Environmental Innovation Dynamics in the Automotive industry

A case study in the framework of the project ‘Assessing innovation dynamics induced by environment policy’

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Abstract

This paper addresses the innovation dynamics induced by environmental policy in the automotive industry. It examines car fuel efficiency programs in the EU, the US and Japan. It concludes that existing programs have not yet succeeded in promoting radical and breakthrough technologies, but that, at the moment, the European and Japanese programs have more success in stimulating incremental innovations than the US program.
1. Introduction

This paper examines policy instruments that aim to promote fuel efficiency in passenger cars. It examines whether such programs in the EU, the US, and Japan have promoted environmental innovation in the automotive industry. Section 2 presents some background on the car industry and environmentally-induced innovation. Section 3 discusses the fuel economy programs of the EU, US and Japan and their results in detail. Section 4 concludes.
2. Drivers of Innovation

2.1 Introduction

In this introductory chapter, the car industry, its drivers of innovation, and technologic options to improve the fuel economy of cars are discussed. This chapter also recalls a previous episode of technology-forcing environmental policies in the car industry and tries to draw some lessons.

2.2 The car industry

The car industry is a highly dynamic and competitive, global industry. The European car industry contributes to the European economy by creating value added (7% of total manufacturing output), employment (7% of total manufacturing employment), trade (5% of total manufacturing exports), and by investing in research and development (20% of total manufacturing R&D) (EC, 2006).

According to CARS 21 High Level Group, “R&D activities in the automotive industry are all the more important as major technological breakthroughs could permanently alter the processes employed by the industry. In light of the fact that the industry’s international competitors have stepped up their innovative efforts and are making technological advances in certain technologies, it is of critical importance that European manufacturers are able to retain high investment levels in R&D as well as to rationalise and pool the use of R&D resources (EC, 2006: 13).”

The EU consumer demands “ever-increasing levels of customisation, comfort, and safety features in increasingly fuel-efficient vehicles” (EC, 2006: 13; italics by OK). Hence, major drivers of (environmental) innovation in the car industry are consumer demand and international competition. The speed with which certain technical innovations in the car industry are diffused internationally is illustrated in Figure 2.1, which shows the speed of market penetration of diesel engines with high-pressure injection technology. The penetration curve exhibits the typical S-shape of technology diffusion processes. Beise and Rennings (2005) point out, however, that there can be large differences in the speed and extent of international diffusion of environmental innovations in the car industry. While the catalytic converter diffused rather quickly from the US to other regions, European innovations in fuel efficiency and especially in diesel technology for passenger cars did affect the US market very much. Reasons for this include the low petrol prices in the US that do not stimulate demand for fuel efficient cars in general, and the fact that diesel engines generally do not meet the strict US Clean Air Act requirements with respect to the emissions of NOx. (Beise and Rennings, 2005).

In a survey among firms of the automotive sector in Southern Germany, a distinction was made between drivers for product innovation on the one hand, and process innovation on the other hand. Product innovations change the final product, such as changes in the overall design and the substitution of plastic for metal parts; process innovations concern the way that cars are produced, for example by using water-solvent paints, and
also changes in motor technology (gas, hydrogen). The main motives for environmental product innovations were: customer and cost pressure, as well as environmental regulation and company environmental policy. The main motives for process innovation were the opening of new markets, gaining of competitive advantage as well as the saving of resources, CO$_2$ reduction because of the Kyoto Protocol and company environmental policy objectives, and various pieces of environmental regulation, i.e., the EU Directive on alternative car fuels, and the Euro 4 and 5 emission limit values (Triebswetter and Wackerbauer, 2004).

Figure 2.1  International diffusion of diesel high-pressure injection (Beise and Rennings, 2005).

2.3 Policy-induced innovation

The car industry has been subject to environmental regulation for a number of decades. In the late 1960s, the US government set drastic reduction standards for the emissions of conventional air pollutants from cars in the 1970 Clean Air Act. The Act required 90 percent reductions in tailpipe emissions for new 1975 and 1976 automobiles (Gerard and Lave, 2003). This presented automakers with major technical and economic challenges. As a result, catalytic technologies were developed that eventually became worldwide standards. Especially the introduction of the three-way catalyst in 1981 required major adjustments in motor control technology, leading to the widespread use of computer technology in cars. This computer technology, in its turn, also facilitated further improvements in car performance, safety and fuel economy. In an instructive account of

