Car Scrappage Policy Programs

To what extent does a national car scrappage policy program influence the replacements of cars?

Evidence from the Dutch 2009 Car Scrappage Policy Program

Renzo Koolhaas
s2375931

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University of Leiden

Thesis supervisor: Hendrik Vrijburg
Second reader: Peter van Wijck

In this research, national car scrappage policy programs are studied. In order to do so, the Dutch 2009 Car Scrappage Policy Program will be analyzed. By using a dataset of The Netherlands Environment Assessment Agency (PBL), which covers all vehicles circulating in the Netherlands in the period 2008-2017, an answer to the question 'Car Scrappage Policy Programs: to what extent does a national car scrappage policy program influence the replacements of cars?' will be elaborated on. By studying replacement rates, which are defined as the total number of replacements over the number of Dutch ownership registration spells that are active at the start of a certain time period, I found a strong significant positive volume effect of the policy program. In addition, I found a strong composition effect of relatively more cars being scrapped over cars being scrapped and exported during the policy program. Finally, I found some statistical indications that from the Circular Economy perspective car scrappage policy programs might not be desirable.

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Foreword

Dear reader,

Hereby I present my MSc Thesis 'Car Scrappage Policy Programs: to what extent does a national car scrappage policy program influence the replacements of cars? Evidence from the Dutch 2009 Car Scrappage Policy Program'. I have written this thesis as an elementary component of my Master of Science in Public Administration – track Economics and Governance at the University of Leiden in the academic year of September 2018 until July 2019.

Together with my Thesis Supervisor, Hendrik Vrijburg, I came up with this research subject because of the intersection of subjects of my interests: public administration, economics and environment. By doing an elaborative quantitative analysis, I have been able to find answers to my research question.

It certainly has not always been an easy task to study this research question. Therefore, I especially want to thank Hendrik Vrijburg for his support and his time to help me. Moreover, I would like to thank Hendrik Vrijburg for offering me a dataset on behalf of Netherlands Environmental Assessment Agency (PBL) to make this research possible.

I would like to wish you a pleasant time while reading this MSc Thesis.

Renzo Koolhaas

The Hague, 11th of June 2019

1 Introduction

These days, it is almost impossible to find a good quality daily newspaper that does not report anything in the context of climate change, sustainability or the environment in general. 'Going green' is 'hot'. Not only the public sector showed a trend in going green, also does the private sector (University of Oxford, 2018). One particular consumer good concerning its sustainability has been attracting a lot of attention during the last decades: the possession and use of cars. Very recently for example, the municipality of Amsterdam presented plans to ban gasoline- and diesel-powered cars completely by 2030 (Witteman, 2019). This and other current policies are not surprising after showing figures of the environmental impact of cars and car driving in general. According to The United States Environmental Protection Agency (2016), the transportation/mobility sector causes about 28% of all Greenhouse Gas (GHG) Emissions. Therefore, transportation causes the greatest amount of GHG Emissions of all sectors in the US. The US is no outsider with this percentage: for many Western countries, such a percentage applies (D'Haultfoeuille, Givord and Boutin, 2013, p.1). The following figure shows an example for the environmental damage in monetary value in 2015 per target group for the Netherlands as calculated by PBL:

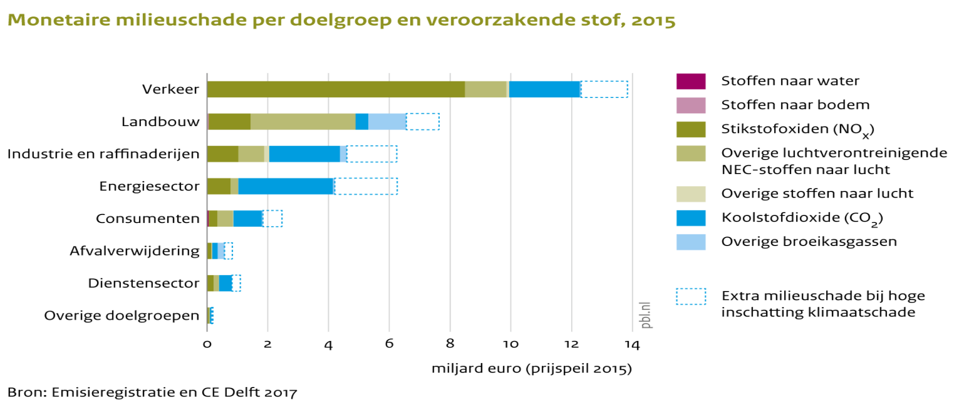

Figure 1: Environmental damage in monetary value by sectors and causing emissions (source: Drissen and Volleberg (2018), https://www.pbl.nl /sites/default/files/cms/publicaties/pbl-2018-monetaire-milieuschade-in-nederland-3206.pdf)

In figure 1, on the left y-axis, the different target groups are depicted and on the right (in color), an explanation of the particular kind of emission is explained. The upper three rows are transportation/mobility, agriculture and industry. What becomes very clear from this figure is that the transportation/mobility group causes the largest environmental damage in monetary value for the Netherlands as well.

From the perspective of these percentages, literature in the field of public policy and public administration regarding environmental damage caused by the transportation/mobility sector is very relevant. It can be expected that governmental policy programs aiming to reduce GHG emissions will focus on this sector largely. Van De Weijer (Volkskrant, 2018) confirms this expectation by indicating that The Netherlands currently invests strongly in governmental policy programs to reduce GHG emissions. For example, the encouragement of car-owners to replace their gasoline- or diesel-fuelled car by electric cars even results in a 600 million shortage of taxes for the Dutch government (RVO, 2019).

An example of an often-discussed policy program to reduce car emissions is a car scrappage policy program. In general, car scrappage policy programs are policy programs whereby a car-owner is offered a subsidy to encourage him or her to bring his or her car to the scrappage to use that subsidy to buy a newer and environmentally friendlier car than he or she possessed (Nationale Slooppregeling, 2010). In other words, the car-owner is stimulated to replace his or her car for an environmental friendlier car. Therefore, the 'life' of older and less environmental friendlier cars will be shortened.

From May 29, 2009, until April 21, 2010 the Dutch government ran such a policy program on the national level. In this research, I study to what extent that Dutch 2009 Car Scrappage Policy Program has been effective in replacing old cars for newer and more environmentally friendly cars in order to be able to answer and derive general conclusions for the following research question:

'To what extent does a national car scrappage policy program influence the replacements of cars?'

This research question is very relevant. In the first place, the question can have a predictive value for the Netherlands and other countries in forming policies concerning the environment. The field of public administration entails governmental intervention, which results to be necessary after interpreting figure 1. Answers to the research question will help us understand how government stimulation via this policy program will have environmental effects, while at the same time having economic effects by boosting an important sector by giving consumers an incentive to consume. The way I address the question is unique by following a different approach than current literature. The research is an explanatory prospective research studying the effect of an intervention (the car scrappage policy program) (Toshkov, 2016, p.156). Because of the fact that the main focus is on the effects of the car scrappage policy program, the study is X-focused. I use a quantitative approach by using difference-in-difference methods based on a dataset provided by PBL. Moreover, I extend on the results from this approach in an environmental perspective through applying the concepts of the Circular Economy (Nederland Circulair in 2050, 2016).

The structure of the research is as follows. In section 2, I firstly elaborate on the theory. In that section, I review the existing literature concerning car scrappage policy programs in general, the Dutch 2009 Car Scrappage Policy Program and the concepts of the Circular Economy. I will display three hypotheses based on this literature in order to find an answer to the research question. Thereafter, in section 3, I will describe the data statistics necessary to conduct the three analyses I will do. For these data statistics and analyses, I will make use of the statistical software package 'STATA'. The three analyses are presented on a one by one base in section 4, 5 and 6. Each of these three sections consists of the methodologies used and the results found for the different hypotheses. I conclude the research and provide an answer to the research question in section 7. Finally, in section 8, I will start a short discussion of the results.

2 Theoretical framework

In this section, I will discuss the theoretical framework of this research. In subsection 2.1, I review current literature necessary to lay the foundations of my hypotheses. Then, in subsection 2.2, I will describe my hypotheses. I will define three hypotheses, which are presented one by one in subsections 2.2.1-2.2.3.

2.1 Literature Review

Various governments have experimented with car scrappage policy programs. The effectiveness of these policy programs has been researched for decades now. In subsection 2.1.1, I will discuss and review this literature. Thereafter, in subsection 2.1.2, I delve into the environmental effectiveness of these policy programs by studying the concepts of the Circular Economy. I will apply these concepts to car scrappage policy programs. Finally, in subsection 2.1.3, I elaborate on the contents of the Dutch 2009 Car Scrappage Policy Program; the car scrappage policy program used to answer the research question.

2.1.1 Car Scrappage Policy Programs

In this subsection, I discuss car scrappage policy programs in general. Why do car scrappage policy programs exist in the first place? What makes car-owners decide to apply for these policy programs? Are the policy programs effective? Current literature will show that answers to these questions are not unambiguous.

As presented in the introduction, the transportation sector and in general mobility has the largest share of emissions in Western countries like the US and the Netherlands. Therefore, environmentally speaking, I showed that governmental intervention is desirable to reduce the emissions this sector causes. A possible intervention thereto can be a car scrappage policy program. In general, the idea is straightforward: by monetarily encouraging car-owners to replace relatively old and environmentally unfriendly cars by relatively new and environmentally friendly cars earlier than car-owners would do without this incentive, the overall car-emissions will reduce (Alberini, Harrington and McConell, 1995, p.93). In other words, the policy program contributes to rejuvenating the current car fleet. The objectives of a car scrappage policy program are not necessarily environmental. Objectives of car scrappage policy programs may differ from policy program to policy program (Van Wee, De Jong and Nijland, 2011, pp.550-552). An example of another objective is economic. It can be expected that car sales increase due to the given subsidy, through which the economy can be boosted. Another example is the public safety objective: relatively new cars tend to have more and better safety standards than relatively old cars.

To elaborate on the environmental motive, the main literature does agree that scrapping older cars in order to replace them for newer cars reduces mobile-source emissions (Van Wee, De Jong and Nijland, 2011, p.566). As Alberini, Harrington and McConell (1995, p.93) make clear, older cars tend to have relatively less pollution-control equipment than newer cars, through which relatively newer cars can be expected to be more environmentally friendly. Alberini, Harrington and McConell (1995, p.94) created a model to review to what extent a car scrappage policy program can be effective regarding the decision-making process of car-owners. Following economic theory, individuals will make decisions that lead them to maximizing utility. Therefore, a car-owner will supply his or her car for scrappage based on the difference between the owner's reservation price (the value of the car to the owner) and the offer price (the rest value of the car and/or the subsidy given for scrappage) (Alberini, Harrington and McConell, 1995, p.94). If the owner's reservation price is higher than the offer price, its Willingness To Accept (WTA) will be too low to bring its car to the scrappage (Alberini, Harrington and McConell, 1995, p.94). In addition to that reasoning, the following conditions should be met in order to decide for car scrappage (Alberini, Harrington and McConell, 1995, pp.96-97 and Van Wee, De Jong and Nijland 2011, p.553):

- A car will not become more valuable than the scrappage value after repairing;
- It is not possible for a car to be sold on the second-hand market for a higher price than the scrappage value.

As defined by Jacobsen and Van Benthem (2013, p.17), a car-owner will scrap its car '*if and only if the price on the second-hand market falls below the realized repair costs plus any residual value'*. In other words, the car scrappage policy program should offer a subsidy high enough to really change human behavior. Van Wee, De Jong and Nijland (2011, p.553) emphasize that next to the amount of subsidy, the prices of second-hand cars and repair and maintenance costs, also the transaction costs for consumers, GDP changes and fuel prices are crucial factors to make a car scrappage policy program effective.

Another reason why the amount of subsidy is crucial is that, if not set high enough, only cars in a very bad condition will be scrapped. This is also called the selection problem. On one hand, it is very likely that cars in a very bad condition would have been scrapped anyways, through which the policy program would not yield additional benefits (Alberini, Harrington and McConell, 1995, p.94). On the other hand, it is even possible that old cars that were not in active use before the policy program will now be scrapped because of the policy program, and therefore not contribute to an additional decrease in emissions from car-using (Santos, 2010, p.20).

The importance of an optimal subsidy is also highlighted by a study of Lavee, Moshe and Berman (2014, p.8). They recently researched a car scrappage policy program in Israel focusing on the scrappage of cars of 20 years and older. By using a cost-benefit analysis, they showed that the subsidy being used was not optimal; more environmental, but also more economic benefits could have been withdrawn if the subsidy was set higher. They proposed a differentiated model whereby the amount of subsidy depends on and increases by the age of the car participating in the car scrappage policy program. This differentiated model would lead to, at least, more economic benefits (Lavee, Moshe and Berman, 2014, p.8).

In addition, more evidence for the important role of the amount of subsidies is shown by a case of France. Not only the amount itself appears to be important, but also the decision for the 'cut-off' / 'pivot-points' at which a car becomes eligible for a car scrappage policy program (D'Haultfoeuille, Givord and Boutin, 2013, p.1). France introduced a 'Bonus/Malus' system in 2008. Cars that polluted relatively less than the 'pivot-point' were being sold with a discount up to 1.000 euro's whereas cars that polluted relatively more than that point were being sold with a tax up to 2.600 euro's (D'Haultfoeuille, Givord and Boutin, 2013, p.1). While such a system is different from a car scrappage policy program, in essence it was also a policy program to monetarily incentivize consumers to choose for relatively newer and environmentally friendlier cars. While being effective in the sense that many consumers reacted to the financial incentives, it appeared to be very difficult to set out the right and optimal pivot-points deciding the tax to pay or discount to obtain (D'Haultfoeuille, Givord and Boutin, 2013, p.39).

Nevertheless, having found the optimal subsidy is not necessarily sufficient for a car scrappage policy program to be effective. The environmental progress through car scrappage policy programs as discussed by Alberini, Harrington and McConell (1995, p.93) remains ambiguous. Whereas main literature does agree that the accelerated replacement of relatively older cars by relatively newer cars can decrease mobile-source emissions, critiques are raised. For example, Van Wee, Moll and Dirks (2000, p.137) do agree that car scrappage policy programs can contribute to a decrease of mobile-source emissions too, because newer cars tend to be more energy efficient than older cars (2000, p.137). However, they discussed objections why there might be reversed effects. They argue that the already discussed economic objective of an increase in sale of new cars automatically results in an increase of car production. This increased car production leads to an increase in life-cycle emissions, since scrapping schemes will reduce the average life span of cars (Van Wee, Moll and Dirks, 2000, p.137). This is in line with the findings by Van Wee, De Jong and Nijland (2011, p.551). This objection is strengthened by the expectation that newer cars will be faster and bigger and therefore probably lead to more emissions (Van Wee, Moll and Dirks, 2000, p.138). In addition, they argue that retrofitting old cars might be more cost-effective than scrappage (Van Wee, Moll and Dirks, 2000, p.138). Concluding, Van Wee, Moll and Dirks (2000, p.138) argue that the objective of car scrappage policy programs to decrease the lifespan of cars might lead to more instead of less mobile-source emissions.

