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Effect of regulations and standards on vehicle prices

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Executive summary

Current practice when analysing and modelling the impacts of legislative action, which imposes tougher requirements on the environmental or safety performance of road vehicles, is to assume that these more stringent requirements will lead to higher production costs and consequently, higher vehicle prices for consumers. However, in practice it is difficult to find real-world evidence that such price increases have actually occurred, especially given that over the last two decades there has been a significant amount of new EU-level legislation focused on road vehicles.

Given the above situation, there is growing evidence that the traditional approach to modelling market reactions to policy proposals (i.e. to assume price increases for road vehicles and then model reactions on that basis) might be seriously flawed. In particular, it is possible that the ex-ante costs of compliance with legislation may be overestimated and there are doubts as to whether vehicle manufacturers actually pass on the extra costs of legislation to consumers. For these reasons, the European Commission contracted AEA to carry out this study to investigate the effects of legislation on vehicle prices. The specific objectives of the study were as follows:

- Analysis of the historical evolution of new passenger car market prices in the EU27 with respect to environmental performance, safety standards and comfort levels

- Understanding the development/composition of manufacturing costs, both of the vehicle itself and of the technical equipment on board the vehicle. This included understanding how these costs have evolved over time

- Estimating the effect of existing legislation (regulations and standards) on the real end-user prices and characteristics of new vehicles in the period up to the year 2010

- Use the findings from this research to develop a quantitative method by which the impacts of vehicle regulations and standards can be translated into real-world price impacts. Such a method could potentially then be integrated into the design of The Commission's modelling tools in order to improve the accuracy and usefulness of modelled outputs.

Meeting these objectives required a systematic and coordinated approach. The findings of three difference research approaches were triangulated to provide the necessary answers. These approaches were as follows:

1. A comprehensive review of the literature on the factors that influence passenger car prices;
2. The development and use of a quantitative hedonic regression model (using commercially purchased data on historical vehicle prices and feature content) that implicitly capture changes in prices caused by changes in product characteristics and other influencing factors; and
3. A brief consultation of key stakeholders to validate the findings and address any gaps from the literature review and quantitative model.

A combination of quantitative and qualitative analysis was used to isolate the impacts of different vehicle attributes on price. The hedonic model served as the primary quantitative analytical tool for this study. The literature review was used to qualitatively support and augment the quantitative modelling process, and to test the assumptions and verify findings from the model. The study team's professional judgement was used to infer appropriate quantitative adjustment factors or the hedonic analysis from the literature review and interviews. The findings from the literature review and interviews were also used to address the limitations of the hedonic model in its ability to meet the objectives of this study.

The main findings from the study are as follows:

- Growth in environmental, safety and product regulation has led a wide range of strategies and practices that are used by manufacturers to balance production costs and regulatory compliance. The last fifteen to twenty years has seen a significant increase in regulation to reduce the environmental and health impacts of car emissions. Manufacturers have had to balance production costs while ensuring that they comply with environmental regulation and meet the high standards of quality and performance that the market demands. This has led to the growth of practices such as platform sharing and collaborative approaches to vehicle development and production, which have been key to cost reductions in the industry. Manufacturers have shifted production of vehicles away from Western Europe to Eastern Europe and Asia, in a bid not only to drive down costs through lower labour rates, but also to satisfy rapidly growing new markets.

- Massive fragmentation on choice of models and variants makes it very difficult to link cost and profit margins. The automotive sector has implemented a range of business strategies aimed at maintaining market share and profitability in an increasingly competitive and liberalised market.

- Direct costs (manufacturing costs) are managed by approaches such as platform sharing, quality control systems and statistical process control techniques (e.g. six sigma). Compliance with safety and environmental regulations introduced since the late 1980s has forced car manufacturers to improve their designs by adopting a systems engineering approach.

- Evidence from the dataset of historical vehicle prices and features does not provide any definite relationship between vehicle emissions standards and car prices. In general, only indicative correlations can be made between emission trends and car prices. Furthermore, the retail list prices for a range of specific vehicle models identified from the datasets and the technology adjusted price index developed from the regression analysis indicate that car prices have fallen more quickly since the announcement in 2007 of the EU Regulation on passenger car CO_2 emissions. Overall cars have become 12% to 22% cheaper – after inflation – in the eight years from late 2002 to late 2010. The average annual reduction in CO_2 emissions was 0.7% and 2.5% in 2002-2006 and 2002-2010 respectively.

- The difficulty in isolating the impact of car attributes on prices stems from the complexity of vehicle production technology, pricing/marketing strategies and compliance with regulations. The introduction of complex engine, vehicle and exhaust after-treatment technologies in the last two decades (partly driven by legislation) that improve environmental performance as well as the introduction of new comfort and safety features and improvements in vehicle performance/engine power output have helped manufacturers absorb any additional costs. In addition, a highly complex and varied pricing strategy across brands and models has changed the time profile of when manufacturers make investments in new technologies and when they recoup the costs of these investments.

- Whether the increased costs of complying with environmental and safety legislation lead to increases in prices depends on *inter alia* the extent to which these costs are offset by cost reductions resulting from economies of scale and improved productivity and whether prices any cost increases can be passed on to consumers.

- The most important factors that influenced car prices and, including the extent to which these costs were passed through to consumers, were environmental standards, market conditions (e.g. tax levels for public and private users, consumers' purchasing power) and competition.

- The outputs from the consultation with stakeholders indicated that generally, it was felt that environmental and safety legislation would always lead to increased production costs. Where such increased costs did not subsequently lead to increased prices, it was argued that this was due to competition in the markets concerned. Reduced costs resulting from, for example, economies of scale or improved productivity (for the reasons identified in the literature review; see above), could offset the increased costs of regulation.

- Where net cost increases could not be passed on to consumers, then the margins of manufacturers and/or their suppliers would be reduced. More generally, if environmental and safety legislation had not increased costs, car prices would be lower than current levels.
- The extent to which increased costs can be passed on to consumers depends on competition and market conditions. Of the respondents that had a view on this, most agreed that the ability to pass on costs varied by brand and the type of vehicle being sold (as well as the market) and exposure to foreign brands.
- Stakeholders provided mixed messages on the future impact of regulation and impact on costs. Some felt that regulatory pressures would reduce costs, as cars would be smaller, while others felt that costs would subsequently increase, e.g. as hybridisation would be required more widely.
- Some stakeholders suggested regulatory impacts assessments should be broadened in Europe to better reflect the impact on the industry's competitiveness and other options for reducing transport's CO_2 emissions.

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1 Objective and purpose

1.1 Introduction

The European Commission has contracted a team led by AEA to carry out a study on the effects of regulations and standards on vehicle prices. The main purpose of this study was to help improve the way in which the impacts of vehicle environmental and safety legislation are modelled. Current modelling and analytical approaches assume that legislative requirements on air pollutant emissions, energy performance / GHG emissions and safety inevitably lead to increased production costs, and therefore higher vehicle prices for consumers. Such assumptions have been used in much of the analysis carried out by or on behalf of the European Commission when assessing the impacts of proposed environmental and safety legislation for road vehicles. These assumptions have filtered through to a number of the Commission's transport sector modelling tools including the TREMOVE[1] model, which was the main tool used for analysing the impacts of recent legislative proposals (Impact Assessments for CO_2 emissions from cars/vans, EURO 5/V and 6/VI limits). However, to date The Commission has found it difficult to find real-world evidence that increases in end-user prices have occurred following the introduction of such legislation. Nonetheless ex-ante analysis usually indicates significant cost increases associated with meeting new environmental and safety legislation. There could be a number of reasons why the impacts of new vehicle legislation do not manifest themselves in increases in vehicle prices. With these issues in mind, the main purpose of this study was to:

- Analyse the historical evolution of new passenger car market prices in the EU-27 with respect to environmental performance, safety standards and comfort levels;

- Understand the development of vehicle manufacturing costs, both of the vehicle itself and of the technical equipment on board the vehicle as well as the cost evolution over time;

- Estimate, using a quantitative model, the effect of existing legislation (regulations and standards) on the real end-user prices and characteristics of new vehicles in the period up to the year 2010;

- Investigate the reasons for why the impacts of new vehicle legislation do not manifest themselves in increases in vehicle prices and to quantify the actual impacts of existing legislation on real end-user vehicle prices;

- Separate out other factors that influence the development of vehicle costs and prices over time. These other factors are likely to include the fitment of additional comfort features and changes in production processes and strategies; and

- Use the findings from this research to develop a quantitative method by which the impacts of vehicle regulations and standards can be translated into real-world price impacts. Such a method could potentially then be integrated into the design of the Commission's modelling tools (such as TREMOVE) in order to improve the accuracy and usefulness of modelled outputs.

1.2 Study method

As recognised by the terms of reference to the study, there are a number of factors that have influenced production costs and end-user prices over the last 10-15 years. Some of these factors are

[1] http://www.tremove.org/

not straightforward to quantify in terms of their effects on vehicle prices. In order to systematically understand and estimate the impacts of different vehicle attributes on vehicle prices and their relationship with environmental regulation, we used three different approaches in the study.

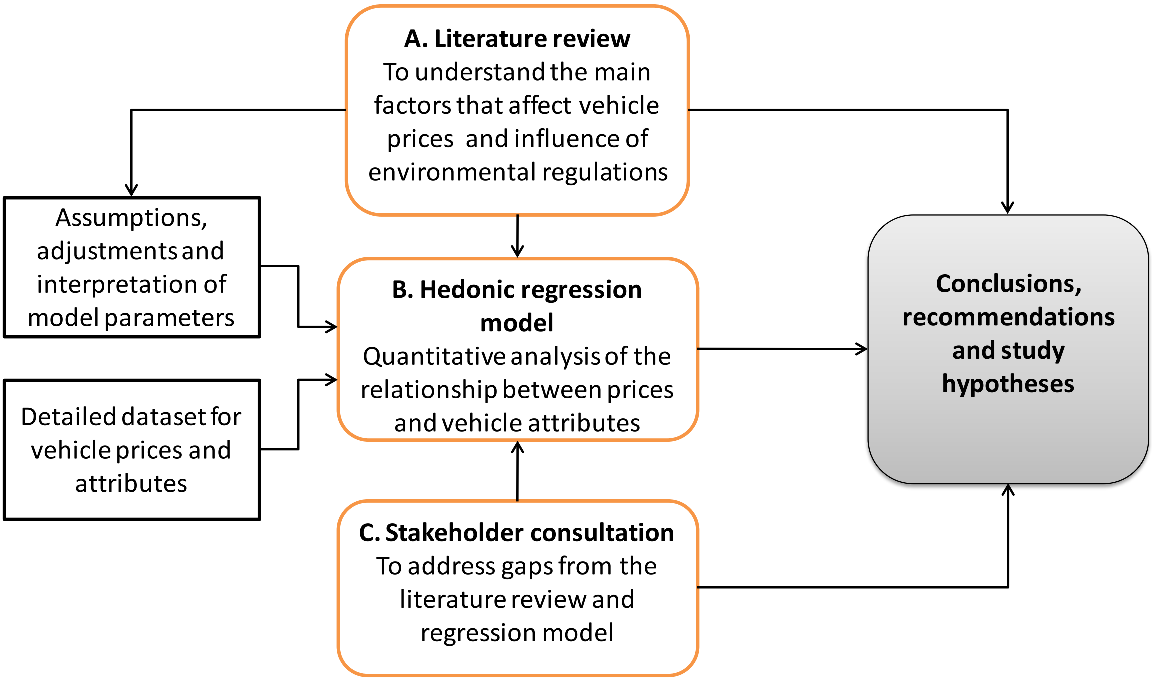
1. A comprehensive review of the literature on the factors that influence passenger car prices;

2. A quantitative regression model (based on commercially purchased data from JATO[2]) that implicitly capture changes in prices caused by changes in product characteristics and other influencing factors; and

3. A brief consultation of key stakeholders to validate the findings and address any gaps from the literature review and quantitative model.

The main conclusions and explanation of the study hypothesis are given in Chapter 7.

