A reconstruction of policy-driven innovations to reduce Dutch car emissions 1960-2010

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Abstract: One of the main drawbacks of mobility are the traffic-related emissions of air pollutants – e.g. nitrogen oxides (NOₓ) – and greenhouse gases – e.g. carbon dioxide (CO₂). In the past governments all over the world aimed at technological innovations to limit the emissions from traffic. Using insights from innovation theory regarding the role of the government in (transport) innovations, we analyse the role of the Dutch government between 1960 and 2010. This analysis is based on a reconstruction of past policies of the EU and Dutch government regarding technological innovations to reduce car-related emissions of air pollutants (e.g. NOₓ) on the one hand and car-related emissions of greenhouse gases (e.g. CO₂) on the other hand. The past shows, amongst others, that, without a sense of urgency by the governments and the industry, policy-driven innovations seem hardly feasible.

Keywords: car emissions, technological innovation, government

1. Introduction

Some of our current transport problems with respect to traffic safety, accessibility, and the environment might not be solved without technological innovation. For example, the recent EU White Paper (EC, 2011) is very clear on politicians’ expected role of new technologies: one of the key goals in the White Paper is that by 2050 no more conventionally-fuelled cars are used in cities. However, promising technological transport innovations, in terms of their contribution to the solution of transport problems, are not always developed or implemented as fast as politicians may think or hope for. Governments are able to stimulate the development and implementation of transport innovations, but what are good policies with respect to transport innovations, given the fact that it is always uncertain what the actual effects of the innovation will be?

In this paper we take a look into the history of transport policy, focusing on policies regarding technological innovations to reduce car-related emissions. Using insights from innovation theory regarding the role of the government in (transport) innovations, we analyse the role of the Dutch government between 1960 and 2010. This analysis is based on a reconstruction of past policies of the EU and Dutch government regarding technological innovations to reduce car-related emissions of air pollutants (e.g., nitrogen oxides, NOₓ) on the one hand and car-related emissions of greenhouse gases (e.g., carbon dioxides, CO₂) on the other hand. The policies for these types of emissions have been quite different, and have also shown differences in successfulness in terms of emission reduction.

We have chosen car air pollutant emission as one case because already since the early 1960s policy-makers all over the world have started to worry about air pollution problems related to

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transport. As a result, there is a long policy history which can be used to identify different innovation policy roles. To be clear, transport air pollution is a multi-faceted problem. It concerns exposure of people to chemical substances such as nitrogen oxides (NO$_x$), volatile organic compounds (VOCs), lead, sulphur oxides (SO$_x$) and physical components such as particulate matter (PM$_x$). As a result of vehicles emitting these substances (and many more) human health problems and damage to buildings and nature (via the phenomenon of so-called acid rain) can occur. In order to limit the scope of this paper we have chosen NO$_x$ and PM$_{10}$ (here, the subscript ‘10’ means the particles fraction comprising particles with a diameter less than 10 µm) as indicator substances for the story of air pollution. We have also chosen to tell the story of air pollution innovations only related to car technology.

As the other case we have chosen car fuel efficiency policy (or CO$_2$ emission reduction policies), because also for this problem there is a relatively long policy history to reconstruct which can be used to identify the different innovation policy roles. These car CO$_2$ innovation policies can be contrasted with the car air pollution policies. Since roughly the beginning of the 1970s policymakers worry about fuel efficiency in transport. At that time Meadows et al. (1972) published their famous book with the telling title ‘Limit to Growth’. This book, commissioned by the Club of Rome, modelled future population growth and the usage of natural resources, showing, amongst others, that oil is a finite resource. Two worldwide oil crises in 1973 and 1979 showed the Western world politicians that the supply of cheap oil was indeed less self-evident than they perhaps previously thought. In the 1980s the political worries about oil use in transport in general became accompanied by worries about climate change. Oil use and climate change are directly interrelated problems. In essence, oil products such as petrol and diesel consist of long carbon chains. Burning these carbon chains in internal combustion engines result in desired propulsion energy but also in undesired by-products such as carbon dioxide (CO$_2$). CO$_2$ is a chemical substance held responsible for contributing to climate change.