Van Wee, De Jong and Nijland (2011) express even more critiques on car scrappage policy programs. Not only do they fear the emissions related to the decrease of the average life span of cars as described, they also question the cost-effectiveness of the policy program with respect to location and time. According to them, effects with respect to an improvement in emissions only occur at the short term and in large densely populated areas (Van Wee, De Jong and Nijland, 2011, p.567). Therefore, in general, Van Wee, De Jong and Nijland (2011, p.567) are quite skeptical about nationally implemented car scrappage policy programs. Moreover, they argue the characteristics of cars being scrapped through car scrappage policy programs. According to Van Wee, De Jong and Nijland (2011, p.567) only scrappage through the policy program of those cars that do not have pollution-control technologies lead towards additional environmental gains.

Summarizing, researchers agree with each other with respect to the effectiveness of car scrappage policy programs regarding the environment and economic growth to some extent. However, there are many critiques as well. Why would, if environmental and economic progresses do not hold, car scrappage policy programs exist according to the criticists? Van Wee, De Jong and Nijland (2011, p.567) argue that the reasons for this existence are threefold: lobbyism in the car industry, the need for politicians to do something in times of economic crises and public choice theory, whereby policymakers seek for re-election by maintaining visible and obvious economic and environmental policies.

2.1.2 The Circular Economy and Car Scrappage Policy Programs

In this subsection, I will continue focusing on the effectiveness of car scrappage policy programs. Whereas in subsection 2.1.1 I highlighted the characteristics and effectiveness in a broad sense, here I will use the perspective of a particular popular phenomenon called the Circular Economy to assess the environmental effectiveness of car scrappage policy programs.

It is highly relevant to assess the environmental effectiveness of car scrappage policy programs by the relatively new concepts of the Circular Economy, because of the fact that the main literature does still not have this perspective. The basic principle of the Circular Economy is the closing of material loops (Reike, Vermeulen and Witjes, 2017, p.247). In other words, each raw material being used for a particular good will 'never' be discarded: instead of a linear model whereby taking, making, consuming and disposing takes place, a circular model will be strived for. Thereby, the so-called loops are of great importance, which are defined as the length of time between a raw material that lost its function for one particular good and the moment it will be in function for another particular good. Various lengths can exist, whereby Reike, Vermeulen and Witjes (2017, p.247) argue that shorter loops are environmentally more desirable than longer loops.

In current literature, different classifications of loops have been created. In this research, I will follow the classification made by Reike, Vermeulen and Witjes (2017, pp.255-257): the R-imperatives. I use this classification because of its base on 69 peer-reviews, its clarity and its applicability to the car industry. In short, a distinction has been made between three classes of imperatives: short loops (refuse, reduce and reuse), medium long loops (refurbish, remanufacture and repurpose) and long loops (recycling) (Reike, Vermeulen and Witjes, 2017, pp.255-257). In explaining the difference between the three classes, I will directly apply these terms to the car industry. In case of the shortest loops, current car-owners will decide to keep the car in possession and, if necessary, repair some small elements. Another option is that a car-owner sells its car (as a whole) on the second-hand market. In case of medium long loops, the car-owner also chooses to keep its car, but repairs its car to a large extent. Examples can be a complete replacement of the motor or the addition of pollution-control equipment for a car to be able to remain existent. Another possibility is to refurbish or remanufacture the car whereby it is possible that the car loses its original function. In case of the longest loop, a car will be completely recycled. In other words, the car will be scrapped and its parts will be used in new products.

Following the concepts of the Circular Economy, it is desirable to scrap a car if and only if the shorter loops are no possible options. Therefore, from that perspective, it might be the case that a car scrappage policy program sometimes incorrectly incentivizes consumers. Consider an abstract example whereby a car-owner drives and old car for which still some reparations can be done in order to make it somewhat environmentally friendlier. In case of a car scrappage policy program, the car owner will be incentivized to choose for car scrappage over keeping the car or selling it at the second-hand market (shortest loops), or over reparations/applications (medium long loops). If, for example, the car had undergone the reparations (the medium long loop), the emissions to produce a new car (the longest loop via recycling) would have been prevented. While the car scrappage policy program would incentivize car-owners to scrap, from a Circular Economy perspective it could be the case that scrappage and the production of a new car would lead to more emissions than reparations and the continuing existence of the old car. Then, the objective of such a policy program would result in reversed effects.

As shown in subsection 2.1.1, current literature does form critiques from the environmental perspective, but still does not use the above-described perspective. Nevertheless, research does question what the optimal age of a car should be to be scrapped. And it is this question that is in line with the concepts of the Circular Economy and the focal point to assess whether a car should be scrapped or not. Until what age can we expect that, environmentally speaking, it is better for a car to remain part of the car fleet? According to Van Den Brink and Van Wee (2001, p.82) mainly two driving forces depict when it is time for a car to be replaced: 1) how much energy is necessary to operate and to manufacture and 2) the fuel economy improvement per year.

This focal point is very relevant, because it reveals more information about the discussion to what extent car scrappage policy programs are desirable from the environmental perspective and why the Circular Economy perspective is so important. As indicated by Van Wee, De Jong and Nijland (2011, p.554), there will always be a day on which a car ends up in scrappage. However, it makes sense to study whether car scrappage policy programs really lead to cars ending up in scrappage earlier than without such a policy program. And, if being the case, if this is truly desirable from the environmental perspective.

Correlating with finding such an optimal age is the easiness in which cars can be recycled. As Genovese et al. (2017, pp.354-355) make clear; the Circular Economy is not only about stopping the taking, making, consuming and disposing economy, but also about the creation of products and production systems that can be easily used over and over again. Therefore, a well functioning supply chain system is crucial. Krausmann et al. (2017, pp.5-6), who study the total physical economy and the reductions of material and energy use, highlight the importance of efficient product design. Therefore, besides delving into the study for an optimal age for car scrappage, the complete production system of cars is of interest with respect to the Circular Economy perspective.

2.1.3 The Dutch 2009 Car Scrappage Policy Program

This third and last subsection within the literature review will be an elaboration on the Dutch 2009 Car Scrappage Policy Program (as explained, the X in the analysis). I will study this car scrappage policy program in order to derive general conclusions in answering the research question.

The Dutch 2009 Car Scrappage Policy Program ran from May 29, 2009, until April 21, 2010. The objective of the policy was to '*to contribute to the improvement of air quality in the Netherlands by dismantling old environmentally unfriendly passenger cars and stimulating the purchase, as a replacement, of cars with a lower emission of environmental pollutants*' (Tijdelijke slooppregeling personen- en bestelauto's, 2009, Article 1.2). Moreover, the Minister of Housing, Spatial Planning and the Environment (Minister van Volkshuivesting, Ruimtelijke Ordening en Milieubeheer, 2009) declared that the car scrappage policy program had the objective to support the Dutch car industry in the economic downturn those years. A total amount of 85 million euro's had been made available, of which 65 million euro's by the Dutch government and 20 million euro's by Autorecycling Nederland, a Dutch fund created by the Dutch car industry (Minister van Volkshuivesting, Ruimtelijke Ordening en Milieubeheer, 2009). The original plan was to continue the policy program until the end of 2011; however, by April 2010 the policy program was already exhausted (Minister van Volkshuivesting, Ruimtelijke Ordening en Milieubeheer, 2009). This shortening of the policy program can have affected the choices consumers were about to make. These choices and effects will be discussed in subsection 2.2.1 and subsection 3.1.

For a car to be eligible for the Dutch 2009 Car Scrappage Policy Program, the following criteria held (Tijdelijke slooppregeling personen- en bestelauto's, 2009, Article 2.2):

1. Only gasoline and autogas (LPG) cars built before January 1, 1996, and diesel cars built before January 1, 2000 could apply for the subsidy;

2. The car had to be in possession of the current owner before March 1, 2008. This criterion is quite general along car scrappage policy programs in order to prevent car dealers or car importers misusing the policy program (Van Wee, De Jong and Nijland (2011, p.553).

The policy program only applied to passenger cars and small cargo vans. The amount of subsidy a car-owner of an eligible car could obtain depended on the characteristics of the car (Tijdelijke sloopregeling personen- en bestelauto's, 2009, Article 2.5). Characteristics like age, fuel and building year were crucial factors determining the residual value of a car, which in turn determined the amount of the subsidy. The next distinction has been made (Tijdelijke sloopregeling personen- en bestelauto's, 2009, Article 2.5):

Category	***Fuel***	***Building year***	***Subsidy***
Car	Gasoline	<1990	750
		1990-1995	1.000
	LPG	<1990	750
		1990-1995	1.000
	Diesel	<2000	1.000
Van	Gasoline	<1990	750
		1990-1995	1.000
	LPG	<1990	750
		1990-1995	1.000
	Diesel (weight <1800kg)	<2000	1.000
	Diesel (weight >1800kg)	<2000	1.750

Table 1: Amount of subsidy per category (Tijdelijke sloopregeling personen- en bestelauto's, 2009, Article 2.5)

As can be withdrawn from Table 1, replacing heavy diesel vans is most lucrative: the subsidy is 1.750 euros. For all other cars and vans, the subsidy is 750 or 1.000 euros. The municipalities of The Hague and Amsterdam decided to extend on the national policy program by making an additional subsidy available via a local car scrappage policy program (Minister van Volkshuivesting, Ruimtelijke Ordening en Milieubeheer, 2009).

After receiving the subsidy, the car or van owner had the obligation to replace its scrapped car or van (in what follows I use the word car for cars as well as vans). The replacing car had to be a car with gasoline or LPG as fuel with a building year after December 30, 2000 or a car with diesel as fuel with a maximum emission of particular matter by 5 milligram per kilometer (Tijdelijke sloopregeling personen- en bestelauto's, 2009, Article 2.3). In addition, the replacing car could have also been electric-, CNG- or hydrogen-powered (Tijdelijke sloopregeling personen- en bestelauto's, 2009, Article 2.3). As a matter of fact, the replacing car was not necessarily a new car (Tijdelijke sloopregeling personen- en bestelauto's, 2009, Article 2.3).

As described, the Dutch 2009 Car Scrappage Policy Program ended on April 21, 2010. Huizinga, Minister of Housing, Spatial Planning and the Environment in 2010, called the policy program very successful: in total, 80.000 cars had been replaced through the policy program (Van Keken, 2010). Therefore, according to Minister Huizinga, the policy program had contributed to a better air quality and it had stimulated the sale of cars (Van Keken, 2010).

Despite of the fact that the Dutch government was very positive about the results of the car scrappage policy program, there were also critiques. For example, PBL questioned to what extent the policy program had been successful with respect to the environment. Calculations of PBL showed that minimally 40.000 of the 80.000 cars would have ended up in scrappage in a very short term even if the policy program had not existed (Van Keken, 2010). In addition, other political parties were critical. These parties confirmed the increase of car sales, and therefore did not see reason to reintroduce the policy program at that moment (Van Keken, 2010).

In this subsection, I have studied current literature with respect to car scrappage policy programs in general, the perspective of the Circular Economy concerning these policy programs and I elaborated on the Dutch 2009 Car Scrappage Policy Program. Now, I am able to elaborate on the hypotheses of this research using this review as base.

2.2 Hypotheses

In subsection 2.1, I showed that research is not unambiguously clear about the effectiveness of car scrappage policy programs. In this research, I will study the effects of the Dutch 2009 Car Scrappage Policy Program in order to derive new conclusions about the effectiveness of such programs in general. In order to derive these new conclusions, I will formulate three hypotheses. I will explain these separately in subsections 2.2.1-2.2.3.

2.2.1 Hypothesis I: Replacement rates of replaced cars

In this subsection, I will elaborate on the first hypothesis: hypothesis I. Hypothesis I addresses the effect of the Dutch 2009 Car Scrappage Policy Program on the total replacement of cars before, during and after the policy program.

A car replacement takes place when an ownership registration of a car ends because of:

- The sale on the second-hand market;
- Exportation;
- Scrappage.

In the case of a car replacement by the sale on the second-hand market, the car being replaced remains existent in the Dutch car fleet. In both other cases, the car being replaced disappears from the Dutch car fleet. By either one of these three expirations of car ownership, a car can be ‘replaced’ by another car or can be simply discarded. In case of replacing, the replacing car can be a new car or a car of the second-hand market. In this research, the focus lays on the car being replaced or discarded, for which from now I will simply use the term replacement. I will measure the effect of the Dutch 2009 Car Scrappage Policy Program on the total replacement, which I will define as the total amount of cars being sold on the second-hand market, being exported or being scrapped. I will study whether the total overall replacement of cars eligible for the policy program will follow a different trend during the policy program than the total replacement of cars ineligible for the policy program. In other words, I study whether a volume effect in total replacement is visible. Thereto, I use replacement rates. Replacement rates are defined as the total number of replacements over the number of Dutch ownership registration spells that are active at the start of the time period being studied.

Using this definition for replacement rates, hypothesis I reads:

H_0:

'The replacement rate of cars eligible for the Dutch 2009 Car Scrappage Policy Program will follow the same trend during the policy program as the replacement rate of cars ineligible for the Dutch 2009 Car Scrappage Policy Program'.

H_1:

'The replacement rate of cars eligible for the Dutch 2009 Car Scrappage Policy Program will follow a different trend during the policy program than the replacement rate of cars ineligible for the Dutch 2009 Car Scrappage Policy Program'.

The methodology used to conduct the analysis of this hypothesis and the analysis itself will be presented in section 4. I will describe hypothesis II and hypothesis III in the following subsections.

2.2.2 Hypothesis II: Ratio of replaced cars

As described in subsection 2.2.1, for hypothesis I, I will study the total overall replacement rates. In other words, I research to what extent the Dutch 2009 Car Scrappage Policy Program has a volume effect on the total overall replacement rates. For hypothesis II, I will use a different perspective. Here, I will study composition effects of the policy program on the overall replaced cars. Thereto, I will make use of ratios. I will define the ratio I make use of as the total amount of cars scrapped over the total amount of cars scrapped and exported. Hence, I will research whether there are visible trends regarding different replacement options. My focus is on cars that will not be existent in the Dutch car fleet after replacement anymore. In other words, I will only focus on cars being replaced through scrappage and exportation.

Using this definition for the ratio I study, hypothesis II reads:

H_0:

'The ratio of cars eligible for the Dutch 2009 Car Scrappage Policy Program will follow the same trend during the policy program as the ratio of cars ineligible for the Dutch 2009 Car Scrappage Policy Program'.

H_1:

'The ratio of cars eligible for the Dutch 2009 Car Scrappage Policy Program will follow a different trend during the policy program than the ratio of cars ineligible for the Dutch 2009 Car Scrappage Policy Program'.

The methodology used to conduct the analysis of this hypothesis and the analysis itself will be presented in section 5. First, I will describe hypothesis III in the following subsection.

2.2.3 Hypothesis III: The Circular Economy perspective

For hypothesis III, I will extend my focus on the scrapped cars being studied. I will research the characteristics of the scrapped cars in order to study the Circular Economy perspective on car scrappage policy programs as elaborated on in subsection 2.1.2.

As it turned out in current literature, from the perspective of the Circular Economy it would be ideal and be the focal point to find an optimal age for a car to be scrapped. I discussed the factors that might be of influence to find such an optimal age in subsection 2.1.2. Research about optimal ages to scrap cars is still in its infancy and would ask a very elaborative framework accounting for all differing characteristics between cars. As a matter of fact, it would be beyond the scope of this research to find such an optimal age. Therefore, instead, I will focus on factors on which the optimal age is based. Two interesting characteristics of cars presented in the dataset being studied in this research, can have an additional value on the current state of the art: the fuel economy and the emissions of CO_2.