1 Triebswetter and Wackerbauer do not explain the criteria for this classification.

2 Encompassing the objective that by 2020 20% of all fuels shall be replaced by alternative fuels of which 10% shall be gas. This stated objective was an important motive for the surveyed company keep on investing in the development of a series-produced natural-gas bus.
the implementation process of the emissions standards of the Clean Air Act, Gerard and Lave (2003) point out that the success of the Clean Air Act in inducing the advanced emissions control technologies in cars was in part due to favourable technical, political, economic and administrative dynamics at that time. These dynamics included the nature of the innovation (higher chance of success with incremental improvements of existing but yet unproven technologies), the credibility of the regulator (in terms of the likelihood of it taking punitative action and its technical expertise), and ‘robust’ competition between domestic manufacturers, foreign suppliers, and suppliers of component parts. But even with favourable conditions, Gerard and Lave (2003) argue, a technology-forcing strategy is uncertain, with no guarantees of technological breakthroughs and extremely vulnerable to pressures from many different stakeholders and to unforeseen consequences (and something as banal as a change in macroeconomic conditions).

There is some evidence that the costs of emissions regulations for cars fall over time, through ‘learning’, or simply because a change in vehicle design only needs to be developed once but can be used in later years at no additional costs (Chen et al., 2004). The US Office of Science and Technology estimated that initial investment costs per vehicle in 1976 due to the Clean Air Act decreased by approximately 30 percent in the following ten years due to “increased production efficiency, which will reduce the initial investment costs as experience is gained in production” (Chen et al, 2004) (see Figure 2.2).

![Learning curve for vehicle production](image)

**Figure 2.2** ‘Learning’ curve for emissions controls in cars due to the 1976 emission standards in the US, as estimated by the US Office of Science and Technology (Chen et al., 2004).
It has also been estimated that the cost-effectiveness of the three-way catalyst in the Netherlands (in terms of kg NO\textsubscript{x} reduction per Euro) approximately doubled in the three years after its introduction around 1993 (Dings, 1996).

### 2.4 Fuel economy

The fleet-average fuel economy in Europe is second highest in the world, only to be surpassed by Japan. Figure 2.3 shows the development of fleet-average fuel economies from 2002 to 2006 across major countries and world regions, and projects likely trends into the future. The fuel economy in the US is low. Initiatives in California have the potential to improve State fuel economy in the near future. Interesting in Figure 2.3 is the position of China with its medium fleet-average fuel economy. With the current concern in China about urban air pollution, China may well step-up fuel economy standards for cars sold in China. From the perspective of China being the potentially largest growth market for automobile sales, it is of major importance that European carmakers do not fall behind Japanese carmakers in improving fuel economy.

![Comparison of Fuel Economy and GHG Emission Standards](image)

*Figure 2.3  Comparison of Fuel Economy and GHG emission standards (Sauer, 2005).*

There are various technological options to improve the fuel economy of cars above its present level. The following two tables present options for petrol and diesel cars, respectively. The options relate not only to engines, but also to transmission, aerodynamics, and tyres.
### Table 2.1  Impact on technical improvements on fuel economy of petrol cars (%).