2. **Insights from innovation theory regarding the role of the government**

Technological innovations are predominantly developed within industrial organisations or firms. These firms are motivated to develop innovations, because innovations can potentially help them to gain a competitive advantage over other firms, which is important for their survival. However, not all innovations are successful in gaining a substantial market share or in competing with other innovations. Which innovations are successful is determined by the selection environment, which consists of markets, institutions, and the spatial environment (Boschma et al., 2002). Nelson and Winter (1982) explain this process of innovation as part of their theory of evolutionary economics, which is a reaction to neoclassical economics that did not give a clear explanation of change due to innovation.

There are several situations in which the government might want to influence this process. For example, if innovations that are desirable from a societal point of view lose the competition with the less desirable existing technology, or if the market share of a successful innovation increases slower than desirable from a societal point of view. Van den Berg et al. (2006) have formulated guidelines to influence the development of alternative fuels within environmental policy in general, based on the theory of evolutionary economics. Their main message is as follows: “In the neoclassical economic theory of policy the governmental role is restricted to removing market failures. Public policy from an evolutionary angle is more focused on influencing the selection environment and the effectiveness of innovation.” (p. 61) Furthermore, they suggest that the government should refrain from picking winners, since the development of innovations is not very well predictable as a result of the dynamics of the
evolutionary process, and that they should mainly create conditions that will lead to socially desirable outcomes. Their specific guidelines for environmental policy include:

- **Diversity management**: diversity of technologies and strategies introduces resilience and robustness in environmental policy;
- **Extended level playing field**: conditions for this level playing field are that (1) prices reflect external costs, (2) promising technologies low on the learning curve need support and avoid lock-in of unsustainable technologies, (3) different technological options should be exposed to similar selection mechanisms;
- **Stimulate unlocking**: remove explicit and implicit stimuli of the dominant technology, give preferential treatment to desirable alternatives;
- **Innovation**: establish innovative networks for cross-fertilisation and also isolated experiments and initiative
- **Balance between diversity and selection**: balance between short-term costs and long-term benefits; and
- **Bounded rationality**: policymakers should take into account that bounded rationality prevents them from making optimal choices.

Focusing on variation and selection, Schot et al. (1994) contribute to theory by proposing a quasi-evolutionary model coupling the processes of variation and selection. This coupling (or coevolution) is not addressed by the theory of evolutionary economics. The idea behind this coupling is that variation is influenced by expectations about the selection environment by which they will be selected, and the selection environment is influenced by expectations of variations that will develop. Schot et al. propose three strategies for governments based on this model:

1. Development of alternative variations not developed in the marketplace (by means of strategic niche management);
2. Modification of the selection environment (e.g. regulation);
3. Creation or utilization of institutional links between places that produce variations and their selection environments (technological nexus).

Based on empirical knowledge about the electric vehicle in California and in the Netherlands, they conclude that these three strategies have both strengths and weaknesses, but can certainly work in the right combination. Technological forcing (regulation) can result in a fight between industry and government. Furthermore, if the government is the only actor involved in experiments to bring a certain alternative to the market (strategic niche management), this alternative is bound to fail. A technological nexus, possibly by means of a new actor, can be crucial to overcome drawbacks and increase successfulness.

We use these insights about the role over the government in innovation to analyse the policies in Europe and the Netherlands with respect to traffic emissions.

3. **Reconstruction of 50 years environmental car innovations – the role of policy**

In this section the story is reconstructed of 50 years of car innovations towards more environmental-friendly technologies in the Netherlands. The purpose of the reconstruction is to give empirical proof for the role of policies in achieving (or not achieving) desired technical innovations used in practice. We have limited the reconstruction to two environmental issues: reducing air pollution problems related to road vehicle technology and decreasing road vehicle fuel use or carbon dioxide emissions (CO₂).
The story of car emission factors in the Netherlands is illustrated in Figure 1, by means of the development in car emissions between 1960 and 2009. Three different periods are distinguished:

- **Period 1 (1960 – 1970): environmental free policy**;
- **Period 2 (1970 – 1990): emission standards for air pollutants**;
- **Period 3 (1990 – 2009): more attention for greenhouse gas emissions**.