Firstly, the dataset that I will use lends itself to study one factor determining the optimal age of cars to be scrapped that is in line with research by Van Den Brink and Van Wee: the fuel economy (2001, p.82). Despite of the fact that fuel economy alone does not determine such an optimal age, from the Circular Economy perspective it is an interesting characteristic of cars to study. From an environmental perspective, it can be assumed that it is preferable to scrap cars with a high fuel economy before scrapping cars with a low fuel economy (the higher the fuel economy, the more fuel is necessary to drive an X number of kilometers). However, there is a certain 'trade-off'. Is scrappage always a legitimate choice, as long as cars with a high fuel economy are scrapped first? From a Circular Economy perspective, it might be desirable to not scrap cars with a 'somewhat lower' fuel economy, because scrappage and the production of a new car to replace the old car might contribute relatively more to the total emissions than the old car remaining to be existent. It is interesting to know whether the Dutch 2009 Car Scrappage Policy Program has an influence on the distribution of the fuel economies of the cars being scrapped.

Secondly, the dataset that I will use lends itself to elaborate on another factor determining the optimal age of cars to be scrapped: the emissions. From an environmental perspective, it can be assumed that it is preferred to scrap cars contributing to a larger extent to the total emissions before cars contributing to a lower extent. However, as is the case for fuel economy, also here there is a 'trade-off' from the Circular Economy perspective. For example, it might be possible to renew cars by adding pollution-control equipment, through which scrappage and the production of a new car to replace the old car might contribute relatively more to the total emissions than the old car being renewed. Therefore, also for this case, it is interesting to know whether the Dutch 2009 Car Scrappage Policy Program has an influence on the distribution of the emissions of the cars being scrapped.

Based on these two factors influencing the optimal age for car scrappage, it is interesting to know which cars Dutch 2009 Car Scrappage Policy Program attracts. Does the policy program lead to relatively more or relatively less scrappage of cars that would have been desirable to scrap from the Circular Economy perspective? In order to study this perspective, I will make use of scrappage rates. I created a categorical variable that divides the total Dutch car fleet into four classes of car fuel economy and a categorical variable that divides the total Dutch car fleet into four classes of car emissions. This division is based on creating classes with more or less the same number of observations, which will be elaborated on in section 3. For every class, I will calculate the scrappage rate, which I define as the total amount of cars scrapped over the total amount of cars within the class per time period. I will study to what extent the distribution of scrappage rates changes regarding the fuel economy and the emissions over all twelve time periods studied. This will be done for eligible and ineligible cars for the Dutch 2009 Car Scrappage Policy Program.

Hypothesis III reads:

H_0:

'Regarding the fuel economy and emissions, the distribution of scrappage rates for eligible cars for the Dutch 2009 Car Scrappage Policy Program will follow the same trend during the

policy program as the distribution of the scrappage rates of cars ineligible for the policy program'.

H_1:

'Regarding the fuel economy and emissions, the distribution of scrappage rates for eligible cars for the Dutch 2009 Car Scrappage Policy Program will follow a different trend during the policy program than the distribution of the scrappage rates of cars ineligible for the policy program'.

The methodology used to conduct the analysis of this hypothesis and the analysis itself will be presented in section 6. First, I will move on to the data statistics in the following section.

3 Data Statistics

In this section, I will elaborate on the data statistics of this research. Therefore, I will firstly depict the data being used in subsection 3.1. I will describe the dataset and elucidate the most important features of this dataset. Thereafter, in subsection 3.2, I will explain how I manipulated the data in order to be able to analyze the three hypotheses. I will use graphs and tables to illustrate all relevant information.

3.1 The dataset

In order to analyze the hypotheses, I will use a very extensive anonymous dataset provided by The Netherlands Environmental Assessment Agency (PBL). The PBL is the Dutch national institute for strategic policy analysis in the field of environment, nature and space (PBL, 2019). PBL uses data from the Netherlands Vehicle Authority (RDW) that covers all vehicles circulating in the Netherlands in the period 2008-2017. PBL merged three RDW-datasets on vehicle characteristics, ownership registration history and special replacement status (as discussed in subsection 2.2.1: scrappage, exportation and sale on the second-hand market) of vehicles for the period 2008-2017, with a dataset from the Netherlands Enterprise Agency (RVO) containing all vehicles that participated in the Dutch 2009 Car Scrappage Policy Program. As the car scrappage policy program only applied to passenger cars and small cargo vans as shown in subsection 2.1.3, PBL removed the data on other vehicles from the datasets. In addition, PBL removed company stock registration spells from the registration data as the policy program only applied to active owner registrations by natural and juridical persons. Finally, for all periods, the active registrations of cars that are less than five years old have been removed, such that for every period at least five years old cars are included. Here, the assumption is that for cars younger than five years old, the owners' replacement decision will typically not lead to scrappage. This results in a rough dataset of 5.495.831 observations of vehicles.

For most of these observations, many interesting characteristics are included in the dataset. The following figures and table illustrate most important characteristics:

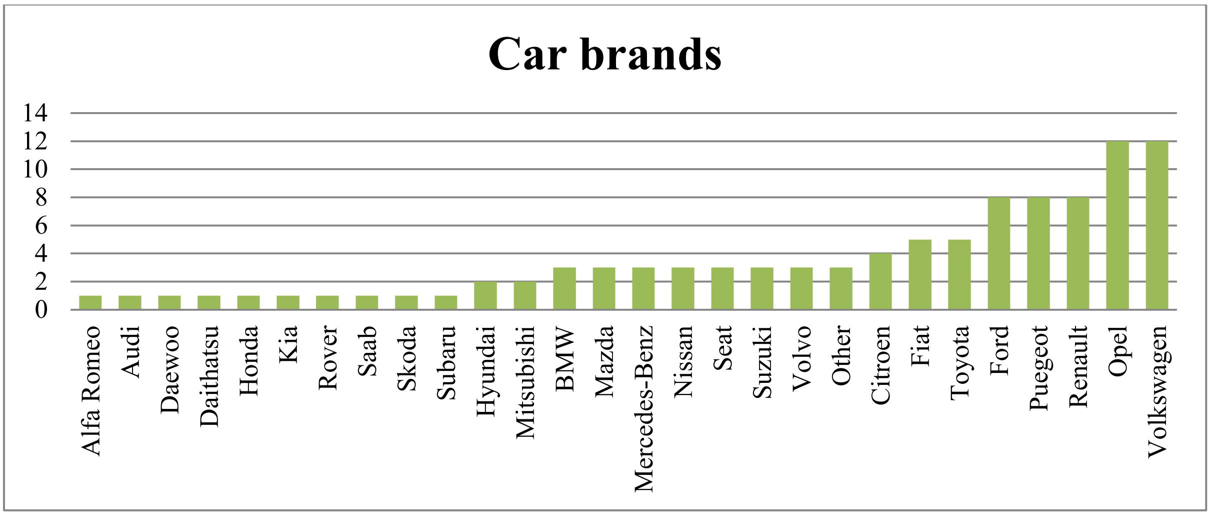

Figure 2: Share of car brands

	Term	*Mean*	*Standard deviation*
Curb weight vehicle	Kg	1.100	304
Motor power	HP	68	27
Emission NO_x	g/km	0,15	0,25
Emission HC NO_x	g/km	0,32	0,24
Emission CO_2	g/km	173	34
Fuel economy	L/100km	7,2	1,43

Table 2: Means and standard deviations for all cars concerning the curb weight vehicle, motor power, emission NO_x, emission HC NO_x, emission CO_2 and the fuel economy

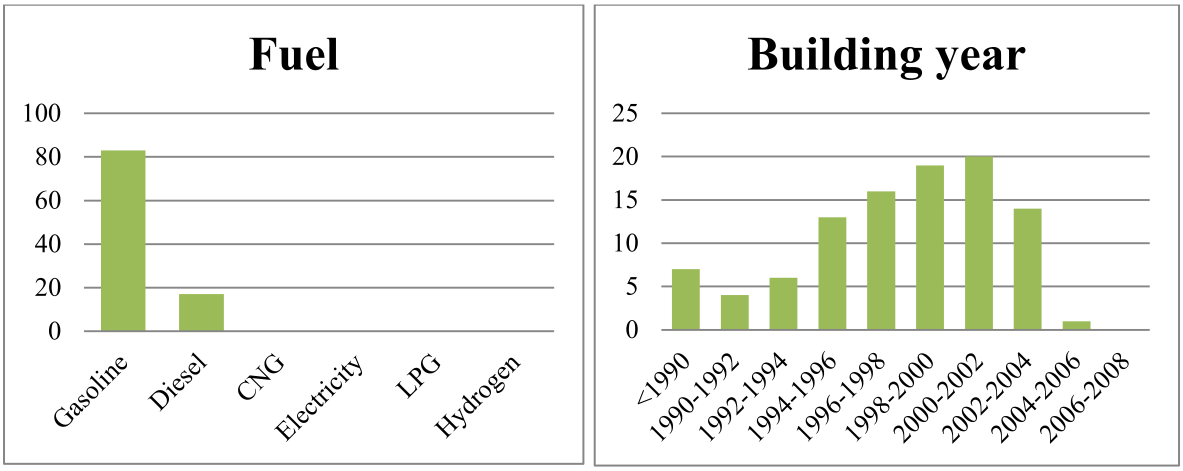

Figure 3: Share of fuel and building year for all cars

Figure 2 shows the share of car brands within the dataset with at least a 1% share. It can be observed in this figure that Volkswagen, Opel, Renault, Peugeot and Ford represent almost 50% of all car brands. Table 2 shows for all cars the mean and standard deviation (corrected for outliers) for the curb weight, the motor power, the emissions of NO_X, the emissions of HC NO_X, the emissions of CO_2 and the fuel economy. Figure 3 illustrates that most cars in the dataset are gasoline-powered. For CNG, electricity, LPG and hydrogen almost no cars are reported. With respect to the building year of the cars, it can be seen that most cars are built in the years 1996-2002 (which is also due to the fact that active registrations of cars that are less than five years old have been removed).

Having clarified general information about the dataset and the car characteristics, I will move to the information on replacement statuses. In subsection 2.2.1, I defined a replacement rate as the total number of replacements over the number of Dutch ownership registration spells that are active at the start of the time period being studied. More specifically, I defined a replacement as an ownership registration of a particular vehicle by a natural or juridical person that ended on date X and thereby i) being discarded or ii) being followed by a subsequent ownership registration of another vehicle by the same natural or juridical person that has started within 31 days after X. As presented in subsection 2.1.3, the Dutch 2009 Car Scrappage Policy Program ran from May 29, 2009, until April 21, 2010. The data being studied is an aggregation of observations by PBL over twelve time periods of three months. The fifth period spans from May 29, 2009 until Augustus 29, 2009. Therefore, the fifth period is the first period in the dataset in which the Dutch 2009 Car Scrappage Policy Program held. The first period starts one year earlier on May 29, 2008 and the ninth period begins one year later on May 29, 2010. Replacements rates are thus calculated for four within time periods before (time period 1, 2, 3 and 4), four within time periods during (time period 5, 6, 7 and 8) and four within time periods after (time period 9, 10, 11 and 12) the policy program.

For the 5.495.831 vehicles in this rough dataset, there is anonymous information on the date of registration and, if applicable, deregistration of the cars. On the base of that information, there are dummy variables included (1 if applicable, 0 otherwise) to assess whether a car was registered during a time period as described above. Moreover, there are dummy variables included to show whether a car was eligible for the Dutch 2009 Car Scrappage Policy Program, how a car have been replaced if replaced (scrappage, exportation or sale on the second-hand market) and whether a car participated in the Dutch 2009 Car Scrappage Policy

Program. By tabulating these dummies, 1.696.878 cars are being scrapped, exported or sold on the second-hand market in total during the twelve time periods of study. For 1.459.209 cars there is a replacing car registered. In other words, for 237.669 cars there is no replacing car; the car has been discarded. In the following figure, I show the total quantity of cars replaced per period and the average total cars replaced. I show how many cars have been replaced by scrappage, exportation or sale on the second-hand market and how many cars have been discarded:

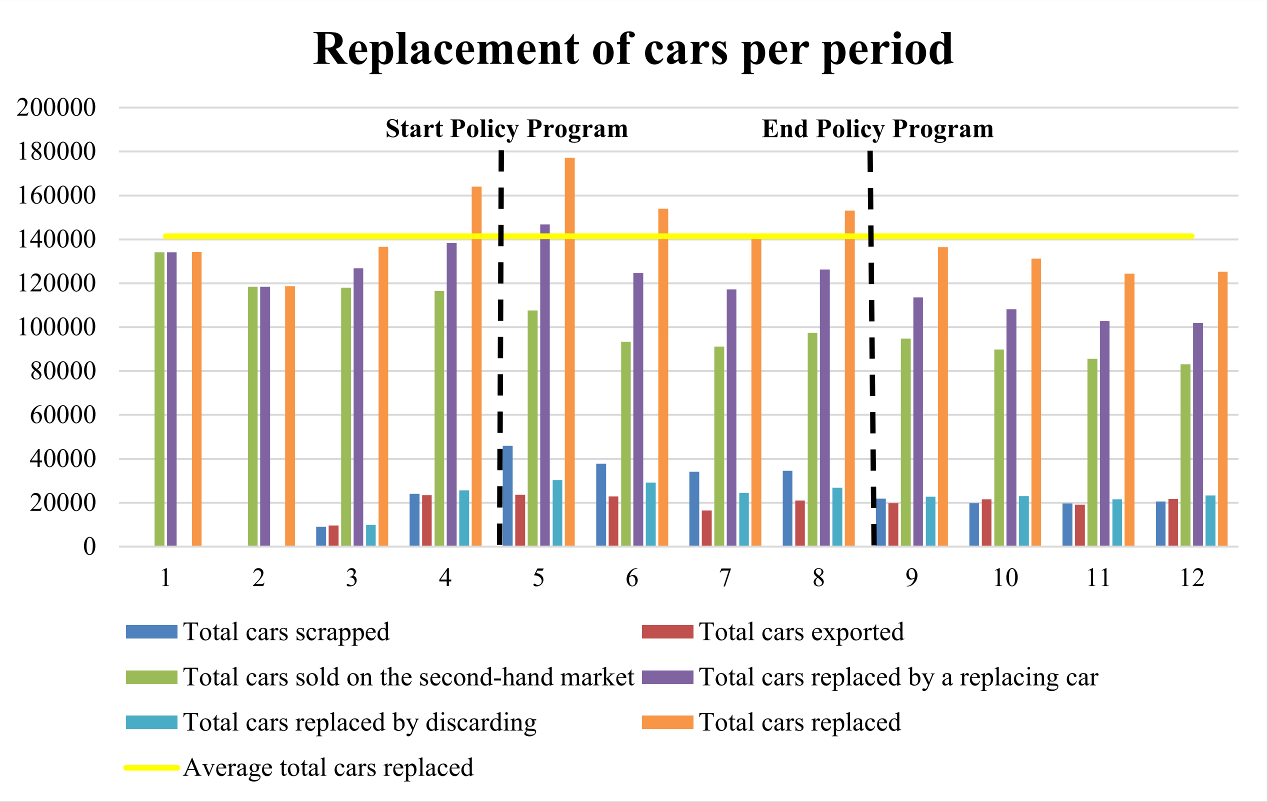

Figure 4: Replacement rates of the cars studied per period

In figure 4, it can be seen that, roughly speaking, for every period the total cars being replaced by discarding is only small fraction of all cars being replaced. With respect to the replacement options, the sale on the second-hand market is the most often used one, but decreases somewhat over time. It is also visible that, as mentioned above, the total replacement of cars is between 115.000 and 175.000 cars per period, with an average of circa 140.000. Already a small indication of the effects of the Dutch 2009 Car Scrappage Policy Program can be observed. Not only the total amount of cars replaced during time periods 5, 6, 7 and 8 is higher than in other periods, also the total amount of cars being scrapped is higher; the time periods in which the policy program held. This observation will be discussed in sections 4-6. Another clear observation is that for periods 1 and 2 almost all cars being replaced are replaced through the sale on the second-hand market. This appears to be missing information with respect to the type of replacement. PBL clarifies that for these two periods almost all replaced cars have been registered as being replaced through the sale on the second-hand market, because of missing information about scrappage and exportation. Therefore, in the rest of the research, while not discarding the first two periods immediately, the focus will be on the other ten time periods, for which there is no missing data.