<table>
<thead>
<tr>
<th>Source</th>
<th>Description</th>
<th>Car size</th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine</td>
<td>Optimised engine efficiency</td>
<td></td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Direct injection/ stratified charge (lean burn)</td>
<td></td>
<td>10</td>
<td>10</td>
<td>10</td>
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<tr>
<td></td>
<td>Direct injection/ homogenous charge (stoichiometric)</td>
<td></td>
<td>5</td>
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<tr>
<td></td>
<td>Mild downsizing with turbo charging</td>
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<td>10</td>
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<td></td>
<td>Medium downsizing with turbo charging</td>
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<td>15</td>
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<td>15</td>
</tr>
<tr>
<td></td>
<td>Strong downsizing with turbo charging</td>
<td></td>
<td>20</td>
<td>20</td>
<td>20</td>
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<tr>
<td></td>
<td>Variable valve timing</td>
<td></td>
<td>6</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Variable valve control</td>
<td></td>
<td>8</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Cylinder deactivation</td>
<td></td>
<td>10</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>Transmission</td>
<td>6-speed manual/automatic gearbox</td>
<td></td>
<td>3</td>
<td>3</td>
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<tr>
<td></td>
<td>Piloted gearbox</td>
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<td>5</td>
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<td>5</td>
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<tr>
<td></td>
<td>Continuous variable transmission</td>
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<td>9</td>
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<td>9</td>
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<tr>
<td></td>
<td>Dual-clutch</td>
<td></td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Hybrid</td>
<td>Start-stop function</td>
<td></td>
<td>6</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Regenerative braking</td>
<td></td>
<td>5</td>
<td>7</td>
<td>8</td>
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<tr>
<td></td>
<td>Mild hybrid (motor assist)</td>
<td></td>
<td>8</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Full hybrid (electric drive)</td>
<td></td>
<td>17</td>
<td>20</td>
<td>23</td>
</tr>
<tr>
<td>Body</td>
<td>Improved aerodynamic efficiency</td>
<td></td>
<td>2</td>
<td>1.5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Mild weight reduction</td>
<td></td>
<td>3</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Medium weight reduction</td>
<td></td>
<td>5</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Strong weight reduction</td>
<td></td>
<td>8</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>Other</td>
<td>Low friction tyres</td>
<td></td>
<td>2</td>
<td>2</td>
<td>2</td>
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<tr>
<td></td>
<td>DeNOx catalyst</td>
<td></td>
<td>–1</td>
<td>–1</td>
<td>–1</td>
</tr>
</tbody>
</table>

Source: IEEP/TNO/CAIR, 2005

### Table 2.2  Impact on technical improvements on fuel economy of diesel cars (%).

<table>
<thead>
<tr>
<th>Source</th>
<th>Description</th>
<th>Car size</th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine</td>
<td>Optimised engine efficiency</td>
<td></td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>16 valve cylinder head</td>
<td></td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Piezo injectors</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Mild downsizing with turbo charging</td>
<td></td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Medium downsizing with turbo charging</td>
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<td>20</td>
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<tr>
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<td>Cylinder deactivation</td>
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<td>10</td>
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<td>6-speed manual/automatic gearbox</td>
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<td></td>
<td>Piloted gearbox</td>
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<td>5</td>
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<td>Continuous variable transmission</td>
<td></td>
<td>9</td>
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<td>9</td>
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<td></td>
<td>Dual-clutch</td>
<td></td>
<td>4</td>
<td>4</td>
<td>4</td>
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<tr>
<td>Hybrid</td>
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<td>4</td>
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<td>Regenerative braking</td>
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<tr>
<td></td>
<td>Full hybrid (electric drive)</td>
<td></td>
<td>15</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>Body</td>
<td>Improved aerodynamic efficiency</td>
<td></td>
<td>2</td>
<td>1.5</td>
<td>1</td>
</tr>
</tbody>
</table>
The emissions reduction percentages of the tables above cannot always be added as some technologic options are mutually exclusive. In addition, the impact of implementing several options simultaneously is multiplicative rather than additive (Kampman and Boon, 2005). According to TNO, hybrid drives in combination with a host of other technical adaptations can consume 30 to 40 percent less fuel than conventional petrol cars; for diesel cars a fuel consumption benefit of 15 percent may be feasible (Kampman and Boon, 2005).

It would be interesting to study how fuel efficiency programs in various regions have stimulated or are expected to stimulate specific technologies as listed above. As far as we know, no study along these lines has been carried out as yet.

As yet, no ‘learning’ or ‘experience’ curves for energy efficiency improvements in cars have been estimated. Experts in this area suggest that the multi-functionality of technological improvements in consumer products such as cars complicates their measurement relative to supply side technologies such as wind energy and solar PV. At the moment, research on experience curves of demand side options in energy efficiency is being carried out in the Netherlands (Junginger, 2006).

2.5 Conclusions

In sum, the European car industry is highly dynamic and innovative. It’s R&D expenditures are well above average in Europe’s manufacturing sector. Among the most important drivers of innovation are consumer demand (for performance, comfort, safety and fuel economy), international competition, and environmental objectives and regulations. The catalytic converter and the three-way catalyst were induced by tough US regulation in the late 1960s and early 1970s. From that episode, the lesson was drawn that technology-forcing regulation may sometimes be successful but that it will always remain a risky strategy. One element of success of technology forcing is to build on one or more existing technologies that have not yet been proven (commercially) in the area of application. For improvements in the fuel economy of cars, many technological options are potentially available.
3. Policy Instruments and Innovation

In this chapter, three different fuel-economy instruments are discussed. Section 3.1 discusses the European ACEA Agreement, Section 3.2 discusses the US CAFE program, and Section 3.3 discusses the Top Runner program from Japan.