**Figure 1: Real world car emission factor indices for CO$_2$ (is equal to fuel use per kilometre), NO$_x$ and PM$_{10}$ 1960 – 2009 (own data analysis based on CBS, 1982; CBS, 1983; Van den Brink, 1993; PBL, 2011).**

### 3.1. Period one (1960 – 1970): environmental free policy

Period one (1960 – 1970) is still the environmental policy free period for cars in the Netherlands. NO$_x$ and PM$_{10}$ emission factors stay more or less constant (Figure 1), while CO$_2$ emission factors or car fuel use per kilometre driven increased slightly in this period, probably because of an increased average car weight. The latter is uncertain because average car weight data for this period are not very reliable. Still, what is certain is that this period can be characterized as the high car volume growth period. Between 1960 and 1970 the amount of cars registered in the Netherlands increased from 552,000 to 2,405,000 cars (BOVAG-RAI, 2011): a yearly average increase of approximately almost 17%. This trend was occurring in every Western economy at that time, which makes it not surprising that in this period the first political negotiations started within Europe between politicians and representatives of European car manufacturers to address air pollution problems related to this huge growth in number of cars.

These European negotiations were partly based on developments elsewhere, more specifically in the state of California. Already in 1940 California’s population rose to 7 million with the number of registered vehicles approaching 2.8 million and an amount of vehicle miles travelled of 24 billion (California Environmental Protection Agency, Air Resources Board, 2011). Three years later the first of many recognized episodes of smog occurred in Los Angeles. In the 1950s it became clear that concentrations of nitrogen oxides (NO$_x$) and volatile organic compounds (VOC) in the air, in the presence of ultraviolet radiation from the sun, caused the smog (a key component of which is O$_3$, ozone) (Bauner, 2011). In that period it also became clear that the continuously growing amounts of road vehicles emitted an
increasing amount of these substances (Bauner, 2011). The first legislation requiring controls of vehicle emissions was already passed in California in 1959, followed within a year by the creation of the state-wide Motor Vehicle Pollution Control Board, the first of its kind, to test and certify devices to clean up California’s cars (Sperling and Gordon, 2009). This led to the use of positive crankcase ventilation in 1961, the first automotive emission control technology ever required (Walsh, 1993). Tailpipe standards for carbon monoxide and hydrocarbons were adopted by California in 1966 and then for oxides of nitrogen in 1971.

Europe lagged somewhat behind. However, in the 1970s the EEC (European Economic Community, later European Union) directives 1970/220, 1974/290 and 1978/665 were issued which set emission standards for petrol light duty vehicles (vehicles weighing less than 3,500 kg) for carbon monoxide (CO), VOCs, and in the later versions also NOx. Nevertheless, NOx and PM10 emission factors increased at first in the period 1970 – 1990 (Figure 1). This can be explained because NOx increase was an unintentional side-effect of the first technical measures taken to reduce carbon monoxide (CO) and VOCs. The increase of the PM10 emission factor in the period 1970 – 1984 is mainly caused by the increase in the share of diesel cars (from 11% in 1970 to 20% in 1980) as a result of relative price changes and tax incentives (CBS, 1983). Diesel cars at that time emitted more PM10 per kilometre driven compared to petrol cars. The 1970 EEC Directives can be considered the start of highly effective European innovation policy. This policy consists of setting emission standards for new cars (so-called Euro 0, 1, 2, 3 and so forth standards) which become in time step by step stricter. As in the older 1970 Directives CO, VOC’s and NOx are regulated but in later policy steps also PM10 is included. It is not possible ex post to estimate the precise impact of purely these regulatory steps on vehicle NOx and PM10 emission factors because we cannot know what would have happened without these regulatory policy rules. Perhaps the car industry had taken innovative steps also to make their vehicles cleaner albeit at lower speed and less strict. Nevertheless, looking at the many studies in the Netherlands which, amongst others, evaluate ex post vehicle emission developments (Regiegroep, 1991; RIVM, 1995 to 2000; MNP, 2001 to 2007; PBL 2008 to 2010a) the conclusion is clear: these regulatory steps have contributed to decreasing vehicle NOx and PM10 emission factors. This process continued in period 3. The EU regulatory steps resulted in widespread use of innovative vehicle technologies such as three-way-catalysts, oxidation catalysts, particle filters, exhaust gas recirculation, innovative motor management technologies, selective catalytic reduction catalysts and so forth. The Dutch government used fiscal measures to stimulate sales of cleaner vehicles. People who bought a new car that already met new emission standards before these standards became mandatory received car purchase tax deductions (e.g., VROM, 1990).

