The Effects of CO_2 emission based taxes on the Composition of the Dutch Car Fleet

A research on the effects of the registration tax and the company car tax liability on the new car markets of 2013, 2014 and the connection to the second-hand market of 2017 in the Netherlands.

Abstract

The thesis studies the effects of CO_2 emission based taxes on the composition of the Dutch car fleet. By using the bunching analysis, the significance of the effects can be determined. Almost all thresholds in the new car market have a significant effect on the distribution. By comparing the significant effects with the insignificant suggestions, regarding the company car tax liability as well as the second-hand car market, are proposed for further research.

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1.0 Introduction

In 2010 the total amount of cars on Earth had crossed the one billion mark and kept growing. In 2014 this amount was more than 1.2 billion. By 2035 a record of two billion cars is predicted (Sutkowski, 2014). With this growth the demand for mobility grew as well. The increase in use of fossil fuels by cars has increased the air pollution, and climate change in general, as a result of more cars on the road. The World Health Organisation [WHO] estimated that in 2018 more than four point two [4.2] million people died due to ambient air pollution (2019). One of the goals the WHO explained that had key priority is expanding the knowledge base about air pollution. To find the solution for this global problem it is important to lower the scale to specific cases and with it look for effective ways of solving the general problem. These effective ways are small steps towards a greener and more sustainable world.

The focus of this thesis lies with the Dutch car fleet in 2013 and 2014. From 2000 till 2018 the Dutch car fleet has grown with 32 percent and with it more cars that contribute to the air pollution problem. With the dataset provided by the 'Planbureau voor de Leefomgeving' this thesis looks into the difference between private and company car markets which Dimitropoulos lacked data of. This research analyses the effect of CO_2 emission based taxes in the Netherlands also. These taxes are the 'Belasting op Personenauto's en Motorrijwielen' [BPM] and the company car tax liability. Besides building on Dimitropoulos' research this thesis focussed on 2013 and 2014 since these are the first two years in which the BPM was solely based on the CO_2 emissions of cars. Due to this change in policy this thesis tries to answer the research question:

Do the registration tax [BPM] and company car tax liability have a significant effect on the composition of the Dutch car fleet in 2013 and 2014?

These results may, as said earlier, function as building blocks to reduce environmental damage. While the theory suggests a significant effect of these taxes on the composition it is important to look into other aspects that might influence the composition of the car fleet as well. With data that makes it possible to make a distinction between private and company cars it could be possible to isolate the effect of the company car tax liability also. While this thesis focuses on this new aspect (compared to other research), the research is for the majority of evaluating nature. The question is whether the results presented by others will withhold the data used in this thesis. After which, a small section will be dedicated to the connection between the new and second-hand car markets.

The thesis is divided into eight different chapters to answer the research question. In the next chapter a more in depth analysis of the policy instruments will be presented After which, a theoretical framework will be presented and in it the existing literature on the matters discussed in this research along with the implications of these policies. Subsequently, the methodology will be explained as well as the justification for using these methods. The raw data will then be presented followed by the results gathered from this data. After the results are presented a discussion will include the explanation of the results as well as gaps in the research and suggestions for further research. Finally, the conclusion will summarize the thesis and to answer the research question followed by the references that were used.

2.0 Policy Instruments

The two policy instruments that are the main focus of this thesis are the BPM and the company car tax liability. Both instruments have changed greatly over the years and are subject to changes still. Both are based on car-specific CO_2 emissions since 2013 and thus could have an effect on the dependent variable of this thesis: the amount of purchased cars in the tax brackets according to CO_2 emissions. A brief description of both instruments follows below.

2.1 BPM

The first car registration tax, the BPM, is a tax that consumers have to pay with the car its first registration in the Netherlands. This tax, first introduced in 1992 and implemented on the 24th of December 1992, was based on the catalogue price of the cars. One of the major concerns that resulted in the implementation of this tax is the ever growing car fleet of the Netherlands. The 'Rijksinstituut voor Volksgezondheid en Milieu' [RIVM] argued that the car fleet would increase with 18 to 23 percent between 1986 and 2000 (RIVM, 1994, p. 23). Even then, a difference in tax existed between types of fuel the cars used. Consumers whom owned a petrol car were levied a tax of 45.2 percent of the catalogue price minus 1540 euros, compared to the 580 euros that consumers with a diesel car could subtract (Belastingdienst, 2019). The difference in tax rates between petrol and diesel cars grew until the Dutch government decided to move away from the percentage of the catalogue price and move towards a tax that was partially based on the CO_2 emission of the purchased cars in 2008. In 2010 the tax based on catalogue price was reduced and CO_2 emission became the new standard and with it a new incentive was given to the consumers to look for more sustainable cars.

This change is based on the work program 'Schoon en Zuinig' in which the Dutch government showed its ambition to reduce the CO_2 emission with thirteen [13] to seventeen [17] megatons in 2020 and in doing so move back towards the emission levels produced by traffic in 1990 (Cramer, 2008, p. 15). Alongside this CO_2 based tax other innovation programs were set up to move towards sustainable mobility in the form of hybrid- and electric cars (which will later be implemented in the BPM) and the implementation of hydrogen technology.

The CO_2-based tax is also the first step in differentiating on the spectrum of CO_2 emission. The exemption of the BPM for cars with very low (mean) CO2 emissions was first introduced in the Netherlands in 2008 and was primarily interesting for private car users (Meerkerk, et al., 2018, p. 32). Over the years these CO_2 emission thresholds declined to lower amounts of emission, as can be observed in table 1, to give consumers incentives to keep looking for more sustainable car substitutes. In 2010 the tax consisted of four different tax brackets per fuel type. For instance, petrol cars from zero till 110 gCO_2/km in 2010 were excluded from the BPM (besides a reduced percentage of the catalogue price). Cars which produced 111 till 180 gCO_2/km cars were seen as efficient and these car owners had to pay a small amount relative to the consumers whose cars were located in higher CO_2 emissions. In 2013 the percentage of the catalogue price was abolished and the tax from then on was solely based on CO2 emission (Belastingdienst, 2019).

Table 1. *gCO_2/km thresholds per fuel type per registration year.*

	Tax Bracket Thresholds per Year									
	Diesel Passenger Cars					Petrol Passenger Cars				
Year	Tax bracket 1	Tax bracket 2	Tax bracket 3	Tax bracket 4	Tax bracket 5	Tax bracket 1	Tax bracket 2	Tax bracket 3	Tax bracket 4	Tax bracket 5
2010	0	95	155	232	N.A.	0	110	180	270	N.A.
2011	0	95	155	232	N.A.	0	110	180	270	N.A.
2012	0	91	143	211	225	0	102	150	237	242
2013	0	88	131	192	215	0	95	140	208	229
2014	0	85	120	175	197	0	88	124	182	203
2015	0	82	110	160	180	0	82	110	160	180
2016	0	79	106	155	174	0	79	106	155	174
2017	0	76	102	150	168	0	76	102	150	168

Source: Both tables are derived from the BPM-tariffs article by the Belastingdienst, 2019. The tax thresholds are defined in gCO_2/km.

It would be difficult to present all the tax rates to their according emission brackets in the according years. To stay close to the focus of this thesis table 2 presents the tax rates for the years 2013 and 2014. The values in column I show to lower thresholds of the brackets, while column II shows the upper thresholds. The amounts in column III are fixed taxes that have to be payed if the car of the consumer is located in that bracket. Column IV shows the amount of euros that has to be paid per CO_2 omitted. The amount of gCO_2/km that has to be paid over is the emission minus column I. As will be discussed in the theory chapter we see kinks occur in the tax rates due to the thresholds that separate the emission brackets. The tax rate is only for the emission bracket since all the emission below the emission bracket have to be subtracted of the total amount of omitted gCO_2/km.

Table 2. *Tax rates per bracket*

Petrol							
2013				2014			
I	II	III	IV	I	II	III	IV
0	95	0	0	0	88	0	0
95	140	0	€ 125	88	124	0	€ 105
140	208	€ 5.625	€ 148	124	182	€ 3.780	€ 126
208	229	€ 15.689	€ 276	182	203	€ 11.088	€ 237
229	-	€ 21.485	€ 551	203	-	€ 16.065	€ 474
Diesel							
2013				2014			
I	II	III	IV	I	II	III	IV
0	88	0	0	0	85	0	0
88	131	0	€ 125	85	120	0	€ 105
131	192	€ 5.375	€ 148	120	175	€ 3.675	€ 126
192	215	€ 14.403	€ 276	175	197	€ 10.605	€ 237
215	-	€ 20.751	€ 551	197	-	€ 15.819	€ 474

Source: Table is derived from the BPM-tariffs article by the Belastingdienst, 2019

2.2 Company Car Tax Liability

One cause of heterogeneity in the car fleet of the Netherlands is the difference in car ownership. Next to the private passenger cars which are privately owned by the consumers, there are company cars also. These cars are leased at lease firms by companies and used by their employees. If employees wish to use the car for private purposes, that is to say that the car is driven more than 500 kilometres per year for other purposes than work, they have to pay tax liability (Belastingdienst, 2019). Just like the BPM (since 2013) tax liability is solely based on the CO_2 emission of the leased car. The height of the owed tax is a percentage of the catalogue price of the leased car. The lowest tax rate (four percent [%]) can, however, only be obtained by purchasing a car that costs less than 50.000 euros. The tax rates can be seen below in table 4. The reason why consumers have to pay tax liability is since the private use of lease cars is seen as a wage in kind and thus a tax is levyed (Belastingdienst, 2019).

The company car tax liability has more resemblance with the BPM in that over the years the Dutch government keeps lowering the emission thresholds and thus make emissions, in general, more expensive. The tax is not just used to give consumers incentives to invest in cars with lower emissions, but the Dutch tax authorities will move the company car tax liability in 2021 to one single threshold for privately used company cars. Even zero emission company cars will locate in the 22% tax liability rate (Belastingdienst, 2019). These reforms will make emissions more expensive for every car since there are no more exemptions. Due to the price elasticity, discussed earlier, this would result in less purchased cars. This is also the case for the

BPM. The BPM will be applied on zero emission cars from 2025 also with a minimum of 350 euros (Kieboom, 2019).