3.1 ACEA Agreement – EU

One important element of the EU’s strategy to reduce CO₂ emissions from passenger cars and to improve fuel efficiency are the voluntary agreements that it concluded with the automobile industry to reduce total new passenger fleet average CO₂ emissions according to specific targets and timetables. The voluntary agreements were in 1998 concluded with the European Automobile Manufacturers’ Association (ACEA), the Japan Automobile Manufacturers Association (JAMA), and the Korea Automobile Manufacturers Association (KAMA). Henceforth we will label these agreements collectively as the ACEA Agreement. The target for new passenger fleet average CO₂ emissions is 140 g CO₂/km by 2008/9. The Community’s target for 2012 is 120 g CO₂/km. This longer-term target has not yet been included in any formal agreement with the car industry.

Table 3.1 below shows how these targets can be translated into fuel efficiency standards for petrol and diesel cars. The Commission has stated on several occasions that a failure of the car industry to meet the 2008/9 targets might lead to mandatory regulation in the future.

Table 3.1 Relationships between CO₂ targets and fuel consumption

<table>
<thead>
<tr>
<th>Target</th>
<th>Fuel consumption (ℓ) per 100 km</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>petrol</td>
</tr>
<tr>
<td>120 gCO₂/km</td>
<td>5.1</td>
</tr>
<tr>
<td>140 gCO₂/km</td>
<td>5.9</td>
</tr>
</tbody>
</table>

Source: Kågeson, 2005.

Figure 3.1 below shows average specific CO₂ emissions for each association and for the EU-15 as a whole for the period 1995-2003, and the final target for 2008/9.

Over the period 1995-2003, overall specific CO₂ emissions of new passenger cars on the European market fell by almost 12 percent. In the context of this study, three questions are of prime importance:

1) Is the reduction in specific CO₂ emissions of new passenger cars due to technological improvements or are they due to ‘autonomous’ changes in market demand?

2) What technological improvements have contributed most to the observed reductions in specific CO₂ emissions?

3 Other elements include fuel-economy labelling on cars, and the promotion of car fuel efficiency by fiscal measures (EC, 2005).

4 The target year is 2008 for ACEA and 2009 for JAMA and KAMA.
3) To what extent can these technological improvements be attributed to EU policies, i.e., the voluntary agreements with the car manufacturers’ associations?

![Figure 3.1: Average specific CO₂ emissions of new passenger cars and target.](image)

*Source: EC, 2005.*

**Figure 3.1** Average specific CO₂ emissions of new passenger cars and target.

A change in average specific CO₂ emissions of new passenger cars can have different causes. It can be caused by changes in the composition of the fleet because of changes in consumer demand. Changes can also occur because of changes in the average weight of passenger cars due to increasing comfort and safety features. A notable change in European car sales in the past decade is the increasing share of diesel cars. Diesel engines have lower specific emissions of CO₂ than petrol engines.

Although changes in consumer demand that have influenced specific CO₂ emissions of new passenger cars have occurred over the period 1995-2003, a detailed investigation into the causes of changes in specific CO₂ emissions over that period found no evidence that “the observed total reduction of ACEA’s and JAMA’s CO₂ fleet average was significantly influenced by other factors than technological developments” (DLR, 2004:81).

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5. Average weight of passenger cars increased from 1.100 kg to 1.200 kg between 1995 and 2002. A number of safety features such as (additional) airbags and anti-block braking systems, contributed to this increase in average weight (DLR, 2004).

6. The complete quote is: “Overall, the investigation finds some evidence of the influence of non-technical factors on average CO2 emissions. Given the magnitude and mixture of negative and positive effects of these influences, however, no evidence could be found that the observed total reduction of ACEA’s and JAMA’s CO2 fleet average was significantly influenced by other factors than technological developments.” (DLR, 2004:81).
This strongly suggests that the observed emissions reductions were indeed primarily caused by technological developments.

What kinds of technological development have contributed most to emissions reductions? For petrol cars it was primarily the change from singlepoint to multipoint injection that improved fuel efficiency, for diesel cars it was the almost complete penetration of the direct injection/high pressure technology over the period 1995-2003. The share of direct injection in petrol cars is still very low (DLR, 2004).