The car manufacturers (and oil industry) have played worldwide an important role in shaping the car emission standard policies. Partly they have determined the pace and direction of these policies (see, for example, Bauner, 2011, p. 380 - 381). Also in the so-called Auto-Oil Programs I and II from the 1990s (AOPs) which have shaped European vehicle emission standard policy car and oil industry played an important role. For example, on AOP (I) Directorates General (2000, p. 14) states: ‘At the end of 1992 the Commission invited the European automobile and oil industries to participate in a technical work programme with the aim of providing policy-makers with an objective assessment of the most cost-effective measures for reducing emissions from the road transport sector to a level consistent with the attainment of the new air quality standards which were being developed for adoption across the European Union’.
In contrast to the NO\textsubscript{x} and PM\textsubscript{10} emission factors, in the second half of period 2 (1980 – 1990) Dutch average fuel efficiency of cars increased only slightly. In fact, looking at Figure 1, this is the only period between 1960 and 2009 where an actual improvement in fuel efficiency is noticeable. The main explanation is that due to the worldwide oil crises in the 1970s petrol prices rose quickly (BOVAG-RAI, 2011). This urged car manufacturers to implement car fuel efficiency innovations in order to keep their products attractive for consumers. They invested in engine improvements and in all kinds of car design measures to lower air and rolling resistance (Rijkeboer, 1984). Sivak and Tsimhoni (2009) show similar developments for US vehicles in this period. Also, the Dutch government reacted to the 1970s oil crises. In 1979 they published the so-called ‘Nota Energiebeleid’ (Memorandum on Energy Policy) (Kroon and Cornelisse, 1989). The main aim was to save energy and to diversify energy supply (i.e., to become less oil dependent). Some car policy measures were announced such as a voluntary agreement between the European Union (at that time named European Community) and car manufacturers to make their cars on average 10\% more fuel efficient in 1985 compared to the 1978 level. This goal was already met in 1983. It is not known if this policy agreement was effective or that the car fuel efficiency improvements were mainly driven by autonomous developments.

3.3. Period three (1990 - 2009): more attention for greenhouse gas emissions

The EU vehicle emission regulatory steps continued to be highly successful in this period: emission factors decreased with 60 to 80\%. The cost effectiveness of the regulatory steps were considered good with estimates in the order of 0.5 to 3 euro per avoided kilogram NO\textsubscript{x} (RIVM, 1997, in prices 2009). CPB (2000) carried out a cost benefit analysis of the three-way-catalyst and concluded that the benefits outweighed the costs. Also, the further improvements (Euro 3 to 6, see appendix 1) were considered cost effective with less than 10 euro per avoided kilogram NO\textsubscript{x} (Smeets \textit{et al.}, 2007, in prices 2009).

The car fuel efficiency or CO\textsubscript{2} emission factor developed less favourable in period three, 1990 - 2009 (figure 1). Hardly any technical improvement is observable. This despite the fact that, next to fuel use, CO\textsubscript{2} emission attracted political attention. In 1989 the Dutch government stated that they aimed at stabilizing transport fossil fuel use and CO\textsubscript{2} emission in the long term (V&W, 1989). In fact, Dutch transport CO\textsubscript{2} emissions rose with roughly 30\% between 1990 and 2009 (PBL, 2011). We can identify four main reasons for this disappointing result, that are further explained below:

1. The fuel price was relatively low (until 2005);
2. Consumers bought bigger and heavier cars;
3. Policies were too weak to be effective;
4. CO\textsubscript{2} emission levels in car test did not correspond to real world emissions.

Related to 1: Between approximately 1986 and 2005, fuel price did not increase much compared to the Dutch consumer price index (BOVAG-RAI, 2011). This means that in this period there was hardly any fuel price pressure that could urge car manufacturers to make cars more fuel efficient or car buyers to buy the most fuel efficient types.