Table 3. *Types of efficiency under the company car tax liability and the according tax percentages.*

Company Car Tax Liability Brackets					
Year	Zero emission	Ultra-efficient	Very Efficient	Efficient	Other
2010	0%	14%	14%	20%	25%
2011	0%	14%	14%	20%	25%
2012	0%	0%	14%	20%	25%
2013	0%	0%	14%	20%	25%
2014	4%	7%	14%	20%	25%
2015	4%	7%	14%	20%	25%
2016	4%	15%	21%	21%	25%
2017	4%	22%	22%	22%	22%

The gCO2/km thresholds that determine the percentages can be observed in table 3.

Table 4. *The Company Car Tax Liability Brackets according to the* gCO_2/km thresholds.

Company Car Tax Liability Thresholds (gCO_2/km)			
2013		2014	
Other than Diesel		Other than Diesel	
		4%	0
0%	>= 50	7%	>= 50
14%	51 - 95	14%	50 - 88
20%	96 - 124	20%	89 - 117
25%	> 124	25%	> 117
Diesel		Diesel	
		7%	>= 50
14%	50 - 88	14%	51 - 85
20%	88 - 112	20%	86 - 111
25%	> 112	25%	> 111

Source: Both tables are derived from the 'bijtelling' article by the Belastingdienst, 2019

The BPM and company car tax liability both apply on the leased car, at the same CO_2 emission thresholds which could, in theory, result in a strong combined effect of both instruments.

3.0 Theory

To analyse the effects of the BPM and company car tax liability in the Netherlands it is important to understand the theory behind both and ultimately tax in general. First and foremost, tax is the main financial resource for governments to operate. Without tax revenues, no budget, and consequently the inability of the government to act. These tax revenues can, to keep in the field of study of this thesis, subsequently be used to develop relatively more sustainable technologies and decrease air pollution (Pettinger, 2019). The second argument for taxes, on which the thesis' focus lies upon, is the correcting of market failures. The main market failure studied in this thesis is the negative externality of climate change due to car emissions. Without a tax, consumers will not have to pay for the external costs and will consume as if these costs do not exist (Pettinger, 2019). Both the BPM and company car tax liability, which are both based on CO_2 emission, are implemented to counter the neglection of these external costs. To structure the theoretical framework this thesis will divide the theory into subsections, starting with the Pigouvian tax.

3.1 Pigouvian Tax

This type of taxes is levied on activities that generate negative externalities, which creates costs that are felt by unrelated third parties. Due to the fact that these costs, created by the negative externalities, are not incorporated in the final cost of a product, the market becomes inefficient which can be corrected with a tax (CFI, 2019). The essence of Pigouvian taxes is to combat market failures by increasing the marginal private cost by the costs generated by the negative externality. By applying the Pigouvian tax, the final cost will reflect the full social cost of the economic activity. This results in the negative externality to be internalized (CFI, 2019).

Figure 1. *The effect of a Pigouvian tax.*

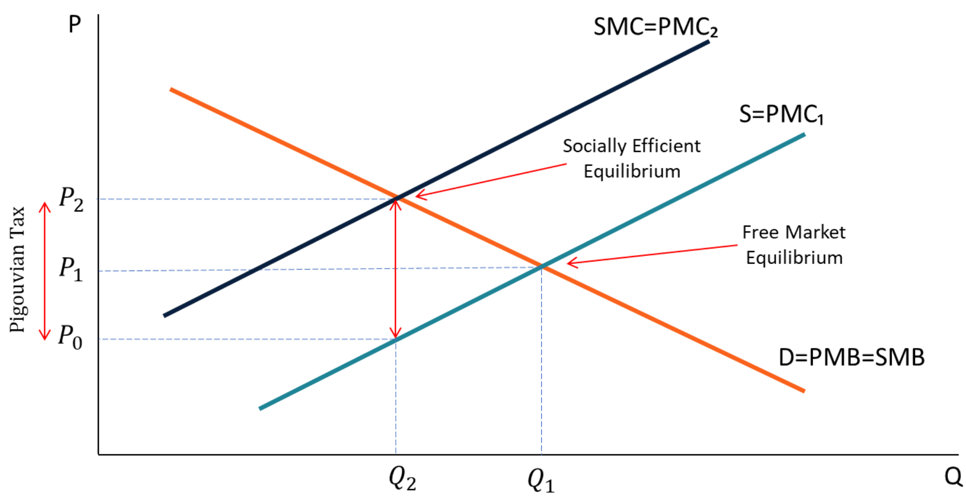


Figure 1 shows the effect of the Pigouvian tax on the supply of the economic activity, in this thesis air pollution. Under free market conditions, a negative externality establishes a market equilibrium on the intersection between the social marginal benefit (SMB) and the personal marginal cost (PMC_1). This equilibrium is located below the social marginal cost (SMC) due to the additional costs created by the economic activity. Due to the damage costs that are not internalized the market equilibrium is not efficient (CFI, 2019). In an ideal world the Pigouvian taxes will be equal to the costs created by the negative externality. As can seen in the figure the supply (Q) decreases when the Pigouvian tax is imposed to a point where the SMC is equal to the PMC. Thus, by implementing this type of tax it is possible to reach an optimal level of pollution.

The Corporate Finance Institute explains the advantages and disadvantages of the Pigouvian tax. The advantages comply with the two arguments why taxes should be levied, as discussed before, namely: correcting market failures and generate additional government revenue. The last advantage they give is more in accordance with this thesis, namely that it discourages harmful activities such as the carbon tax that stimulates companies to operations that produce fewer emission gases (CFI, 2019). The disadvantages are that the costs generated by the negative externality are hard to measure and thus difficult for the Pigouvian taxes to be precise. Secondly, imposition of Pigouvian taxes is frequently associated with political problems. Governments that attempt to implement these taxes are often faces with an opposition of parties whom supports are affected by the taxes (for example, tobacco producers) (CFI, 2019).

Knittel & Sandler examined whether a true Pigouvian emissions tax would be preferable regarding the car pollution question. They conclude that gasoline taxes are a poor substitute for a Pigouvian tax since a small number of very high polluting vehicles would increase the overall tax and thus overtax the majority with the poorest households paying substantially more as a fraction of their income. Instead of uniform Pigouvian tax the optimal policy would be an indirect Pigouvian tax that is differentiated based on the vehicles' emissions (Knittel & Sandler, 2018, pp. 240 – 241). The BPM and company car tax liability are examples of these differentiated taxes.

3.2 The Purchase of a New Car

Many factors influence the behaviour of the consumers in their process of purchasing a new car. This subsection, divided in smaller sections, will address these factors. The hypotheses tested in this thesis will be included in their corresponding sections.

3.2.1 Elasticities

Meerkerk et al. looked at the Dutch car fleet as well and examined not only the different taxes, but the price elasticities also (2014, p. 11). In their research they concluded that the sales-tax elasticities of all sorts of cars were negative, meaning that an increase of one percent in purchase price would show a decline in demand for these cars. Meerkerk et al. determine that the overall price elasticity is between minus 2.5 to minus 3.1 (2014, p. 11). The Ministry of Infrastructure and Water Management [IenW] determined that the BPM was solely responsible for an effect of minus 0.4 to minus 0.5 on the overall price elasticities in the Dutch car fleet (2010, p. 1).

Besides the behaviour, and thus elasticity, concerning the purchase of the new car De Borger & Mayeres looked at the behaviour regarding the usage of the car. The same effect was found on the price elasticity of fuel. They found that the key factor that determines the behaviour of consumers is essentially the price of the planned annual mileage (2007, p. 1181). According to the planned mileage consumers will choose the type of fuel and eventually whether to purchase a car or not due to the costs. This would result in consumers, whom planned a high mileage, buying a car less often with the increase in taxes.

Overall, consumers would be less willing to buy a car when it becomes more expensive in purchase price as well as usage. The negative sales-tax elasticity is an important finding concerning the BPM and company car tax liability since these taxes will make purchasing a new car, in general, more expensive. The differentiation of CO_2 emission brackets in these taxes will result in high emission cars to be relatively more expensive since higher CO_2 emission cars will relatively be more expensive and thus less bought. Theoretically, the negative sales-tax elasticity suggests that the tax differentiation in the BPM would cause the sale of high emission cars to drop, relative to cars with lower levels of emission. This would imply that the tax differentiation affects the composition of the Dutch car fleet (Meerkerk, et al., 2014, p. 12). Meerkerk et al. found that small petrol cars, with low emissions, were 27 percent more likely to be purchased than petrol cars with higher emissions. This effect was the same, but in smaller proportion, for small diesel cars with 22 percent. They conclude that the differentiation in BPM is a more effective way to stimulate the purchase of small fuel efficient cars as opposed to an overall increase that can be seen in fuel types. The uniform tax on fuel types does not differentiate between the cars' emission levels and solely looks at the type of fuel used. With the differentiation in BPM it is possible to target the most efficient cars only without encouraging the purchase of other types of cars which happens with the uniform changes in the fuel tax. It is possible to change the fuel tax to a differentiated one but due to the tax increase, which has to be substantial, this is unlikely (Meerkerk, et al., 2014, p. 13).

3.2.2 BPM

As discussed earlier, Knittel & Sandler concluded that a uniform Pigouvian tax would not be preferable concerning car emissions. A more differentiated tax should be implemented based not on the consumption of gasoline, but on their emissions. This is where the BPM comes into place. As an indirect substitute for the Pigouvian tax the BPM is differentiated in emission brackets. The argument is the same as that of the BPM its Pigouvian alternative, namely an attempt by the Dutch government to reach an optimal level of pollution where the marginal social costs equal the marginal social benefits as discussed earlier. Instead of internalizing the costs generated by the negative externality the BPM levies a tax on cars with an emission higher than the set goal and subsequently making cars with the preferred emissions more attractive to consumers.

This theory is based on the assumption that consumers are rational agents, and will therefore act, with a cost-benefit analysis in mind. Due to the differentiation in tax brackets, and their different tax rates, emissions become a part of the cost-benefit analysis (not only for consumers, but manufacturers as well). The consumers at the thresholds between BPM emission brackets are given a strong incentive to change their behaviour to the more favourable side of the separation, whom we from now on call 'bunchers'. Dimitropoulos addresses, however, the aspect of this rather simple and transparent tax system. He assumes that these incentives to shift outweigh the external benefits or costs of these behavioural changes (Dimitropoulos, 2014, p. 126). In other words, consumers will primarily shift to a more favourable bracket not due to a potential decrease in pollution, but rather for the decrease in tax that they have to pay. Secondly, this differentiated tax system will give almost no incentive to, and thus have no effect on, consumers whom are located away from the thresholds (Dimitropoulos, 2014, p. 126).