Figure 1-1: Study method



A combination of quantitative and qualitative analysis was used to isolate the impact of different vehicle attributes on price. The hedonic model served as the primary quantitative analytical tool for this study. The literature review was used to qualitatively support and augment the quantitative modelling process, and to test the assumptions and verify the findings from the model. The study team's professional judgement was used to infer appropriate quantitative adjustment factors for the hedonic analysis from the literature review and interviews. The findings from the literature review and interviews were also used to address the limitations of the hedonic model in its ability to meet the objectives of this study.

This report is accompanied by another document containing detailed annexes on the study method, findings and datasets.

[2] http://www.jato.com/In/Pages/default.aspx

1.2.1 Dataset for vehicle attributes

Sufficiently detailed data on vehicle prices and attributes was not available in the public domain. For the purposes of this study, car prices and attributes were required for a wide range of car models in a number of EU Members States over a long time period (10-15 years). A specialist data provider, JATO Dynamics Ltd, was selected to provide a suitable dataset. The dataset covers list price and selected feature data for the top ten selling models in 2010 for six Member States, plus twenty other models that are representative of each particular nation's vehicle choices in 2010[3]. More details of the JATO dataset is given in Chapter 2 of the Annex document. The terms and conditions of accessing the data does not allow it to be reproduced in its original form.

[3] More details of the JATO dataset are provided in the supplementary Annexe document to this report.

2 Literature review and qualitative analysis

2.1 Introduction

There are a number of ways in which the automotive industry has responded to pressures to reduce costs over the past 20 years. These changes can be related not just to the effect of regulations and standards, but to wider competitive pressures, and it is often difficult to separate the two. The 1990s and 2000s were a period of significant change for the European motor industry. Over this period the industry became truly globalised. The creation of the Single European Market on 1 January 1993 removed many trade restrictions, increasing competition and opening up new markets in Eastern Europe.[4]

Most of the existing literature which assesses the impact of regulations on vehicle prices has focused on the major environmental and safety legislation implemented during the 1970s and 1980s. Back then the car industry was much simpler than it is today, with fewer options open to the consumer and manufacturers independently developing products. As shown below, the modern car industry is complex, with highly differentiated products, vehicle brands changing ownership on a relatively regular basis, and joint ventures and collaborative vehicle development being the norm.

It is important to start by making a distinction between cost and price:

- The **price** is what the end-user, the consumer, pays for the car, and
- The **cost** is the expense incurred by the manufacturer to develop, produce, market and distribute the car.

In order for a manufacturer to be profitable, the price must generally be greater than the production cost. There is usually a distinction between ex-works cost and market price. Typically, on average ex-works costs are 60% to 75% of market price. However, a manufacturer may choose to sell vehicles at prices that do not cover production costs for wider business strategy reasons (for example retaining a presence in the market, retaining market share, introducing expensive new technology). In their responses to proposed legislation, vehicle manufacturers often emphasise the cost implications of compliance rather than the price implications. Undoubtedly, implementing new technology in a car has cost implications, but the extent to which these costs filter through to car prices is not clear. Investigating this link is the main focus of this study.

Task 1 consists of three main parts:

- A review of safety and environmental legislation which has been implemented during the time period in question;
- A discussion of other factors which could affect vehicle manufacturing costs and therefore have the potential to affect vehicle prices, based on a literature review; and In order to inform the scope of the literature review, a long list of the factors which could influence vehicle pricing was developed and grouped into six broad categories as given in Table 2-1.

[4] KPMG (2010), Brand and Ownership Concentration in the European Automotive Industry – Possible scenarios for 2025

Table 2-1: Factors influencing vehicle prices

Regulatory Factors	Direct Safety Standards
	Direct Environmental Standards
	Block Exemption
	Indirect Safety Standards (e.g. Euro NCAP)
	Indirect Environmental Standards (e.g. Voluntary agreement)
Business Strategy Factors	Cost Pass through
	Spin off of supplier
	Financing offers
	Import share / trends
	Shared platforms / collaboration
	Relocation of production
	Purchasing strategies
	Manufacturer margin
	Dealer and distributor margin
	Cross Subsidising Across Brands / Across Divisions
Direct Cost Factors	Resource prices (raw materials, energy)
	Resource taxes
	Component costs
	Labour costs
	Exchange Rates
	Shipping Costs
Indirect Cost Factors	Research & Development
	Plant maintenance & depreciation
	Marketing
	Warranty
	Administration (including pensions & healthcare)
Market Factors	Market competition
	Market conditions and openness
Consumer Factors	Model choice
	Option choice
	Quality

This section discusses the most important factors in terms of how they have affected the European new car market since 1990 and what influence they have over both vehicle manufacturing costs and end user prices. It includes a review of relevant academic literature, industry media reports and other data sources. The academic literature focuses on more readily quantifiable factors (for example comfort features, safety etc.), but does not tend to cover the more indirect or strategic elements of the car manufacturing industry. While industry media reports help to bridge some of these gaps, there is limited quantitative information on many aspects of the passenger car market.

2.2 Summary of vehicle environmental and safety legislation

2.2.1 Environmental regulations

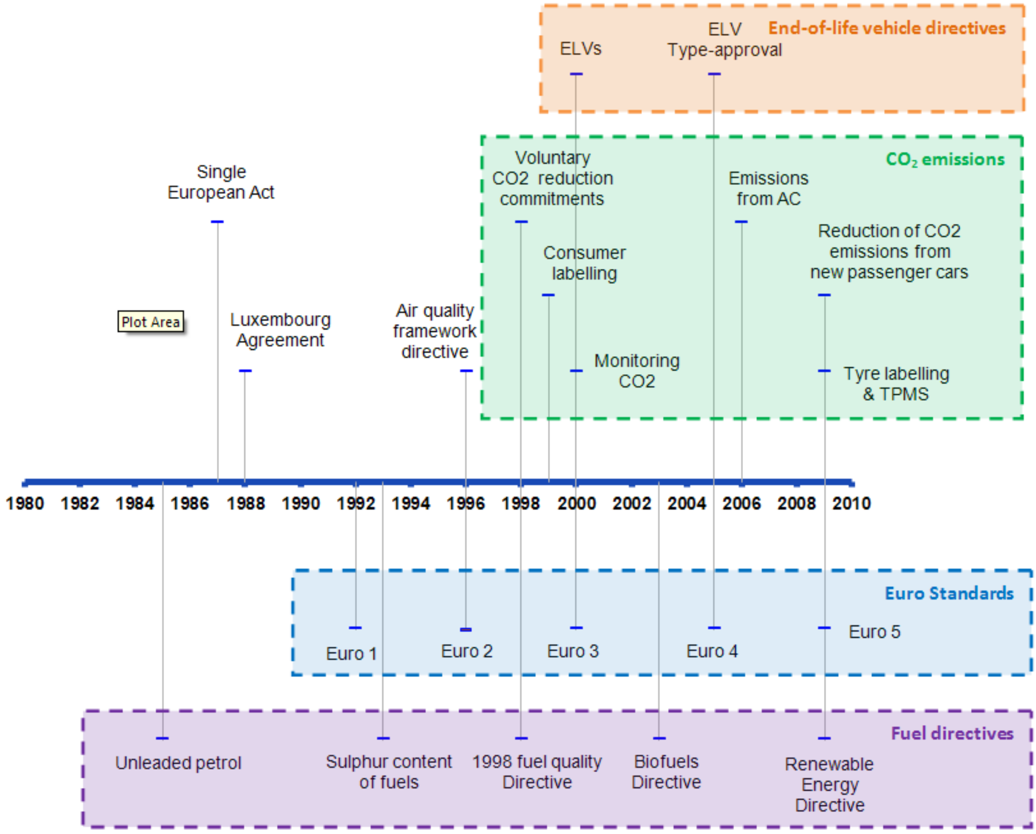
This section discusses the major European environmental regulations that affect the car industry. In keeping with the rest of this report, the period examined is between 1990 and 2010. Over time, amendments are often made to regulations; the important amendments have been noted, but in the interest of brevity a full account has not been provided. Other significant regulations which have fallen outside of this period are mentioned although they have not been considered in detail.

The scope of vehicle environmental regulation spans several different aspects associated with human health, climate change and waste. Figure 2-1 illustrates a timeline of the regulations which, for clarity, have been divided into the following categories (Table 2-2):

Table 2-2: Categories of environmental regulations

Background legislation	Including: • Regulations introduced before 1980 • Regulations which influence other environmental legislation, but which have not had a direct impact on the automotive industry.
Euro standards (blue)	The Euro standards are a series of regulations which limit the exhaust emissions of harmful air pollutants from vehicles. They are numbered from Euro 1 to Euro 6, indicating progressively tighter limits that have been introduced since 1992.
CO_2 emissions (green)	This covers: • Regulations to limit CO_2 emissions from vehicles • Non-legislative events related to the overall strategy on CO_2 reduction, such as voluntary commitments in 1998 by manufacturers to reduce CO_2 emissions • Related regulations which influence greenhouse gas emissions, such as tyre pressure monitoring and air conditioning
Fuel directives (purple)	The fuel directives include specifications on the quality of petrol and diesel sold within Member States, as well as measures relating to biofuels. These regulations impact the automotive industry because the fuel used in car engines affects their performance and design.

Figure 2-1: Major European environmental legislation that effect car manufacturers



Note: Dates refer to date of the Directive/Regulation

This section contains a discussion of the following:

- Overview of each piece of significant legislation;
- The date of effect, including any delays to implementation;
- The technology changes needed to comply (expected and actual);
- Ex-ante and ex-post cost estimates, where available; and
- The general reaction of the motor industry.

2.2.2 Background legislation

The first attempts to control vehicle air pollutant emissions appeared in the US and Europe in the 1970s; however progress in Europe tended to be slower. A major reason for this was because until the mid-1980s, vehicle emission standards were developed by the Economic Commission for Europe (ECE) and then adopted by individual countries. The requirement for unanimous agreement hampered the introduction of environmental regulations. The Single European Act[5] which entered into force in 1987 replaced consensus with majority voting. This was an important step in establishing a common ground for vehicle emission regulation and allowing proposals to be accelerated through to legislation. Table 2-3 summarises the significant items of background legislation that underpinned subsequent regulations on vehicle emissions and fuel quality.

[5] OJ L 169 of 29.06.1987

Table 2-3: Background legislation

Directive 70/220/EEC	In 1970, The European Community issued its first directive (Directive 70/220/EEC) which limited emissions of carbon monoxide and hydrocarbons from petrol engines. All Member States adopted this directive from 1971. Directive 70/220/EEC also introduced the process of "type approval", which sets out the process by which a vehicle design is tested and approved against the requirements of the directive. Type approval is required before a vehicle is permitted to be sold within the EU. Later amendments[6] to Directive 70/220/EEC have progressively strengthened the standards that have been set, and extended them to incorporate emissions of oxides of nitrogen (NO_x) and emissions from diesel engines. Although amended considerably since its introduction, Directive 70/220/EEC remains the basis for current European air pollutant emission laws.
The Single European Act	The Single European Act entered into force on 1 July 1987. It allowed the rule of qualified majority voting to apply to the adoption of proposals, instead of unanimity. There were also changes relating specifically to environmental matters. Article 100A(3) stated that *"the Commission in its proposals... will take as a base a high level of protection".*
The Luxembourg Agreement Directive 88/76/EEC	The Luxembourg Agreement illustrates how the Single European Act helped environmental legislation to be implemented at greater speed. The regulation set down limits for gaseous and particulate emissions from diesel vehicles. It was approved in June 1985 but Denmark blocked the measure for two years. The agreement was only able to pass after the Single European Act came into force, at which point Denmark was overruled by the preferences of the majority. Thus, the regulation was adopted in December 1987. It was not, however, implemented in national legislation by any Member State, in anticipation of Euro 1 which consolidated exhaust emissions standards for passenger cars.
Air Quality Framework Directive Directive 96/92/EC	In recognition of the needed to protect the environment and human health, the EU introduced limits on the concentrations of harmful pollutants. The Framework describes how air quality should be assessed and managed within Member States, and lists the pollutants for which air quality standards would be developed. The air quality Framework Directive has been amended by several Daughter Directives - these are not examined in any further detail here, save to note that the impacts of air quality requirements on car manufacturers are reflected in the Euro standards for vehicles. This directive has been replaced by Directive 2008/50/EC.

