those of the OECD and EU averages. The mean excise rate over the period is 0.14 US-$, with the minimum of 0.08 US-$ charged in 1982 and the maximum of 0.17 US-$ in 1985.

All in all we can see similar patterns for each of the regions for both gasoline and diesel fuels. First of all, the EU charges the highest excise rates of all of the regions, and the USA the lowest, by far. Secondly, the excise rate charged in the USA has been far more stable

Table 5: Descriptive Statistics Diesel Excise Rates

	OECD Average	EU Average	USA
Mean	0.330	0.387	0.135
Standard Error	0.016	0.019	0.004
Median	0.342	0.39	0.138
Standard Deviation	0.084	0.100	0.021
Variance	0.007	0.010	0.000
Range	0.276	0.318	0.081
Minimum	0.181	0.207	0.084
Maximum	0.457	0.525	0.165
Observations	29	29	29

than in any of the other regions. This is also shown by the relatively low sample variances and standard deviations. Finally, the patterns of the EU and the OECD countries are very similar: the excise rates evolve in a W-shaped manner. For the USA, on the other hand, both the rate for gasoline and diesel increased relatively sharply in the early 80s, before slowly decreasing to their pre-1980 level.

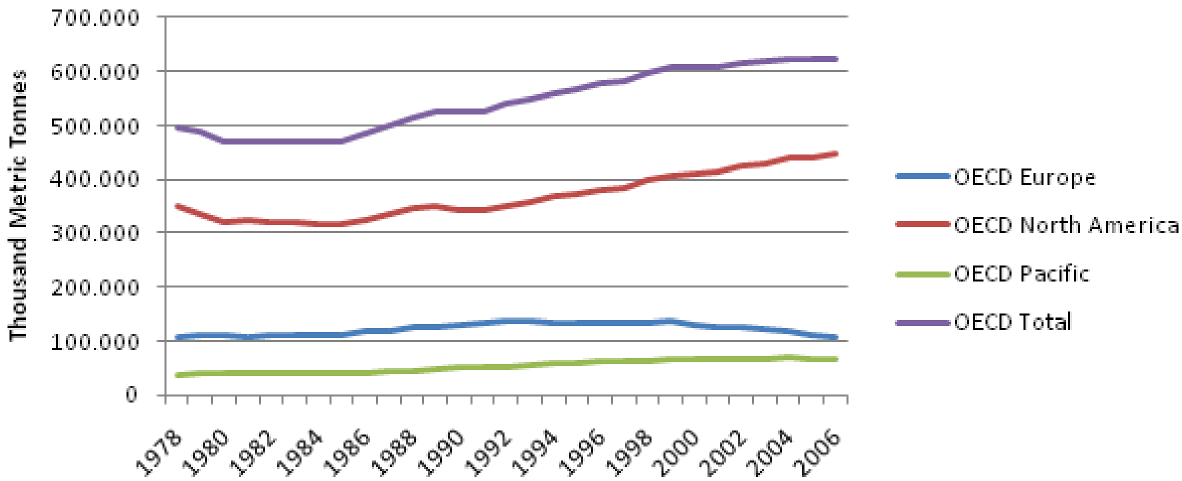
6 Development of Fuel Consumption

The data I use for the statistical analysis in this paper stems from the OECD. This has the advantage that the methodology is most likely to be coherent for all data, increasing the reliability of the findings. For the analysis I use both consumption data as well as data on the real excise rates on diesel and petrol fuels. Data on both consumption and excise rates is available on a host of countries, 20 in total, over the time range of 1978 until 2006. In the remainder of this section I shall describe the data at hand, including descriptive statistics and overall trends, for both the consumption data and the data on the excise rates.

6.1 Absolute Gasoline Consumption

The overall trend in gasoline consumption is upward, as expected. Strikingly, however, the aggregate gasoline consumption in the European OECD countries has slowly started to drop since the year 2000. The aggregate consumption for all other OECD regions, as well as for the OECD as a whole, has been steadily increasing since the mid 80s.

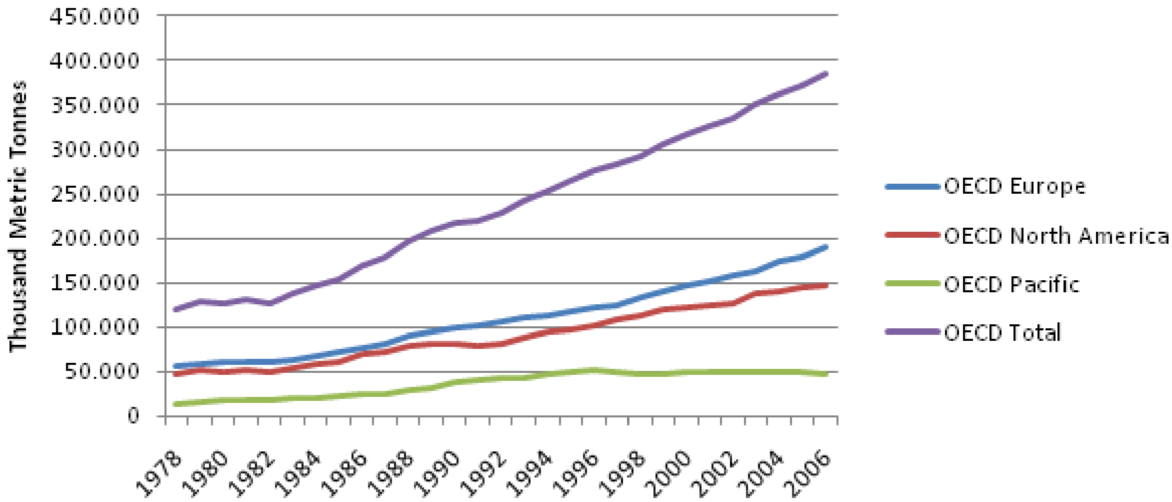
Figure 5: Gasoline Consumption between 1978 and 2006