He continues to describe a similar bracket system implemented in France called the 'Bonus/Malus écologique' which awards consumers rebates according to the emission of the purchased cars. The lower the emission of a car, the higher the rebate. The aspect Dimitropoulos again focuses on is the effect of the thresholds in this system. Just like the effect of BPM, manufacturers and consumers whom are located just above the threshold will have a strong incentive to move to the lower bracket, but those whom are located away from the thresholds or just beneath them will have little to no incentive to change their behaviour (Dimitropoulos, 2014, p. 127). The problem of consumers that are given no incentives occurs in both bracket systems, but can be countered by an annual adjustment in emission thresholds to keep pushing manufacturers and consumers to relatively lower emission cars each year.

With this theoretical framework concerning the BPM the thesis assumes the thresholds, that divide the emission brackets in the BPM, to have a significant effect on the distribution of the purchased cars in the Dutch car fleet. The first hypothesis, therefore, is:

H1. The BPM has a significant effect on the composition of purchased cars, regarding the CO_2 emission brackets, in the Dutch car fleet in 2013 and 2014.

3.2.3 Company Car Tax Liability

While Dimitropoulos focused mainly on the BPM, this thesis focuses on the company car tax liability as well. The theory is, however, the same for company car tax liability. Again, a differentiated tax bracket system is observed based on the cars their CO_2 emissions. The difference lies in that the brackets are expressed in percentages instead of owed tax in euros. The observed percentages show the percentage that has to be paid based on the catalogue price of the cars (Belastingdiest, 2019). The effect of the thresholds is assumed to be the same with the company car tax liability as the BPM and Bonus/Malus écologique. Again, consumers and manufacturers will shift when they are just above the thresholds. Dimitropoulos explains that a double benefit occurs for company cars. Firstly, manufacturers will want to adjust their cars to be just under the thresholds, thus the availability of cars just under the threshold increases greatly. This will be further explained in the ‘supply’ subsection below. Secondly, the tax liability decreases in lower brackets. Consequently, the tax rate decreases in lower brackets and is based on a lower purchase price due to the increased availability (Dimitropoulos, 2014, p. 128).

Again, with this theoretical framework concerning the company car tax liability the thesis assumes the thresholds, that divide the emission brackets in the tax liability, to have a significant effect on the distribution of the purchased cars in the Dutch car fleet. The second hypothesis, therefore, is:

H2. The company car tax liability has a significant effect on the composition of purchased cars, regarding the CO_2 emission brackets, in the Dutch car fleet in 2013 and 2014.

3.2.4 Supply of the New Car Market

The purchase of new cars is not solely based on the emissions of a car and their appropriate taxes, but on the availability of the cars as well. With the improvement in technology Geilenkirchen et al. saw an increase in the purchases of high emission and more powerful cars in 2006 (Geilenkirchen et al., 2014, p. 14). Due to the increased availability of the technology it was easier and cheaper to produce, and thus purchase, these high emission cars. After 2008 a surge in small and low CO_2 emission car purchases occurred and the market share of the 'heavier' cars declined. The effect of a higher availability decreased since the supply of all levels of emission cars was distributed smoothly. It was solely the differentiation in tax rates based on CO_2 emission that caused distortions in the distribution of purchased cars.

In 2014, Dimitropoulos found evidence that manufacturers would shift to the favourable side of the threshold to benefit of the preferable tax rate, on the condition that the shift could be made at a relatively low cost (p. 165). In theory this would result in an increase in the market share of low emission cars relative to cars that are located in higher emission brackets due to lower tax costs for consumers and manufacturers. Researchers did indeed observe a large market share of purchased cars just below the CO_2 thresholds set by the BPM in 2014 (Geilenkirchen et al. 2014, p. 14).

3.3 Second-Hand Car Market

Geilenkirchen et al. continue to explain the interaction between the new and second-hand car markets and discuss that second-hand cars could be seen as cheaper substitutes for new cars. This interaction causes the purchase price of second-hand cars to increase when policies make new cars more costly due to an increase in demand for second-hand cars. Due to the increase in purchase price of new, as well as, second-hand cars the economic lifespan of cars is prolonged due to the fact that reparation costs will be lower than the purchase price of a substitute. With an increase of 192.000 cars in 2008 to 325.000 cars in 2012 it is favourable to increase the lifespan of new and second-hand cars to decrease the production of new cars in respect to climate change (Geilenkirchen et al., 2014, p. 16).

Another subject slightly touched upon by Dimitropoulos, but not incorporated in his results, is the effect of these policy instruments on the second-hand car fleet. The company car tax liability is the same for second-hand cars (but still based on the new catalogue price), while the BPM is not applicable since it has to be paid with the first registration of the car only. Since the company car tax liability is still based on the new catalogue price it is assumed that it will have little effect on the composition, but it is present still (Larkin, 2012). Due to the fact that cars are usually leased for four years (Meerkerk, et al., 2018, p. 11), the thesis predicts that the same distribution observed in the new car fleet can be observed four years later in the second-hand car fleet as well. Since the new car markets of 2013 and 2014 are studied, the thesis will look at the second-hand car market of 2017 and will expect the thresholds of 2013 to have a visual effect on the distribution in 2017.

In this thesis the bunching analysis is used to determine the effect of the BPM and company car tax liability on the purchases of cars regarding CO_2 emissions. The bunching analysis uses a bunching window to exclude the created bunching mass and predicts a counterfactual that shows the distribution of a case without thresholds. Consequently, the null hypothesis would be that there would not exist any significant excess mass at the threshold relative to the counterfactual distribution (Chetty, et al., 2010, p. 23). After predicting the counterfactual it is possible to compare this with the observations in the data and see the increase in purchases just before the threshold. This excess mass represents the effect of the implemented thresholds. The thresholds the thesis analyses are also the bunching points, where on their left the bunching mass will build up. The bunching analysis will be discussed more thoroughly in the 'research design' chapter below.

3.4 Method of Analysis: Bunching

The bunching analysis is a way of analysing the impact of different tax brackets on the behaviour of individuals. The bunching analysis assumes that society is smoothly distributed on the specific tax subject, but analyses a bunch mass in the distribution created by a threshold (Kleven, 2016, pp. 438 – 439). The example Kleven gives is a

Figure 2. *Convex kink in tax system.*

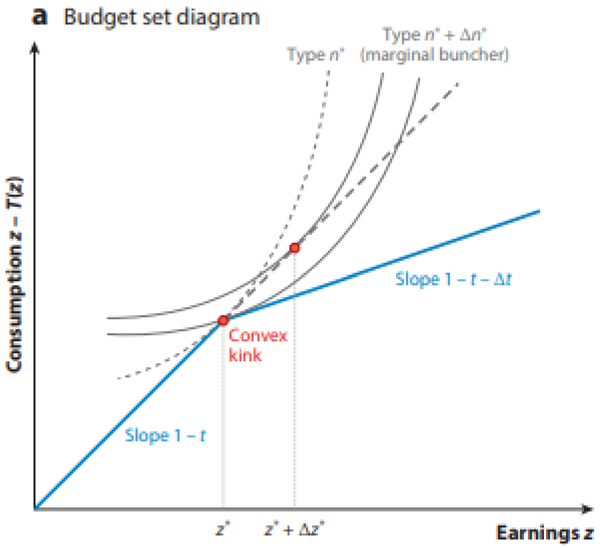
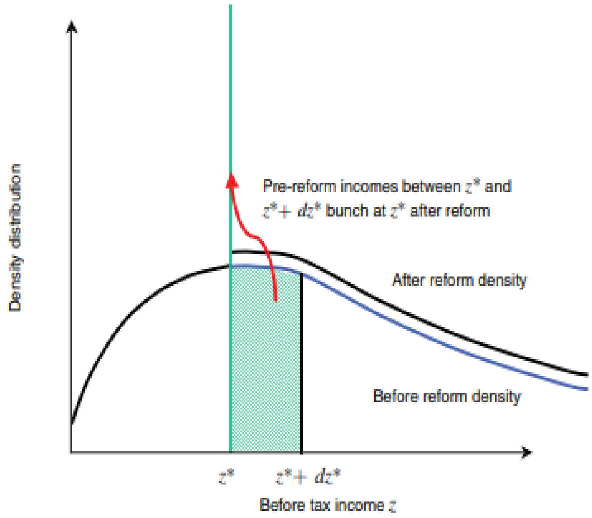


Figure 3. *Bunchers relocate below kink.*



discrete increase in the marginal tax rate at higher earnings. At the threshold a convex kink occurs lowering the consumption compared to the individual's earnings. The individual, the buncher, consequently lands on a slope that is, with their current earnings, under their indifference curves. As a result bunchers will lower their earnings to eventually be on or just below the convex kink to profit from the conditions of the slope before the kink. With the bunching analysis we can measure this bunching mass that is created by the threshold and determine its significance. The bunching mass is created by all the bunchers who would normally, without the threshold, have higher earnings. In figure 2 we can see that individuals will normally have earnings equal to z + delta z. The individuals' outcomes will, due to an increase in the tax rate, relocate underneath their indifference curves with slope 1 – t – delta t. To reach an indifference curve they reduce their earnings to point z right at the kink, thus resulting in a bunching mass. Saez shows this with another figure (figure 3) where we can see the distribution of taxpayers (2010, p. 184). Due to the threshold, the individuals in the green area will move to the left of the green line at point z to pay the same tax rate as before the reform.

Kleven discussed that two types of bunching exist. The used one in the thesis is that of the kinks as explained above. The other type is bunching because of 'notches'. The difference lies in the way tax increases for the consumers. The kink introduces an increase in tax rate when a certain threshold is reached, while the notch increases the average tax in general. Kink bunchers, therefore, look at every additional gram of CO_2 they omit per kilometre and the extra costs they have to pay for. Since an increase in emission would locate the bunchers in a higher tax rate they purchase a car located just below or on the threshold. This is, as discussed earlier, only when the consumer is closely located to the kink.