This section has briefly discussed important regulations that were introduced before 1980, as well as other significant regulations which have influenced the environmental regulation of vehicles.

2.2.3 Euro standards

Earlier regulations were primarily directed at protecting human health. Thus, the exhaust emissions of harmful pollutants were limited though the Euro standards. These standards tended to assume a specific technology would be introduced for compliance, and such

[6] Directive 70/220/EEC *emissions from motor vehicles amended by 74/270/EEC, 77/102/EEC, 78/665/EEC, 83/351/EEC, 88/76/EEC, 88/436/EEC, 89/458/EEC, 89/491/EEC, 91/441/EEC, 93/59/EEC, 94/12/EEC, 96/44/EEC and 96/69/EEC - "Auto-Oil" proposal COM(96) 0163 (COD)*

assumptions were included in the ex-ante impact assessments. However, the technical solutions employed by car manufacturers often ended up being quite different.

Road transport contributes to poor air quality through emissions of harmful pollutants which are linked to health problems such as respiratory and cardiovascular disease and environmental effects such as acid rain. The European emission standards limit the emissions of nitrogen oxides (NO_x), hydrocarbons (HC), carbon monoxide (CO) and particulate matter (PM) for new cars sold in the EU.

The standards have been introduced in progressively more stringent stages since 1992, known as the series Euro 1 – Euro 6, which are summarised in Table 2-4. There is a differentiation between compression ignition engines (diesel) and spark ignition engines (petrol, natural gas, liquefied petroleum gas, etc.). The standards first apply to new vehicles during type approval and then, typically one year later, are extended to the first registration of existing, previously type-approved cars.

Table 2-4: Outline of exhaust emission limits for Euro 1 – 6.

Title	Directive	Date of effect: New type approval (All new cars)	Engine type[a]	CO g/km	HC g/km	HC + NO_x g/km	NO_x g/km	PM g/km
Euro 1	91/441/EEC 93/59/EEC	July 1992 (December 1992)	CI	2.72 (3.16)[b]	-	0.97 (1.13)[b]	-	0.14 (0.18)
			SI	2.72 (3.16)[b]	-	0.97 (1.13)[b]	-	-
Euro 2	94/12/EC 96/69/EC	January 1996 (January 1997)	CI	1.0	-	0.7		0.08
			SI	2.2	-	0.5	-	-
Euro 3	98/69/EC 2002/80/EC	January 2000 (January 2001)	CI	0.64	-	0.56	0.5	0.05
			SI	2.3	0.2	-	0.15	-
Euro 4	2007/715/EC	January 2005 (January 2006)	CI	0.5	-	0.3	0.25	0.025
			SI	1.0	0.1	-	0.08	-
Euro 5	Regulation 715/2007 Regulation 692/2008	September 2009 (January 2011)	CI	0.5	-	0.23	0.08	0.005
			SI	1.0	0.1	-	0.06	0.005[c]
Euro 6	Regulation 715/2007 Regulation 692/2008	September 2014 (September 2015)	CI	0.5	-	0.17	0.08	0.005
			SI	1.0	0.1	-	0.06	0.005[c]

Notes:
[a] CI = compression ignition; SI = spark ignition
[b] refers to *conformity of production limits i.e.* when the vehicle is produced
[c] applies only to vehicles with direct injection engines

The Euro standards tend to be resisted – and in some cases, successfully delayed – by car manufacturers. A summary of the additional technologies required by each stage, and the reactions from industry, is given in Table 2-5. A detailed comparison of ex-ante and ex-post costs is not the purpose of this study; it is instructive to examine them, where available, in order to gain an understanding of where the discrepancies arise.

Table 2-5: The technical requirements of the Euro standards and reactions from industry

Euro 1	Catalytic converters were required to meet the Euro 1 standards. The manufacturers who supplied smaller cars – namely British, French and Italian car manufacturers - were opposed to the regulations, fearing they would lose competitiveness. The costs for introducing catalytic converters were lower for larger, more expensive cars as a percentage of the overall cost of production per car. Indeed, manufacturers who occupied this segment and exported cars to the US and Japan had already fitted the technology[7]. There was no Regulatory Impact Assessment providing ex-ante cost predictions for Euro 1 technology. Industry estimates were reported to be £400-600 per vehicle, with an additional fuel consumption penalty[8]. The same source reports that the manufacturer Johnson Matthey provided catalytic converters to the motor industry for £30-50 per unit. It should be noted that this does not include integration and installation costs or replacement costs during the vehicle lifetime.
Euro 2, 3 & 4	UK Regulatory Impact Assessments were conducted for Euro 2, 3 & 4. The separate appraisals predicted production cost increases of £250-500 for Euro 2 cars; £210-295 for Euro 3 cars and £210-590 for Euro 4 cars[9]. According to a study for the UK Department of the Environment Food and Rural Affairs (Defra), there were no reliable ex-post estimates for these Euro standards. When the Euro 4 standards were set in 1998, the car industry refused to deliver cost estimates because the standards were in their words, "impossible to reach"[10]. The standards were believed to require expensive particulate filters to be fitted to diesel cars. However, advances in engine technology made it possible to use in-cylinder techniques and a diesel oxidation catalyst to meet the standards.
Euro 5	Euro 5 standards have been designed to require closed particulate filters. The Euro 5 Impact Assessment found that many petrol vehicles were already within the proposed limit values – this was thought to be because of the more stringent requirements on petrol cars in other parts of the world. The additional cost incurred for diesel cars was estimated at €377 by the EC[11]. The estimate from ACEA, the European auto manufacturers association, was €900[12]. The group also suggested that there would be a counter-productive effect on reducing CO_2 emissions, predicting an increase of 6%. Notably, the standards were originally intended to come into effect in mid-2008, but were delayed by a year to allow time for building and testing of new machines.

[7] Dietrich, W: *Harmonization of automobile emission standards under international trade agreements*, 1996
[8] Harrington, W: *The design of effective regulation of transport*, International Transport Forum,2008
[9] ED50232: *Evaluation of the air quality strategy* http://www.defra.gov.uk/environment/quality/air/airquality/publications/stratevaluation/documents/chapter2.pdf
[10] *Euro 5 and 6 standards position paper*, Transport & Environment 2006
[11] *Impact Assessment on type approval of motor vehicles with respect to emissions and on access to vehicle repaid information*, European Commission, 2005
[12] *Car emission regulation significantly impacts sales of diesel cars and negatively influences CO_2 emission reductions*, ACEA 2006

Euro 6	Euro 6 standards will apply from 2014. At the time of adoption, it was expected that selective catalytic reduction would be needed for all new diesel cars; however advances in engine technology mean that this requirement is now unlikely to be universal. The additional cost from the Impact Assessment[13] (2005 prices) was an additional €213 over Euro 5 standards. This was recognised as an upper estimate on costs.

Vehicle emissions have been reduced by progressive improvements in engine technology. All new petrol vehicles in Europe are now fitted with three-way catalysts, which can remove more than 75% of CO, HC and NO_x emissions. Before Euro 2 standards, most diesel cars used mechanical fuel injection systems. Today diesel engines have electronic fuel injection and oxidation catalysts.

2.2.4 CO_2 emissions

From the mid 1990s, measures have increasingly targeted CO_2 and greenhouse gas emissions in order to mitigate climate change. The need to improve fuel efficiency while meeting the Euro standards has led to the search for new engine and after-treatment technologies such as the direct injection engine. Such engines have up to 20% better fuel economy than conventional stoichiometric petrol engines.

Road transport CO_2 emissions account for around 20% of total EU27 CO_2 emissions (or 17% if measured for all greenhouse gas emissions).

In 1995, the European Commission announced a target of reducing CO_2 emissions from new cars to 120 g/km by 2005[14]. Subsequent negotiations and implementations delayed this target until the year 2012[15].

The strategy to reduce CO_2 emissions was based on three pillars:

1. Voluntary commitments by automobile manufacturers;
2. Consumer information; and
3. Promotion of fuel-efficient cars by fiscal measures.

Events that directly relate to these pillars are summarised in Table 2-6.

[13] *Impact Assessment for Euro 6 emission limits for light duty vehicles,* European Commission 2006
[14] COM (95)689 A Community strategy to reduce CO_2 emissions from passenger cars and improve fuel economy
[15] COM(2007) 19 Final. Results of the review of the Community Strategy to reduce CO_2 emissions from passenger cars and light commercial vehicles.

Table 2-6: Events relating to the European Strategy on reducing CO_2 emissions from passenger cars

Voluntary commitments	In 1998 the European Automobile Manufacturers Association (ACEA) made a voluntary commitment to reduce average emissions from new cars sold in the European Union to 140g CO_2/km by 2008; the Japan Automobile Manufacturers Association (JAMA) and the Korean Automobile Manufacturers Association (KAMA) made similar commitments in 1999[16]. ACEA represents over 80% of annual registrations in the EU; JAMA represents over 10% and KAMA less than 5%[17].
The Consumer Labelling Directive **Directive 99/94/EC**	As part of the second pillar of the strategy on CO_2 emissions, the consumer labelling directive was aimed at raising awareness among consumers. It requires new cars to display a label showing its fuel consumption and CO_2 emissions. Promotional material used in marketing new cars must also contain this data. The Directive is considered to be useful in raising awareness, but it is difficult to objectively assess its impact.
Promotion of Fuel-Efficient Cars by Fiscal Measures **COM(2005)61**	In order to stimulate Member State action on integrating CO_2 emissions into their vehicle taxation systems, The Commission published a proposal for a Directive on passenger car taxes. The proposal sought to increase the harmonization of circulation and registration taxes across Member States. The proposal proved to be controversial and lacked support in several Member States. As agreement on such taxation proposals requires unanimity among Member States, the proposal did not become EU law.
Monitoring of CO_2 emissions **Decision 1753/2000**	Decision No 1753/2000 established a scheme to monitor the average specific CO_2 emissions from new passenger cars. This would help to monitor the progress of CO_2 reductions by providing an annual report on the effectiveness of the strategy.

Average emissions fell from 186 gCO_2/km in 1995 to 161 gCO_2/km in 2004. Based on these reductions, The Commission thought it unlikely that manufacturers would meet the 140 gCO_2/km target set out in the Voluntary Agreement by 2008/2009. In view of this, The Commission decided that the objective of 120 gCO_2/km would not be met by 2012 without additional measures. A new strategy to regulate new car CO_2 emissions was therefore presented on 7 February 2007.

ACEA warned that such a strategy could have wider effects on employment and economic growth. The German car industry – the world leader in large, luxury cars – pressured its government to demand weaker targets and a delayed target date. Other luxury car makers, such as those in the UK, appealed for special protection. Manufacturers of smaller, more fuel-efficient models objected to subsidising heavier high-performance models.

In February 2007, The Commission adopted Communication COM(2007) 19 final outlining a new strategy to reduce CO_2 emissions from new cars sold in the EU. Regulation EC 443/2009 set a legislative framework to achieve the EU objective of 120 g/km (Regulation EC 443/2009), which replaced both the voluntary commitments and Decision 1753/2000. The Regulation is summarised in Table 2-7. It focuses on mandatory reductions in CO_2 emissions to reach an average of 130 g/km on

[16] As recognised by Commission Recommendation 1999/125/EC
[17] Europa Summaries of EU legislation: *CO_2 emissions from new passenger cars: monitoring,* 2008

average for the new car fleet though improved vehicle motor technology. A further reduction of 10g/km or equivalent should be achieved by other technological improvements and by increased use of biofuels. The 2009 law nominally strives to reduce the average CO_2 emissions from new cars to 130g/km by 2015 (approx. 5.6 litres per 100 km for petrol cars and 5.0 litres per 100km for diesel cars). That is 18% below the average in 2007 and some 7% below the average of 2010.