6.2 Absolute Diesel Consumption

Comparing figure 6 with figure 5 above, a couple of things become immediately apparent. First of all, the overall growth has both been more stable, as well as larger, than was the case for gasoline consumption. For instance, as from 1982, the graph for the OECD Total consumption faces not a single year over the entire period in which the diesel consumption declined. Moreover, starting from 1982, the growth rate has been strikingly stable. A second observation is that, in contrast to the figures for gasoline, the European OECD countries are the largest consumers of diesel in the transport sector. A possible explanation for this is that in Europe, on average, the diesel excise rates are considerably lower than the gasoline excise rates. In the USA and Canada, the opposite is true, although the differences are far smaller. Finally, the diesel consumption in the OECD Pacific area has stagnated since the mid 90s.

Figure 6: Diesel Consumption between 1978 and 2006

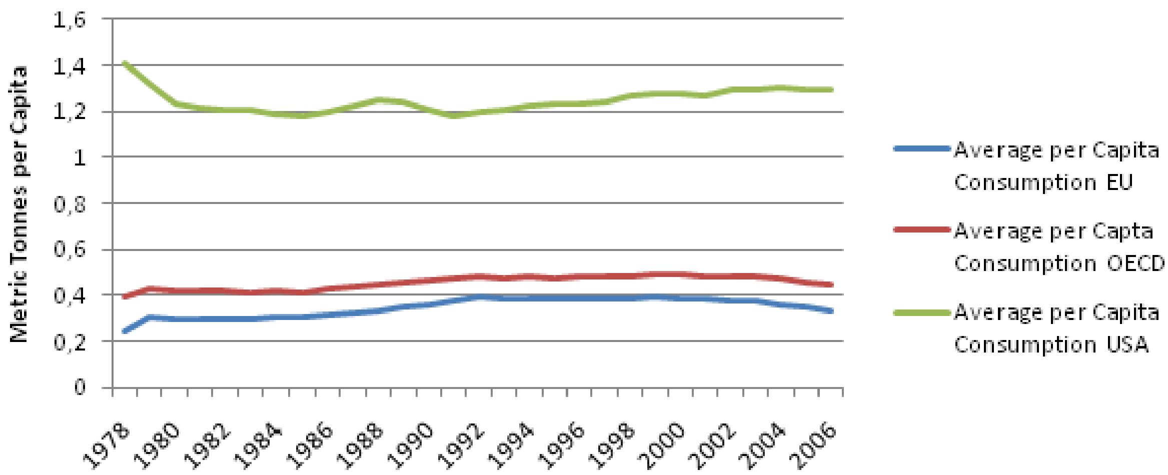


6.3 Per Capita Gasoline Consumption

As can be derived from figure 7 below, the average per capita consumption in the selected regions shows a similar trend as the overall consumption described in the previous section. The average consumption in the EU and OECD have a slight bell shaped form (which is more apparent when the US consumption data are omitted from the figure). For the EU, this corresponds to the bell shaped form of the total consumption curve in figure 5. Interestingly, however, the total consumption for all OECD countries is strictly increasing, whereas the per capita consumption is concave. This implies that the main driver of consumption growth has been population growth, and not an increase in the per capita consumption. The per capita consumption in the US has steadily decreased up until the mid 80s, but as from 1992, the per capita consumption has been increasing steadily. The effect of the growth of the US population outweighs the per capita shrinkage in consumption until the mid 80s, and reinforces the per capita increase in consumption as from 1992. Hence, the overall consumption is strictly increasing.

From the descriptive statistics, we can derive that the mean of the average per capita gasoline consumption in the OECD as a whole is equal to 456 kilos per year. The minimum per capita consumption of 395 kilos is reached in 1978, the maximum of 492 kilos in 1999. In 2006, the per capita gasoline consumption was back at its 1988 level. The trend for the EU countries included in the sample is very similar to that of the OECD as a whole. Its mean

Figure 7: Per Capita Gasoline Consumption between 1978 and 2006



of the average consumption is 349 kilos per year. The minimum consumption also occurs in 1978, and reads 244 kilos per person per year. The maximum of 395 kilos is also reached in 1999. An interesting observation is that the maximum per capita consumption in the EU is equal to the minimum average per capita consumption of all OECD countries together.

One reason for this fact is the extremely large consumption by US citizens. Over the period between 1978 and 2006, the average American consumed 1.246 kilos of gasoline per year, 3.5 times the amount the average EU citizen consumed. The minimum consumption of 1.178 kilos corresponds to the year 1985, and the maximum of 1.405 kilos, oddly enough, is reached in 1978. The trend in the USA thus differs strongly from that in the EU and the OECD as a whole. The complete descriptive statistics are displayed in table 6 below.