Related to 2: Between 1980 and 1999 the average new car bought by Dutch consumers was approximately 20\% heavier and was equipped with a bigger engine; expressed in cylinder capacity, an increase of 15\% for the average car between 1980 and 1999 (Van den Brink and Van Wee, 2001). Still, as can be seen in Figure 1, the average car CO\textsubscript{2} emission factor stayed more and less constant. This implies that the heavier cars bought became increasingly more fuel efficient. Indeed, Van den Brink and Van Wee (2001) conclude that car manufacturers succeeded in technical improvements to make cars per weight class more fuel efficient, but
since the mid-1980s up to 1995 these technical improvements in the Netherlands were traded-off against consumer preferences for bigger and heavier cars.

Related to 3: Compared to the air pollutants policies the car CO₂ innovation policies set in place have apparently been too weak to really curb the trend towards lower car CO₂ emission factors. Different policies were set in place.

- National and local governments experimented with new technologies, starting in the 1980s with electric vehicles and methanol (Kroon and Cornelisse, 1989), and currently with and hydrogen cars and filling stations (for example in the Eastern city of Arnhem). Recently, electric car policy experiments experience a revival, as shown in the cities of Amsterdam and Utrecht, where electric cars and taxis and public recharge locations are subsidized by the local government (Vink, 2010, Agentschap 2011a and b).

- On the EU level it was attempted to make cars more fuel efficient by way of a voluntary agreement between the European Commission and the European, Japanese and Korean car manufacturers. It was agreed upon in 1998 with the European car manufacturers, and in 1999 with the Japanese and Korean car manufacturers, that in 2008 they would sell new cars with an average CO₂ emission factor of 140 g/km according to specific tests. This is roughly a 25% reduction compared to 1998 levels. The EU average CO₂ emission factor for new cars did indeed decrease from around 185 g/km in 1995 to 154 g/km in 2008 (T&E, 2009). Note that these are test values: real-world values are less optimistic (see further below). The technical improvements that led to these results included more efficient petrol and diesel engines, hybrid powertrains, more sophisticated transmissions, low rolling-resistance tires, improved attention to detail, aerodynamics, stop-start technology, and regenerative charging systems. Nevertheless, the target of 140 g/km was not met (EC, 2007a). Therefore, the European Commission decided to propose CO₂ emission factor standards for new cars as from 2013 (e.g. EC, 2007b).

- In 2003, the blending of biofuels became mandatory for the EU (Biofuel directive, 2003/30/EC). EU member states were forced to blend 2% biofuels in transport fossil fuels as from 1 January 2007, increasing to 5.75% in 2010. In 2009 the share of biofuels was 3.75% in the Netherlands (VROM, 2010). This innovation policy ended in much confusing about its actual CO₂ effectiveness. PBL (2010b) analysed that depending on the type of biomass and CO₂ calculation method chosen (e.g. taking into account indirect emissions or not) the emission reduction of biofuels compared to fossil fuels could amount to 95% or to -180% (or, in other words, a CO₂ emission increase). Because of worries about the sustainability of biofuels the Dutch government has decided to reduce the 2010 biofuel blending target to 4% instead of 5.75% (PBL, 2009).

- Finally, on a national level, different kinds of pricing policies were implemented in this period to give car buyers incentives to buy relatively fuel efficient cars (or, in other words, cars with relatively low CO2 emission factors). It concerns policies such as income tax reduction for lease drivers if buying so-called A- or B-label cars ³, car fuel efficiency premiums, purchase tax exemption for hybrid cars (or other fuel efficient cars) and so-called ‘fee bate’ systems (relatively fuel inefficient cars– G-label cars – receive purchase tax fees and relatively fuel efficient cars– A- and B-label cars – receive purchase tax rebates (NP, 2002; PBL, 2010a). Together with autonomous

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³ In the Netherlands car fuel efficiency labeling was introduced in 2001. The Dutch label system is relative. This means that per weight class cars are labeled according to their fuel efficiency in test circumstances. The labels run from A to G. A- and B- labeled cars are most fuel efficient compared to the average (D-label). G-label cars are the least efficient ones compared to the average.
fuel price increases which were higher compared to the consumer price index (especially since the year 2005) these pricing policies have resulted in a higher market share of A and B label cars (Kieboom and Geurs, 2009). For example, A-label cars have a 25% market share in new car sales in 2009 compared to 6% in 2006 and 2007 (MNC, 2011). Still, the real world CO₂ emission factor stays fairly stable in this third period (Figure 1). For one reason this is due to the fact the share of A en B label cars is still relatively modest compared to the total car fleet. The other reason is because there is a difference between test CO₂ and real world emission factors.