Table 2-7: The Regulation EC 443/2009

Reduction in CO_2 emissions of new passenger cars **Regulation EC 443/2009**	This Regulation is the main element of the Strategy on CO_2 emissions from vehicles. Some important elements of the agreement are: • The fleet average to be achieved by all new cars registered in the EU is 130 gCO_2/km. A limit value curve implies that heavier cars are allowed higher emissions than lighter cars while preserving the overall fleet average. Manufacturers will be given a target based on the sales-weighted average mass of their vehicles. • Phasing-in of requirements: in 2012 65% of each manufacturer's newly registered cars must comply on average with the limit value curve set by the legislation. This will rise to 75% in 2013, 80% in 2014, and 100% from 2015 onwards. • Long-term target: a target of 95g CO_2/km for the year 2020 has been set.

Regulation 443/2009 has several mechanisms which allow manufacturers some flexibility in meeting the targets. Emissions are averaged across their new car fleet rather than having to meet CO_2 targets for each car, and manufacturers may pool their targets. In recognition of the different challenges niche manufacturers face, and of their small impact on overall average emissions, derogations apply to small-volume manufacturers. Eco-innovations are awarded a credit of up to 7g CO_2/km to encourage manufacturers to invest in new technologies. Such technologies include improve vehicle propulsion or lower energy consumption for mandatory devices. Manufacturers can also gain 'super credits' for sales of electric vehicles, whereby car manufacturers will be allowed to offset every electric car sold against its average emissions quota.

Regulation of CO_2 emissions from transport is seen as an important part of the overall strategy to meeting long-term economy-wide greenhouse gas reduction targets. As part of the strategy on CO_2 emissions from vehicles, several measures relating to specific aspects of a car's systems have been implemented. These changes require additional or modified equipment on cars where the specified standards are not met; this might be expected to incur some additional cost. These are summarised in Table 2-8. The increased use of biofuels was included as part of the strategy to reduce CO_2 from cars, and is included in the summary of fuel directives below (Directive 2009/28/EC).

Table 2-8: Legislation related to the Strategy on CO_2 emissions

Emissions from air-conditioning systems in motor vehicles **Directive 2006/40/EC**	Directive 2006/40/EC bans air conditioning systems that use greenhouse gases with a global warming potential greater than 150, unless the rate of leakage is within permissible limits. This measure applies to type-approval of all new vehicles from 21 June 2008, and to the sale of new vehicles from 21 June 2009. A total ban on air conditioning systems that use greenhouse gases with a global warming potential greater than 150 will come into effect for type-approval of all new vehicles from 1 January 2011, and the sale of new vehicles from 1 January 2017.
Type-approval requirements for the general safety of motor vehicles, their trailers and systems, components and separate technical units **Regulation 661/2009**	• **Tyre-pressure monitoring systems** (TPMS) and gear shift indicator lights are mandated by Regulation 661/2009. The TPMS alerts the driver when the tyre pressure falls by 20% from its normal warm running pressure. • **Gear shift indicators** advise the driver when to change up to the next gear to maximise fuel economy. The regulations for these technologies apply to type-approval of all new passenger cars from November 2012, and the sale of all new cars by November 2014. • Regulation 661/2009 also requires new car models to be equipped with **low rolling resistance tyres**. For type approval this is phased in between November 2013 and November 2017, and for prohibition of sale, between November 2014 and November 2018 for all new cars.
Tyre Labelling **Regulation 1222/2009**	The fuel efficiency, wet grip and external rolling noise performance of tyres will be rated on a scale of A-G. This Regulation is an extension of the consumer labelling directive.

Further measures as part of the strategy were directed at taxation, and eco driving. The effects of these measures are not considered in detail in this study as they focus on demand/behaviour and therefore do not have a direct influence on costs incurred by manufacturers.

2.2.5 Fuel directives

The fuel used in engines influences their performance and design. High quality fuels had the following benefits for car manufacturers:

- ***Allowed the release of direct injection engines;***
- ***Increased effectiveness of catalytic converters, oxidation catalysts, NO_x absorber catalysts (NACs) and particulate traps;***
- ***Reduced emissions of conventional pollutants from the existing fleet of vehicles.***

The fuel directives relate to the quality of petrol and diesel fuels, where environmental specifications have been introduced in order to reduce pollutant emissions from cars. These regulations are relevant to car manufacturers because the type and quality of fuel used in car engines influences the engine and exhaust after-treatment performance and design.

The lead content of fuel was eliminated in 2000, and all fuels have been sulphur-free since 2009 (sulphur content of less than 10ppm). More recent directives mandate the increased use of biofuels, which are becoming an important part of the overall strategy to reduce greenhouse gas emissions from transport, although this approach has subsequently been replaced with requirements to increase the proportion of renewable fuels in transport and to reduce the carbon intensity of transport fuels. An overview is provided in Table 2-9.

Table 2-9: European fuel directives

Lead content of petrol **Directive 85/210/EEC**	The Directive was agreed in principle in December 1984, and formally adopted in March 1985. Leaded petrol has been banned since 2000, due to its detrimental effects on health, particularly children's.
Sulphur content of fuels **Directive 93/12/EEC**	The sulphur content of fuels was first regulated by Directive 93/12/EEC. It accompanied the Euro 1 standards which were mandatory from 1993 for new cars. The intent was to limit emissions of sulphur dioxide, which is a major contributor to acid rain.
1998 Fuel Quality Directive **Directive 98/70/EC**	The Directive on the sulphur content of fuels was updated and repealed by the 1998 fuel quality standards. These cover physical properties, such as the octane number for petrol, and cetane number and density for diesel. Such properties need to be within certain limits for internal combustion engines to function efficiently. Also included are fuel properties which are directly linked to levels of emissions, such as hydrocarbons, sulphur and lead. The mandatory limit for sulphur was set at 50 ppm for petrol and diesel from 2005, and all fuels were made sulphur-free (<10 ppm) from 2009.[18]
Biofuels Directive **Directive 2003/30/EC**	The Biofuels Directive (2003/30/EC) set "moral commitments" for Member States to ensure that, as of the end of 2005, the minimum share of biofuels sold on their markets is 2%, rising to 5.75% by the end of 2010. A progress report in 2007 found that biofuels were only 1% of the market and that the EU would miss the 2010 target.[19] The report highlighted that legal obligations, rather than voluntary commitments, might be needed to spur progress. This Directive will be replaced by Directive 2009/28 from 1 January 2012.
Renewable Energy Directive **Directive 2009/28/EC**	Subsequently, the EU committed to a binding target to ensure that 10% of the energy content of transport fuels (excluding aviation fuels) would be sourced from renewable sources by 2020 as part of a broader Directive on Renewable Energy (2009/28/EC).
2009 Fuel Quality Directive **Directive 2009/30/EC**	This Directive sets environmental requirements for petrol and diesel fuel in order to reduce their air pollutant emissions. Under this Directive, Member States have been required to implement mandatory full conversion to sulphur-free fuels (<10mg/kg) from 1 January 2009. The Directive legislates the greenhouse gas intensity of transport fuels, introduced a new petrol grade with up to 10% ethanol by volume, and a requirement for suppliers to ensure diesel has a fatty acid methyl ester content of at least 7% by volume.

[18] Amending Directive 2003/17/EC
[19] *COM(2006)0845 Report on the progress made in the use of biofuels and other renewable fuels in the Member States of the European Union,* European Commission 2006

The introduction of unleaded petrol was initially resisted by manufacturers. However, the introduction of the other fuel quality regulations has generally been supported. The development of high quality fuels allowed the introduction of direct injection engines and also reduced emissions of conventional pollutants from the existing fleet of vehicles. The German government explicitly linked the introduction of unleaded petrol to the adoption of the three-way catalytic converter.

Reduced fuel sulphur content was of particular importance to the car industry because the presence of sulphur can reduce the effectiveness of catalytic converters, oxidation catalysts, NO_x absorber catalysts (NACs) and particulate traps. However sulphur-free (<10ppm) petrol improves the fuel economy of future gasoline direct injection cars by 1-5%, compared to similar vehicles using fuel containing a maximum of 50 pap sulphur.[20] The importance of low sulphur fuels for cleaner engine design was reflected in the development of Directive 98/70 and the Euro 3 Directive 98/69 (see Table 2-4), as these two pieces of legislation were developed together.

Engines, fuel and exhaust systems must be designed and specified to suit use of biofuels, otherwise problems may arise. Biofuels can have substantially different characteristics to standard mineral fuels with regard to volatility, viscosity and stability over time. For biodiesel, the characteristics can also vary depending on the feedstock and processes used to produce the biofuel, making it particularly difficult for manufacturers to ensure that durability sign-off testing captures all potential issues. For example biodiesel use can increase fuel dilution of the engine lubricating oil, particularly on vehicles using post-injection diesel particulate filter regeneration strategies. ACEA supported measures to increase biofuels and promised that, by 2010, all new car models would be capable of running on petrol containing up to 10% ethanol and diesel containing up to 7% Fatty Acid Methyl Esters.[21]

2.2.6 Noise regulations

There are two Directives related to type-approval procedures for motor vehicles, with respect to noise emissions. Firstly, Directive 70/157/EEC and its amendments introduce limits on sound levels of road vehicles, and specify procedures for measuring sound levels of exhaust systems and silencers. There have been three significant decreases of noise emission limits (from 82 to 80dB in 1997, to 77dB in 1984 and to 74dB in 1992). The current limit of 74dB for both petrol and diesel engines has now been in place for around 19 years.

The type-approval Directive was amended by 2001/43/EEC to limit tyre rolling noise emissions based on their category and width. The impact of tyre noise regulations on tyre manufacturers has been minimal; a 2006 study into proposals to amend Directive 2001/43/EC concluded that almost all passenger car tyres that have been in service since the regulations were introduced produce noise levels that are significantly below the limit values[22].

Noise regulations have not greatly affected vehicle manufacturers during the period under assessment and so the focus of this work is on other environmental and safety legislation.

2.2.7 Safety regulations

Major improvements in vehicle safety have been achieved in the past decade. Some manufacturers place safety as a high priority and use it as a means of differentiation, proof of technology leadership and branding It appears that while regulations provide for a minimum safety standard, the majority of car manufacturers have been motivated to go beyond these requirements by consumer information programmes.

[20] Fuel quality monitoring summary report, European Commission, 2007
[21] *FAQs on biofuels*, ACEA
[22] http://ec.europa.eu/enterprise/sectors/automotive/files/projects/report_tyre_road_noise1_en.pdf

Road safety has long been an area of concern. A wide variety of vehicle safety ratings have been developed since the 1970s, which have evolved largely independently of each other. Many of the original safety-related Directives are now close to 40 years old.[23] Advances in vehicle design have led to considerable reductions in road traffic causalities. However, in 2009, over 35,000 people died on the roads of Europe, and 1.5 million people were injured. The cost to society was estimated to be in the region of 130 billion Euros in 2009.[24]

Predictive systems are those that measure safety performance before a car is sold, and the ratings are made available as soon as a new car model is launched. They are based on controlled crash tests of whole models and individual components. These types of safety tests will be the main focus of this section as they have greater potential for influencing decisions when purchasing a new car as compared to retrospective systems.[25] Retrospective systems are those which are based on the performance of cars in real collisions using accident data and/or insurance injury claim data. They provide guidance for buyers of used cars; however the information only becomes available late in a car model's production run. Since they are less applicable to new cars, retrospective safety ratings will not be examined in detail here although a notable example of the incorporation of retrospective systems was seen when Mercedes incorporated stability control systems to the Mercedes A Class and Smart Car in response to the Swedish rollover tests.