Can these technological developments be (partly or totally) attributed to the Voluntary Agreements of the European Commission with the car manufacturers’ associations? In other words, what would have happened to car technologies without the voluntary agreements? This question is difficult to answer.

In his PhD-thesis on voluntary environmental agreements, Zerle (2005) argues that the targets of the ACEA agreement are well within the ‘business-as-usual’ pathway of fuel economy in Europe. Figure 3.2 shows the historical trend of fuel economy in Germany (ℓ/100km) between 1970 and 2000 and the ACEA targets for 2003 and 2008. Zerle further argues that this is little surprising, since ACEA has no real power to force European car makers to go beyond their planned (“business-as-usual”) improvements in average fuel economy and to coordinate efforts among the car makers. One reason for the relatively weak position of ACEA in this respect is the ease with which car makers can withdraw from the Association, as happened with Rover/MG in 2002. The German Advisory Council on the Environment (SRU, 2005) confirmed the analysis of Zerle. The Advisory Council writes that: “it must be assumed […] that the achieved reduction was sparked by existing incentives and that the self-regulation [the ACEA Agreement, OK] effected no further reduction in fuel consumption.” (SRU, 2005: 29).

The Advisory Council goes on to argue that a basic flaw in the Agreement is that the organisation that is required to fulfil the agreement – the ACEA – has only limited influence on how the target is reached. First, ACEA cannot dictate CO₂ emissions levels for vehicles produced by individual carmakers, and second, ACEA has no influence on the consumer who ultimately decides on the composition of the fleet sold in Europe. The Advisory Council therefore concludes that achieving the 2012 target would need an alternative set up that would eliminate the mismatch between those who should comply with the standard and those who are really targeted by the standard (SRU, 2005).

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7 In 1995, only Volkswagen/Audi offered some versions of its TDI. Now it is a commonplace engine technology for diesel cars (DLR, 2004).
The car industry should have no difficulties in producing cars with average specific CO₂ emissions of 140 g CO₂/km in 2008 and 120 g CO₂/km in 2012. Kågeson (2005) argues that, under current rules, manufacturers, wholesalers and car dealers have no incentives to sell fuel-efficient cars. Their profit margins are better served by sales of larger and more fuel-consumption vehicles such as Multi-Purpose and Sport Utility Vehicles. Kågeson (2005) further argues that no individual manufacturer can afford to take a different route (than to produce what the market demands) without the support of incentives. If Kågeson is right, this would mean that the “business-as-usual” fuel economy pathway of Zerle (Figure 3.2) would start levelling-off or would even change direction.

Hence, although it cannot be excluded that the ACEA Agreement has contributed to technological innovation in the car industry, its contribution has very likely been modest at best. Whether or not ACEA will comply with the target of 2008 is highly dependent upon autonomous changes in market demand on which ACEA has no influence.

3.2 CAFE – USA

In 1975, US Congress established Corporate Average Fuel Economy (CAFE) standards to conserve petroleum and to reduce US reliance on imported oil (Gerard and Lave, 2003). It has continued to enjoy public support, also as a means to reduce air pollution and to curb greenhouse gas emissions, although it has also been criticised by economists.

For instance, Toyota’s hybrid car, the Prius, only emits 104 g CO₂/km. For overviews of technical options see, a.o., Kågeson (2005), Kampman and Boon (2005), and IEEP/TNO/CAIR (2005).
on the grounds that the aforementioned goals could be achieved with other instruments at less costs (see, for example, NAS, 2002).

The CAFE standards set mandatory average fuel economy standards for automobile manufacturers for passenger cars and light-duty trucks. For passenger cars, the standards have been increased from 18 mpg (miles per gallon) in 1978 to 27.5 mpg in 1985 and have not been raised since. For light-duty trucks, the standard is 20.7 mpg.

Compared to the European targets, the CAFE standards are not very ambitious. The 140 g CO$_2$/km target from the ACEA Agreement translates into a fuel economy standard of 5.9 ℓ/100 km (see Table 3.1). The US CAFE standard for petrol passenger cars is 9 ℓ/100 km and the light-duty truck standards for minivans, pickups and sport utility vehicles are even less ambitious.