4.0 Research Design

The research approach of this thesis is of an observational nature in which the researcher will not interfere with the subjects nor the variables. The research design will be large-N, and will include 1.096.983 observations. The unit of analysis is the bin in which the purchased cars are located, separated in brackets due to the thresholds set by the taxes. This bins are constructed by observing the gCO_2/km of the cars and rounding them up to zero digits. For example, all the cars with emission between 109.5 and 110.5 are located in bin 111 gCO_2/km. The thesis studies the distribution of cars closely around the threshold and subsequently determine the significance of the effects of these taxes. The different populations are based on the number of registrations, years in which these registrations occurred, types of fuel and whether the cars are owned privately or through a company lease program.

4.2 Empirical Design

As discussed above we need to estimate a counterfactual regression that excludes the data around the bunching point. Chetty et al. use the following regression form (2010, p. 22):

$$C_j = \sum_{i=0}^{q} \beta_i^0 \cdot (Z_j)^i + \sum_{i=-R}^{R} \gamma_i^0 \cdot \mathbf{1}[Z_j = i] + \varepsilon_j^0$$

C*j* is the number of purchased cars in emission bin *j*, *Zj* is emission relative to the kink in one gram CO_2 per kilometre intervals (*Zj* = {-95, -94, .., 215} with a kink at 95 gCO_2/km, *q* is the degree of the polynomial, and *R* denotes the width of the excluded region around the kink, the bunching window, and is also measured in bins of one. The initial estimate of the counterfactual is defined as the predicted values the contribution of the dummies around the kink that are omitted by this regression: $\widehat{C}_j^0 = \sum_{i=0}^{q} \widehat{\beta}_i^0 \cdot (Z_j)^i$.

Next, the excess number of purchased cars which locate near the kink relative to this counterfactual density can be formulated as: $\widehat{b}_n^0 = \sum_{j=-R}^{R} C_j - \widehat{C}_j^0 = \sum_{i=-R}^{R} \widehat{\gamma}_i^0$. Chetty et al. discuss that the b_n is overestimated by this 'simple' calculation since it does not account for the fact that this additional mass left of the kink comes from emission bins on the right of the kink (2010, p. 22). To account for this problem they shift the counterfactual distribution to the right of the kink upward until it satisfies the integration constraint (Chetty, et al., 2010, p. 22). In other words, this means that the difference between the counterfactual and the observed distribution on the right of the kink do not account for all the excess mass created. To equal these two the counterfactual is moved upwards. The counterfactual distribution will therefore be defined as fitted values $\widehat{C}_j = \widehat{\beta}_i \cdot (Z_j)^i$ from the regression:

$$C_j \cdot (1 + \mathbf{1}[j > R] \frac{\widehat{b}_n}{\sum_{j=R+1}^{\infty} C_j}) = \sum_{i=0}^{q} \beta_i \cdot (Z_j)^i + \sum_{i=-R}^{R} \gamma_i \cdot \mathbf{1}[Z_j = i] + \varepsilon_j$$

where $\widehat{b}_n = \sum_{j=-R}^{R} C_j - \widehat{C}_j = \sum_{i=-R} \widehat{\gamma}_i$ is the bunching mass extra to the estimated counterfactual. Lastly, the empirical estimate of *b* is defined as the excess mass around the kink relative to the average density of the counterfactual emission of cars between -*R* and *R*, the bunching window: $\widehat{b} = \frac{\widehat{b}_n}{\sum_{j=-R}^{R} \widehat{C}_j/(2R+1)}$

The null hypothesis in this thesis is that there is no excess mass at the kink relative to the counterfactual distribution (Chetty, et al., 2010, p. 23). The results will include an estimate of the excess mass as well as a standard error. By dividing the estimate by the standard error we can determine the t-statistic and determine whether the excess masses are significant. A t-value of 2 or higher results in a significant effect. To determine the t-value it is important also to define the degree of freedom. The degree of freedom is the quantity of values, in this case ‘bins’, minus 1. This results in 301 – 1 = 300. Another way of determining the significance is by estimating the confidence interval by multiplying the standard error by 1.96 and compare it with the estimate. If the estimate falls outside this interval, then the p will be < 0.05 and the excess mass can be assumed to be significant.

Discussed above is the degree of the polynomial used to determine the counterfactual. The higher the degree the more flexible the polynomial will be and will run closer to the measured values in the emission bins. This has an effect on the mean determined by the counterfactual and consequently on significance of the excess mass.

4.3 Estimation of the Bunching Window

One of the major setbacks of the bunching analysis is the selection of the bunching window. The dilemma reseachers are faced with is in the size of the window. In a perfect analysis we want to include all the individuals who purchased a car different from the individuals their own preferences and is due to the taxes. The window should, however, not be too broad since that increases the chance of including non-bunchers. Neither should it be too small since that may result in omitting some individuals who changed their behaviour as a result of the taxes (Dekker, Strohmaier & Bosch, 2016, p. 5)

The default way of determining the bunching window is by a combination of visual inspection and the researcher's discretion. Through a trial-and-error process the researcher will select the most suitable window which preferable is symmetric. The obvious problem with this is the openness for interpretation and thus the results may differ greatly. This reliance on visual inspection and the process of selection are, as Dekker et al. state, not optimal for efficiency and reliability (2016, p. 5).

Dekker et al. come with recommendations on how to find the optimal bunching window using four steps. First of all an excluded region around the threshold should be set. After which a local regression should be conducted through all the data bins that are located outside the excluded region and the frequencies should be predicted. Next, a confidence interval around the prediction should be computed. Lastly, the subsequent bin midpoints outside the confidence interval comprise the bunching window (2016, p. 6). They, however, state in the explanation afterwards that the excluded region and confidence interval are still arbitrarily chosen, thus we conclude that the bunching window is also determined by the researcher's discretion still. This is important to note since the bunching window has a major impact on the results. Without a standard in defining the bunching window the results may vary greatly among researches.

Lessons we can take from Dekker et al. are the risks of picking a bunching window brings with it. The size of the window is too important to neglect. They discuss the tendency of researchers to pick a symmetric bunching window and try to convince that an asymmetric window is far better than the default. Dekker et al. explain that risk-averse individuals will tend to over-adjust to make sure they are under the threshold. Because of this psychological component Dekker et al. prefer an asymmetric window that is larger under the threshold (2016, p. 5).

4.4 Operationalization of Variables

To determine the effect of the BPM and company car tax liability on the composition of the Dutch car fleet in the years 2013 and 2014 first the concepts have to be operationalized. The characteristics of the purchased cars, used in this proposal, are emission, type of fuel and registration year in which it was purchased (second registration for second-hand cars). The operationalization of the type of fuel used in cars is one or a combination of petrol, diesel and/or electricity.

The reason why the focus of this thesis lies on the thresholds of 2013 and 2014 is to build further on the findings of Dimitropoulos (2014) whom looked at the effect of CO_2

emission based taxes as well. The two main arguments for this research to study the same thresholds are the fact that these years are the first in which the taxes were solely based on CO_2 emissions. Secondly, the data of Dimitropoulos was limited in the separation of private and company owned cars. The thesis will look deeper into the effects of the thresholds studied by Dimitropoulos.

5.0 Descriptive Statistics

This chapter will briefly summarize the data used in this thesis. The data is derived from the database of the ‘Planbureau voor de Leefomgeving’. The used data will be compared with thresholds that were active in the according years. A first glimpse of the distribution around the thresholds will be observed with a high percentage on and just under the threshold with a low density above the threshold. This research only used data of the years 2013, 2014 and 2017 to build on the findings of Dimitropoulos with data regarding the distinction between private and company cars. Data from the year 2017 will be used to look at a possible connection between the new and second-hand car markets. The four year gap between 2013 and 2017 is chosen because of the Meerkerk et al. article which assumed a four year lease contract as standard. Table 5 shows the amount of newly purchased cars per year and market. The dataset provided only includes cars that have an age of two years to eight years in the second-hand car markets.

Table 5. *The quantities of the car markets per ownership, number of registrations and year.*

Car Markets per Year					
	New		Second-Hand		Total
Year	Private	Company	Private	Company	
2009	386479		332805		719284
	262987	123492			
2010	481064		439304		920368
	334360	146704			
2011	554823		393271		948094
	382762	172061			
2012	501330		332120		833450
	32255	179075			
2013	418064		286759		704823
	265970	152094			
2014	391269		279280		670549
	245771	145498			
2015	416008		278918		694926
	249547	166461			
2016	382419		284503		666922
	238264	144155			
2017	416008		287650		703658
	264972	151036	266841	20809	

Consequently, the amounts in the car markets are smaller than the actual amount of cars in these markets. The argument for this filtering is to find a possible connection between new and second-hand car markets. With older cars in the data it is impossible to search for connection between car markets. The total amount of purchased cars seems to, in general, decrease compared to the years earlier in the table. This can be explained, as discussed before, by the increasing costs of purchasing a new car relative to the repair costs of an already owned car and thus prolonging its lifespan. The years in which new cars are located is determined by the date of the first registration of the cars. A distinction is made between private and company cars according to years also. The total populations in table 3 are divided by cars privately owned and company cars exclusively for the new car markets, except for the second-hand distribution in 2017 since this thesis analysis the connection between the new car market and second-hand car market also using data of 2017.

Beneath, figures 4 to 7 depict the distribution of the new car fleet in 2013 and 2014. A distinction is made between cars with (primary) fuel source petrol and diesel. Three of the distributions show a distribution which is visually in accordance with the hypothesis, namely the distribution of petrol cars in 2013, diesel cars in 2013 and diesel cars in 2014. The red lines in the histograms are the thresholds that were active during those years according to fuel type which can be looked up in table 1 and 2 in the 'policy instruments' chapter.

Figure 4.