6.4 Per Capita Diesel Consumption

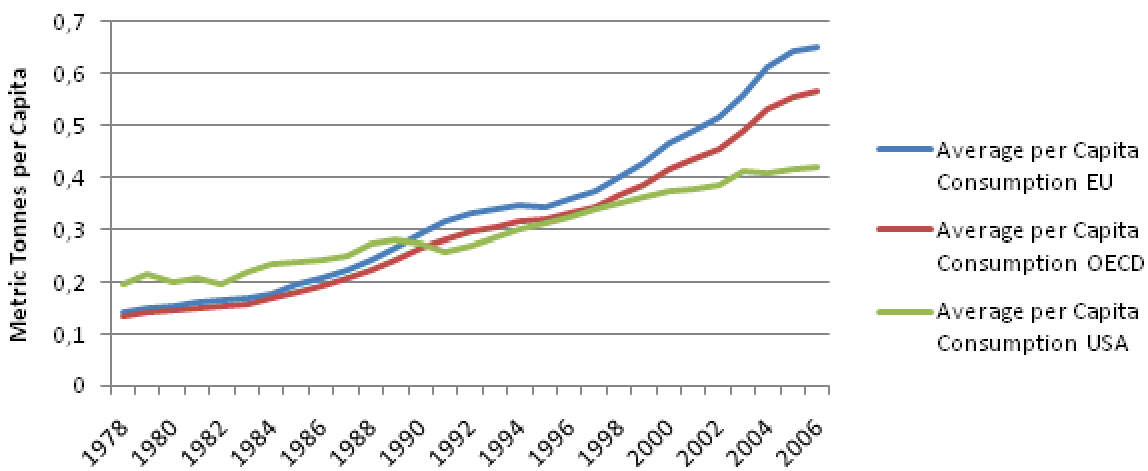
In contrast to the data for gasoline, the per capita diesel consumption has been increasing steadily over the period. The per capita consumption in the US, however, is still significantly larger than the diesel consumption. In the EU and the OECD as a whole, the average consumption of diesel is larger than the consumption of gasoline. The pattern in figure 8 corresponds well to the pattern seen in figure 6, where we saw that the overall consumption is growing rapidly throughout all the OECD regions. Figure 8 below further tells us that the growth in absolute consumption is not only due to population growth, but also due

Table 6: **Descriptive Statistics per Capita Gasoline Consumption**

	OECD Average	**EU Average**	**USA**
Mean	0.456	0.349	1.246
Standard Error	0.005	0.008	0.009
Median	0.466	0.360	1.237
Standard Deviation	0.029	0.041	0.051
Variance	0.001	0.002	0.003
Range	0.097	0.151	0.227
Minimum	0.395	0.244	1.178
Maximum	0.492	0.395	1.405
Observations	29	29	29

to an increase in the per capita consumption, and thus explaining the sharp increase in consumption.

Figure 8: Per Capita Diesel Consumption between 1978 and 2006



The mean of the average per capita diesel consumption in the OECD as a whole is equal to 302 kilos, about 150 kilos less than the consumption of gasoline. The minimum consumption of 135 kilos is reached in 1978, the maximum of 565 kilos in 2006, confirming the strong positive trend for the consumption of diesel. Similar figures apply to the EU. Its mean average consumption is 321 kilos, roughly the same as its gasoline counterpart. Also here, the consumption was least in 1978 (139 kilos), and topped in 2006 at 632 kilos. In the USA, the average consumption of diesel is absolutely dwarfed by the gasoline consumption.

Table 7: Descriptive Statistics per Capita Diesel Consumption

	OECD Average	**EU Average**	**USA**
Mean	0.302	0.321	0.297
Standard Error	0.025	0.028	0.014
Median	0.297	0.311	0.281
Standard Deviation	0.133	0.153	0.073
Variance	0.018	0.023	0.005
Range	0.430	0.493	0.224
Minimum	0.135	0.139	0.196
Maximum	0.565	0.632	0.420
Observations	29	29	29

With an average consumption of 297 kilos, the per capita diesel consumption is not even a quarter of the gasoline consumption in the USA over the same period. Given its lowest consumption of 196 kilos (both in 1978 and 1982) and its maximum of 420 kilos in 2006, we can state that the growth rate of the per capita diesel consumption is far smaller in the USA than it has been in the EU and the OECD as a whole. This can clearly be seen by figure 8 and table 7 above.

7 Analysis

This section covers the analysis of the data. The first step in doing so is the estimation of the price elasticities of demand, for each country and each fuel type. Then I will go on and test the hypotheses that were mentioned in the literature review, using three different regression models.

7.1 Determining the Price Elasticities

The elasticities are derived from individual time-series for each country, so as to allow for the price elasticities to differ between the countries. As noted before, the price elasticities are the long run price elasticities. The results are shown in the table 8 on the next page. The numbers in parentheses are the standard errors of the regression coefficients. The asterisks indicate the level at which the results are significant.