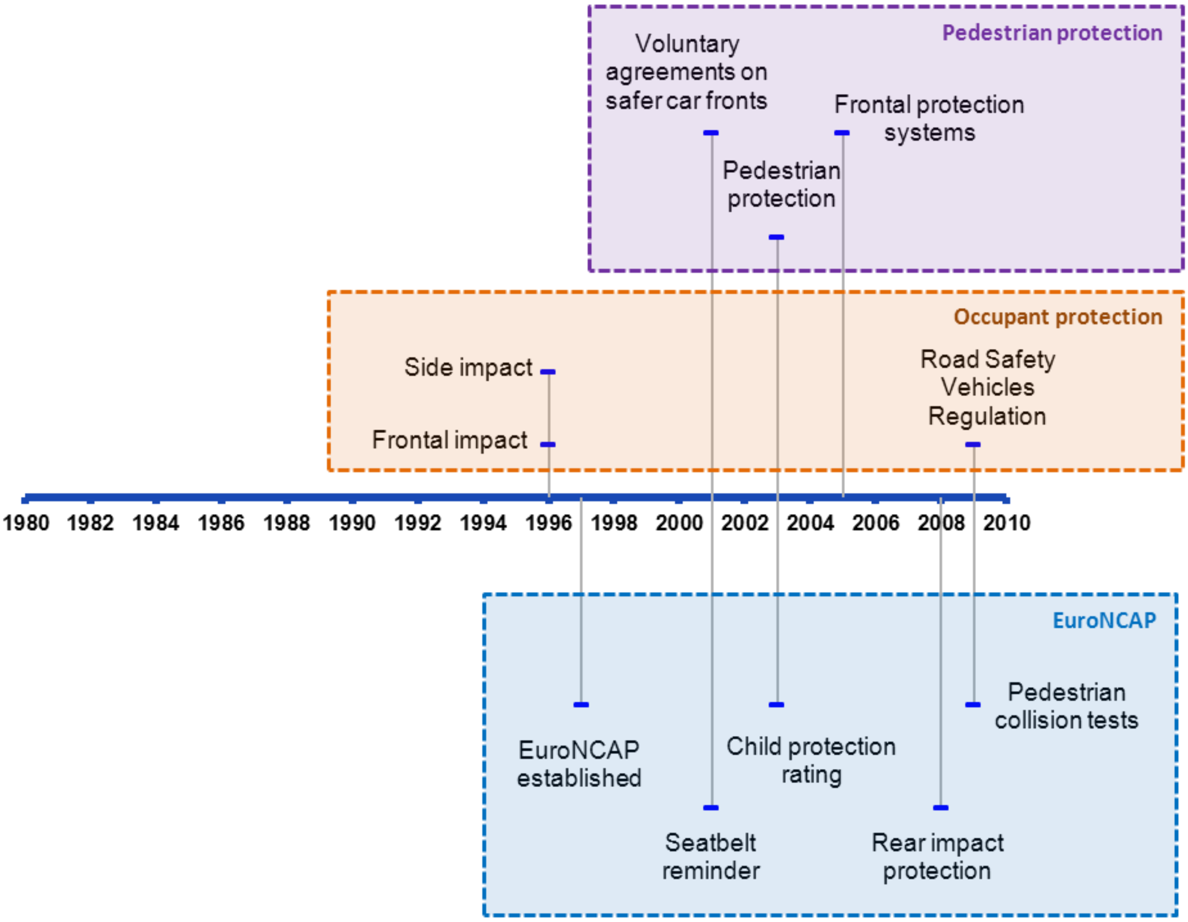
Figure 2-2 shows a timeline of the significant events related to car safety, which have been divided into the following categories (Table 2-10):

Table 2-10: Categories of European safety regulations

Background legislation	Regulations introduced before 1980
Occupant protection ***(highlighted in orange in Figure 2)***	These regulations aim to improve the protection of occupants of motor vehicles.
Pedestrian protection ***(highlighted in purple in Figure 2)***	Regulations which aim to reduce the injury caused to pedestrians and other vulnerable road users in the event of a collision.
Euro NCAP ***(highlighted in blue in Figure 2)***	The main non-regulatory development in Europe is the European New Car Assessment Programme (Euro NCAP), which provides consumer information on the crashworthiness of new cars.

[23] *Impact assessment – proposal for a regulation of the European Parliament and of the Council concerning type-approval requirements for the general safety of motor vehicles*, European Commission, 2008
[24] *Towards a European road safety area: policy orientations on road safety 2011-2020*, European Commission, 2009
[25] *Consumer information on the crash performance of cars*, European Transport Safety Council,1995

Figure 2-2: Timeline of European Safety Regulations



2.2.8 Background legislation

The majority of safety regulations were introduced before 1980; therefore a detailed analysis has not been included in this section. In Europe, two parallel type approval schemes have existed for over 20 years:

EC Motor Vehicle Type Approval **Directive 70/156/EEC**	The EC approval of cars is based around the type approval framework. The original system under framework directive (Directive 70/156/EEC) has changed from one designed to allow free trade of vehicle components between Member States, to a system based on mandatory whole-vehicle type approval (WVTA). WVTA specify a range of aspects that must be approved to separate technical Directives. The Directive has been updated over the years so that there are now around 50 base Directives and over 100 amending Directives. The requirements have been consolidated in the new type approval Directive (661/2009/EC) which is discussed in the section on occupant protection.
UNECE Type Approval ***"The 1958 Agreement"***	The United Nations Economic Commission for Europe (UNECE) produces equivalent standards to the EC type approval process. These test vehicle systems and separate components, but not whole vehicles.

1998 Global Agreement	The Global Agreement seeks to promote international harmonisation through the development of Global Technical Regulations. It is open to countries that are not part of the 1958 Agreement

Many cars sold in Europe are also sold in other countries which have different regulatory requirements. The UNECE framework was originally created for the UNECE region, but opened to all countries in 1995 with Japan joining in 1998, Australia in 2000, South Africa in 2001 and New Zealand in 2002. Most (but not all) European Directives were based on UNECE Regulations. Where vehicle manufacturers have had the choice of meeting either a European Directive or a UNECE Regulation, they have shown an increasing tendency to choose the latter, since this allows them access to markets outside the EU.[26]

Crash test standards have developed in different ways around the world because of the difference in the fleet composition. For example in Europe, the focus has been on developing test procedures which improve compatibility in car-to-car impacts while in the US and Canada, research has focussed on collisions between cars and light trucks or vans. In the US the National Highway Traffic Safety Administration (NHTSA) is responsible for motor vehicle safety standards. The US has not joined the UNECE agreement and does not recognise UNECE approvals.

2.2.9 Occupant protection

Impact performance regulations aim to improve the protection of occupants of motor vehicles. Car-to-car collisions are the most common crash type in Europe with frontal impacts being the most common in fatal and serious crashes, and side impacts being the second most common type.[27] Table 2-11 below summarises the impact performance regulations currently in place in the EU.

Table 2-11: Impact performance regulations

Side Impact **Directive 1996/27/EC**	Protection of occupants against lateral collision. The Directive applied to new car types and new car registrations from October 1998. A car that represents the worst case for the particular model is tested using an adult sized (male) dummy.
Frontal Impact **Directive 96/79/EC**	Protection of occupants in head-on collisions. Under the 1958 agreement, UNECE Regulation 94 provides the same requirements. The Directive applied to new car types from October 1998, and all new cars from October 2003. A car that represents the worst case for the particular model is tested using an adult sized (male) dummy.
Road Safety Vehicles Regulation **Directive 2009/661/EC**	The new regulation simplifies the previous type approval framework by consolidating 50 separate Directives. The remaining 10 separate Directives are those relating to environmental issues (emissions, sound levels, recyclability) and pedestrian protection (see below). It mandates the fitment of electronic stability control (ESC) systems to passenger cars with effect from November 2011 for new types and November 2014 for all new cars.

[26] *Proposal for a Regulation of the European Parliament and of the Council Concerning Type-Approval Requirements for General Safety of Motor Vehicles,* European Commission, 2008
[27] *SafetyNet (2009) Vehicle Safety,* European Commission, retrieved December 2010

Since the mid-1990s there have been significant improvements in the protection systems available to occupants of cars. The frontal and side impact Directives have led to rapid developments in car occupant protection in Europe[28] but the Directives do not specify a particular technology to meet the requirements.

The greatest source of injury for occupants is from contact with the interior of the car: The priority in improving frontal impact test performance has been to strengthen the car structure so that intrusion is limited in a collision. Additional measures include frontal airbags, seatbelt pre-tensioners and load limiters. In side impacts, contact with the interior of the car is difficult to prevent so improvements rely on devices such as side airbags, side impact bars, and padding.[29]

The new type approval directive (Regulation EC 661/2009) mandates the fitment of electronic stability control (ESC) in all new vehicles types from 2011. ESC is an extension of antilock brake technology, which has speed sensors and independent braking for each wheel. It improves the safety of a vehicle by detecting and minimising skids. The increased cost per vehicle has been estimated (Baum et al, 2007) to be €130-250, reducing to €76 assuming the vehicle was already fitted with antilock braking systems (as almost all cars sold in Europe cars are).[30,31]

The system was developed by European manufacturers and has been on the market since 1995. A fitment rating is published by Euro NCAP which highlights the difference in uptake between manufacturers. It shows that some manufacturers fit ESC to all their models (BMW, Jaguar, Jeep, Lexus, Mercedes, Smart, and Volvo) while others choose to supply it as an optional extra[32]. Since 2009, Euro NCAP has incorporated “safety assist” measures into their assessments; in order to gain five stars, electronic stability control is an essential fitment.

The car manufacturing industry distinguishes between passive and active safety technologies, with legislation and Euro NCAP mostly applying to passive systems (body design). Active safety systems (e.g. driver sensing systems to tell if the driver has been drinking or is falling asleep) continue to grow in importance and in the future will be linked to infrastructure management and collision avoidance radars.

2.2.10 Pedestrian protection

Earlier safety regulations focussed on reducing the severity of injury to car occupants during a collision; pedestrian protection measures aim to reduce injury to pedestrians and other vulnerable road users.

A draft legislative proposal for a Directive on safer car fronts for pedestrians was prepared in 1992.[33] After a negative benefit to cost study published by ACEA, the discussions ended that year.[34] A further three draft legislative proposals were produced in 1996, 2000 and 2001, as well as numerous positive benefit to cost studies. At each stage, the legislation was delayed by pressure from industry. In 2001, the Council accepted voluntary agreements from the car industry (See Table 2-12).

The original directive on pedestrian protection (Directive 2003/102/EC) introduced pedestrian protection requirements in two stages. Both stages used the same test procedure, but the injury limits for Stage 2 were more stringent. The technical specifications were finalised after many years of reviews, discussion and cost/benefit analysis. Despite this, manufacturers claimed that it was not possible to reach the Stage 2 limits. In light of this, the Directive specified that a feasibility study of the

[28] Cuerden, R: *A Review of the European 40% Offset Frontal Impact Test Configuration*, 2000
[29] *Priorities for EU Motor Vehicle Safety Design*, European Transport Safety Council, 2001
[30] Baum, H et al: *Cost-benefit Analysis of the Electronic Stability Program (ESP),* 2007
[31] *Impact Assessment Concerning Type-Approval Requirements for the General Safety of Motor Vehicles*, European Commission, 2008
[32] *ESC Survey*, Euro NCAP, 2008
[33] Doc III/4025/92 Brussels
[34] European Transport Safety Council: *Member States put Industrial Convenience over Public Safety – Today's Decision on Safer Car Fronts,* 2001 http://www.etsc.eu/oldsite/pressnotice.pdf

Stage 2 limits would be conducted using data from testing of the Stage 1 requirements. The review was completed in 2007 and the injury limits were relaxed. In order to offset these changes, the European Commission mandated the installation of Brake Assist systems. Brake Assist systems automatically apply maximum braking power when the driver makes an emergency stop. They are not fitted to vehicles as discrete systems since most of the hardware is shared with the antilock braking system. These changes were incorporated into the frontal protection systems directive (Directive 2005/66/EC).