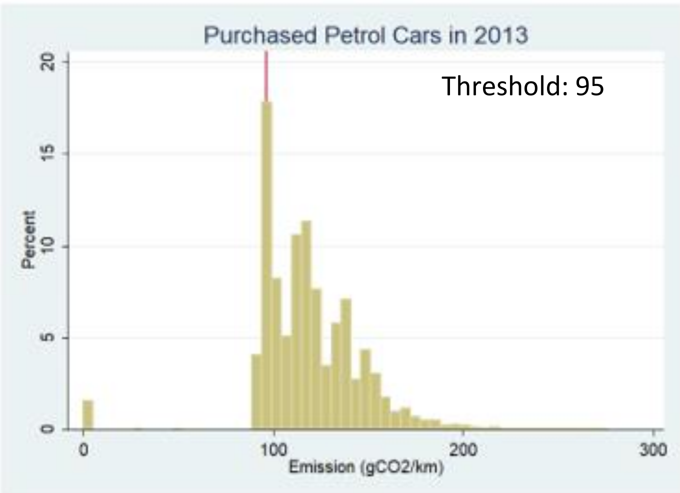


Figure 5.

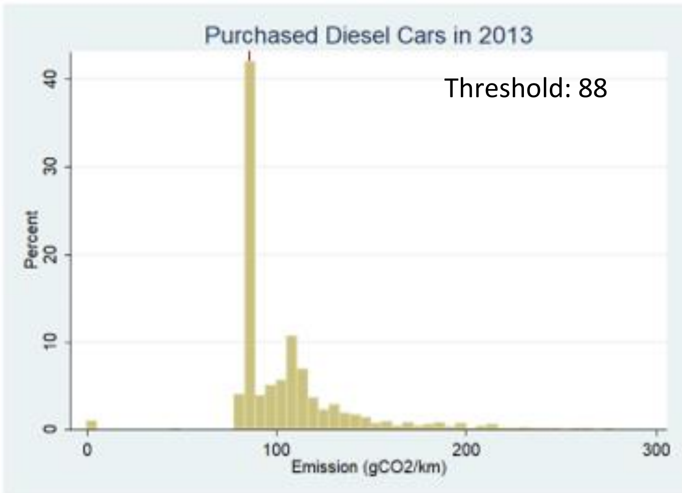


Figure 6.

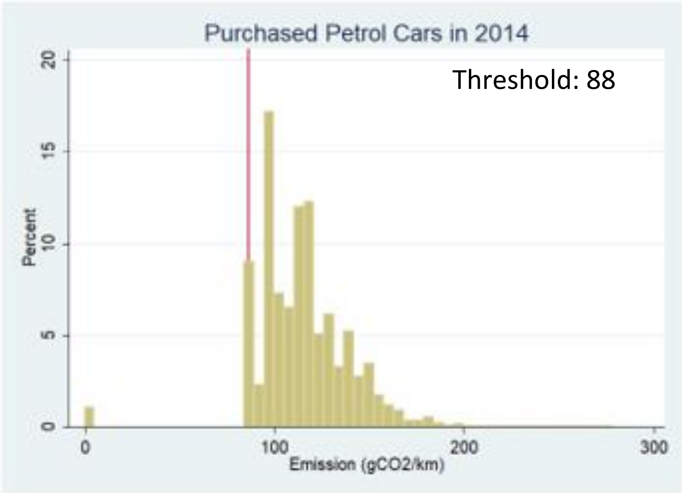
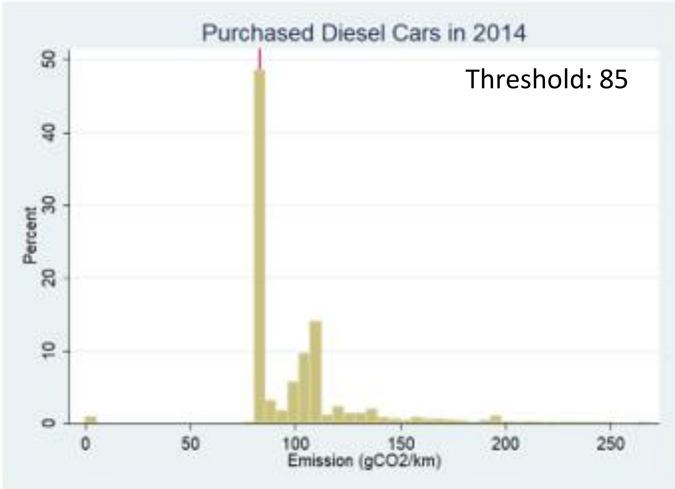


Figure 7.



Another visual distribution which is very interesting is the distribution of the second-hand car fleet in 2017. The interesting thing to observe is that the BPM CO_2-thresholds of earlier years, which are not applicable for second-hand cars, seem to be located at the highest frequencies of cars in the distribution. The thresholds are the red lines with the diesel thresholds at 95, 88, 85 and 82 gCO2/km, while the petrol thresholds are 110, 102, 95 and 88 gCO_2/km. This might indicate that the cars purchased in earlier years have an effect of the purchased second-hand cars in years in the nearby future. This can be explained by the ability of manufacturers to adjust their cars' emission to locate them in lower tax brackets and make them more appealing for consumers. In combination with the high availability of these cars they were the best cost-benefit solution for many consumers resulting in the same distribution in the second-hand market. The relative low quantity of second-hand car purchases might support the assumption that the lifespan of cars extend the four year standard.

Figure 8. *Second-Hand Petrol Market Distribution in 2017*

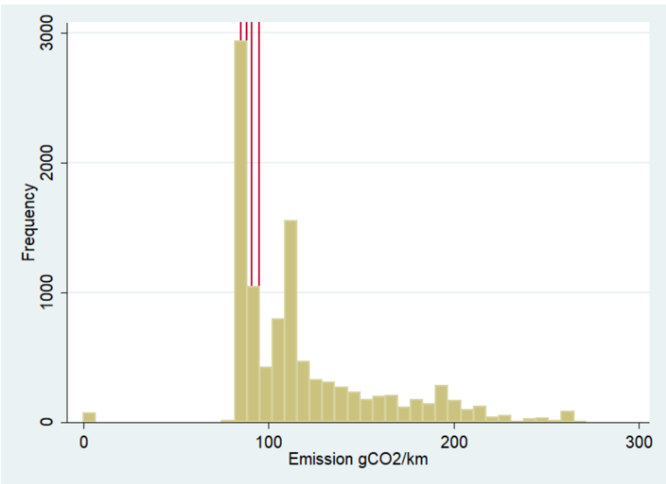
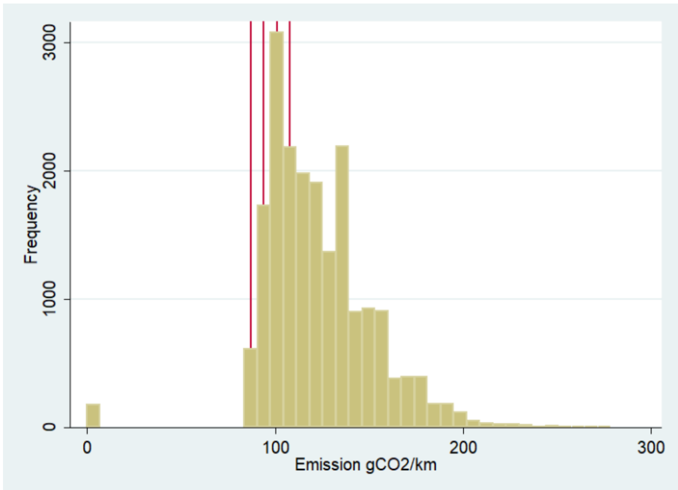


Figure 9. *Second-Hand Diesel Market Distribution in 2017*



6.0 Results

In this chapter the results will be presented and the hypothesis will, subsequently, be tested. By conducting a graphical and empirical analysis the effect of the thresholds will be analysed and subsequently an answer is given on the research question whether these thresholds have a significant effect on the composition of purchased cars, according to the CO2 emission, in the Dutch car fleet.

6.1 Graphical Analysis

The bunching windows used in these analyses are an interval of 5 g/km around the bunching point, in other words between 2 g/km below and 2 g/km above the kink. This width of the windows was chosen according to Dekker et al. article in combination with a visual inspection. Due to the psychological component an extra g/km was added below the threshold to create an asymmetric window with 2 g/km below and 1 g/km above, but the visual inspection suggested that 2 g/km above the threshold was preferred. This was due to the fact that the estimated distribution above the kink was located underneath the counterfactual distribution which indicates where the bunchers were previously located.

Since figures 9 to 14 (diesel 2013, diesel 2014 and petrol 2013), show spikes at the active thresholds in the according years, this visually suggests an effect induced by the threshold for these car markets in these years. Figures 15 and 16 show the distribution of the petrol population in 2014 and with it visually other results. Spikes can be observed on the active thresholds but are, however, not unique in the distribution. Other spikes, that are not located on any active threshold in that year, are present as well.

6.2 Empirical Analysis

All the results that are presented in figure 10 to 17 are included in table 5 in the robustness sections. In figure 10 an excess mass (*b*) = 30.91 is measured with a standard error = 6.64, a t-statistic of 4.66 and a $p < 0.01$. The excess mass around the kink is 3091 percent [%] of the average height of the counterfactual distribution within 2 gCO_2/km of the right side of kink. The excess mass is statistically significant also. Thus: *The kink for the diesel company cars in the population of 2013 has a significant effect on the composition of purchased cars in the Dutch car fleet.*

In figure 11 an excess mass (*b*) = 29.58 is measured with a standard error = 7.49, a t-statistic of 3.95 and a $p < 0.01$. The excess mass around the kink is 2958 percent [%] of the average height of the counterfactual distribution within 2 gCO_2/km of the right side of kink. The excess mass is statistically significant also. Thus: *The kink for the diesel private cars in the population of 2013 has a significant effect on the composition of purchased cars in the Dutch car fleet.*

In figure 12 an excess mass (*b*) = 33.30 is measured with a standard error = 8.34, a t-statistic of 3.99 and a $p < 0.01$. The excess mass around the kink is 3330 percent [%] of the average height of the counterfactual distribution within 2 gCO_2/km of the right side of kink. The excess mass is statistically significant also. Thus: *The kink for the diesel company cars in the population of 2014 has a significant effect on the composition of purchased cars in the Dutch car fleet.*

In figure 13 an excess mass (*b*) = 29.92 is measured with a standard error = 11.96, a t-statistic of 2.50 and a $p < 0.01$. The excess mass around the kink is 2992 percent [%] of the average height of the counterfactual distribution within 2 gCO_2/km of the right side of kink. The excess mass is statistically significant also. Thus: *The kink for the diesel private cars in the population of 2014 has a significant effect on the composition of purchased cars in the Dutch car fleet.*