Table 8: Price Elasticities of Demand

Country	Gasoline	Diesel
Australia	-0.104***	n.a.
	(0.015)	-
Canada	-0.018	n.a.
	(0.090)	-
Denmark	-0.127*	0.429
	(0.066)	(0.407)
Finland	-0.230***	-0.171**
	(0.042)	(0.075)
France	-0.114	-0.387***
	(0.158)	(0.135)
Germany	-0.280***	-0.121
	(0.081)	(0.091)
Greece	-0.351***	-0.394***
	(0.033)	(0.101)
Ireland	0.030	-0.748***
	(0.177)	(0.196)
Italy	-0.238*	-0.393***
	(0.139)	(0.132)
Japan	-0.323**	-0.019
	(0.145)	(0.038)
Luxembourg	-0.488***	-0.289
	(0.127)	(0.263)
Netherlands	-0.004	-0.348***
	(0.093)	(0.115)
New Zealand	-0.083**	-0.297**
	(0.035)	(0.123)
Norway	-0.298***	-0.043
	(0.069)	(0.104)
Portugal	-0.461***	-0.378*
	(0.062)	(0.185)
Spain	-0.387***	-0.474*
	(0.083)	(0.263)
Sweden	-0.120***	-0.153
	(0.038)	(0.187)
Switzerland	-0.363***	0.103
	(0.042)	(0.225)
U.K.	-0.310***	-0.205***
	(0.047)	(0.085)
U.S.A.	0.037	0.004
	(0.055)	(0.063)

***Significant at the 1% level **Significant at the 5% level *Significant at the 10% level

In general one can say that the elasticities for gasoline are relatively low in all countries, with the most elastic demand being in Luxembourg with a price elasticity of -0.488. The demand is least elastic in Canada, where it is just -0.018. However, not all elasticities are significant at the 10% level. The elasticities are insignificant in Canada, France, Ireland, the Netherlands and the USA. Hence, the country with the lowest, significant elasticity is New Zealand with -0.083. This implies that in New Zealand, a 1% increase in the price of gasoline causes the demand for gasoline to drop by only 0.083%, whereas in Luxembourg, an equivalent price increase would result a reduction of the demand of 0.488%.All in all, however, the notion of gasoline being an inelastic good seems to be justified on the basis of the above results.

The elasticities for diesel are also in the line of expectation, even although the range of the elasticities is larger than in the case of gasoline. The elasticities for Australia and Canada are not given, because data on the diesel consumption were not available, so that the price elasticities could not be determined. The elasticities for Denmark, Germany, Japan, Luxembourg, Norway, Sweden, Switzerland and the USA are insignificant at the 10% level. The demand is most elastic in Ireland, where a 1% increase in the price of diesel leads to a reduction in the demand for diesel of 0.748%. The lowest elasticity is found in Finland, where it is -0.171.

7.2 Testing the Hypotheses

In this section, I will test the hypotheses that have been introduced in the literature review. The price elasticities used were derived in the previous sub-section. The externalities caused by fuel consumption are not included in the regression model. Rather, hypothesis 4 will be tested in a more qualitative manner, by testing whether or not this model gives a justification for some countries to overcharge the estimated externality cost, and other countries to undercharge it. The reason for this is that the estimate of the externality cost is constant for all countries, so that no inferences can be made on the effect of the externality cost on the excise rate. By using a cost which is constant for all countries, one cannot infer whether or not countries facing higher externality costs, also charge higher excise rates.

7.2.1 The Model for Gasoline

As stated before, I have used a multiple regression analysis to estimate the effects of the variables presented in section 4 on the excise rates countries charge on fossil fuels. First, I will present the results derived using a standard least squares regression model, and then the extension using an OLS regression model with fixed time effects to allow for differences between time periods. The corresponding Wald test results can be found in appendix 1. The Wald test is used to test the hypothesis that all the variables are jointly significant. The null hypothesis is that all variables do not differ significantly from zero. Hence, by rejecting the null, one can confidently say that the variables are jointly significant.

Table 9: Results of the Regressions for Gasoline

Y = Excise Rate	**No Fixed Effects**	**Fixed Time Effect**	**Full Fixed Effects**
Constant	0.504***	0.503***	0.532***
	(0.060)	(0.065)	(0.170)
PRICE ELASTICITY	0.264***	0.240***	n.a.
	(0.086)	(0.084)	-
PUBBAL	-0.011*	-0.010	0.001
	(0.006)	(0.007)	(0.004)
PE*PUBBAL	0.007	0.001	0.007
	(0.022)	(0.023)	(0.014)
CARDENS	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
DIESEL	0.004***	0.004***	-0.001
	(0.001)	(0.001)	(0.001)
OIL	0.002***	0.001***	0.001
	(0.000)	(0.000)	(0.001)
AUTOINDUSTRY	-0.066**	-0.067***	n.a.
	(0.026)	(0.024)	-
SIZE	0.023	0.035	n.a.
	(0.027)	(0.026)	-
GREENGOV	0.093***	0.104***	0.044***
	(0.019)	(0.019)	(0.012)
R^2	0.307	0.514	0.849
***Sign. at 1% level	**Sign. at 5% level	*Sign. at 10% level	

Table 9 above shows the regression coefficients and the standard errors for each of the variables (the standard errors are in parentheses) for both the model with and without fixed time effects. The asterisks indicate the level at which the coefficient is statistically significant. All coefficients but those of the price elasticity, the car density and the country size are significant at the two percent level, most, except the automotive industry dummy, even at the one percent level. The R^2 of 0.307 of the model implies that about a third of the variation in the excise rates can be explained using the nine variables introduced in section 4.