In total, 73.753 cars have been replaced by scrappage by making use of the Dutch 2009 Car Scrappage Policy Program. The following figure shows these cars per time period:

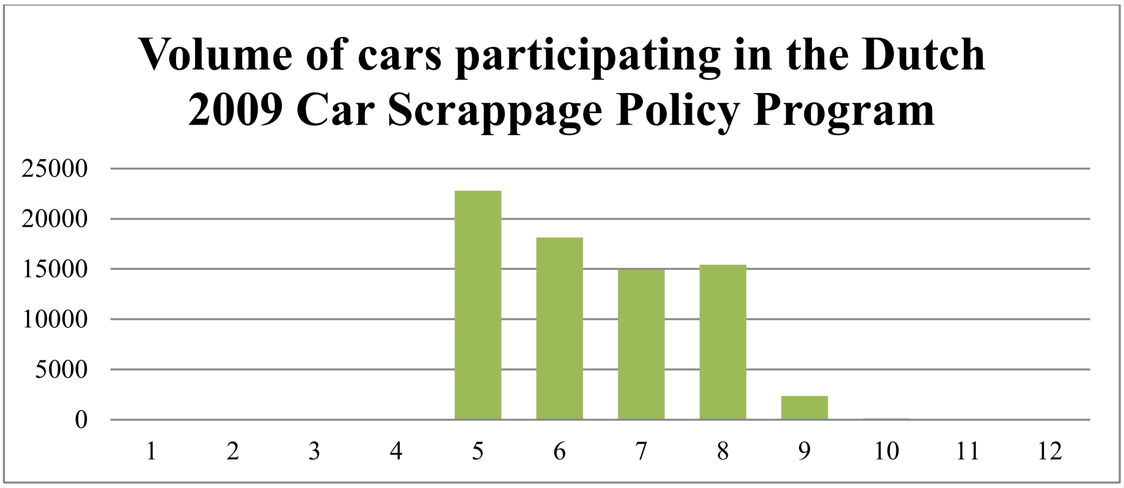

Figure 5: Volume of cars being scrapped in the policy program

As can be withdrawn from figure 5, not surprisingly, no cars ended up in the policy program during the first four periods. This is simply because of the fact that the policy program still not existed in those four time periods. From the existence of the policy program on in period 5, it has been used extensively. Most car-owners used the policy program during the first period. It can be assumed that this period has attracted most cars because of car-owners waiting for the policy program to start after the announcement. In the three periods thereafter the program remained being used, but to a lower extent. In the 8th period, the policy program stopped to exist. In period 9, 10 and 11, there are still some cars being replaced by making use of the policy program. This is possible if arrangements between car-owners and car scrappage companies have been made during the policy program, whereas the execution took place after the policy program. Moreover, as explained in subsection 2.1.3, the policy program stopped earlier than planned. Therefore, consumers who might have wanted to make use of the policy program later in time might have chosen to scrap their cars earlier than planned in order to be able to make use of the policy program. For that reason, it comes at no surprise that for period 9 still many cars are being scrapped via the policy program. As expected, a sharp decline is visible from that period onwards.

In the next figure, I show for period 5, 6, 7, 8 the total volume of cars eligible for the Dutch 2009 Car Scrappage Policy Program, the total volume of cars replaced, the total volume of cars scrapped, the total volume of eligible cars scrapped and the total volume of cars participating in the policy program:

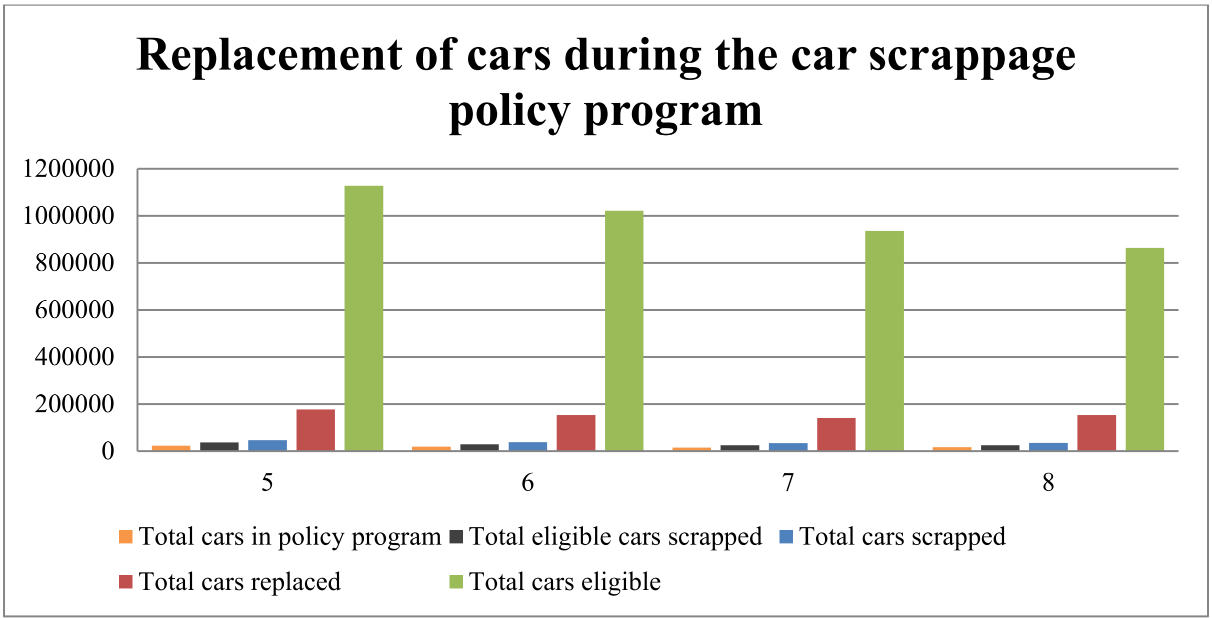

Figure 6: Overview of all cars replaced during the Dutch 2009 Car Scrappage Policy Program

Figure 6 displays interesting rough figures about the Dutch 2009 Car Scrappage Policy Program. The first striking result is that only a very small fraction (about 2% for every time period) of total cars eligible for the policy program makes use of the policy program (comparing the first and the last column of every time period). Comparing the third and the fourth column of every period, 20-25% of all replaced cars are replaced though scrappage (as was also visible in figure 4). This seems not to be that much. However, comparing with the other periods in figure 4, relatively more cars are scrapped during the policy program than before or after. Another interesting feature in figure 6 is that, roughly speaking, only 50% of all cars being scrapped during the policy program made use of the policy program (comparing the first and the third column of every time period). For every period during the policy program there are even 30%-40% of cars being scrapped and being eligible for the policy program, while not making use of the policy program (comparing the first and the second column for every time period). This is a surprising result, since economic theory would suggest that a rational consumer would always maximize its utility and therefore would choose to make use of the policy program and obtain a subsidy.

In the next subsection, I will discuss how I manipulated the dataset in order to make it usable for the analyses.

3.2 Manipulations of the dataset

In this subsection I will describe how the dataset offered by PBL will be manipulated in order to be able to analyze the three different hypotheses.

As explained in subsection 2.1.3, the population being studied in this research is the total amount of cars circulating in the Netherlands in the period close to and during the Dutch 2009 Car Scrappage Policy Program. For all three hypotheses, I study those cars eligible for the policy program as the treatment group and those cars being ineligible for the policy program as the control group. By definition, only owners of eligible vehicles 'received' the treatment, in the sense that the policy program only applies to these owners. It can be assumed that aside from seasonal effects, time-varying confounding factors (such as other policy changes or economic situations) affected replacement rates for eligible and ineligible cars similarly within these three years.

In this research, the unit of analysis will not be the micro-level of individual cars. As a matter of fact, I will make use of baskets of cars with similar characteristics as the units of analysis. For example, as will become clear later on, I will compare a basket of 17-years old gasoline cars eligible for the Dutch 2009 Car Scrappage Policy Program with a basket of 17-years old gasoline cars ineligible for the policy program over time. Therefore, the focus will be on baskets of cars rather than individual cars. For all hypotheses, I will study at least two ‘large’ baskets, which are a basket of cars eligible for the Dutch 2009 Car Scrappage Policy Program and a basket of cars ineligible for the policy program. Therefore, as described in subsection 2.1.3, the treatment group is the basket of eligible cars for the Dutch 2009 Car Scrappage Policy Program, whereas the control group is the basket of ineligible cars for the policy program. Depending on the hypothesis, I will divide the dataset further in several ‘smaller’ baskets. I will explain these divisions per hypothesis later on.

The division of baskets concerning eligibility depends on the building year of the car and the date of registration, as elaborated on in subsection 2.1.3. To know to which basket an individual car belongs, I needed to create a variable to assess whether a car could be eligible for the car scrappage policy program. In order to create this variable, the following available data has been used and manipulated:

- In order to fulfill the criterion with respect to the building year of the car, the variable ‘primary fuel’ and ‘first date of existence’<‘X’ have been used. Along the different criteria for the different fuels and along the different time periods (all possible X’s) as explained in subsection 3.1, the first criterion regarding the building year to assess the eligibility of baskets of cars have been created;
- In order to fulfill the criterion with respect to ownership, I have used the variable ‘eligibility_X==1’. Here, the length of the ownerships spell becomes clear. X represents whether along the different time periods an individual car is eligible with respect to the ownership criterion. An important underlying dummy has been used to assess whether the car has been registered for all time periods separately. For every period, the dummy dummy_period_X, whereby period_X can vary from 1 to 12, shows if an individual car was registered during that period. This dummy is based on the date of registration, which needs to lay before the start of the period of study, and the date of deregistration, which has to lay after the end of the period of study.

Combining these two data manipulations, I have been able to create a treatment group of a basket of cars eligible for the Dutch 2009 Car Scrappage Policy Program and a control group of a basket of cars ineligible for the policy program. This combination, which has been called ‘eligibility’, will be represented as a dummy variable, whereby 1 means that the basket of cars is eligible and 0 means that the basket of cars is ineligible.

Besides dividing the whole dataset in two baskets of eligible and ineligible individual cars, for hypothesis I, I will further divide the dataset in more baskets. I created a panel dataset of sixteen baskets. The two categories of eligible and ineligible cars for the Dutch 2009 Car Scrappage Policy Program as described in subsection 3.2.1 are further subdivided in fuel and building year. The category of fuel has been subdivided in gasoline and diesel. I decided to focus on these two fuels and to discard other fuels, because most cars were gasoline- and diesel-powered (as concluded in subsection 3.1). Then, a further subdivision will be made, through studying four different age-categories of cars. For gasoline, I took the age of 19, 18, 17 and 16 years old. These ages are not arbitrarily taken; I took four ages that are minimally necessary in order to make a car eligible for the policy program during all periods being studied. I did the same for diesel-powered cars. Because of the fact that in the case of diesel-powered cars younger cars can be eligible for the policy program, I took the age of 15, 14, 13 and 12 years old. By using these ages, all baskets of cars (gasoline as well as diesel) fulfill one of the two conditions of being eligible for the policy program: the building year. Therefore, the difference in eligible and ineligible cars lays in the criterion of ownership. For all baskets, the ownership criterion will decide whether the basket consists of eligible or ineligible cars for the policy program. In total, this results in a panel dataset of 16 observations (baskets of cars).

With these 16 observations in the panel data for hypothesis I, there is only one step left to be able to move to the methodology sections: shifting the eligibility criteria over time to be able to compare the baskets of similar characteristics. As I already mentioned shortly in the introduction, I will conduct a difference-in-difference analysis. Therefore, it is necessary to fulfill the common trends assumption (Angrist and Pischke, 2015, p.178). As described in subsection 3.1, I will study four periods of three months each before the policy program, during the policy program and after the policy program. Thus, in order to make these similar eligible and ineligible baskets, the cut-off points to be eligible are:

- ❖ The year before the policy program: January 1, 1995 for gasoline and LPG, January 1, 1999 for diesel and March 1, 2007 for ownership;
- ❖ The year after the policy program: January 1, 1997 for gasoline and LPG, January 1, 2001 for diesel and March 1, 2009 for ownership.

In other words, shifting the eligibility criteria makes it possible to analyze the replacement rates of baskets of cars before and after the policy program as if the policy program would have existed in those years with the same eligibility criteria. Thereto, it has become possible to use the difference-in-difference method for hypothesis I. Now, I can assume that I have ruled out any differences between the treatment and control group other than caused by the treatment.

To follow the shifting criteria over time, the explained dummy ‘eligibility’ has been adjusted for the three different years, in order to make distinction between:

- ❖ A dummy to assess whether a car was eligible the year before the policy program, would the policy program have been applied that year ('eligibility one year earlier');
- ❖ A dummy to assess whether a car was eligible during the year of the policy program ('eligibility during');
- ❖ A dummy to assess whether a car was eligible the year after the policy program, would the policy program have been applied that year ('eligibility one year later').

As explained in subsection 2.2.1, for hypothesis I the focus will be on the total overall replacement rates of eligible and ineligible cars for the Dutch 2009 Car Scrappage Policy Program. I will research to what extent the policy program causes a volume effect of the total overall replacement rate. For all 16 baskets of cars in the panel data, I calculated two forms of replacement rates:

1. Narrow replacement rates. These replacement rates display for every time period and per basket the total amount of scrapped and exported cars over the number of Dutch ownership registration spells that are active at the start of a certain time period;
2. Broad replacement rates. These replacement rates display for every time period and per basket the total amount of scrapped and exported cars plus the cars sold at the second-hand market over the number of Dutch ownership registration spells that are active at the start of a certain time period.

I made these two categories in order to be able to make a distinction between cars being discarded from the Dutch car fleet (scrappage and exportation; narrow) and all cars being replaced (scrappage, exportation and sale on the second-hand market; broad).