Figure 3.3 below indeed shows that the average fuel economy of new cars in the United States has not improved since the mid-1980s. There are many reasons for this trend, perhaps most importantly the low US petrol prices. NAS (2002) remarks that there are many advanced technologies on the market, including direct-injection, direct-injection compression-ignition (diesel) engines, and hybrid electric vehicles that could improve vehicle fuel economy by 20 to 40 percent. With respect to diesel technology, that has, as discussed earlier, produced large fuel economy gains in Europe, the US has problems with emission standards of nitrogen oxides and particulates under the (1990 amendments to the) Clean Air Act. According to NAS (2002), if direct-injection gasoline and diesel engines are to be used extensively to improve fuel economy, significant technical developments concerning emissions control have to occur or adjustments have to be made to the Clean Air Act emissions standards (NAS, 2002: 5).


*Figure 3.3 New Vehicle Fuel Economy in the United States (1974-2000).*
What has been the effect of the CAFE standards on the average fuel economy in the US? Figure 3.3 shows that average fuel economy increased sharply from the mid-1970s to the mid-1980s and then stabilized. Analysts have argued that the initial increase in fuel economy was the effect of increases in gasoline prices of the oil shocks of the 1970s and not due to CAFE regulations (see, Gerard and Lave, 2003). But according to Gerard and Lave (2003), it was after the mid-1980s, when gasoline prices dropped, that “CAFE was responsible for maintaining the fleet fuel economy gains of the past decade.” (Gerard and Lave, 2003: 4).

According to an econometric study by Goldberg (1998), the main effect of CAFE has been to stimulate the sales of small cars at the expense of larger cars. This effect has been partially undone, however, by the loophole that was provided by the lighter light-duty vehicles standards, that are applicable to large and growing segment of modern, larger passenger cars, including the minivans, pickups, and sports utility vehicles. Gerard and Lave (2003) note that passenger cars accounted for 90 percent of the passenger-vehicle fleet in 1975, but now vehicle sales are about equally split between cars and light trucks.

Moreover, Kågeson (2005) observed that the low level of compliance penalty fees, which, according to him, have not effectively stopped manufacturers from non-compliance, has also undermined the effectiveness of the CAFE program.

Concluding then, CAFE may have avoided a collapse of average fleet fuel economy in the 1980s when gasoline prices dropped, it has probably not stimulated environmental innovation in the US automobile industry very much. It is also probably not a good model for Europe, as it gives few incentives to manufacturers of small cars to improve fuel efficiency (Kågeson, 2005).

### 3.3 Top Runner – Japan

The Top Runner Program was introduced in Japan in 1999 as part of the revision of the Law on the Rational Use of Energy (Naturvårdverket, 2005). The objective of Top Runner Program is to address energy use in the transport, commercial and private sectors. One of the targeted sectors is the automobile industry. Among the targeted product groups (e.g., passenger cars), the most energy-efficient product (the “Top Runner”) becomes the basis of the standard in 3 to 12 year time, taking into account the potential for technological innovation and diffusion. The standards in the Top Runner Program are used in the Green Purchasing law and the green automobile tax scheme. There is also an annual award for the most energy-efficient products and systems.

The experience with the Top Runner Program has been good. For certain product groups – air conditioners, TV sets, and videocassette recorders – the results have exceeded expectation, and not only have manufacturers met standards on a weighted average basis but also on an individual model basis (Naturvårdverket, 2005). It is expected that cars will manage to meet the Top Runner standards prior to the target year (Naturvårdverket, 2005).

Naturvårdverket (2005) lists a number of stronger and weaker points of the Top Runner Program. Stronger points include that the program gives incentives for industry-wide environmental improvements, because the standards do not only look at the best product on
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the market, but also to the potential for other producers to realistically meet the standards. The mandatory nature of the program forces producers to meet the standards. The standards apply to individual companies, which probably gives more incentives to companies to comply than industry-wide standards such as the ACEA standards. The relationships of the standards with other policy instruments, public procurement, tax systems, is interesting. In Japan, the “name-and-shame” element of the program (with its annual awards) is also of great importance.

Weaker points include that the “realistic” levels of the standards (see above) may not stimulate radical or break-through innovations, and that the differentiation of standards within product groups ensures the availability of a wide range of products, which may not all be preferable from an environmental or sustainability perspective. The Top Runner Program for cars, for example, differentiates between weight classes (see Table 3.2).

Table 3.2  Top Runner Fuel Economy Standards (km/ℓ)\(^9\).