Table 2-12: Developments relating to pedestrian protection

Voluntary agreements on safer car fronts ***2001 & 2002***	European, Japanese and Korean Automobile Manufacturers Associations (ACEA, JAMA and KAMA) committed themselves to a voluntary agreement to improve pedestrian protection. The agreement was criticised for implementing weaker test methods that offered a lower level of protection than those proposed by the EU.[35]
Pedestrian Protection **Directive 2003/102/EC**	The Directive sets the safety requirements to reduce injury to vulnerable road users if they are hit by the front of a motor vehicle. It applies mainly to the bonnet and bumper. The Stage 1 requirements were required to be met by all new vehicle types from October 2005, and for all new vehicles from December 2012. EuroNCAP now uses a percentage score on pedestrian protection to make their rankings. To get 5* the car has to achieve 60% or better on pedestrian protection.
Frontal protection systems **Directive 2005/66/EC**	This Directive introduces revised Stage 2 limits for pedestrian protection and mandates Brake Assist systems. New passenger cars undergoing the type approval process must be fitted with Brake Assist systems and comply with Stage 1 limits from November 2009 – the Stage 2 limits must be met by February 2013. In the case of new registrations, passenger cars must be fitted with Brake Assist systems by February 2011, meet Stage 1 requirements by December 2012 and meet Stage 2 requirements by February 2018.[36]

The costs of the amended passive safety requirements have been estimated in the Impact Assessment to be between €27 per vehicle (small family car) and €95 per vehicle (sports car).[37] Additional items such as pop-up bonnets and front spoilers could increase the costs to €397. The Phase 2 requirements and Brake Assist were not included in these figures. However, since Brake Assist systems are generally incorporated as part of the antilock braking system, the installation cost is considered to be small.

Car manufacturers have adopted different approaches to pedestrian safety. BMW states that it prefers to avoid collisions by using "dynamic stability control" to improve brakes and handling. Renault did not adopt safer designs until the European directives were certain. Evidence from the Euro NCAP tests suggests that some manufacturers prefer to focus on adult occupant safety as the NCAP ratings achieved for this area tend to be higher. In contrast, Honda demonstrated a pedestrian-friendly car front in 1996. Additionally, Honda released a version of its Civic model in 2001 which incorporated an

[35] European Transport Safety Council: *ETSC's Response on the European Commission's Proposal Relating to the Protection of Pedestrians and Other Vulnerable Road Users in the Event of a Collision with a Motor Vehicle COM(2003)67 Final*, 2003
[36] InterRegs: *New EC Regulation on Pedestrian Protection Published*, 2009 http://www.interregs.com/spotlight.php?id=78
[37] European Commission: *Impact Assessment on the Protection of Pedestrians and Other Vulnerable Road Users,* 2007

easily deformable bumper to absorb shock on impact with pedestrians. Peugeot, Jaguar and Citroen pursued similar strategies using a bonnet raised by airbags.[38]

2.2.11 Euro NCAP

The distinction between legislation and consumer pressure is made clear by the influence of EuroNCAP in raising the safety standards of new cars. Some manufacturers have set themselves a target of scoring five-star ratings for every model across their range. Most vehicles now gain a maximum 5-star rating on EuroNCAP crash tests.

Safety regulations stipulate a minimum level of safety. However, consumer test programmes can motivate safety standards above that required by legislation. Such programmes grade performance as opposed to assigning a simple pass/fail outcome. The main consumer test programme in Europe is the European New Car Assessment Programme (Euro NCAP), which assesses the majority of popular European cars.

Consumer information based on crash tests started in Europe in the late 1980s. In 1982 the UK Consumers' Association and Vehicle Safety Consultants developed a safety rating system for cars. An adapted version has been used by the Dutch Consumers' Group since 1989, and the French Consumers' Group since 1992.[39] This later became the basis for The European Secondary Safety Rating System for Cars.

Table 2-13: Euro NCAP developments

Euro NCAP established **1997**	The programme consists of whole vehicle crash tests on new car models. Established in 1997, it is now backed by the European Commission as well as motoring and consumer organisations in every Member State. Star ratings are assigned to the performance in each safety aspect, on a scale of 1-5 (with the exception of pedestrian collision tests, which are rated from 1-4 stars). In addition to the star ratings, colour-coded dummy injury diagrams are provided to show how specific areas of the body performed in the impact tests.

The crash tests mainly report on passive safety measures, and compares vehicles in the same class.[40] Results are made available to the public on the Euro NCAP website, press releases and consumer magazines. The Euro NCAP procedure has grown over time to cover more safety aspects. In 2001, an assessment of seatbelt reminder systems was added; in 2003 a child protection rating was introduced based on restraints for an eighteen-month old and a three-year old child; in 2008 a rear impact (whiplash) protection assessment was incorporated and in 2009 the tests included safety assist measures such as electronic stability control.

In 1997, carmakers said "the assessment criteria are so severe, no car will ever be able to achieve four stars in Adult Occupant Protection".[41] That year, the Volvo S40 achieved four stars. On the other hand, Rover was effectively forced to withdraw the Rover 100 from production due to its poor performance in the tests.

A study by the European Transport Safety Council suggests that car manufacturers monitor test results closely and seek to improve poor performing models.[42] It examined the change in safety

[38] The Guardian: *Crash course in safety*, 2005 http://www.guardian.co.uk/science/2005/jul/07/6
[39] European Transport Safety Council: *Consumer information on the crash performance of cars*, 1995
[40] Superminis, family cars, executive cars, roadsters, off-roaders and multipurpose vehicles
[41] Euro NCAP: *A History of the Future of Safety*, 2009
[42] European Transport Safety Council: *Cost Effective EU Transport Safety Measures*, 2003

performance of nine cars that have undertaken repeated Euro NCAP tests. Most of these improved their ratings from the first to the second test, with an average improvement in impact rating from 2.6 stars to 3.7 stars.

Zachariadis (2008) used the Euro NCAP test results to investigate whether improving car safety led to increases in weight and fuel consumption. The results suggested that enhanced safety does not significantly affect either. Although in the 1970s and early 1980s, there was a trade-off between making lighter, more fuel efficient cars and safety, this correlation seems to have disappeared. The author attributes the change in relationship to the increased use of high-strength steel, which improves safety without adding weight.

The European Commission, in its Communication on Road Safety (2000), credited the Euro NCAP with accelerating passive safety design by six years and saving an estimated 2,000 lives each year. An overall rating from 1-5 stars was introduced in 2009 to encourage manufacturers to focus on the overall safety of a vehicle, rather than concentrating on achieving good scores in adult occupant protection. A key point of difference to note is that the Euro NCAP tests the most popular model variant, whereas for regulatory purposes, the worst case is tested.

2.3 Regulatory factors

This section discusses the various effects of the legislations described in Section 2.2 on new vehicle prices.

Key points:

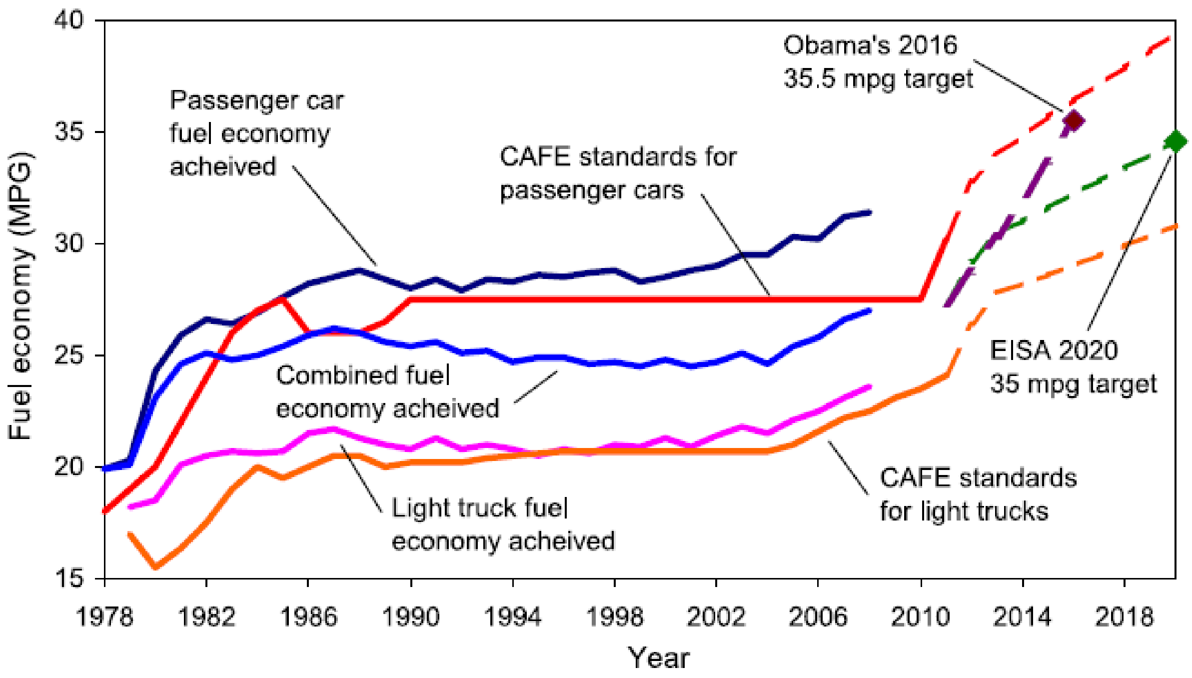
- ***Early regulations involved step changes in vehicle performance which directly led to increases in car prices, as they required the manufacturers to incorporate new technologies such as catalytic converters.***
- ***More recent legislation has involved a progressive tightening of existing standards which are not linked to specific technologies, therefore the cost implications are less clear***
- ***Manufacturers may prefer to pay penalties for violating environmental legislation, where this option is available. For example, the level of penalty imposed by US emission standards (CAFE) is low enough to be absorbed by the market.***
- ***Examples from the US show that manufacturers have met emission standards through a combination of shifting sales towards smaller, less polluting vehicles (through relative price reductions) and by changing the design of models on offer.***
- ***Manufacturers tend to spend more on R&D and tooling prior to new regulations taking effect***
- ***Even if additional costs arise due to reductions in emissions, it has increasingly been achieved by benefits in other areas, such as acceleration, top speed and decreased fuelling costs***
- ***A review of the impacts of the 2002 changes to Block Exemption concluded that competition in the industry had significantly increased but that this was primarily due to external factors.***

2.3.1 Environmental and safety regulation

The academic literature tends to focus on the environmental and fuel economy regulations introduced during the late 1970s in the US. These regulations involved a step change in vehicle fuel economy and pollutant emissions and in order to comply with these regulations, manufacturers had to incorporate significant, and costly, new technologies. In more recent years these technologies have become standard on all new vehicles and European legislation has focused on progressively tightening existing standards (for example the Euro standards).

In the US, the Corporate Average Fuel Economy (CAFE) regulations have set limits on the fleet average fuel economy for new cars since the late 70s. Over the last two decades these standards have not changed for passenger cars and have seen relatively modest increases for light trucks. Over the coming decade, significant increases are expected as shown in Figure 2-3:

Figure 2-3: Historical and prospective changes of CAFE standards and average fuel economy records of US passenger cars and light trucks



Source: Shiau et al (2009)

The Corporate Average Fuel Efficiency standards have been met by US manufacturers using a combination of reducing the price of less polluting vehicles (to increase their market share) and by producing more efficient vehicles.

A study by Shiau et al (2009) concludes that:

> *"[car manufacturing] firms ignore CAFE when the standard is low, treat CAFE as a vehicle design constraint for moderate standards, and violate CAFE when the standard is high. Thus, increasing CAFE standards will eventually have no further impact on vehicle design if the penalty for violation is also not increased... Results indicate that equilibrium vehicle design is not bound by current CAFE standards, and vehicle design decisions are directly determined by market competition and consumer preferences... [and] that firms' design responses are*

more sensitive to variation in fuel prices than to CAFE standards, within the examined ranges."

Therefore if penalties are to be imposed then they need to be set at a sufficiently high level in order to be effective. The problem with the CAFE standards has tended to be that the level of penalty for high consumption vehicles has been set too low relative to the price of the vehicle, and easily absorbed by the market. In turn, this suggests that much of the market is relatively insensitive to price, at least in terms of the size of price movements that this legislation incurred.

Falvey (1986) studied the effects of US CAFE standards on new car prices between 1978 and 1980 and found that there were two main options open to manufacturers. The first option was to maintain the same product line up and adjust the pricing so that they sold a higher proportion of the smaller, more fuel efficient models in order to bring the sales-weighted average fuel consumption of the fleet down. The second was to maintain the existing pricing strategy and adjust the model line-up. These two options could also have been used in combination. The author noted that one of the main issues to address in this analysis would be to establish the additionally which could be attributed to the standard, and its impact on vehicle price, over and above the normal product development process.