In figure 7, I present all replacement rates over the twelve time periods of the sixteen researched baskets of cars. Starting in the upper left quadrant, I show the narrow replacement rates of all studied baskets of eligible cars for the Dutch 2009 Car Scrappage Policy Program over time. In the upper right quadrant, I present the narrow replacement rates of all studied baskets of ineligible cars for the policy program over time. In the lower left quadrant, I illustrate the broad replacement rates of all studied baskets of eligible cars for the policy program over time. In the lower right quadrant, I present the broad replacement rates of all studied baskets of ineligible cars for the policy program over time. Much interesting findings can be withdrawn from figure 7. I will elaborate on these findings one by one.

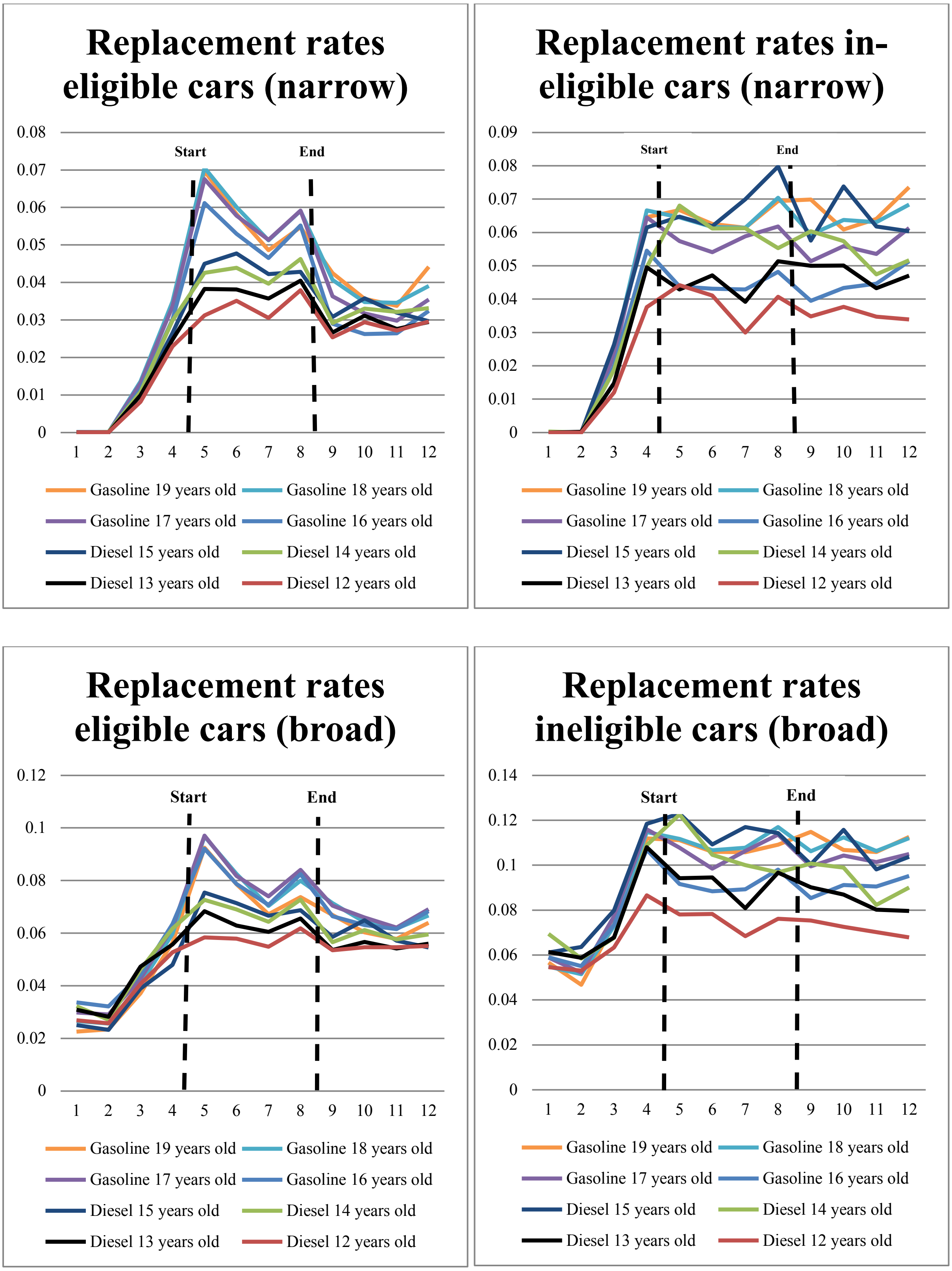

Figure 7: Overview of the broad and narrow replacement rates of eight baskets of cars (in)eligible for the Dutch 2009 Car Scrappage Policy Program

First of all, as clarified in subsection 3.1, figure 7 shows that for time periods 1 and 2 it can indeed be withdrawn that almost all replacement options have been reported as replacement through sale on the second-hand market. For the narrow replacement rates, for as well as the baskets of eligible cars as the baskets of ineligible cars, there is no replacement visible: this follows logically the definition of narrow replacement rates by not including replacement by sale on the second-hand market. This is different for the broad replacement rates: here time period 1 and period 2 show positive replacement rates. This also logically follows the definition for broad replacement rates by including sale on the second-hand market.

Despite of the fact that for time periods 1 and 2 many car replacements by scrappage and exportation have been reported as replacements by sale on the second-hand market, for the first two periods the broad replacement rates still seem to be low when comparing them with the other periods. In general, for all baskets of cars, the broad replacement rates seem to show a huge increase from period 2 to 3. By carefully researching the nominators and denominators determining the broad replacement rates of all studied baskets of cars over time, it appears to be the nominator that differs largely for many studied baskets of cars between time periods 1 and 2 and the other time periods. This gives reason to believe that for time periods 1 and 2 there might not have been reported car replacements by scrappage and exportation as replacements by sale on the second-hand market only, but also that there are replacements missing. Therefore, in order to play it safe and to prevent withdrawing possibly wrong conclusions, time periods 1 and 2 will be discarded for the difference-in-difference analysis.

Secondly, figure 7 shows a rough indication for a different trend for the replacement rates of baskets of eligible cars for the Dutch 2009 Car Scrappage Policy Program during the policy program in comparison to the time periods before and after the policy program. It also shows that this different trend does not hold for the replacement rates of ineligible cars over time. In the left quadrants, it becomes clear that most baskets of cars reflect a large spike in period 5. The right quadrants show that for ineligible baskets of cars there are, in general, no huge spikes. For most baskets of cars for as well as narrow as broad replacement rates in the case of ineligibility, time periods 4-12 do not evidently show differences over time. For those baskets, a rough constant trend is visible. With the knowledge that period 5 is the period in which the Dutch 2009 Car Scrappage Policy Program started, and with the knowledge that the treatment group and the control group only differ in eligibility for the policy program, figure 7 shows a rough indication for the influence of this policy program.

Thirdly, figure 7 shows that as well as for the narrow replacement rates as for the broad replacement rates for most baskets of eligible cars, the spike of period 5 flattens somewhat during the remaining periods of the policy program. Then, again, when the policy program is about to end in time period 8, a moderate spike is visible for most baskets of eligible cars. Then, for both replacement rates, a notable decrease starts in period 8 for most baskets of eligible cars. Also here a difference between the trends for eligible and ineligible cars can be seen. Whereas in the case of the baskets of eligible cars an obvious trend influenced by an external factor can be observed around period 8, this does not hold for the baskets of ineligible cars. The overall replacement rates of ineligible cars again seem to be quite constant over time. With the knowledge that period 8 is the period in which the Dutch 2009 Car Scrappage Policy Program has ended, and with the mentioned knowledge that the treatment group and the control group only differ in eligibility for the policy program, figure 7 again shows a rough indication for the influence of this policy program.

Then, in figure 8 and figure 9, I will zoom in into two randomly chosen specific baskets of cars eligible as well as ineligible for the Dutch 2009 Car Scrappage Policy Program: the basket of gasoline 18-years old cars and the basket of diesel 14-years old cars. By putting the same basket of eligible and ineligible cars in the same graph, I am able to show the difference between one specific treatment and control group. Thereto, the difference-in-difference over time becomes clear. Figure 8 and 9 will show the broad replacement rates of these baskets:

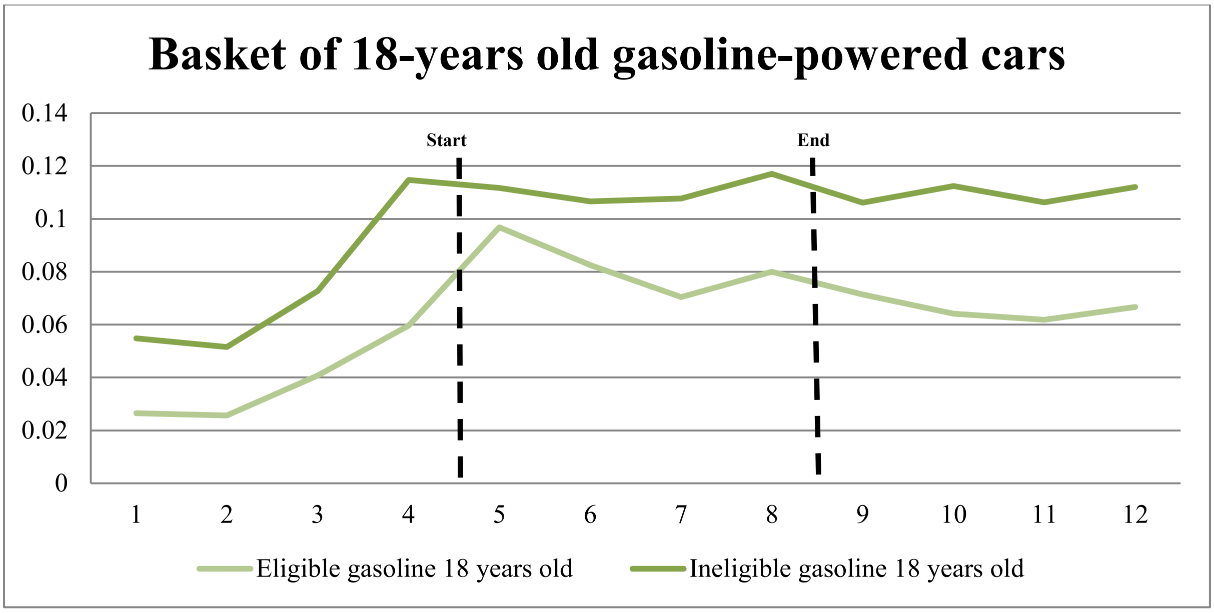

Figure 8: Difference-in-difference for the basket of 18-years old gasoline-powered cars

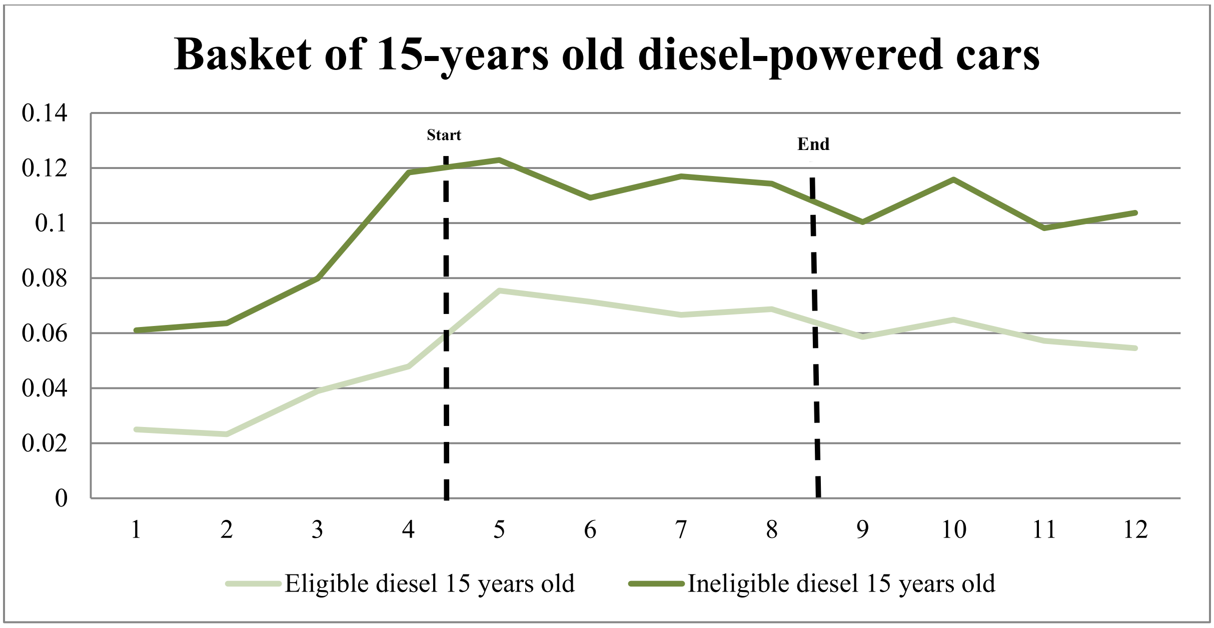

Figure 9: Difference-in-difference for the basket of 15-years old diesel-powered cars

Two things become clear in figure 8 and 9. Firstly, as is in line with the explanation given for figure 7, it is clear that for the baskets of eligible cars there seems to be an upward trend during the policy program. This is not true for the baskets of ineligible cars; the baskets of ineligible cars follow a constant trend from time periods 4 to 12. Therefore, with the knowledge that the Dutch 2009 Car Scrappage Policy Program held in period 5-8 and with the mentioned knowledge that the treatment group and the control group only differ in eligibility for the policy program, figure 8 and 9 show a rough indication for the influence of this policy program. Secondly, the overall broad replacement rates for baskets of ineligible cars are obviously higher than the overall replacement rates for baskets of eligible cars. Interpreting figure 7 lead to the same conclusion for the majority of the baskets of cars. By carefully researching the nominators and denominators determining the broad replacement rates of all studied baskets of cars over time, it appears that the denominator mainly causes the difference between the treatment group and the control group. The baskets of eligible cars are larger than the baskets of ineligible cars. However, the larger baskets do not translate into the same larger proportion of replaced cars. There can be multiple reasons for the replacement rates of baskets of ineligible cars to be higher. The sale on the second-hand market seems to be the driving force of the difference, because of the fact that for the narrow replacement rates the difference is less visible. All calculated replacement rates, also for the other baskets, will be put together in order to do the analysis, as I will present in section 4.