Related to 4: We consider this difference between test and real-world an important factor which explains the disappointing car CO₂ emission factor development in period 3 (1990 – 2009). Ligterink and Bos (2010) have analysed car fuel filling data from Dutch lease drivers based on 240,000 users of tank cards. They could relate the real-world amount of petrol and diesel tanked to the amount of kilometres driven. Their main conclusion is that there is large difference between test values and real-world values. Especially the A- and B-label cars (including hybrids) showed in the real-world to being up to 40% less fuel-efficient compared to the test values. As these data apply to lease drivers, it should be noted that these findings are most reliable for car users who drive more than 10,000 km per year and use, more than average, highways for travelling. Nevertheless, the implication of these findings is that policies based on test values (the EU covenant, the A- and B-label pricing policies) are less effective in real-world than perhaps thought or hoped for.

4. Analysis and discussion

Policies to improve air quality by means of reducing air pollutant emissions from traffic have been implemented since the 1950s, starting in the US. These policies mainly included regulation, by means of car emission standards, and have been quite successful in improving air quality. One could characterize these norms as an intervention by the government (in this case at the EU level) in the selection environment. This might seem at the first glance an unilateral pressure to innovate by the government. However, looking closer at the process in which these standards were established, it can be observed that the EU (and, thus, the individual governments of which the EU was composed) was well aware of the technological progress that automobile industry was making on car emissions. As a result the standards were established in mutual agreement and, more or less, in mutual cooperation between the government and the car industry. In fact this process took place as described by the quasi-evolutionary model proposed by Schot et al. (1994). In that respect, it is worth mentioning that, to our best knowledge, there were no government-led experiments with respect to technology to reduce air pollutant emissions (e.g., three-way catalyst). Bauner (2011) shows that in the 1970s Japanese, US and European car manufacturers, suppliers and consultants developed and experimented in abundance with catalyst technology (they experimented, amongst others, with the substrate, wash coats, noble metals, coating, canning). From this fact it seems to us that the problem of air pollution formed an intrinsic motivation for the industry to develop new technologies. After all, the people who bought (and produced) cars were experiencing bad air quality themselves.

In contrast to the car air pollutants case, policies to increase car fuel efficiency (later also aimed at decreasing car CO₂ emission factors) were hardly effective in a measurable way. These policies included (1) voluntary agreements with the car industry to improve fuel efficiency (in the 1980s) and to reduce greenhouse gas emission (in the 2000s), (2) experiments with cars running on alternative fuels (e.g. hydrogen, electric vehicles), (3)
subsidies and all kinds of tax measures to boost sales of the most fuel-efficient car and (4) mandatory blending of biofuels. We will now discuss these policies.

In a sense, the emission standards set for reducing air pollution are comparable to the voluntary agreements regarding CO₂ emissions. Both are based on an agreement between the government and the industry, and both concern the limitation of emissions. Only the first policy is sanctioned an the second is not. This might of course be the main reason why the emission norms were more effective. So, the question is why in the case of air pollution it proved to be possible to set standards (in mutual agreement and co-operation), while in the case of fuel efficiency it was not. Air pollution seems to be a more recognized problem by the industry as a result of which they have autonomously worked on developing innovations, such as the three-way catalyst. With respect to CO₂ emissions, the problem seems to be less well recognized by the industry as well as by the government. In addition, as a result of high fuel taxes, Europe already has relatively fuel efficient cars as compared to Japan and the United States – countries that have in history always preceded Europe in setting air pollutant emission standards. Summarizing, the main factor determining the success of these policies is potentially the sense of urgency.