In figure 14 an excess mass (*b*) = 7.35 is measured with a standard error = 1.52, a t-statistic of 4.83 and a $p < 0.01$. The excess mass around the kink is 735 percent [%] of the average height of the counterfactual distribution within 2 gCO_2/km of the right side of kink. The excess mass is statistically significant also. Thus: *The kink for the petrol company cars in the population of 2013 has a significant effect on the composition of purchased cars in the Dutch car fleet.*

In figure 15 an excess mass (*b*) = 9.45 is measured with a standard error = 1.93, a t-statistic of 4.90 and a $p < 0.01$. The excess mass around the kink is 945 percent [%] of the average height of the counterfactual distribution within 2 gCO_2/km of the right side of kink. The excess mass is statistically significant also. Thus: *The kink for the petrol private cars in the population of 2013 has a significant effect on the composition of purchased cars in the Dutch car fleet.*

In figure 16 an excess mass (*b*) = 4.83 is measured with a standard error = 2.29, a t-statistic of 2.11 and a $p < 0.04$. The excess mass around the kink is 483 percent [%] of the average height of the counterfactual distribution within 2 gCO_2/km of the right side of kink. The excess mass is statistically significant also. Thus: *The kink for the petrol company cars in the population of 2014 has a significant effect on the composition of purchased cars in the Dutch car fleet.*

In figure 17 an excess mass (*b*) = 0.71 is measured with a standard error = 2.30, a t-statistic of 0.31 and a *p* = 0.76. The excess mass around the kink is 71 percent [%] of the average height of the counterfactual distribution within 2 gCO_2/km of the right side of kink. The excess mass, however, is statistically insignificant. Thus: *The kink for the petrol private cars in the population of 2014 has* <u>*no*</u> *significant effect on the composition of purchased cars in the Dutch car fleet.*

The first aspect of the results to notice is the difference in (significant) excess mass between diesel and petrol cars. The excess mass created by the diesel thresholds in both years differs with a mean of 2442% from the mean excess mass of the petrol populations (*b* = 24.42). This is derived by the difference of the two means of the petrol and diesel markets. The mean of the diesel markets in both years is 30.92, while the mean of the petrol markets is 6.50. The difference between these two is 24.42. This is in accordance with the findings of Dimitropoulos that diesel cars are more popular among company car drivers and thus are more affected by the kinks (2014, p. 125 – 138). Dimitropoulos explains that the company car taxation induces strategic responses from car manufacturers. This would result in an increase in availability of cars at the threshold. This is why the entire diesel populations have a greater excess mass than the petrol counterpart.

A relatively smaller, but significant, difference of 169% (*b* = 1.69) is observed between company cars and privately owned cars. With the company mean being 19.10 and the private 17.42 This could be due to the combined effect of the BPM and company car tax liability that, in these years, are located on the same gCO2/km.

Besides the relatively smaller effect of the threshold in the petrol population it shows that the threshold for the privately owned car case has no significant effect on the composition of the Dutch car fleet in 2014. To find the confidence interval of 95 percent [%] the standard error is multiplied by 1.96. While the petrol company car threshold in 2014 is barely above the t-value 2, it is significant still.

The thresholds of diesel in 2013 and 2014 are all statistically significant. Meaning that the kinks in the diesel populations in 2013 and 2014 have a significant effect on the composition of purchased cars in the Dutch car fleet.

All the thresholds in the petrol populations in 2013 and 2014, with an exception of the threshold in the private car market in 2014, have a significant effect on the composition of purchased cars in the Dutch car fleet. A possible reason for the threshold to be not significant for petrol private cars in 2014 is due to the availability of cars produced by manufacturers in 2013 that were located on the threshold of 2013. A large spike is observed on the 95 gCO_2/km which is the BPM threshold for petrol cars in 2013. This could be due to an increased availability of cars located in that bin and would thus be cheaper for consumers to purchase. The decrease in purchase price would outweigh the benefits of a lower tax rate.

Company car drivers are, besides the BPM, aware of the company car tax liability also. Since the tax liability lies on the same emission level, that is 88gCO_2/km in 2014, this has an effect also on the consumers behaviour. This makes the difference in significance between excess masses created in the private and company populations in 2014. Due to the overlap of both taxes in the company car markets it is, however, hard to determine the separate significance of this tax. The important things to see in the figures are the vertical and horizontal red lines. The vertical red lines are the active tax thresholds active in the according years. The horizontal red lines are the predicted counterfactuals created with the program by Chetty et al. The dashed black lines indicate the width of the bunching window (R). On the y-axis the amount of cars located in the bins is presented, that are defined on the x-axis as gCO_2/km. In the top right corner of the figures the excess mass (b) and standard error are presented as well. The excess mass is the mass of the spike in the bunching window that exceeds on top of the counterfactual.