For hypothesis II, I explained in subsection 2.2.2 that I calculated 'the ratio' I make use of as the total amount of cars scrapped over the total amount of cars scrapped and exported. By defining the ratio this way, I will study to what extent a composition effect is visible for cars eligible for the Dutch 2009 Car Scrappage Policy Program in comparison to cars ineligible for the policy program. In other words, for this hypothesis, the baskets I use are only defined by the difference in eligibility. In the next figure, I present the ratios over time:

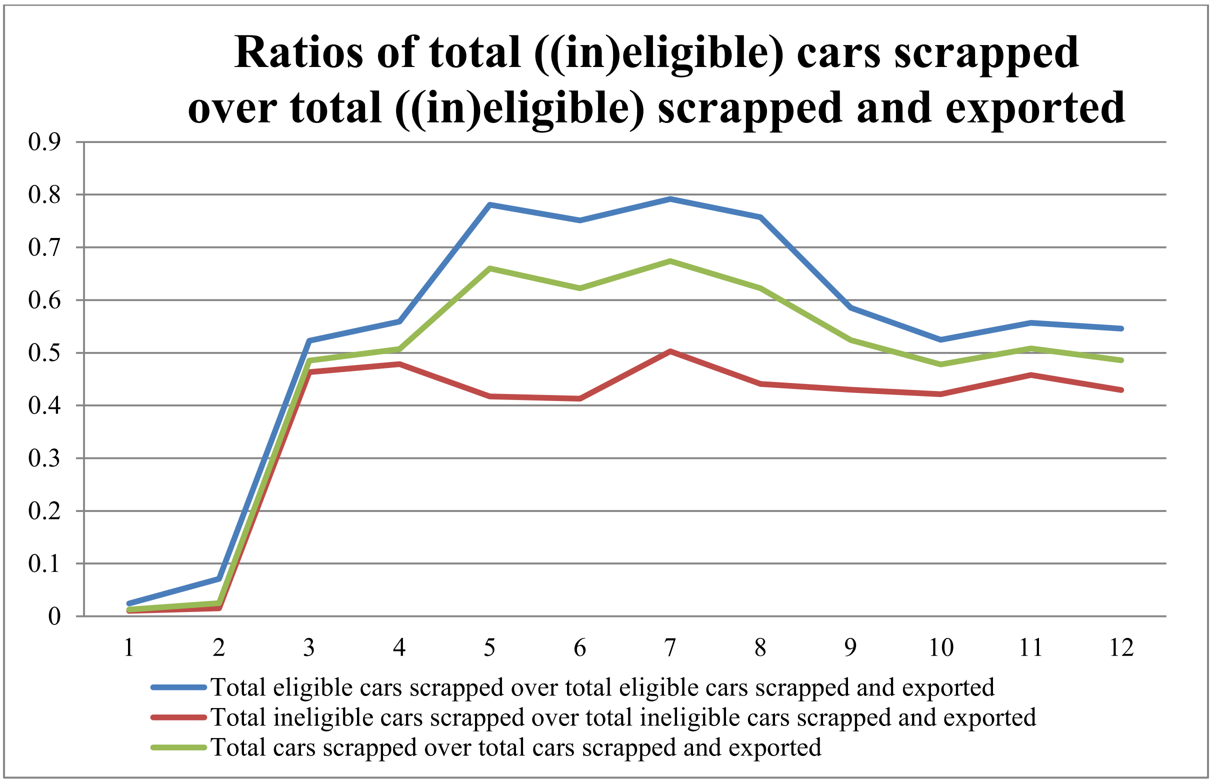

Figure 10: Ratios of total ((in)eligible) cars scrapped over total ((in)eligible) scrapped and exported over time

In figure 10, the green line represents the ratio of the total cars scrapped over total cars scrapped and exported over time. The blue line represents the ratio of the total eligible cars scrapped over the total eligible cars scrapped and exported over time and the red line represents the ratio of the total ineligible cars scrapped over the total ineligible cars scrapped and exported over time. Some interesting features can be withdrawn from this figure. As indicated in subsection 3.1, again time periods 1 and 2 have a value of about 0. This follows logically the definition of the ratios being used, because of the fact that there is no sale on the second-hand market included. From the third period on, the lines tend to move together until and including the fourth period. All three lines move constantly during these two periods. Then, from the fifth period onwards, a divergence between the three lines can be observed. The ratio for the basket of ineligible cars follows a more or less constant trend over time.

During period 5-12, it moves constantly between 0.4 and 0.5. This does not hold for the ratios of the basket of ineligible cars for the Dutch 2009 Car Scrappage Policy Program. Period 5, 6, 7 and 8 show huge spikes for the ratios, with ratios of circa 0.65. Then, in period 9, for these cars the ratios start to decrease again. From period 9 until period 12, there is again a constant trend visible for the ratios of the basket of eligible cars. From that period onwards, all three lines tend to move together again. Therefore, with the knowledge that period 5 is the period in which the policy program started and that period 8 is the period in which it ended, and with the knowledge that the treatment group and the control group only differ in eligibility for the policy program, figure 10 shows a rough indication for the influence of the policy program. All calculated ratios will be put together in order to do the analysis, as I will present in section 5.

For hypothesis III, I calculated a distribution of scrappage rates of eight baskets of cars in order to be able to derive conclusions with respect to the Circular Economy perspective. These eight baskets are subdivided by eligibility and four classes of fuel economy or emissions of CO_2. Regarding the fuel economy, class 1 exists of cars with the lowest fuel economy (from an environmental perspective the least desirable class to scrap), whereas class 4 exists of the cars with the highest fuel economy (from an environmental perspective the most desirable class to scrap). With respect to the emissions, I focus on CO_2 emissions. Class 1 exists of cars with the least emissions of CO_2 (from an environmental perspective the least desirable class to scrap), whereas class 4 exists of cars with the most emissions of CO_2 (from an environmental perspective the most desirable class to scrap).

Figure 11 shows all scrappage rates by fuel economy class (upper left and lower right) and by emissions of CO_2 class (upper left and lower right) as defined in subsection 2.2.3. The left figures in figure 11 show the scrappage rates for the baskets of eligible cars for the Dutch 2009 Car Scrappage Policy Program, whereas the right figures show the scrappage rates for the baskets of ineligible cars for the policy program. Much interesting information can be withdrawn from figure 11. I will elaborate on these 'rough' indications one by one.

First of all, Figure 11 shows that only a small fraction of all cars are being scrapped. Again, for time periods 1 and 2 there are almost no cars reported for scrappage, as I explained in subsection 3.1. For all other time periods, it can be seen that for eligible cars for all classes of fuel economy and emissions of CO_2 about 0,01-0,02% of cars are being scrapped. For ineligible cars, this scrappage rate is even lower: 0,001%-0,002%. This huge difference

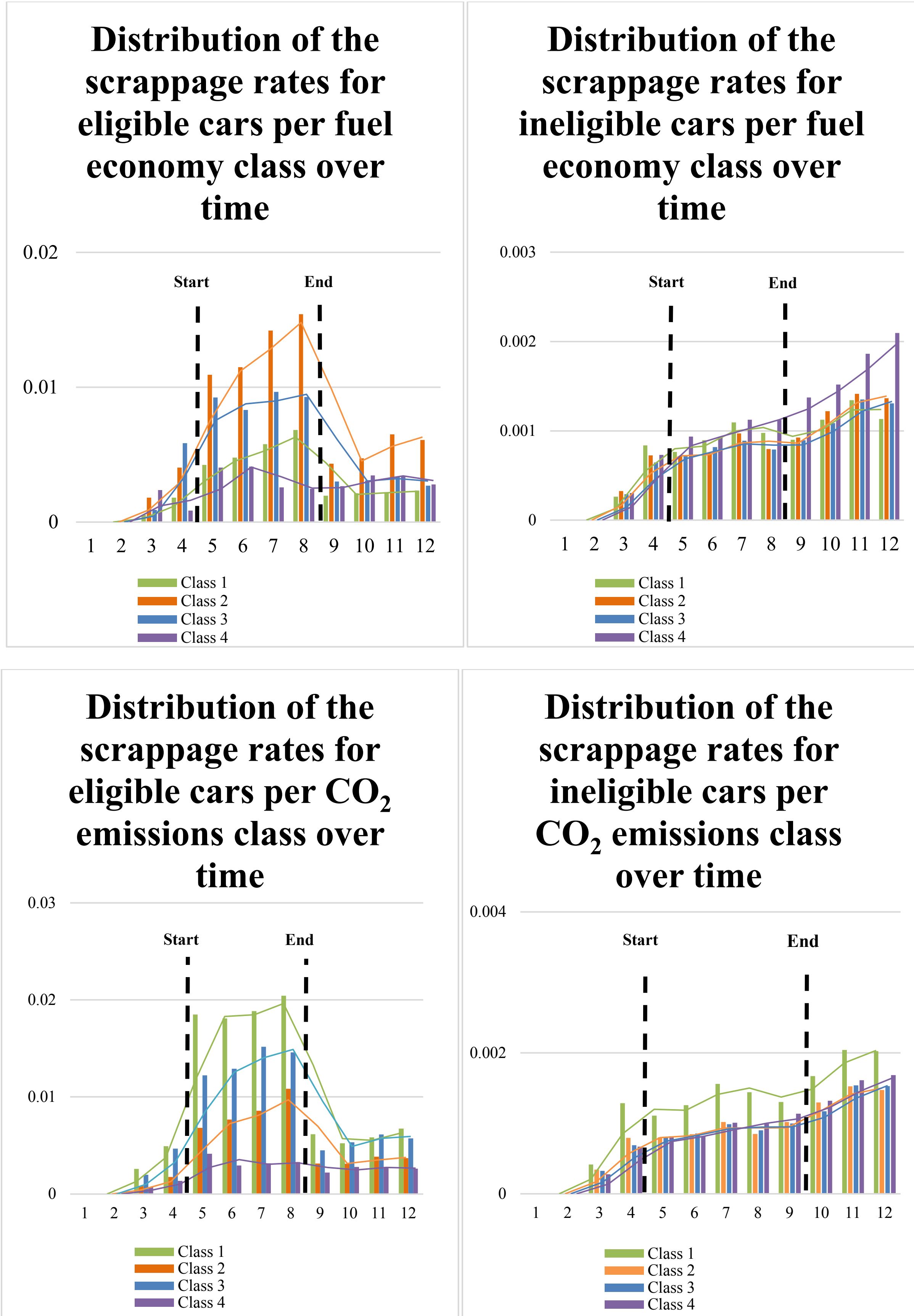

Figure 11: Distribution of the fuel economy and CO_2 emissions per class over time of the (in)eligible cars being scrapped

mainly lies in the fact that the denominator (the total amount of cars within the class) is much higher for ineligible cars than for eligible cars, such that the scrappage rate becomes smaller.

Secondly, focusing on the distribution of the scrappage rates per fuel economy class over time (the upper figures in figure 11), it can be observed that for eligible cars for the Dutch 2009 Car Scrappage Policy program relatively most cars are being scrapped for class 2 and 3. During the policy program, these classes increase tremendously, whereas class 1 increases to a small extent. Class 4 moves constantly over time. Then, after the policy program has ended, the scrappage rates for class 2 and class 3 decrease again. The four classes move constantly over time after the policy program. For ineligible cars for the Dutch 2009 Car Scrappage Policy Program, the distribution of classes moves constantly over time. During the policy program, no class shows an observable increase or decrease in scrappage rate. Only one trend for ineligible cars is visible: over all twelve time periods, class 4 increases to a large extent.

With the knowledge that the treatment group and the control group only differ in eligibility for the policy program, it can be seen that the policy program seems to have led towards a small undesirable direction of cars being scrapped from the Circular Economy perspective. As indicated, from an environmental perspective, class 1 is the least desirable class to scrap, whereas class 4 is the most desirable class to scrap. As figure 11 indicates, during the policy program mostly cars from class 2 and class 3 are being attracted (both not very desirable to scrap), whereas class 4 does not show any increase. For the control group no trend is visible during the policy program, through which the figure seems to indicate that the policy program did not lead to an attraction of car scrappage of cars desirable to scrap from the Circular Economy perspective.

Thirdly, focusing on the distribution of the scrappage rates per CO_2 emissions class over time (the lower figures in figure 11), it can be withdrawn that for eligible cars for the Dutch 2009 Car Scrappage Policy program relatively most cars are being scrapped for class 1 and 3. During the policy program, these classes increase considerably, whereas class 2 increases to a small extent. Class 4 moves constantly over time. Then, after the policy program has ended, the scrappage rates for class 1 and class 3 decrease again. The four classes move constantly over time after the policy program. For ineligible cars for the Dutch 2009 Car Scrappage Policy Program, the distribution of classes increases constantly over time. During the policy program, no class shows an observable increase or decrease in scrappage rate.

Again, with the knowledge that the treatment group and the control group only differ in eligibility for the policy program, it can be seen that the policy program seems to have led towards an undesirable direction of cars being scrapped from the Circular Economy perspective. As indicated, from an environmental perspective, class 1 is the least desirable class to scrap, whereas class 4 is the most desirable class to scrap. As figure 11 indicates, during the policy program mostly cars from class 1 and class 3 are being attracted (both not very desirable to scrap), whereas class 4 does not show any increase. For the control group no trend is visible during the policy program, through which the figure seems to indicate that the policy program did not lead to an attraction of car scrappage of cars desirable to scrap from the Circular Economy perspective.

So, all information together, figure 11 indicates that the policy program have led towards an undesirable direction from the Circular Economy perspective. For both characteristics, the policy program seems to fail to attract the cars most desirable to scrap (in both cases class 4). In section 6, I will elaborate on the analysis of these figures. But first, I will move to the analysis of the first hypothesis in section 4.

4 Analysis Hypothesis I

4.1 Methodology Hypothesis I

In this subsection, I will elaborate on the methodology used in order to be able to do the difference-in-difference analysis for hypothesis I.

As described in subsection 3.2, for hypothesis I, I use a panel dataset of replacement rates derived from the dataset provided by PBL. This panel dataset exists of a cross-section variable (the basket) and a time-variable (period). This reveals 16 x 12 time periods = 192 observations. I discarded the first 32 observations. These 32 observations are discarded, because these observations belong to time periods 1 and 2. I explained in subsection 3.2 that these two time periods suffer from missing information with respect to the replacement option scrappage. Therefore, to play it safe, I do not take these two time periods into account.

By having this dataset, I generated the variable 'Time'. This variable consists of three time dummies that are always 0, except for the specific time period where they equal 1:

- Time_before: the time periods before the policy program (3 and 4);
- Time_between: the time periods during the policy program (5, 6, 7 and 8);
- Time_after: the time periods after the policy program (9, 10, 11 and 12).

Then, I created the variable 'Treat'. As explained in subsection 3.2, I made a categorical variable dividing the dataset into a basket of cars eligible and a basket of cars ineligible for the Dutch 2009 Car Scrappage Policy Program. I converted this categorical variable into a dummy variable called 'eligibility'. This dummy variable equals 1 if the basket of cars is eligible for the policy program (treatment) and 0 otherwise (control). Thereafter, I created the 'difference-in-difference' variable. This variable displays the interaction between the variable 'Time_between' and the variable 'Treat'. With these variables, I am able to run the difference-in-difference analysis.

As explained in subsection 3.2, I will run two difference-in-difference analyses: one on the defined broad and one on the defined narrow replacement rates. The difference-in-difference analyses read:

$$Y_{dt} = \alpha + \beta Treat_d + \Sigma_s \gamma_s Time_t + \delta_u (Treat_d * Time\_between_t) + \varepsilon_{dt}$$

Whereby:

- ❖ Y_{dt} = The narrow (broad) replacement rates for the baskets of cars eligible and ineligible for the Dutch 2009 Car Scrappage Policy Program per period;
- ❖ α = Outcome for the narrow (broad) replacement rates for the baskets of ineligible cars before/after the policy program;
- ❖ β = Difference in the outcome for the narrow (broad) replacement rates for the baskets of eligible cars and ineligible cars irrespective of the treatment over time;
- ❖ $Treat_d$ = Group dummy; 1 for the basket of eligible cars, 0 for the basket of ineligible cars for all periods;
- ❖ $\Sigma_s \gamma_s Time_t$ = Multiple time dummies. As explained above, I use three time dummies. The time dummy time_before will be discarded in the analysis for reasons of multicollinearity;
- ❖ $\delta_u(Treat_d*Time\_between_t)$ = Treatment effect for the time dummy time_between. The difference-in-difference variable;
- ❖ ε_{dt} = Error term.