The coefficient for the price elasticity of the demand for gasoline is 0.264, which implies that an increase in the price elasticity in absolute terms leads to an increase in the excise rate. Given that the elasticities are negative, however, this actually confirms the prediction made in hypothesis 1. The further the price elasticity is below zero, the lower the excise rate tends to be. An inelastic demand (where the elasticity is closer to zero), is associated with a higher excise rate, as prescribed by the Ramsey rule. Moreover, this result is highly significant, also at the 1% level.

The result for the public balance of a country makes intuitive sense and confirms the expectations formulated by hypothesis 2. The negative, significant coefficient for the public balance implies that countries with a positive public balance tend to charge a lower excise rate on gasoline. When the public balance is negative, then the excise rates will rise, as a means to try to close the deficit in the governments finances. The effect, however, albeit significant, is very small. On average, a 1% negative public balance will increase the excise rate by a little over 1 US-$ cent. In this model, however, there does not appear to exist a significant interaction between the price elasticity of gasoline and the public balance, as the coefficient for this variable is insignificant. Nevertheless, the direction of the coefficient is in line with what hypothesis 3 predicted. A positive value of this variables implies that both the price elasticity and the public balance are negative (given that there were no significant, positive price elasticities). An increase in that value will mostly be caused by the public balance, as its values are far larger than the price elasticities. Hence, if it had been significant, one could have said that a public deficit leads countries to increase their higher excise rates by more, the less elastic the demand for gasoline becomes.

The coefficient for the car density in a country does not differ significantly from zero, thus implying that the car density does not instigate a change in the excise rate. The coefficient for the share of diesel cars, on the other hand, is significant at the 1% level. *A priori*, I expected that a greater share of diesel cars would increase the excise rate on diesel, as the externalities caused by diesel are larger than those of gasoline. From this model, however, it seems that a larger proportion of diesel cars leads to a higher gasoline excise rate. To make a more sensible conclusion, note that a larger proportion of diesel cars is equivalent to a smaller proportion of gasoline cars[4]. Hence, a smaller share of gasoline cars leads to a higher excise rate, i.e. a larger share of gasoline cars leads to a lower excise rate. Hence, it seems that the exact opposite of hypothesis 6 applies.

The existence of an oil industry in a country leads on average to a higher excise rate than in countries where an oil industry is absent. This finding is somewhat striking, especially when comparing it to the coefficient of the dummy variable for the existence of an automotive industry, which is negative (hence, the existence of an automotive industry leads to a lower excise rate on gasoline). The prior result contradicts hypothesis 7, the latter, however, confirms hypothesis 8, which in essence say the same. So whilst countries do try to stimulate the car manufacturers by charging a lower excise rate, they do not do so for the oil industry. But why is this the case? One reason could be that the measurement of the variables is different. The variable for the oil industry is measured by the volume of crude oil that is extracted by oil companies in a particular country. Hence, when, for instance, the United Kingdom decides to implement a lower excise rate on gasoline, this may benefit BP, but also all other gasoline companies. Moreover, it does not benefit BP in other countries. For the automotive industry, the dummy measures whether or not there are large car manufacturers originating from a particular country. So regardless of the production location of the cars, the policy may stimulate the domestic car industry.

Another point is that a low excise rate reduces the government tax income from the sale of one litre of gasoline. Thus the consumption increase must outweigh the unit income decrease for the policy to become financially viable. However, a lower excise rate may boost car sales and thus income from sales. So the condition at which the policy becomes profitable is far less stringent. Finally, crude oil is an intermediate product, which is also used in other industries. Thus a low excise rates only affects part of the oil industry. But as a car is a final good, any stimulus of the car industry affects the domestic market as a whole, and will work

[4]Given that the market shares of other fuel types are relatively small (± 5%, U.S. Energy Information Administration, 2008), this result is approximately true

through the economy right away. A final note: countries that feature both an automotive as well as an oil industry, governments cannot discriminate between the two industries. Hence, these countries have to weigh the total effects on the oil industry and the automotive industry.

In order to incorporate the effect of tax competition, the countries were clustered into two groups: large and small countries. The large countries are the member states of the G20 (except of course the EU as a whole). As has been derived from the existing literature, tax competition works through two channels. First, the larger the population of a country, the more attractive it becomes for (smaller) neighbouring countries to lower their tax rates, as their potential market growth from tax competition becomes larger. The second mechanism has to do with the infrastructure in a country: a better infrastructure leads to more economic output and will thus attract foreign companies. Thus, the tax rates can be higher, as the value proposition of the country is superior to that of other countries. The result from the regression analysis confirms the hypothesis that larger countries with a high level of output charge higher taxes. To be precise, large countries on average have an excise rate that is 2.3 cents higher than in small countries.

The final variable in the regression model is the dummy variable for a green government. As was expected, the excise rate on gasoline is higher when the government in office is left-winged. The effect is also relatively large: whenever a left-wing government is in office, excise rates tend to be 9.3 cents higher than they were/are expected to be under a right wing government.