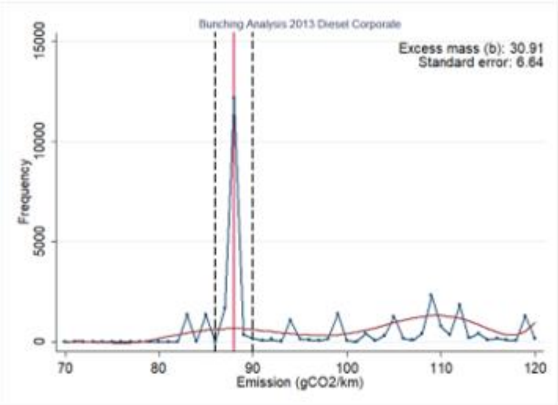


Figure 10

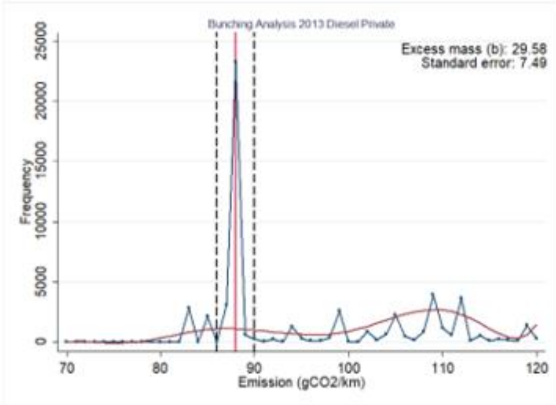


Figure 11

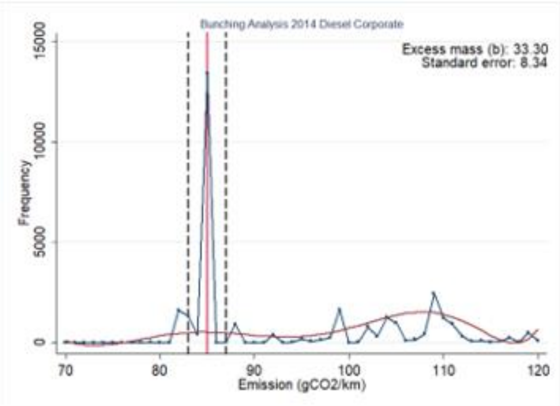


Figure 12

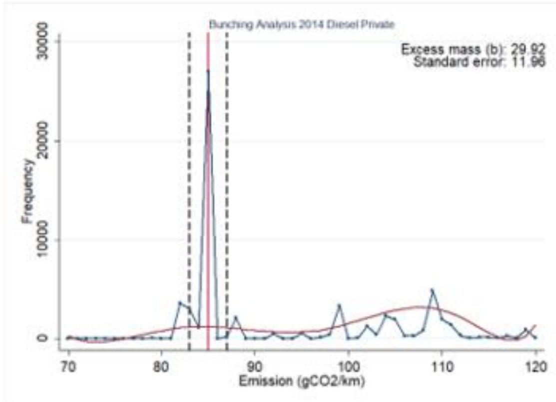


Figure 13

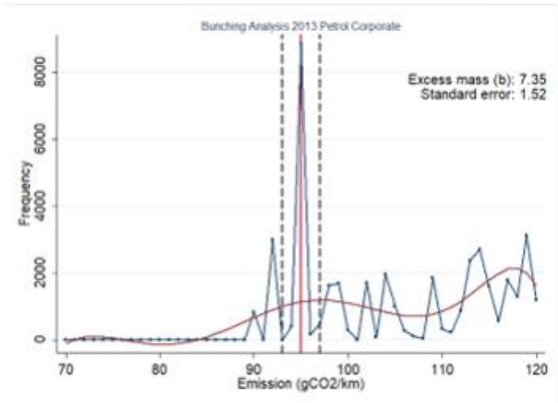


Figure 14

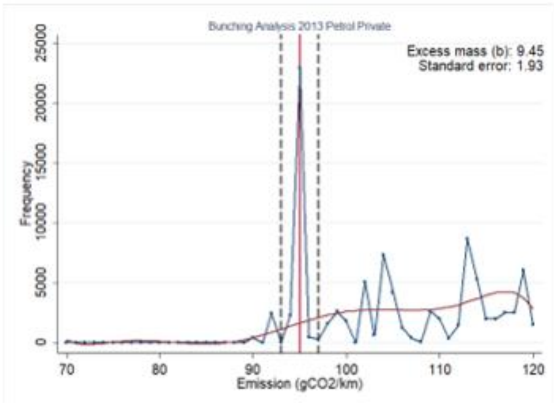


Figure 15

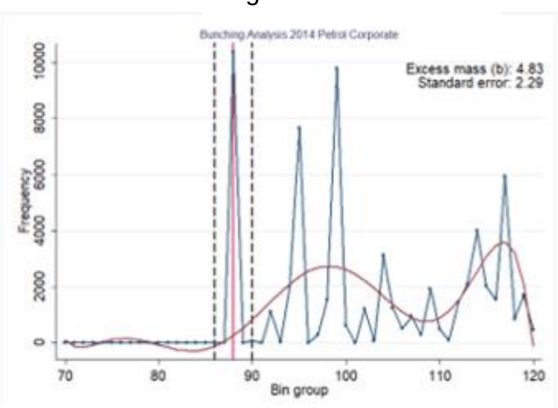


Figure 16

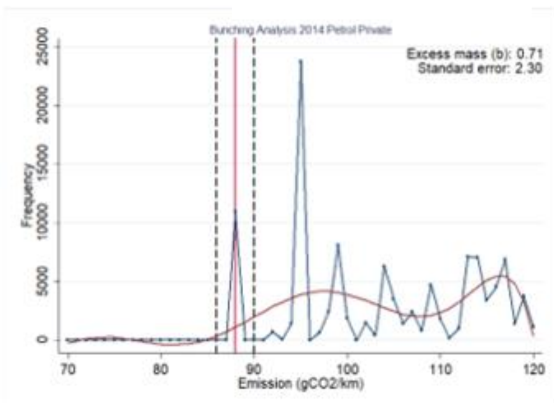


Figure 17

6.3 Robustness

Table 6. *Empirical Bunching Analyses*

2013							2014						
Fuel	Market	*R*	*q*	*b*	*t*	*p*	Fuel	Market	*R*	*q*	*b*	*t*	*p*
Petrol	Private	5	7	9,45	4,90	**<0,01**	Petrol	Private	5	7	0,71	0,31	*0,76*
Figure 15		4	7	10,61	5,26	**<0,01**	**Figure 17**		4	7	1,84	0,81	*0,21*
		5	4	13,07	3,35	**<0,01**			5	4	1,78	0,47	*0,32*
		4	4	14,05	3,58	**<0,01**			4	4	2,82	0,85	*0,20*
Petrol	Company	5	7	7,35	4,83	**<0,01**	Petrol	Company	5	7	4,83	2,29	**<0,04**
Figure 14		4	7	7,96	5,43	**<0,01**	**Figure 16**		4	7	6,01	2,71	**<0,01**
		5	4	10,11	3,44	**<0,01**			5	4	6,45	1,49	*0,07*
		4	4	10,48	3,84	**<0,01**			4	4	7,49	1,95	**<0,03**
Diesel	Private	5	7	29,58	3,95	**<0,01**	Diesel	Private	5	7	29,92	2,50	**<0,01**
Figure 11		4	7	30,85	4,00	**<0,01**	**Figure 13**		4	7	31,29	2,62	**<0,01**
		5	4	38,48	1,99	**<0,02**			5	4	38,00	1,07	*0,14*
		4	4	39,33	1,99	**<0,02**			4	4	38,96	0,98	*0,16*
Diesel	Company	5	7	30,91	4,46	**<0,01**	Diesel	Company	5	7	33,30	3,99	**<0,01**
Figure 10		4	7	32,17	4,86	**<0,01**	**Figure 12**		4	7	35,11	4,00	**<0,01**
		5	4	38,77	3,77	**<0,01**			5	4	40,29	2,71	**<0,01**
		4	4	39,62	3,29	**<0,01**			4	4	41,65	2,63	**<0,01**

The Fuel column describes the type of fuel used in the car. The Market column describes the type of ownership. The R column shows the width of bunching window. The q column shows the degree of the polynomial used. The b column shows the estimated bunching mass created. The t column shows the t-values. The p column shows the p-values.

To test for robustness a variation is made in the used width of the bunching windows as well as the degree of the polynomial. The values used in the thesis are those that are a result of the "standard" settings. These are a bunching window with a width of 5 gCO_2/km and a polynomial degree of seven. The standard width is a result of the visual inspection of the data, while the standard degree is adopted from the bunching program created by Chetty et al. The alternative width is chosen due to the suggestions discussed by Dekker et al. (2016). The psychological component makes consumers overcompensate to the left of the kink. This results in a bunching window reaching from 2 gCO_2/km to the left of the kink and 1 gCO_2/km to the right. The alternative polynomial degree is a result of a visual inspection of the counterfactual created by the different degrees. Degrees 1 to 3 were inflexible regarding the disruptions in the distribution. Degree 4 is less flexible than 7, but shows a counterfactual that slightly follows the distribution.

While the width of the bunching window had a small effect of the p-value, but no effect on the significance of the results, the degree of the polynomial did. The degree caused higher standard errors which resulted in the insignificance of some bunching analysis. This shows the importance of setting standards for these two components.

6.4 Second-Hand Car Market

This small section is dedicated to the connection between the new and second-hand car market. While there is no hypothesis that will be tested it is interesting to see a possible connection between the new and second-hand car markets. As discussed in the 'theory' chapter, a link is assumed between the new and second-hand markets since the lifespan of cars lies around four years. Therefore, the thesis assumed that the thresholds of four years earlier could be seen in the distribution. Since 2013 and 2014 are observed the research takes a look at the distribution of the second-hand car market of 2017.

Figure 18. *Bunching Analysis Second-Hand Diesel Market 2017*

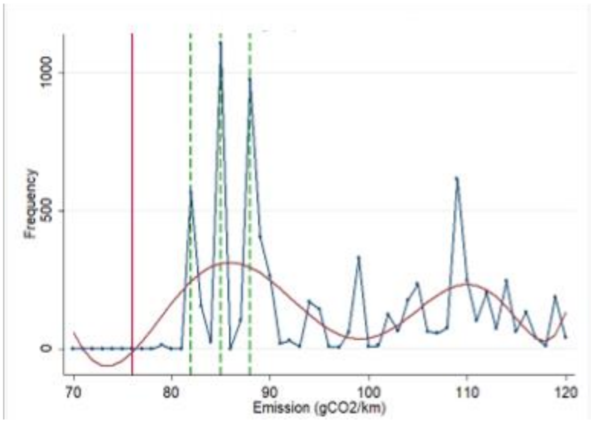
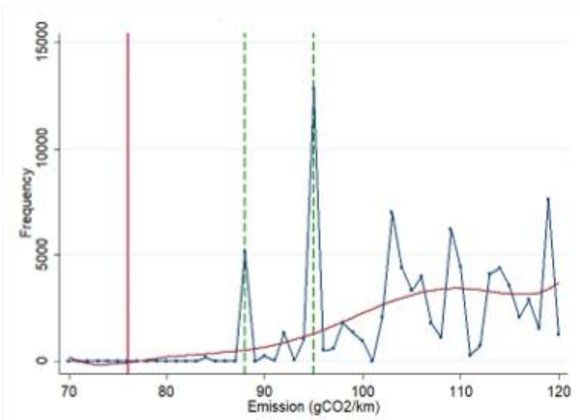


Figure 19. *Bunching Analysis Second-Hand Petrol Market 2017*



6.4.1 Graphical Analysis

First of all, a visual inspection of the results indicates that there seems to be a connection between the new and second-hand car markets. As in the bunching analyses of the new car market the vertical red lines are the active thresholds of the observed year. The horizontal red lines are the predicted counterfactuals. The green dashed lines are the inactive thresholds of earlier years. The diesel CO_2 emission thresholds of 2013, 2014 and 2015 are present in the distribution of the 2017 second-hand diesel car purchases, namely: 88, 85 and 82 gCO_2/km. The same is observed in the distribution of the second-hand petrol car purchases in 2017 with the threshold of 2013 and 2014 present: 95 and 88 gCO_2/km.

6.4.2 Empirical Analysis

In figure 18 an excess mass (b) = 5.45 is measured with a standard error = 2.97, a t-statistic of 1.86 and a p = 0.03 for the threshold of 88 gCO_2/km. The excess mass is statistically significant. Thus: *The threshold that was active in 2013 has a significant effect on the composition of purchased second-hand petrol cars in the Dutch car fleet of 2017.*

In figure 18 an excess mass (*b*) = -2.24 is measured with a standard error = 0.93, a t-statistic of -2.41 and a $p = 0.01$ for the threshold of 85 gCO_2/km. The excess mass is statistically insignificant since the b is negative and thus there is no excess mass. Thus: *The threshold that was active in 2014 has no significant effect on the composition of purchased second-hand petrol cars in the Dutch car fleet of 2017.*

In figure 18 an excess mass (*b*) = -3.05 is measured with a standard error = 1.77, a t-statistic of -1.72 and a $p = 0.04$ for the threshold of 82 gCO_2/km. The excess mass is statistically insignificant since the b is negative and thus there is no excess mass. Thus: *The threshold that was active in 2015 has no significant effect on the composition of purchased second-hand petrol cars in the Dutch car fleet of 2017.*

In figure 19 an excess mass (*b*) = 2.25 is measured with a standard error = 1.38, a t-statistic of 1.63 and a $p > 0.05$ for the threshold of 95 gCO_2/km. The excess mass is statistically insignificant. Thus: *The threshold that was active in 2013 has no significant effect on the composition of purchased second-hand petrol cars in the Dutch car fleet of 2017.*

In figure 19 an excess mass (*b*) = -1.76 is measured with a standard error = 2.04, a t-statistic of -0.86 and a $p = 0.20$ for the threshold of 88 gCO_2/km. The excess mass is statistically insignificant. Thus: *The threshold that was active in 2014 has no significant effect on the composition of purchased second-hand petrol cars in the Dutch car fleet of 2017.*

While most inactive thresholds have no significant effect on the composition of purchased second-hand petrol cars in the Dutch car fleet of 2017, it is observed that the diesel threshold of 2013 does have a significant effect. Due to the limitations of the bunching analysis program it is impossible to analyse all thresholds together. The combination of the graphical analysis and the significance of the diesel threshold of 2013 suggests a connection between the new car markets and their four year later counterparts, the second-hand markets.

7.0 Discussion

This chapter relates the observed results with the existing literature this thesis discussed in its theoretical framework and explains the significance of these findings. This chapter will then continue to explain questions that arose during this research and gives suggestions for further research.

7.1 Explanation of Results

The results of the bunching analysis that are observed are in accordance with the theoretical framework presented earlier. The thesis focuses on the first kink between the first and second tax brackets in all population. This kink separates cars which are located in a bracket where no BPM has to be paid and a bracket with a (low) tax rate. The thresholds with a significant effect show the impact of the economization of the costs created by the negative externality, climate change. The results show that, due to this economization, consumers adjust their behaviour to avoid these extra costs. The significance shows that the taxes give a strong enough incentive to reduce the emission per car and in general reduce the negative externality.