In order for STATA to know that I use a panel dataset, I will use the commands of xtset and xtreg. Moreover, I use the r-command in order to have robust standard errors. Now having clarified all taken steps in order to do the analysis, I will describe the results for hypothesis I in the next subsection.

4.2 Results Hypothesis I

This subsection will present the results for hypothesis I by having followed the methodology described in subsection 4.1. The next table shows the results for the analysis of hypothesis I:

Replacement rates	*Narrow*	*Broad*
Time_between	0,0164 (0,0019)***	0,0122 (0,0021)***
Time_after	0,0138 (0,0011)***	0,0081 (0,0018)***
Treat	-0,0203 (0,0035)***	-0,0367 (0,0040)***
did	0,0133 (0,0030)***	0,0096 (0,0026)***
_cons	0,0395 (0,0029)***	0,0885 (0,0032)***
Observations	160	160
R^2 overall	0,5243	0,6773

The coefficient is followed by the robust standard error and the level of significance
*** significance at the 1%-level, ** significance at the 5%-level, * significance at the 10%-level

Table 3: Results STATA for the difference-in-difference analysis for the broad and narrow replacement rates

Table 3 shows the STATA output for the narrow replacement rates on the left side of the table and the STATA output for the broad replacement rates on the right side of the table.

As can be observed in table 3, the variables as explained in subsection 4.1 are displayed. As indicated, for 'Time' I used three dummies, of which one (Time_before) has been discarded in order to prevent multicollinearity. Then the variable 'Treat' is presented, followed by the difference-in-difference variable 'did'. Thereafter, I show the constant (the α). Finally, the number of observations and the R^2 overall are presented.

It can be withdrawn from table 3 that, as described in subsection 4.1, the dataset consists of 160 observations. The R^2 overall is 0,5243 for the narrow replacement rates and 0,6773 for the broad replacement rates. This means that from a statistical perspective for both models the independent variables explain the variability of the dependent variable quite well.

Table 3 shows that the two time dummies for as well as the narrow replacement rates as for the broad replacement rates are positively significant at the 1% level. The coefficients of the time variables represent the difference in the expected values of the replacement rates between the period of treatment and the other periods studied in the control group only. In other words, it is the time trend in the control group; the time dummies show what happens with the replacement rates over time for the baskets of cars ineligible for the Dutch 2009 Car Scrappage Policy Program. Therefore, because for both replacement rates Time_between' and 'Time_after' are significant at the 1%-level, time alone has a positive significant effect on the replacement rates for the baskets of cars ineligible for the policy program.

With respect to the variable 'Treat' in table 3, I find significant negative results at the 1%-level. The coefficient of the variable 'Treat' represents the difference in the expected values of the replacement rates for the treatment group and control group in the periods of non-existence of the treatment only. So, since the variable 'Treat' shows for both replacement rates a negative significant effect, the replacement rates of the baskets of eligible cars are significantly lower than the baskets of ineligible cars without the existence of the Dutch 2009 Car Scrappage Policy Program.

Then, interestingly, according to the results shown in table 3, the difference-in-difference coefficient (did) appears to be positively significant at 1% level for as well as the narrow replacement rates as the broad replacement rates. This coefficient determines the difference in the changes between the treatment and control group. Therefore, I am able to conclude that I find a strong significant statistical effect of the treatment. From a statistical perspective, it can be concluded that eligibility for a car scrappage policy program leads towards a strong significant increase of the narrow and the broad replacement rates. For the narrow replacement rates, the coefficient is 0,0133. This means that statistically the existence of the policy program leads to an increase in the narrow replacement rate of 0,0133. The mean narrow replacement rate of all baskets of cars over time periods 5 to 12 is 0,0477. With that mean replacement rate, the installment of the Dutch 2009 Car Scrappage Policy Program has statistically led to an increase in replacement rates of circa 27,7%. For the broad replacement rates, the coefficient is 0,0096. This means that statistically the existence of the policy program leads to an increase in the broad replacement rate of 0,0096. The mean broad replacement rate of all baskets of cars over time periods 5 to 12 is 0,0827. With that mean replacement rate, the installment of the Dutch 2009 Car Scrappage Policy Program has statistically led to an increase in replacement rates of circa 11,6%.

As indicated in subsection 3.2, the statistical difference between the effect of the Dutch 2009 Car Scrappage Policy Program on the narrow replacement rates (27,7%) and on the broad replacement rates (11,6%) lays in the fact that the broad replacement rates also account for the replaced cars on the second-hand market. The different effect between the two is not very surprising. As discussed in subsection 2.1.1, the subsidy should be set high enough to encourage car-owners to choose for scrappage rather than choosing for sale on the second-hand market. In subsection 2.1.3 I showed that most cars obtained a subsidy of 1.000 euro's. Because of the fact that it can be assumed that a large amount of cars can be sold on the second-hand market for a price higher than 1.000 euro's, it is not surprising that including the replacement rates for the sale on the second-hand market does show a weaker effect in total than only accounting for the replacement rates by scrappage and exportation.

Concluding, I find a strong significant positive volume effect of the Dutch 2009 Car Scrappage Policy Program on the overall total replacement rates of the eight baskets of cars being studied. In the next section, I will study the analysis for hypothesis II.

5 Analysis Hypothesis II

5.1 Methodology Hypothesis II

In this subsection, I will elaborate on the methodology used in order to be able to do the difference-in-difference analysis for hypothesis II.

As described in subsection 3.2, for hypothesis II, I use a panel dataset of ratios derived from the dataset provided by PBL. This panel dataset exists of a cross-section variable (baskets of eligibility) and a time-variable (period). This reveals 2 (eligible or ineligible) x 12 time periods = 24 observations. I discarded the first 4 observations. These 4 observations are discarded, because these observations belong to time periods 1 and 2 (as I did for the same reasons for hypothesis I as explained in subsection 4.1).

By having this dataset, I follow the steps as I did for hypothesis I as explained in subsection 4.1. I generated the variable 'Time' that consists of three time dummies following the same definitions as for hypothesis I. The same holds for the 'Treat' variable. This dummy variable equals 1 if the basket of cars is eligible for the policy program and 0 otherwise. Thereafter, I created the 'difference-in-difference' variable. As is the case for hypothesis I, this variable displays the interaction between the variable 'Time_between' and the variable 'Treat'. With these variables, I am able to run the difference-in-difference analysis.

As explained in subsection 3.2, I will run one difference-in-difference analysis, which reads:

$$Y_{dt} = \alpha + \beta Treat_d + \Sigma_s \gamma_s Time_t + \delta_u (Treat_d * Time\_between_t) + \varepsilon_{dt}$$

Whereby:

- Y_{dt} = The ratios (as defined in subsection 2.2.2) of cars eligible and ineligible for the Dutch 2009 Car Scrappage Policy Program per period;
- α = Outcome for the ratios for ineligible cars before/after the policy program;
- β = Difference in the outcome for the ratios for eligible and ineligible cars irrespective of the treatment over time;
- $Treat_d$ = Group dummy; 1 for eligible cars, 0 for ineligible cars for all periods;
- $\Sigma_s \gamma_s Time_t$ = Multiple time dummies. As explained in subsection 4.1, I use three time dummies. Again, the time dummy time_before will be discarded in the analysis for reasons of multicollinearity;

- ❖ $\delta_u(Treat_d * Time\_between_t)$ = Treatment effect for the time dummy time_between. The difference-in-difference variable;
- ❖ ε_{dt} = Error term.

As is the case for hypothesis I, for hypothesis II I will use the commands of xtset and xtreg in order for STATA to know that I use a panel dataset. Moreover, I use the r-command in order to have robust standard errors. Now having clarified all taken steps in order to do the analysis, I will describe the results for hypothesis II in the next subsection.

5.2 Results Hypothesis II

In this subsection, I will show the results for hypothesis II by having followed the methodology described in subsection 5.1. The next table shows the results for the analysis of hypothesis II:

Ratios	
Time_between	-0,0114 (0,0181)
Time_after	-0,0120 (0,0272)
Treat	0,1024 (0,0000)***
did	0,2243 (0,0000)***
_cons	0,4548 (0,0181)***
Observations	20
R^2 overall	0,9641

The coefficient is followed by the robust standard error and the level of significance
*** significance at the 1%-level, ** significance at the 5%-level, * significance at the 10%-level

Table 4: Results STATA for the difference-in-difference analysis for the ratios

As can be observed in table 4, the variables as explained in subsection 5.1 are displayed. As indicated, for ‘Time’ I used three dummies, of which one (Time_before) has been discarded. Then the variable ‘Treat’ is shown, followed by the difference-in-difference variable ‘did’. Thereafter, I present the constant (the α). Finally, the number of observations and the R^2 overall are shown.

Table 4 shows that, as described in subsection 5.1, the dataset consists of 20 observations. The overall R^2 is 0,9641. On one side, this means that from a statistical perspective the independent variables explain the variability of the dependent variable very well. On the other side, the model only contains 20 observations, through which the R^2 might become less reliable.

Then, table 4 shows that the two time dummies are insignificant. The coefficients of the time variables represent the difference in the expected values of the ratios between the period of treatment and the other periods studied in the control group only. Therefore, because 'Time_between' and 'Time_after' are insignificant, time alone does not have a significant effect on the ratios for the baskets of cars ineligible for the policy program.

With respect to the variable 'Treat' in table 4, I find significant positive results at the 1%-level. The coefficient of the variable 'Treat' represents the difference in the expected values of the ratios for the treatment group and control group in the periods of non-existence of the treatment only. So, since the variable 'Treat' shows a positive significant effect, the ratios of the baskets of eligible cars are significantly higher than the baskets of ineligible cars without the existence of the Dutch 2009 Car Scrappage Policy Program.

The difference-in-difference coefficient (did) appears to be positively significant at 1% level for the ratios as can be observed in table 4. This coefficient determines the difference in the changes between the treatment and control group, as explained in subsection 4.1. Therefore, I am able to conclude that I found a strong significant statistical effect of the treatment. From a statistical perspective, it can be concluded that eligibility for a car scrappage policy program leads towards a strong significant increase of ratios. The coefficient is 0,2243. This means that statistically the existence of the policy program leads to an increase in the ratio of 0,2243. The mean ratio of all cars over time periods 5 to 12 is 0,5717. With that mean ratio, the installment of the Dutch 2009 Car Scrappage Policy Program has statistically led to an increase in the ratio of circa 39,2%.

Concluding, next to finding a strong significant positive volume effect of the Dutch 2009 Car Scrappage Policy Program on the overall total replacement rates of eight baskets of cars being studied, I also managed to find a strong overall composition effect of relatively more cars being scrapped than being scrapped and exported during the policy program than in the periods before and after the policy program. In the next section, I will study the analysis for hypothesis III.

6 Analysis Hypothesis III

6.1 Methodology Hypothesis III

In this subsection, I will elaborate on the methodology used in order to do the difference-in-difference analysis for hypothesis III.

As described in subsection 3.1.2, I questioned to what extent car scrappage policy programs are desirable from the Circular Economy perspective. I explained that for this perspective, it would be crucial to find the so-called 'optimal age' for cars to be scrapped. I showed that, according to current literature, the optimal age of a car to be replaced mainly depends on its energy use and the general fuel economy improvement per year. I concluded in subsection 2.2.3 that the determination of such an optimal age is beyond the scope of this research. However, as explained, the data lends itself to study to interesting car characteristics: the fuel economy and the emissions.

As described in subsection 3.2, for hypothesis III, I will use a panel dataset of scrappage rates derived from the dataset provided by PBL. This panel dataset exists of a cross-section variable (the baskets) and a time-variable (period). For both characteristics, the panel dataset reveals 8 x 12 time periods = 96 observations. For both characteristics I discarded the first 16 observations. These 16 observations are discarded, because these belong to time periods 1 and 2, because these belong to time periods 1 and 2 (as I do for the same reasons as explained in subsection 4.1).

By having these two datasets, again I follow largely the same steps as I did for hypothesis I. I generated the variable 'Time', which consists of three time dummies following the same definitions as for hypothesis I. The same holds for the 'Treat' variable. This dummy variable equals 1 if the basket of cars is eligible for the policy program and 0 otherwise. Thereafter, I created the 'difference-in-difference' variable. As is the case for hypothesis I, this variable displays the interaction between the variable 'Time_between' and the variable 'Treat'. With these variables, I am able to run the difference-in-difference analysis.

What is different for the analysis of hypothesis III in comparison to the analyses of hypothesis I and II, is that I will conduct multiple analyses per two baskets instead of analyzing all baskets together. I will compare the effects of the different classes on the scrappage rates, through which I will carry out four difference-in-difference analyses per characteristic; for each class of emissions and each class of fuel economy, I perform one difference-in-difference analysis. Consequently, I will do 8 analyses whereby I have 20 observations per class. Therefore, the difference-in-difference analyses read:

$$Y_{dt} = \alpha + \beta Treat_d + \Sigma_s \gamma_s Time_t + \delta_u(Treat_d * Time\_between_t) + \varepsilon_{dt}$$

Whereby:

- Y_{dt} = The scrappage rate for the baskets of cars eligible and ineligible for the Dutch 2009 Car Scrappage Policy Program per period;
- α = Outcome for the scrappage rate for the baskets of ineligible cars before/after the policy program;
- β = Difference in the outcome for the scrappage rate for the baskets of eligible cars and ineligible cars irrespective of the treatment over time;
- $Treat_d$ = Group dummy; 1 for the basket of eligible cars, 0 for the basket of ineligible cars for all periods;
- $\Sigma_s \gamma_s Time_t$ = Multiple time dummies. As explained in subsection 4.1, I use three time dummies. Again, the time dummy time_before will be discarded in the analysis for reasons of multicollinearity;
- $\delta_u(Treat_d * Time\_between_t)$ = Treatment effect for the time dummy time_between. The difference-in-difference variable;
- ε_{dt} = Error term.

As is the case for hypothesis I and II, for hypothesis III I will use the commands of xtset and xtreg in order for STATA to know that I use a panel dataset. Moreover, I use the r-command in order to have robust standard errors. Now having clarified all taken steps in order to do the analysis, I will describe the results for hypothesis III in the next subsection.

6.2 Results Hypothesis III

In this subsection, I will show the results for hypothesis I by having followed the methodology described in subsection 6.1.