<table>
<thead>
<tr>
<th>Weight (kg)</th>
<th>Gasoline</th>
<th>Diesel</th>
<th>LPG</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 703</td>
<td>21.2</td>
<td>18.9</td>
<td>15.9</td>
</tr>
<tr>
<td>703-828</td>
<td>18.8</td>
<td>18.9</td>
<td>14.1</td>
</tr>
<tr>
<td>828-1016</td>
<td>17.9</td>
<td>18.9</td>
<td>13.5</td>
</tr>
<tr>
<td>1016-1266</td>
<td>16.0</td>
<td>16.2</td>
<td>12.0</td>
</tr>
<tr>
<td>1266-1516</td>
<td>13.0</td>
<td>13.2</td>
<td>9.8</td>
</tr>
<tr>
<td>1516-1766</td>
<td>10.5</td>
<td>11.9</td>
<td>7.9</td>
</tr>
<tr>
<td>1766-2016</td>
<td>8.9</td>
<td>10.8</td>
<td>6.7</td>
</tr>
<tr>
<td>2016-2266</td>
<td>7.8</td>
<td>9.8</td>
<td>5.9</td>
</tr>
<tr>
<td>&gt; 2266</td>
<td>6.4</td>
<td>8.7</td>
<td>4.8</td>
</tr>
</tbody>
</table>

Source: (Naturvårdverket, 2005).

Concluding then, the Top Runner Program has interesting features. It provides for dynamic incentives to improve energy efficiency and it affects companies directly. It may not, however, provide incentives for radical innovations and some of its success factors may by culturally determined and not directly exportable to Europe.

\(^9\) x km/ℓ is equivalent to 100/x ℓ/100km. The highest fuel efficiency standards are for small gasoline cars, they are 4.7 ℓ/100km. Note that the fuel efficiency standard for small diesel cars is 5.3 ℓ/100kg, which is comparable to the average ACEA 140 standard.
4. Summary and Conclusions

The European car industry is highly dynamic and innovative. It’s R&D expenditures are well above average in Europe’s manufacturing sector. Among the most important drivers of innovation are consumer demand (for comfort, safety and fuel economy), international competition, and environmental objectives and regulations. The catalytic converter and the three-way catalyst were induced by tough US regulation in the late 1960s and early 1970s. From that episode, the lesson was drawn that technology-forcing regulation may sometimes be successful but that it will always remain a risky strategy. One element of success of technology forcing is to build on one or more existing technologies that have not yet been proven (commercially) in the area of application. For improvements in the fuel economy of cars, many technological options are potentially available.

The three fuel-efficiency instruments discussed in Chapter 3 all have different elements and specific features. The ACEA program in Europe and the Top Runner program in Japan are clearly more ambitious in their targets than the CAFE program in the US. A further difference is that the Japanese and US programs are mandatory, while the EU program is voluntary. Finally, while the EU and US programs set industry-wide standards, the Japanese system sets company standards.

With respect to innovation, the EU and Japanese policy instruments perform better than the US CAFE program. This is not surprising, given the large gap between the stringency of fuel-efficiency standards in Europe and Japan on the one hand and the US on the other. None of the standards, however, is expected to give incentives for radical or break-through innovations. Both ACEA and Top Runner seem to be focusing more on the rapid diffusion of new technologies and incremental innovations. As yet, however, the ACEA agreement has not been extremely successful in stimulating promising technologies such as direct injection in gasoline cars and the production of hybrid cars.

It is not yet clear whether the mandatory or voluntary nature of the policy instruments makes much of a difference. It is not known yet whether the car industry will meet the final ACEA standards in 2008, and how the European Commission will react on a possible failure. The US CAFE program has mandatory standards, but it also has legal loopholes and according to some observers the non-compliance penalties are too small to make a big impression on automakers.

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10 One of the reasons for the persistence of this difference is that the US is not a significant exporter of cars to the European and Japanese markets.
One interesting distinction between the European ACEA approach and the Japanese Top Runner approach is that ACEA sets standards at the industry level, while Top Runner sets standards at the company level. Perhaps this latter approach has the advantage that companies are more directly involved in the process. It is, for example, remarkable that only half of the European automakers mentioned the ACEA standard and progress towards this standard in their annual reports (WRI, 2005).¹¹

¹¹ Only BMW included information in its 2003 annual report on its strategy to meet the ACEA standard (WRI, 2005).
5. References


WRI (2005). Transparency Issues with the ACEA Agreement.