Falvey concluded that three US car manufacturers adopted a strategy of adjusting relative prices in order to meet the standards between 1978 and 1980. However by the end of that period it appeared that the standards were being partly met by manufacturers starting to produce more efficient vehicles and partly by shifts in demand towards smaller models.

Estimating the impact of CAFE standards in terms of the additional cost of emission control technologies suggests a significant cost to vehicle manufacturers

Wang et al (1993) adopted a part-pricing approach to estimating the impact on manufacturer costs and vehicle prices which relies on manufacturer's suggested retail prices of the major components necessary for achieving emissions reductions. They sourced manufacturer-suggested retail prices of emission control components and then discounted them using the profit and cost mark-ups of dealers and manufacturers to arrive at manufacturer costs. These costs were then converted into manufacturer costs for initial parts and estimated the cost of engine modifications.

The authors acknowledge that there are weaknesses in this methodology. For example it relies on subjective assumptions made by individual manufacturers in accounting for a range of cost components in order to determine the price of parts and differences in accounting methodologies will necessarily result in differences in the estimated costs. Furthermore it assumes that the function of a vehicle part is independent from that of another, when in fact a systems design approach to vehicle manufacture is the norm. Finally it also assumes a competitive vehicle parts market which the authors considered to be broadly correct at that time, but not universal.

The study concludes that the cost to vehicle manufacturers for emission control of vehicles sold in California in 1990 ranged from $220 per vehicle to $1,460 per vehicle, depending on the size of the vehicle and the manufacturer, with a sales weighted average cost of $445 per vehicle. This translated into a cost to consumers ranging from $370 to $2,430 with an average of $748. However learning and scale production benefits were not taken into account in this study so this headline cost may not be passed on in the first cohort of new cars, but amortised over the lifetime of vehicle production.

One reason this additional cost may not have been passed through to consumers is that they tend to be highly sensitive to increases in upfront cost, whereas benefits from improved fuel economy are not as influential. Goldberg (1998) studied the effects of the US CAFE standards, considering whether consumers in the US respond more to changes in vehicle costs than to fuel costs. The study found that the average fuel cost elasticity was 0.5 (i.e. a 2% increase in fuel costs would result in a 1%

decrease in demand) while average vehicle price elasticity is 3 indicating that increases in vehicle prices will have a larger effect on vehicle choice than a proportional increase in fuel costs. However the authors point out that the absolute changes in cost associated with an increase in vehicle price is much greater than the same proportional increase in fuel costs, and when this is taken into account by discounting the vehicle cost over a period of ownership. The elasticities are broadly similar and "hence, changes in operating costs can, from an environmental perspective, be as effective as changes in vehicle prices." In practice, consumers do not necessarily behave purely rationally and tend to prefer to pay a lower purchase price even when the true lifetime costs (even over a period of a few years) are high due to low fuel efficiency.

The result of this is that in the absence of CAFE regulation, manufacturers would be likely to set increased prices for small, efficient vehicles and decreased prices for larger vehicles, which would reduce fleet average efficiency but would increase vehicle sales. As such, "CAFE seems to function as a set of internal taxes (on fuel inefficient) and subsidies (on fuel efficient vehicles) within each firm."

Emission control technologies can lead to increased vehicle performance in other areas. Hence, even if reduced emissions are achieved at additional cost, the quality of the vehicle may be significantly improved

A study by Chen and Sperling (2004) analysed the car manufacturers' response to emission regulations in the US in the late 1970s and early 1980s, with a view to identifying lessons that might be applicable to future legislation. The study investigated two periods of regulation: the introduction of oxidising catalysts to meet 1975 standards and the introduction of three-way catalysts to meet standards phased in between 1979 and 1981.

For each standard the authors attempted to answer a selection of questions including whether increased costs pushed manufacturers to change the volume and line-up of vehicles on offer; how they reflected the costs of these technologies in vehicle prices in both the short and long term; to what extent manufacturers were able to raise prices to cover cost increases; and how manufacturers overcame consumer resistance to the price increases.

Chen and Sperling (2004) note that the manufacturers tend to make the larger expenditures on R&D and tooling prior to the new regulations taking effect, citing Ford and GM exceeding their average R&D expenditure of 3% of revenues in the years ahead of regulation. However they emphasise that "R&D expenditures cannot be solely attributed to emissions controls" as fuel economy standards were also introduced in the late 1970s in response to the oil crisis.

Chen and Sperling (2004) add that:

> *"In addition to the difficulties of accounting for all costs, further complexities arise as vehicles are designed as integrated systems and a single vehicle part may serve multiple functions. Thus, accurately apportioning the costs of emissions control systems to only actual emissions control can be difficult...Technologies such as electronic controls and fuel injection significantly increase vehicle quality while simultaneously contributing to emissions reductions."*

A paper by Sprei et. al (2008) also found that technology developments to reduce fuel consumption and emissions are offset by diverting technology gains into non-fuel saving vehicle features – ''service attributes". Changes between 1975 and 2002 were mapped through statistical analysis and modelling of a combination of sales statistics and vehicle attributes. About 35% of the effects of enhanced technology and design resulted in a net reduction in fuel consumption. The remaining 65% served to meet consumer demands for such things as increased passenger space and improved acceleration.

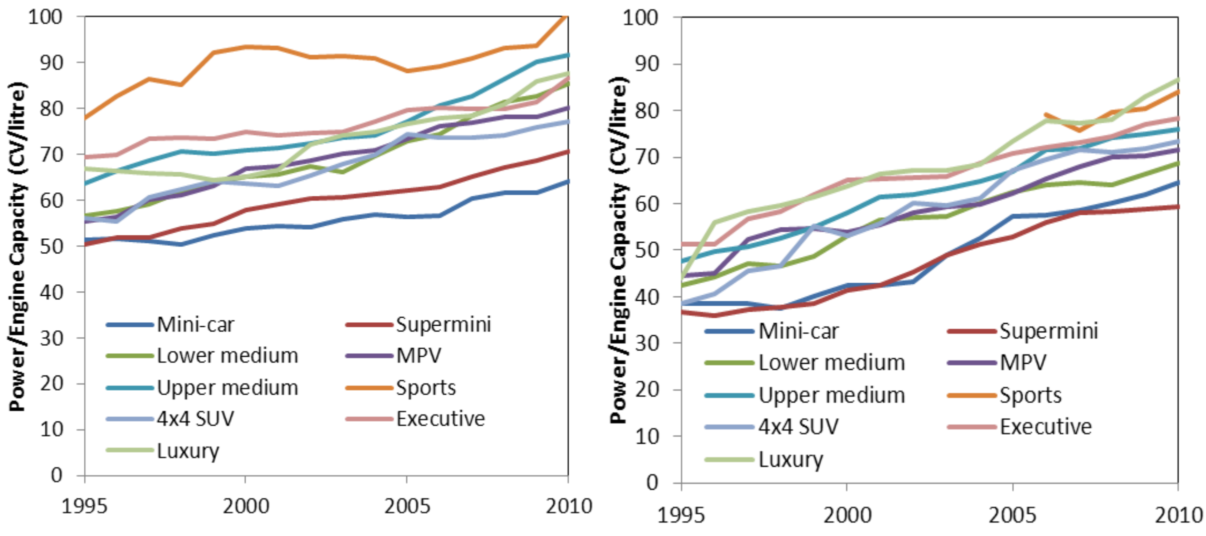
Hence, even if additional costs arise due to reductions in emissions, it has increasingly been achieved by benefits in other areas, such as acceleration, top speed and decreased fuelling costs.

The industry trend has been towards increased vehicle power per litre of engine capacity

Figure 2-4 illustrates the increases in vehicle power per litre of engine capacity for each of the vehicle categories. It can be seen that there have been sizeable increases, with petrol lower medium vehicles increasing from 57 to 85 CV/litre, equating to an increase of 51% over the 15 years. Diesel vehicles have improved their average power/engine capacity by more than the petrol counterparts due to the increasing standardisation of turbochargers. This can be seen in the below diesel chart, where the average power/engine capacity has increased by between 53 to 96%. This has meant that the diesel vehicles are now approaching petrol in their average power/engine capacity ratio. For example the luxury category has an average power/engine capacity of 87CV/litre for both diesel and petrol fuelled vehicles.

This increase in power/engine capacity is a benefit to consumers as they have an increase in power without having the traditional increase in vehicle weight due to a larger cylinder block.

Figure 2-4: Power/Engine Capacity (CV/litre) for both diesel and petrol vehicles. Here petrol is illustrated on the left, and diesel on the right.



Source: JATO dataset

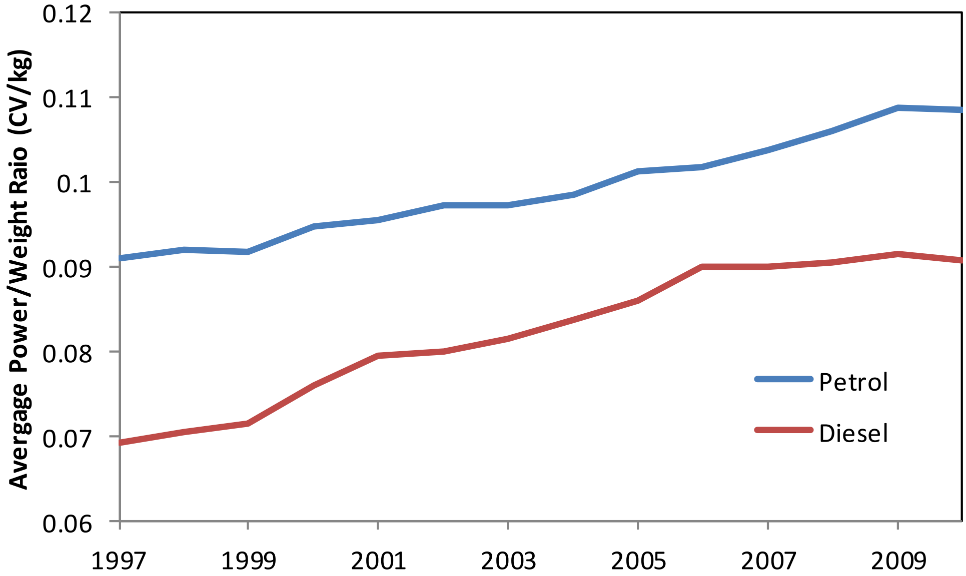
These benefits can be sold to consumers as they are willing to pay for it. This increase in power/engine capacity leads to an increase in the power to weight ratio of the vehicle, which leads to an increase acceleration.

Figure 2-5 illustrates this increase for the average petrol and diesel vehicles within the dataset, here it can be seen that the average petrol vehicle has increased its power/weight ratio by 19%, and diesels by 31%.

Figure 2-6 assumes the same ratios of power and weight to fuel consumption but keeping the power/weight ratio at 1995 levels. The red line assumes the same relationship between with power /weight ratio as the grey line but compared to a constant 1995 value. We find that fuel consumption in 2010 given a static power/weight ratio is between 65-70% of what it was in 1995 (red line) compared to 68% to 82% if power/weight ratio was not static (grey line).