The regression has been repeated by using a regression with fixed effects for different time periods, in order to correct for unobserved heterogeneity between periods. Unfortunately, it was not possible to use fixed cross-section effects, because it would lead to the omission of the automotive industry and the country size as an explanatory variable, and the omission of Denmark, Norway and Sweden from the sample, drastically decreasing the number of observations in the sample. The results from the regression with time fixed effects are also shown in table 9.

The overall result from this regression is largely the same as that from the normal regression, in the sense that the signs of all variables are the same. Hence the overall interpretation of the results does not change. However, the levels of significance have changed through the inclusion of time fixed effects. To be more precise, the coefficient for the public balance is no longer significant at the 10% level. Hence, upon inclusion of fixed time effects, the public balance of a country does not appear to have a significant impact on the excise rate. The overall explanatory power of the model, however, has risen to more than 50% (the R^2 is equal to 0.514). Hence, this model yields more reliable results.

The third regression model includes fixed effects for both time and cross-sections. As a result, three variables and three countries were omitted. This model, however, yields strongly differing results from the prior two regressions. All variables except for the green government dummy have become insignificant at the 10% level (and often even far beyond the 10% level). The effect of the green government dummy, however, is in line with the expectations formed in hypothesis 10. On average, left-wing governments charge excise rates that exceed the excise rates charged by right-wing governments by 4.4 cents. Although all variables but one have rendered insignificant, the explanatory power of the model is very large, given the R^2 of 0.849. Hence this model explains 84.9% of the variation in the excise rates. The conclusion must thus be that the results from the two previous regressions are not very robust, and that a lot of the variation between countries excise rates can be explained through unobserved heterogeneity between these countries.

7.2.2 The Model for Diesel

The methodology and data sources used for the analysis of the determinants for the excise rate for diesel are exactly the same as that used for the gasoline case. As before, I will first estimate the effects using a simple OLS regression. Later, I will do so using a model with fixed time effects, and compare the results. The regression results for both the model with and without the inclusion of fixed effects are shown in table 10 below. The results of the corresponding Wald tests can be found in appendix 2.

The model for diesel has very different results than those derived from the analysis of the determinants for the gasoline excise rate. All but the coefficients for the public balance, the magnitude of the domestic oil industry and the country size dummy are insignificant. As none of the insignificant coefficients from the model without fixed effects can be used in assessing the respective hypotheses, I will only deal with these fairly briefly. The R^2 of 0.253 is not extremely low (for a panel study), and more than 25% of the variation of the excise rate for diesel is explained by the model below.

Table 10: Results of the Regressions for Diesel

Y = Excise Rate	No Fixed Effects	Fixed Time Effect	Full Fixed Effects
Constant	0.320***	0.407***	0.876***
	(0.060)	(0.057)	(0.168)
PRICE ELASTICITY	0.043	0.041	n.a.
	(0.042)	(0.038)	-
PUBBAL	-0.008*	-0.005	0.003
	(0.005)	(0.005)	(0.004)
PE*PUBBAL	-0.013	-0.008	-0.005
	(0.015)	(0.014)	(0.009)
CARDENS	0.000	0.000	-0.001***
	(0.000)	(0.000)	(0.000)
DIESEL	-0.001	-0.003***	0.000
	(0.001)	(0.001)	(0.001)
OIL	0.001***	0.001***	0.003***
	(0.000)	(0.000)	(0.001)
AUTOINDUSTRY	-0.027	-0.014	n.a.
	(0.026)	(0.024)	-
SIZE	0.085***	0.103***	n.a.
	(0.028)	(0.027)	-
GREENGOV	0.006	0.004	0.055***
	(0.020)	(0.019)	(0.012)
R^2	0.253	0.495	0.844
***Sign. at 1% level	**Sign. at 5% level	*Sign. at 10% level	

The price elasticity has a positive effect on the excise rate, which, as was seen in by the model of gasoline, confirms the first hypothesis. Moreover, a positive price elasticity should also imply a higher excise rate, as a higher price actually increases sales. In the model for diesel, however, the coefficient is highly significant. The coefficient for the public balance is in line with the expectations. We see that a public deficit leads to higher excise rates, a public surplus to lower ones. More precisely, for every increase of the deficit by 1% GDP, the excise rates on diesel will on average increase by 0.8 cents. As was the case in the model for gasoline, the interaction variable between the public balance and the price elasticity does not yield any significant results. The coefficient of the car density is barely above zero, but not significantly so. The result for the share of diesel cars is just below zero, but it neither is significant.

The effects of the oil industry and the automotive industry are again opposite in sign. The existence and the magnitude of the oil industry lead to higher excise rates on both gasoline and diesel. The effect, however, is quite small: on average, an increase in the volume of crude oil extracted of 1 million tonnes leads to an increase in the excise rate of a mere 0.2 cents. However, large oil producing countries produce oil in the order of several hundred million tonnes, so that in isolation, a country extracting 100 million tonnes of crude oil is expected to have an excise rate that is 20 US-$ cents higher than that of a country that does not extract oil. The effect of the automotive industry is again negative, showing that in general countries tend to try to support the car industry by charging lower excise rates, but is not significant in the model for diesel.

Finally, large countries (in terms of both population and economic output) tend to have higher excise rates than smaller countries, whereas we cannot confirm that green governments charge higher excise rates on diesel than right-wing governments do, as the coefficient is insignificant.