Meerkerk et al. discussed the negative price elasticity of all sorts of cars resulting in a reduction of the consumers' willingness to purchase a car. The differentiation in CO_2 emission brackets has as a consequence that high emission cars become more expensive relative to low emission cars. The results support this assumption that the density of high emission cars is lower than the density of low emission cars due to the negative elasticities. As Meerkerk et al. explained also is that the purchase of a new car is not solely based on the tax costs, but on the availability of the cars also. The results of the petrol private car market in 2014 show a high density around the threshold that was active in 2013. This implies that the availability of cars produced, according to the thresholds of 2013, made the purchase of these cars cheaper regardless of the different tax rates in the emission brackets.

In general, these results confirm the research of Dimitropoulos with his assumption that bunchers will move towards the more favourable side of the kink to benefit of the lower tax costs. While his research was mainly based on the BPM the thesis looked at the company tax liability also. Most years showed a greater excess mass created in the company markets suggesting an effect of the tax liability. The most interesting thing for this subject to observe is the difference in the petrol market in 2014. While the effect of threshold for private petrol cars in 2014 was insignificant we see a significant one in its counterpart, the company petrol market. The difference in significance could be due to the combined effect of the BPM and the company car tax liability which make the threshold of 88 gCO_2/km more impactful. Since the thesis assumes the company car tax liability to have an effect on the composition of the Dutch car fleet, the research assumes that the difference in significance could be a result of the extra effect of company car tax liability on top the BPM.

Lastly, the connection between the new and second-hand car markets was studied with the assumption that the new car market of four years earlier would possibly have an effect on the distribution of the second-hand car market. The graphical analysis of the 2017 markets confirms this assumption with spikes on emissions that had active thresholds in 2013 as well as 2014. Since there was a limitation in the analysis of these spikes it was not possible to test the combined effect of the thresholds and could only be tested separately. The recommendation for further research on this subject would be to find a way of testing these combined effects. Besides the subject the thesis will present other recommendations for further research in the subsection below.

7.2 Recommendations for Further Research

With the results the research question can (for the majority) be answered, but further research has to be conducted to analyse certain aspects that compromise the preciseness of the results to a certain level.

Results are observed that indicate that the company car tax liability has an effect on the composition of the Dutch car fleet, but it is unclear to what extent. The majority of the populations observed show a bigger excess mass in the company market than in the private market, but to what extent this is due to the tax liability cannot be determined with these results. The thesis saw a difference in significance in the petrol market of 2014 and suggests that this is a result of the combined effect of the BPM and the company car tax liability, but whether the effect of the tax liability is in itself significant is unclear. Further research needs to separate these effects and determine their separate effect.

Another aspect the literature discussed was the fact that due to the negative price elasticity consumers would be less willing to purchase a car. In the raw data the sizes of new sales and second registrations are observed that shows some signs of a decrease in purchased cars relative to earlier years. The question rises whether this is the result due to the ever rising tax costs based on more severe emission thresholds each year or due to a decrease of the availability of cars. Building upon this aspect is the question on the effects of the taxes and the availability of the cars. The results of the petrol market in 2014 showed that a high density of cars was located at the petrol threshold of 2013 and resulted in an insignificance of the active threshold. This shows an effect of the availability of the cars, but it is unclear to what extent. Since this applies for all markets in the observed years the assumptions are based on an unclear combination between tax costs and purchase costs.

A concern Dimitropoulos addressed in his research is the principle that convinces consumers to adjust their behaviour, and thus bunch. Do bunchers move to the left side of the kink due to the lower emission bracket and benefit from the decrease in tax rate or is a part of the cost-benefit analysis based on the reduction of the negative externality of car pollution. Dimitropoulos suggests, as discussed earlier, that the former is the main driver for consumers to bunch, but to what extent is unclear. Further research could analyse the factors that consumers include in their cost-benefit analysis to decide what the separate impacts of these factors are.
Dimitropoulos discussed the strength of the incentives provided by the BPM which the thesis assumed to be the same for the company car tax liability. The results give no clarity on the strength of these incentives which is especially interesting for his assumption that consumer located away from the kink do not receive a strong incentive. Further research could focus on the reach of these thresholds.

Another source of uncertainty, that was integrated in this research, is that the bunching window is chosen arbitrary still. The article of Dekker et al. suggested an asymmetric bunching window due to the psychological component that moves consumers lower than the threshold to obtain certainty. Since the bunching window has a major impact on the results it is key to find a way to determine a standard for the width of the window. After applying an asymmetric window the thesis found that the mass that lay under the counterfactual distribution reached further than the bunching window on the right of the kink and had to be extended. As a result a symmetric bunching window was used in the analysis. Since the distribution is different for every population it is hard to draw conclusions out of the results.

To build further on the arbitrary aspect of the analysis it is important to note the impact of the degree of the polynomial that is used. The standard degree used in the analysis designed by Chetty et al. is seven and is used in this research. Since the degree is subject to the researcher's discretion it is an aspect that poses uncertainty in the validity of the results as could be observed in the 'robustness' section.

Lastly, Dimitropoulos discussed the difference between emission levels that were measured in the laboratories and under real-world conditions. According to Dimitropoulos these real-world emissions were often 50% or higher compared to the test levels. Since a high density is observed on and just under the threshold it is important for further research to analyse the real difference in these emission levels. If the assumption of Dimitropoulos is supported by evidence this would mean a setback in the progress towards the target emissions. Meerkerk et al. (2018, p. 45) discussed this subject as well and found that cars which were efficient 'on paper' would receive a tax deduction while there was no actual emission reduction.

7.3 Policy Implications

One of the major implications of CO_2 emission based tax is the ability of car manufacturers to adjust the emissions of a car during testing, mainly diesel cars, which has occurred and is known as the "Dieselgate scandal" (Amelang & Wehrmann, 2019). This scandal came to light when the United States Environmental Protection Agency [EPA] formally accused Volkswagen of violating the emission standards of the United States [US]. Volkswagen admitted that they implemented a "defeat device" in more than eleven million diesel cars worldwide. This device was able to detect whether it was in a laboratory for testing and could active its emissions control system to comply with the emissions standards (ECA, 2019, p. 12). Dimitropoulos suggests that the measuring of CO_2 emissions of cars in Europe gives manufacturers the ability to strategically adjust responses to the thresholds. The vehicle emission testing procedures should be revisited to test cars for their emissions under real-world conditions. The level of real-world emissions are, according to Dimitropoulos, often 50% or higher compared to the tested emissions (2014, p. 124).

The ability for consumer and manufacturers to change brackets bring, as a result, large distortions in the car market. Dimitropoulos suggests that the best way to smooth out the distribution of purchased cars in respect to CO_2 emission should be a tax on every additional gram of CO_2/km according to its marginal cost. The kinks in the tax system should be removed and be redesigned as a continuous schedule of CO_2 emissions. Dimitropoulos continues that the optimal tax system should incorporate other air pollutants, such as nitrogen dioxide also (2014, p. 147).

Lastly, the policy instruments used could have a different effect than what they are made created for. As Meerkerk et al. (2018, p. 44) discussed, the policy focuses mainly on tax deductions for consumers whom drive 'greener' cars. Meerkerk et al. argue that the focus should alter to one that creates costs for environmental damaging activities. Promoting greener activities partly reduces the air pollution, but these greener activities still cause air pollution in general (Meerkerk et al., 2018, p. 44).

8.0 Conclusion

The research question discussed in this thesis is whether the thresholds, created by the BPM and company car tax liability, would have a significant effect on the composition of purchased second-hand petrol cars in the Dutch car fleet.

The method of the bunching analysis provides a clear way of analysing the effect of the thresholds by presenting the excess mass that was created by bunchers whom moved from the emission bracket with the higher tax rate to one with a lower tax rate. By excluding the created excess mass, with a bunching window, a counterfactual distribution could be predicted and with it create a case without a kink in the tax system. By comparing the created excess mass with the situation which would be without a kink the significance of the thresholds could be analysed.

In the search for solutions for the climate change problem the thesis found an effective instrument to adjust the consumers' behaviour in an effort to reduce the pollution caused by car travel. While this is just a small step towards a solution for the CO_2 question it is still a step. This thesis builds further on this confirmation by looking at similar tax systems like the BPM. Further research needs to analyse the effect of the company car tax liability since the thesis observed a difference in significance between the private and company petrol car markets in 2014. The effect of the tax liability is, while it is observed, hard to measure since it is located on the same emission threshold as the BPM, resulting in a combined effect.

The findings of this research have built further upon the findings of other researchers. The thesis confirms the findings Dimitropoulos observed in his research. The thesis tried to answer the research question whether the BPM and company car tax liability had an effect on the composition of purchased cars in the Dutch car fleet in 2013 and 2014. The significant effect of the thresholds that divide the emission brackets in the tax system has been proven. The BPM has a significant effect on the composition of purchased cars of the Dutch car fleet in 2013 and 2014 with an exception of the private market of petrol cars in 2014. A presence of the effect of the company car tax liability has been observed also, but it is unclear if this effect is statistical significant on its own.

The literature suggested also that the instruments would have a significant effect on the composition of the Dutch car fleet. Due to the negative price elasticity of cars, discussed by Meerkerk et al., an increase in the tax inclusive price will result in a reduction in the consumers' willingness to buy (expensive) cars. By economizing the costs of the negative externality the Dutch government attempts to correct the market failure of neglecting the external costs that car pollution creates and thus make the cars more expensive. Another effect that had an impact on the purchase price of cars was the availability of them. An increase in availability would result in a decrease in the price of purchasing a car. All these factors, that determine the price of purchasing a car, have an effect on the decision which car is bought, if any.

The results are promising in the process of 'greening' the Dutch car fleet, but the composition of the fleet is affected by numerous other factors such as the catalogue price of the car, the availability of the car and the reason of the purchase. Another aspect is the focus of the taxes in reducing air pollution. The policy might need to change the focus from tax deductions to one that creates costs for air damaging activities. While all of these factors are active at the same time it is difficult to separate them from one another. This understates the fact that this research has only 'touched the tip of the iceberg' since many aspects of altering the car fleet to a more sustainable one are still unclear. It is important to explore these ventures since the literature is uncertain about the effect of these instruments, but the government keeps enforcing them still without knowledge about the consequences. By exploring these aspects, a greater comprehension can be acquired of the consumers' behaviour and these results could be relevant in other aspects of making the Netherlands and, in general, the world a more sustainable place.

9.0 References

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