With respect to government-led experiments, it was found that these were performed in the field of climate change, but not in the field of air quality. It may well be that with respect to air quality, the apparent problem recognition by the industry has led to (incremental) innovation development that did not need support from the government to survive. In case of more radical innovation development, such as the electric vehicle, experiments are necessary in order to develop the technology to the level that it can compete with existing technology. But in this case it can be argued that, with an industry that acts on a global level, government-led experiments on the level of a small country like the Netherlands, in which there are few car manufacturers, are unlikely to make the difference. And, the rationale that experiments are needed for people to get used to new technology is mainly valid when the technology is very different than current technology, or if opposition is expected. Driving an electric vehicle is very similar to driving current cars with combustion engines, as recharging electric vehicles is very similar with the way we already charge our mobile electronic applications. Industrial experimenting with battery technology (as in the case of the three-way catalyst) seems to be of a higher priority than user-related issues. In any case, it is difficult to assess the effects of experiments on emission levels. These effects of experiments are mainly on the level of knowledge about the technology. This knowledge increases the probability of positive effects in the future, but never removes the uncertainty regarding technology development.

The mandatory blending of biofuels in conventional fuels is outstanding in this paper in that it is the only case in which the government has actually chosen for a certain technology. According to evolutionary economic theory, governments should refrain from picking winners (Van den Bergh et al., 2006). Maybe this is an interesting case to show why: it is still uncertain if biofuels contribute to decrease or increase of emission, and it is still uncertain if biofuels have more advantages compared to alternatives such as highly fuel-efficient conventional cars, electric vehicles, fuel-cell vehicles and so forth.

When claiming that emission standards have been a success, we might be accused for short-sightedness. If we zoom out and consider reducing emissions as part of the larger objective of a more sustainable transport systems, there are reasons to consider the emission regulations as potentially undesirable. Van den Bergh et al. (2006) suggest that if you want to create a level playing field for old and new technology, one of the things to do is to remove incentives that stimulate the dominant technology. By improving the performance characteristics of the
internal combustion engine vehicle (ICEV), it will be harder for technology that is still lower on the learning curve, such as fuel-cell and electric vehicles, to compete with the ICEV on technical performance. We think that the question whether or not improving ICEV technology is a long term versus short term trade-off. Improvement of the ICEV technology has shown to have substantial short term effects, but it might delay the implementation of vehicles with alternative drivetrains. A counterargument to this discussion could be that industry is free to choose for any technology to achieve the emission norms, including more radical ones than they do now. But with the relatively relaxed norms for CO$_2$ they are not stimulated to take the risk of introducing a radical innovation. The state of California tries another approach to advance zero-emission vehicles (ZEV) on their market by implementing so-called ZEV-regulation. This idea started with relatively simple 2.5 and 10% requirements: x% of car sales on the Californian market had to be ZEV from a certain future date. However, as Sperling and Gordon (2009) point out, the ZEV rule led a tortured life, undergoing industry lawsuits and continuing modifications. The simple 2.5 and 10% requirements have given way to complex of arcane rules. The latest revision in 2008 requires automakers to produce a total of 7,500 fuel cell vehicles or 12,500 battery electric vehicles (or some combination thereof) between 2012 and 2014, along with 58,000 plug-in hybrids (Sperling and Gordon, 2009). In conclusion, the above discussion shows that there are different (and potentially conflicting) ways of looking at the successfulness of innovation policy. As authors of this paper we do not want to take position, but do want to show that different views are possible.

5. Conclusions

In this paper we have reconstructed 50 years of EU and Dutch policy on technological innovations to reduce car emissions. From the analysis of this reconstruction, based on theory regarding innovations, we conclude that (1) air pollutant emission standards are a good example of a successful intervention of the government in the selection environment, while from a long term perspective it improves dominant combustion engine technology, making the competition for alternative drivetrains harder; (2) voluntary emission agreements are, like the emission standards, also based upon negotiations between government and industry, but are less successful due to the lack of intervention in the selection environment; (3) sense of urgency plays a large role in the feasibility of policies for technological innovations to reduce car emissions, it influences the success of negotiations between the government and the industry; (4) the experience with biofuels shows the risk of choosing a technology in an early stage of its development: the effects may turn out to be negative; and (5) it is questionable if it is necessary to perform government-led experiments with a globally emerging technology that is quite compatible to current practice – electric vehicles, in a country with no large car manufacturers like the Netherlands.

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