To control the results, I have yet again performed the regression using fixed time effects. The signs of the coefficients in the regression are equal to those of the results of the OLS regression model, however, the levels of significance have changed. The coefficient of the public balance is no longer significant at the 10% level, the share of diesel cars, on the other hand, is now significant even at the 1% level. The R^2 of 0.495 is about 0.25 higher than in the OLS model, hence using time fixed effects has improved the accuracy of the model.

The interpretation of the results is largely identical to that of the previous section, so that the magnitude of the oil industry tends to increase the excise rate on diesel, and the size of a country exhibits the opposite effect. However, given that the coefficient is now significant, the excise rate on diesel is decreasing with an increase with the share of diesel cars. This is quite contrary to what hypothesis 6 prescribes. A possible explanation could be that whilst the *per litre* externality cost of diesel is higher than that of gasoline, the fuel economy of diesel cars is far better than that of gasoline powered cars. Hence it may be that the *per kilometre* externality cost is in fact smaller than for gasoline. This explanation is also consistent with the fact that a larger share of diesel cars raises the excise rate on gasoline.

The regression model with full fixed effects will again be used as a robustness analysis for the results of the two other regressions. As table 10 shows, the explanatory power of this model (the R^2) is very large, far larger than the respective figures for the two other models. In this model, the variables for the car density, the oil industry and the green government dummy are highly significant. The results, however, are largely not in line with the hypotheses formulated in the literature review. A greater car density should lead to greater externality costs, thus giving governments an incentive to increase the excise rates. However, the model with fixed effects shows that for every car per thousand inhabitants, the excise rate on diesel tends to decrease by 0.1 cents.

The influence of the oil industry is also contrary to the corresponding hypothesis (hypothesis 7), but consistent to the findings of the previous models for both diesel and gasoline. Finally, the coefficient for the green government dummy shows what we expected: left-wing governments charge higher taxes of diesel than right-wing governments do, on average by 5.5 cents. These results lead me to believe that the results from the previous models are not very robust, apart from the variable for the oil industry (which remained significant in all models for diesel). Also here, the unobserved heterogeneity between countries appears to play a great role.

7.3 Evaluation of the Hypotheses

So where do these results leave us with the testing of the hypotheses? The first hypothesis states that countries with a less elastic demand for either type of fossil fuel will be inclined to charge higher excise rates, following the Ramsey rule of efficient taxation. This hypothesis has been confirmed on the basis of either model for gasoline, where the results where significant at the 1% level, but is to be rejected by the models for diesel. It would not make any sense that a country only bases its gasoline excise rate to the price elasticity of demand, but not its diesel excise rate. Given that the evidence is quite inconclusive, I cannot confirm this hypothesis.

The fourth hypothesis stated that countries tend to incorporate the externalities of consumption into their excise rate, and should thus increase the excise rate when the externality increases. This hypothesis is truly hard to test, as no readily observable variables are available. However, what is striking is that Australia, Canada and the US are the only countries that charge below the externality cost as estimated by Parry, whereas all other countries have excise rates which are significantly above the externality cost. There are two exceptions: New Zealand charged 32 cents is 2006, and Greece charged 39 cents, which are both within the range of the externality cost of Parry.

But do the countries have reasons to deviate from the marginal externality cost? Using the values for the variables of the two most extreme taxation regimes, namely that of the USA (which features the lowest excise rate) and the UK (which has the highest excise rate) in the model of gasoline, the predicted 2006 excise rate for the US is 90.5 US-$ cents, for the UK 76.2 us-$ cents. The predicted value for the US deviates from its real value by 80 cents, whereas the figure for the UK deviates only 10 cents. So the model for gasoline fails to explain the low excise rate for the US, whereas it does give a justification for the high excise rate charged in the UK.

The public balance has shown its expected influence in both models without any fixed effects. However, the outcomes did not appear to be at all resistant, as the coefficients in the four other models were insignificant. Given that the models that include fixed (time) effects are more reliable, I reject the second hypothesis on the basis. Hence, the public balance does not have a significant influence on the excise rates of either fuel. The interaction variable between the public balance and the price elasticity has not proven to be significant in any model, and can thus be confidently rejected.

The car density, has only shown a significant effect in the diesel model including full fixed effects. All other models have shown it to have an insignificant effect on the excise rates. Given the contradicting evidence (with the majority of it justifying a rejection of hypothesis 5), I also cannot confirm the fifth hypothesis. Interestingly, the effect of the share of diesel cars the excise rates on either type of fuel is completely the opposite of what was expected on the basis of hypothesis 6. The relevant externality cost is not the]textslper litre externality, but the *per kilometre* externality. Diesel cars have better fuel economy, so that it may well be possible that the greater *per litre* externality is offset by the fuel economy. Based on the evidence, I can say that a greater share of diesel cars in the vehicle fleet leads to higher excise rates on gasoline, and lower excise rates on diesel.

Hypothesis 7 has been rejected by all of the regression models. The effect of oil production in a country was significant, yet positive in all five out of six regression models. The reason for this in not entirely clear, and further research may be necessary to qualify the results. Nevertheless, the evidence against the hypothesis is quite clear, and thus I reject hypothesis 7. In fact, the exact opposite is true: countries impose higher taxes on fossil oil based fuels the more crude oil that country extracts.