In the next table, I show the results for the analysis of hypothesis III with respect to scrappage rate among the four different classes of CO_2 emissions:

Scrappage rate – CO_2 emissions	*Class 1*	*Class 2*
Time_between	0,0009 (0,0005)*	0,0008 (0,0005)
Time_after	0,0016 (0,0007)**	0,0014 (0,0007)*
Treat	0,0038 (0,0000)***	0,0017 (0,0000)***
did	0,0138 (0,0000)***	0,0059 (0,0000)***
_cons	0,0004 (0,0004)	0,0005 (0,0005)
Observations	20	20
R^2 overall	0,9899	0,9354
	Class 3	*Class 4*
Time_between	0,0008 (0,0005)*	0,0006 (0,0002)***
Time_after	0,0014 (0,0007)**	0,0013 (0,0003)***
Treat	0,0037 (0,0000)***	0,0009 (0,0000)***
did	0,0092 (0,0000)***	0,0015 (0,0000)***
_cons	0,0001 (0,0005)	0,0003 (0,0002)
Observations	20	20
R^2 overall	0,9744	0,9216

The coefficient is followed by the robust standard error and the level of significance
*** significance at the 1%-level, ** significance at the 5%-level, * significance at the 10%-level

Table 5: Results STATA for the difference-in-difference analysis for the scrappage rate – emissions

As can be seen in table 5, for all four classes, the variables as explained in subsection 6.1 are displayed. As is the case for hypothesis I and II, I used three 'Time' dummies, of which one (Time_before) has been discarded. I show the variable 'Treat' and the difference-in-difference variable 'did'. Thereafter, I present the constant (the α), the number of observations and the R^2 overall.

As was the case for hypothesis II, also for this hypothesis for all classes the overall R^2 is very high, as can be observed in table 5. Therefore, again, on one side this means that from a statistical perspective for all four analyses the independent variables explain the variability of the dependent variable very well. However, on the other side, the models contain only 20 observations, through which R^2 might become less reliable.

Table 5 shows that there are differences between the four different analyses with respect to significance of the two time dummies. Only for class 4 time alone does have a strong significant effect on the scrappage rate. For class 1, 2 and 3 the variable 'Time_between' is not or weakly significant and the variable 'Time_after' only weakly or moderately significant. Therefore, overall, time alone does not have a strong significant effect on the scrappage ratios for cars ineligible for the policy program.

Concerning the variable 'Treat' in table 5, I find significant positive results at the 1%-level for all four classes of CO_2 emissions. So, since the variable 'Treat' shows a positive significant effect for the scrappage rates for all classes, the scrappage rates of the eligible cars are significantly higher than the scrappage rates of the ineligible cars without the existence of the Dutch 2009 Car Scrappage Policy Program.

The difference-in-difference coefficient (did) appears to be positively significant at 1% level for the scrappage rates of all four classes as can be observed in table 5. Therefore, I am able to conclude that I found a strong significant statistical effect of the treatment for all classes. For that reason, the Dutch 2009 Car Scrappage Policy Program has attracted cars of all different classes. However, there is a difference in the magnitude of the effects per class. The coefficient for class 1 is 0,0138. This means that statistically the existence of the policy program leads to an increase in the ratio of 0,0138. The mean scrappage rate of all cars within class 1 over time periods 5 to 12 is 0,0070. With that mean ratio, the installment of the Dutch 2009 Car Scrappage Policy Program has led to an increase in the scrappage rates of circa 197,1%. By studying the coefficients for class 2, 3 and 4 and by comparing these coefficients with the mean scrappage rate of all cars within the own class over time periods 5 to 12 as I did for class 1, I find the following increases in scrappage rates respectively: 167,0%, 172,4% and 72,2%.

Comparing these four increases, I have found statistical evidence that the Dutch 2009 Car Scrappage Policy Program led to a huge relative increase of cars being scrapped from classes with relatively low emissions. As can be observed in figure 11, not only this huge increase for classes 1, 2 and 3 is visible, also it can be seen that in general for the twelve time periods the scrappage rate is relatively low for class 4. It can be concluded that the Dutch 2009 Car Scrappage Program failed to attract those cars with high emissions. Therefore, from a Circular Economy perspective, car scrappage policy programs might be undesirable if implemented like the Dutch 2009 Car Scrappage Program.

Then I turn to the other indicator for the Circular Economy perspective, the fuel economy. In the next table, I show the results for the analysis of hypothesis III with respect to scrappage rate among the four different classes of fuel economy:

Scrappage rate - fuel economy	*Class 1*	*Class 2*
Time_between	0,0005 (0,0002)***	0,0009 (0,0007)
Time_after	0,0008 (0,0002)***	0,0016 (0,0010)
Treat	0,0009 (0,0000)***	0,0036 (0,0000)***
did	0,0036 (0,0000)***	0,0086 (0,0000)***
_cons	0,0004 (0,0002)***	-0,0001 (0,0007)
Observations	20	20
R2 overall	0,9192	0,9506
	Class 3	*Class 4*
Time_between	0,0000 (0,0004)	0,0006 (0,0001)***
Time_after	0,0002 (0,0006)	0,0013 (0,0001)***
Treat	0,0022 (0,0000)***	0,0013 (0,0000)***
did	0,0060 (0,0000)***	0,0010 (0,0000)***
_cons	0,0008 (0,0004)**	0,0004 (0,0000)***
Observations	20	20
R2 overall	0,9313	0,8123

The coefficient is followed by the robust standard error and the level of significance
*** significance at the 1%-level, ** significance at the 5%-level, * significance at the 10%-level

Table 6: Results STATA for the difference-in-difference analysis for the scrappage rate – fuel economy

Table 6 is identical to table 5; it shows the same variables for the fuel economy classes as table 5 does for the emissions classes. As was the case for the scrappage rates with respect to the emissions classes, also for the scrappage rates with respect to the fuel economy classes the overall R^2 is very high, as can be observed in table 5. Therefore, again, on one side this means that from a statistical perspective for all four analyses the independent variables explain the variability of the dependent variable very well. However, on the other side, the models contain only 20 observations, through which R^2 might become less reliable.

Table 6 also shows differences between the four different analyses with respect to significance of the two time dummies. For class 1 and class 4 time alone does have a strong significant effect on the scrappage rate. Classes 2 and 3 do not show a significant effect of the time variables on the scrappage rates. Therefore, overall, only for classses 1 and 4 time alone does have a strong significant effect on the scrappage ratios for cars ineligible for the policy program.

Then, for the variable 'Treat' in table 5, I find significant positive results at the 1%-level for all four classes of fuel economy. So, since the variable 'Treat' shows a positive significant effect for the scrappage rates for all classes, the scrappage rates of the eligible cars are significantly higher than the ineligible cars without the existence of the Dutch 2009 Car Scrappage Policy Program.

Table 6 also shows that the difference-in-difference coefficient (did) appears to be positively significant at 1% level for the scrappage rates of all four classes. Therefore, I am able to conclude that I found a strong significant statistical effect of the treatment for all classes. For that reason, the Dutch 2009 Car Scrappage Policy Program has attracted cars of all different classes. However, there is a difference in the magnitude of the effects per class. The coefficient for class 1 is 0,0036. This means that statistically the existence of the policy program leads to an increase in the ratio of 0,0036. The mean scrappage rate of all cars of class 1 over time periods 5 to 12 is 0,0024. With that mean ratio, the installment of the Dutch 2009 Car Scrappage Policy Program has led to an increase in the scrappage rates of circa 150%. By studying the coefficients for class 2, 3 and 4 and by comparing these coefficients with the mean scrappage rate of all cars within the own class over time periods 5 to 12 as I did for class 1, I find the following increases in scrappage rates respectively: 168,0%, 170% and 43,9%.

Comparing these four increases, I find a same distribution in relative increases of scrappage rates for the classes of fuel economy as I found for the relative increase of scrappage rates for the classes of emissions. I found statistical evidence that the Dutch 2009 Car Scrappage Policy Program led to a huge relative increase of cars being scrapped from classes with relatively low fuel economy. As can be observed in figure 11, not only this huge increase for classes 1, 2 and 3 is visible, also it can be seen that in general for the twelve time periods the scrappage rate is relatively low for class 4. Only for the ineligible cars in class 4 an increase of scrappage rate can be seen after the car scrappage policy program. Therefore, also in this case, it can be concluded that the Dutch 2009 Car Scrappage Program failed to attract those cars it should from the Circular Economy perspective. Therefore, from that perspective, car scrappage policy programs might be undesirable if implemented like the Dutch 2009 Car Scrappage Program.

Concluding, as indicated, the objective of this subsection has been to be able to derive some conclusions with respect to the desirability of the Dutch 2009 Car Scrappage Policy Program from the Circular Economy perspective. Current literature is still in its infancy for the combination of these two subjects. Finding an optimal age for cars to be scrapped would be necessary to set out a perfect scrappage policy program, but this is not an easy task. In this subsection, I have shown two interesting features of influence when it comes to the Circular Economy perspective. Both features show that the Dutch 2009 Car Scrappage Policy Program did not lead to the scrappage of cars most desirable from the perspective of the Circular Economy.

In the next section, I will elaborate on the main conclusions of this research.

7 Conclusion

In this research, I studied the Dutch 2009 Car Scrappage Policy Program in order to find an answer to the research question: 'To what extent does a national car scrappage policy program influence the replacement of cars?' I explained the relevance of finding an answer to this question concerning the environmental and economic impact of such a policy. Especially the environmental impact is interesting, because the environmental impact of cars and car driving is tremendous. As I have shown, the US transportation/mobility sector causes about 28% of all Greenhouse Gas (GHG) Emissions. This figure is not unique; many countries have similar fractions of this sector contributing to the total GHG emissions.

Therefore, governmental intervention seems to be desirable in order to reduce the share of emissions of this sector. A form of governmental intervention is a car scrappage policy program. As explained, car scrappage policy programs are policy programs whereby a car-owner is offered a subsidy to encourage him or her to bring his or her car to the scrappage to use that subsidy to buy a new and environmentally friendlier car than he or she possessed. On the one hand, policymakers believe that such a policy program can boost the economy offering a subsidy to buy a new car, through which the car production will increase. On the other hand, they believe that through the policy program the life span of cars in use will be shortened, through which relatively newer and environmentally friendlier cars will be part of the car fleet.

There has been much scientific research on this topic, whereby the effectiveness of such policy programs is discussed largely. While researchers to some extent agree with each other about the effectiveness of car scrappage policy programs, there are many critiques as well. Researchers question the difficulty in finding the optimal amount of subsidy in order to make a car scrappage policy program most effective. However, having found that optimal subsidy is not necessarily sufficient for a car scrappage policy program to be effective. For example, the increased car production may lead to an increase in life-cycle emissions, since scrapping schemes will reduce the average life span of cars. Moreover, it can be assumed that newer cars will be faster and bigger and therefore can lead to more emissions. Finally, some researchers argue that an improvement in emissions only occurs in the short term, in large densely populated areas and if and only if the cars being scrapped do not have pollution-control technologies. In all other cases, no improvement can be expected.

In this research, I have focused on the Dutch 2009 Car Scrappage Policy Program in order to derive general conclusions about the effectiveness of national car scrappage policy programs. I made use of a very extensive anonymous dataset provided by The Netherlands Environmental Assessment Agency (PBL). I used several steps in order to research three hypotheses, for which I found the following conclusions.

For hypothesis I, I found statistical evidence for a volume effect of more cars being replaced during the Dutch 2009 Car Scrappage Policy Program than before or after the policy program by researching eight baskets of cars. Despite of the fact that for the control group also significant results were found, still the difference-in-difference variable was strongly significant. This hints to a strong impact of the policy program on the replacement rates, since eligibility for this program functioned as the one and only difference between the treatment and control group.

Hypothesis II showed statistical evidence for a composition effect of an increase in the ratio (cars being scrapped over the total amount of cars being scrapped and exported) during the Dutch 2009 Car Scrappage Policy Program. Here, I also found significant results for the control group. However, as I concluded for hypothesis I, still the difference-in-difference variable was strongly significant. This hints to a strong impact of the policy program on the ratios, since eligibility for this program functioned as the one and only difference between the treatment and control group.

Finally, for hypothesis III, I showed that for two car characteristics (CO_2 emissions and fuel economy), the Dutch 2009 Car Scrappage Policy Program did not attract the most desired cars for scrappage. Whereas the scrappage rate increases significantly and enormously for all cars during the policy program, the scrappage rate for cars with the least emissions and least fuel economy take the cake. Again, it is a strong influence of the policy program at which the difference is hinted, since eligibility for this program functioned as the one and only difference between the treatment and control group. However, I should notify here that for a complete perspective of the Circular Economy, more research is necessary than these two characteristics only. Still, the two found results show an important indication about the environmental impact.

Concluding, I found statistical evidence for the Dutch 2009 Car Scrappage Policy Program having a strong influence on the replacement rates of cars. Not only the replacement rates have been affected to a large extent, also the ratio of replacement options changed in favor of scrappage. Therefore, I can conclude that I found statistical evidence for the effectiveness of the Dutch 2009 Car Scrappage Policy Program. However, as discussed in section 2, also this research shows unambiguous results with respect to the environmental effects. I found statistical evidence that from a Circular Economy perspective a policy program like the Dutch 2009 Car Scrappage Policy Program might lead to undesirable effects. Therefore, while being effective in the sense of increased scrappage and therefore a shortening of the average life span of the car fleet, it remains the question whether this increased scrappage is environmentally desirable.

In the next section, I will discuss these found conclusions and bring the conclusions to a broader perspective.

8 Discussion

In section 7, I described the conclusions I managed to find during this research. In this section, I will delve into these conclusions. How do these conclusions fit into the current literature? To what extent can policymakers take action on these conclusions? And, how can future research improve found results?

First of all, the conclusions found with respect to the replacement rates and the ratios can be classified in the class of optimist literature with respect to the effectiveness of car scrappage policy programs. In that sense, the implementation of car scrappage policy programs contributes to the objective of an increase of cars being scrapped. This evidence contributes to the current literature of the effectiveness of car scrappage policy programs and can be used to define future policies. Environmental policies with respect to cars and car using have been on the agenda for decades now and will be on the agenda in the future due to its great importance. This research can function as a base to make decisions in the nearby future. Not only for the Netherlands. As indicated, although I used the case of the Netherlands to find an answer to the research question, the conclusions I derived can be used to a broader extent. The Netherlands is one of the many countries that experimented with car scrappage policy programs. As seen in this research, many other countries (and regions within countries) have implemented similar policy programs during the last decades. Because of the fact that it can be assumed that the Dutch car fleet will not differ to a large extent from other Western countries, the results of this research can be used as an example for other countries.

Secondly, the conclusion with respect to the perspective of the Circular Economy contributes to the current literature by finding some statistical undesirable indications. Still, as I explicitly called it, these findings are indications. Here, much possibilities for future research can be found. As indicated, I only reviewed the characteristics of cars being scrapped concerning the fuel economy and the emission of CO_2. These characteristics are important with respect to the Circular Economy perspective, however these are not sufficient. To maximize environmental benefits from that perspective, an optimal age for scrappage needs to be found. Ideally, such an optimal age needs to be found for every sort of car. Future research should focus on estimating this optimal age in order to make car scrappage policy programs also desirable from the Circular Economy perspective. Moreover, as indicated in subsection 2.1.2, more research can be done with respect to the complete production system of cars in order to make efficient production designs.

Finally, future research can delve into the weaker points of this research. First of all, in order to conduct better difference-in-difference analyses the way I did, for the year before the policy completer data need to be used. Moreover, a more specific analysis can be conducted in which the effects on consumer behavior for specific cars can be studied. Such a study can contribute in finding the optimal car scrappage policy program per car sort. In line with the literature review on the importance of the amount of subsidy, potential different effects of the differing amount of subsidies for the Dutch 2009 Car Scrappage Policy Program can be studied. To conclude, international comparative research can be used in order to find the optimal subsidy from the Circular Economy perspective.

Appendices

Appendices can be shared separately upon request.

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