The evidence for the hypothesis that the presence of a domestic automotive industry has a moderating effect on excise rates, on the other hand, is quite mixed. The variable could not be included in the model with full fixed effects. In the two other models for gasoline, the automotive industry dummy variable has proven to have the expected effect (and quite a large one), at a very low significance level. However, the effect proved insignificant in the models for diesel. In conclusion, however, I feel that the mixed evidence does not allow me to confirm hypothesis 8.

Similarly, hypothesis 9, which is based on tax competition literature, cannot be confirmed due to inconsistent evidence. Using a dummy variable that incorporates both the population size and economic performance, it shows that larger and economically better performing countries charge significantly higher excise rates on diesel than smaller ones, or countries with inferior economic performance. This phenomenon can be explained from a game theoretical perspective, as well as from a FDI and macroeconomic point of view. The results are highly significant in all models, and the coefficients are always positive. For gasoline, however, these results do not hold. These results, however, are interesting, because it could indicate that the tax competition for diesel is simply larger than it is for gasoline. Due to the better fuel economy of diesel cars, it may prove beneficial for more people to buy their fuel abroad (in case the diesel fuel is cheaper abroad) than it does for diesel. Hence, tax competition definitely plays a role for determining the diesel excise rates.

Finally, and little surprisingly, the analysis has shown that green governments on average charge higher excise rates, as it to be expected based on the literature used to derive hypothesis 10. The effect is both positive and significant in all models for gasoline, and in the diesel model with full fixed effects (which is the most reliable of the three). The average difference between the tax rates of left-wing governments and right-wing governments is between 4 and 10 cents for gasoline, and around 5.5 cents for diesel. An interesting note, however, is that given the relatively low elasticities of demand for both fuels in all countries included in the sample, taxation of fuel is a relatively inefficient tool to reduce the consumption of fossil fuels. It is, on the other hand, a good tool to finance government spending.

8 Conclusion

The above analysis has shown that neither of the two major theoretical concepts on taxation treated in this thesis properly serves as a sole explanatory base for the excise rates that countries charge on gasoline and diesel. For one, it is not the case that countries with less elastic demand also tax gasoline with the highest rate. On the other hand, not all countries internalise the externalities into the prices of gasoline and diesel through the excise rate, and many countries charge well above the monetary value of the marginal damage of the consumption of 1 litre of fuel.

This implies that other factors have to play a strong role in the taxation policy to which a country adheres. A selection of possible factors has been analysed in this thesis. Factors that lead countries to charge higher excise rates are the presence and magnitude of an oil industry, the size of a country (both in terms of GDP and population) and whether or not a left-wing government is in office. The presence of an automotive industry, on the other hand, has a moderating effect on the excise rate, just as a public surplus does. The effects, however, have been shown to differ strongly between the two types of fuel dealt with here.

As the two streams of theory fail to capture these (and probably more) factors, using just these to explain the taxation policy of a country is invalid and inaccurate. However, some merit accrues to both the Ramseyan and the Pigouvian taxation theory, as we have seen that countries tend to charge higher excise rates, the less elastic the demand for the types of fuel become *within* that country. We also saw that countries at least to some extent try to internalise the consumption externality, but that this remains unobserved as other factors intervene.

9 Limitations and Further Research

The major limitation to this thesis is that due to the measurement bases of four variables, the price elasticity, the automotive industry, the country size and green government dummies, a model with both fixed cross-sectional and time period effects was impossible. A trade-off between choosing the most accurate technique and the most accurate model was thus inevitable. By means of a robustness test (using a model with full fixed effects) showed that a lot of explanatory power can be attributed to unobserved heterogeneity between the different countries. Unfortunately, the ideal case scenario (using all variables in a model with full fixed effects) was not a viable option. Altering the measurement base of for instance the automotive industry variable would enable a regression model with fixed cross-sectional effects if Denmark, Norway and Sweden are omitted from the sample (as there has not been a government change between 1978 and 2006). Measuring the industry in terms of their profits would be an option, but reliable data are scarce. Also, constructing a cardinal scale for the country size (including both population and output) is advisable. Also, using short-run elasticities would enable the inclusion of the price elasticities of demand in the model with full fixed effects, but this, too, requires an alternative measurement base. Once this has been done, I would recommend redoing the analysis with fixed effects for both the cross-sections and the time periods, boosting the reliability of the findings, and possibly leading to more conclusive results.

Another limitation is that there is not one best way to calculate the price elasticities. Each of the models proposed in Hughes et al (Hughes et al., 2006) has its theoretical and or practical drawbacks. Changing the method could possibly (read: most likely) lead to different outcomes.

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Appendix

Appendix 1: Wald Test for Gasoline

	No Fixed Effects		Time Fixed Effects		Full Fixed Effects	
	t-statistic	χ-square	t-statistic	χ-square	t-statistic	χ-square
Value	3.294	10.847	9.286	86.228	3.200	10.243
df	198	1	171	1	160	1
Probability	0.001	0.001	0.000	0.000	0.001	0.001

Appendix 2: Wald Test for Diesel

	No Fixed Effects		Time Fixed Effects		Full Fixed Effects	
	t-statistic	χ-square	t-statistic	χ-square	t-statistic	χ-square
Value	4.288	18.386	5.971	35.652	5.353	28.658
df	186	1	159	1	149	1
Probability	0.000	0.000	0.000	0.000	0.000	0.000