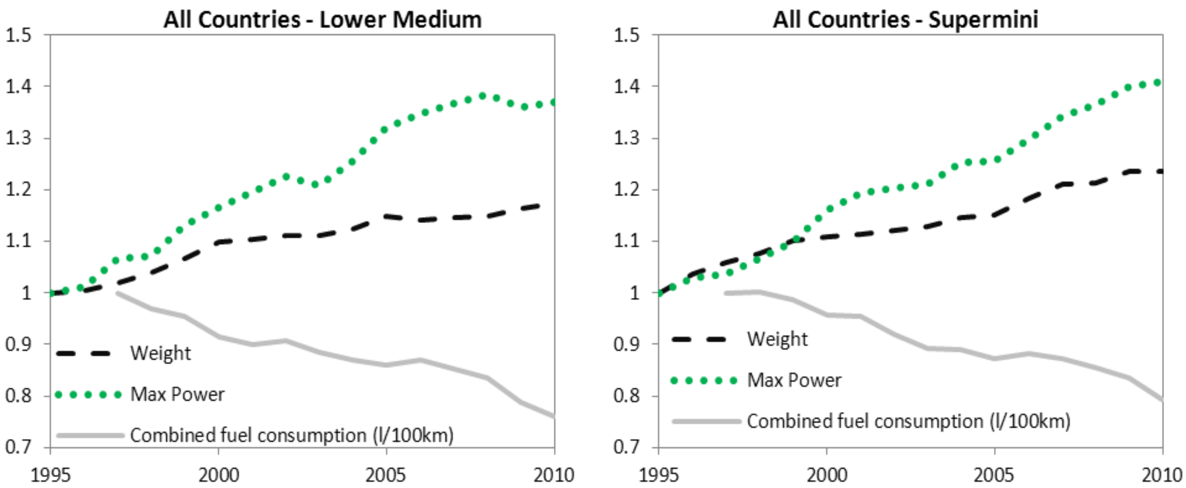
Figure 2-7 illustrates this case with lower medium and supermini vehicles, where the average vehicle power has increased by around 40% while the average fuel consumption has decreased by around 20%.

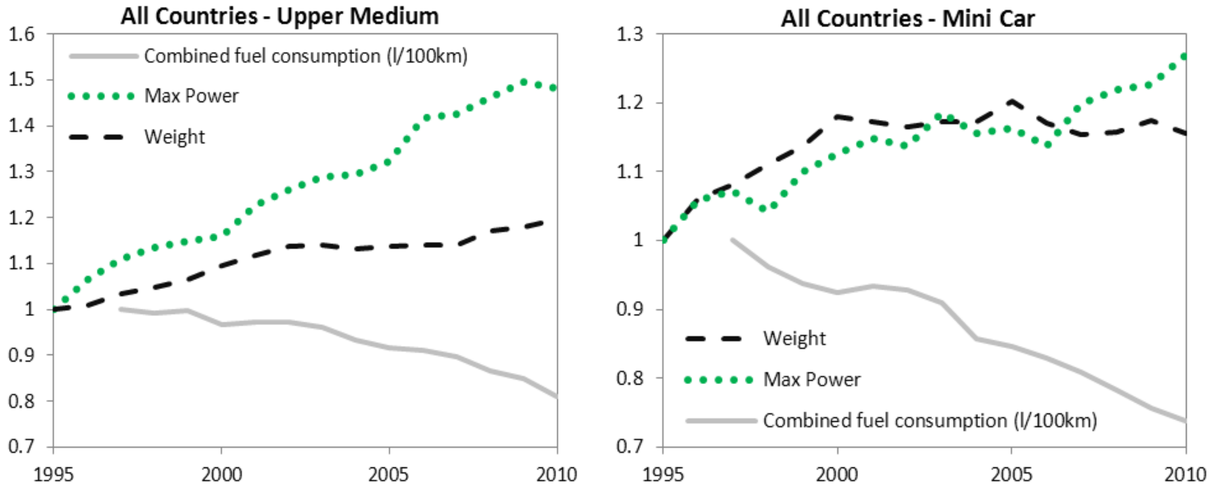
Figure 2-5 - Change in Power/Weight Ratio (CV/kg) over time



Source: JATO Dataset

Figure 2-6 - Comparison of Normalised values of Average Vehicle weight (kg), Max power (CV), and Combined Fuel Consumption (l/100km) for period of 1995-2010 (fuel consumption measured from 1997)

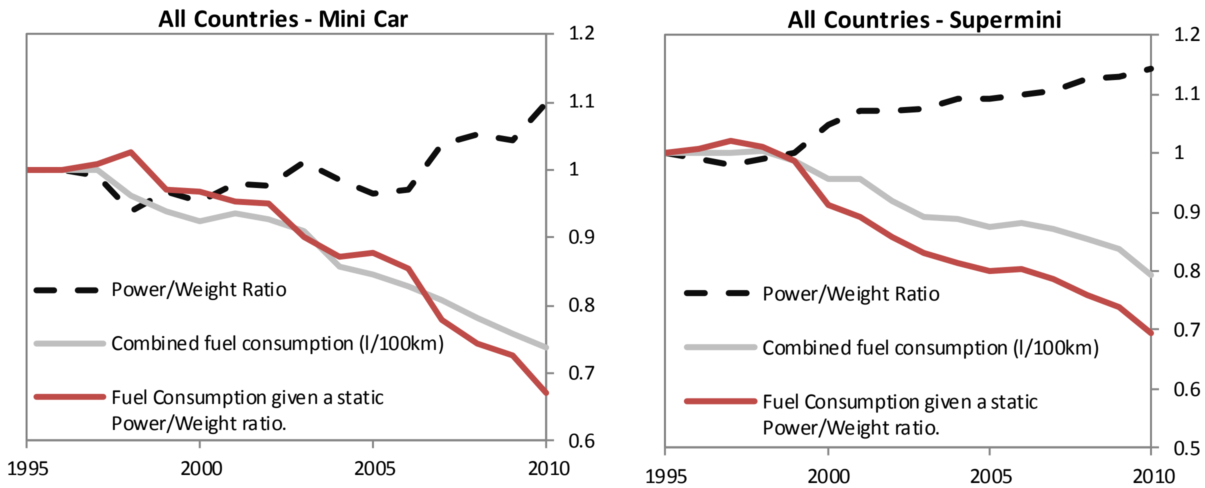


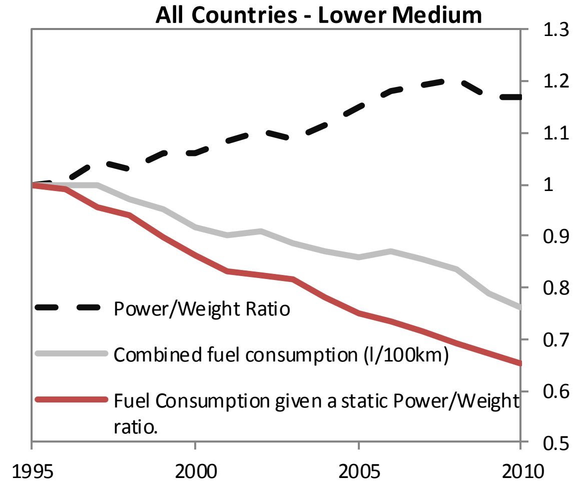


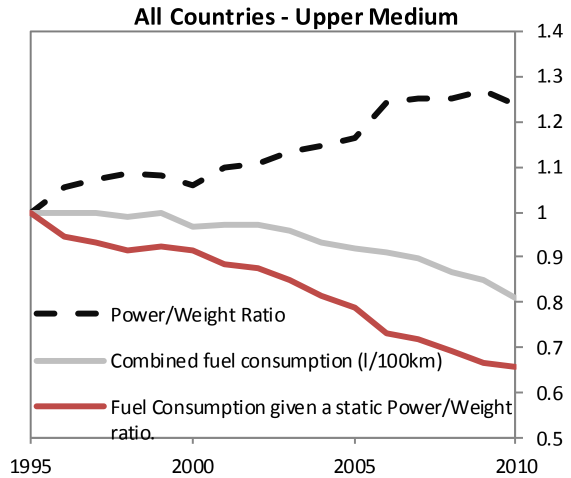
Note: Values have been normalised with the first year of the sample having the value of 1. This is achieved by dividing all the values by the first year, which is 1995, (or 1997 for fuel consumption). All other vehicle categories illustrate a similar relationship, and can be found in the Annex 1.2.
Source: JATO dataset

Figure 2-6 assumes the same ratios of power and weight to fuel consumption but keeping the power/weight ratio at 1995 levels. The red line assumes the same relationship between with power /weight ratio as the grey line but compared to a constant 1995 value. We find that fuel consumption in 2010 given a static power/weight ratio is between 65-70% of what it was in 1995 (red line) compared to 68% to 82% if power/weight ratio was not static (grey line).

Figure 2-7 - Comparison of Normalised values of Average Max power/Average Weight Ratio, Combined Fuel Consumption (l/100km), and fuel consumption given a static power/weight ratio.







Note: Values have been normalised with the first year of the sample having the value of 1. This is achieved by dividing all the values by the first year, which is 1995, (or 1997 for fuel consumption). For the purpose of this analysis, the value of the fuel consumption for 1995 and 1996 is assumed to be the same as 1997.
All other vehicle categories illustrate a similar relationship, and can be found in the Annex Section 1.2.
Source: JATO dataset

The literature finds that the cost of compliance with emission regulations (to the manufacturers) tends to exceed the change in vehicle prices, suggesting that manufacturers either absorb the costs or employ other strategies to reduce vehicle costs.

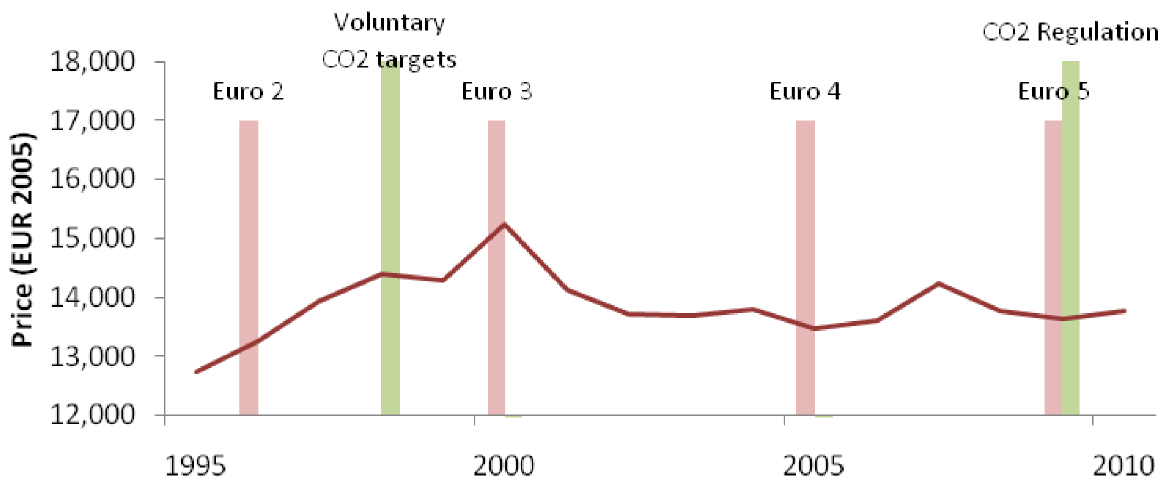
Chen and Sperling (2004) found notable increases in vehicle prices correlating with new emissions regulations, but they note that the picture varies depending on whether a sales-weighted average or an unweighted average is used. The sales-weighted average is more representative of the consumer response, while the unweighted average reflects the response of the manufacturer. The analysis showed that “the change in compliance cost [to the manufacturer] exceeded the change in vehicle price for four years”. However for an unweighted average of prices, “the change in cost exceeded the change in price for only two years”. The authors propose that the reason for this could be that:

> *“Although the change in prices for vehicles offered by automakers increased, consumers heavily favoured the less expensive models which lowered the weighted average. The fact that vehicle prices decreased during periods when emission control costs were estimated to have increased suggests that manufacturers were either absorbing the costs of compliance or reducing the cost of vehicles using other strategies. Whether these costs were fully passed on to consumers in the remaining years depends on what other changes were made to the vehicles for competitive purposes.”*

Evidence from the JATO dataset does not provide any definite relationship between Euro standards and car prices (see Figure 2-8, Figure 2-9 and Figure 2-10 below). The price trends show slight peaks around Euro 3 for the selected vehicle sizes. However, this could be due a multitude of factors and the figures below do not provide a definitive answer. It is difficult to visually deduce if there has been an increase in prices as a result of the environmental standards. While there are circumstances where the introduction of standards does coincide with an increase in vehicle prices, such as Euro 4 introduction on 4x4 vehicles, there are situations where prices decrease during Euro 4 introduction, such as in luxury cars. Hence it is not possible to give a strong analysis

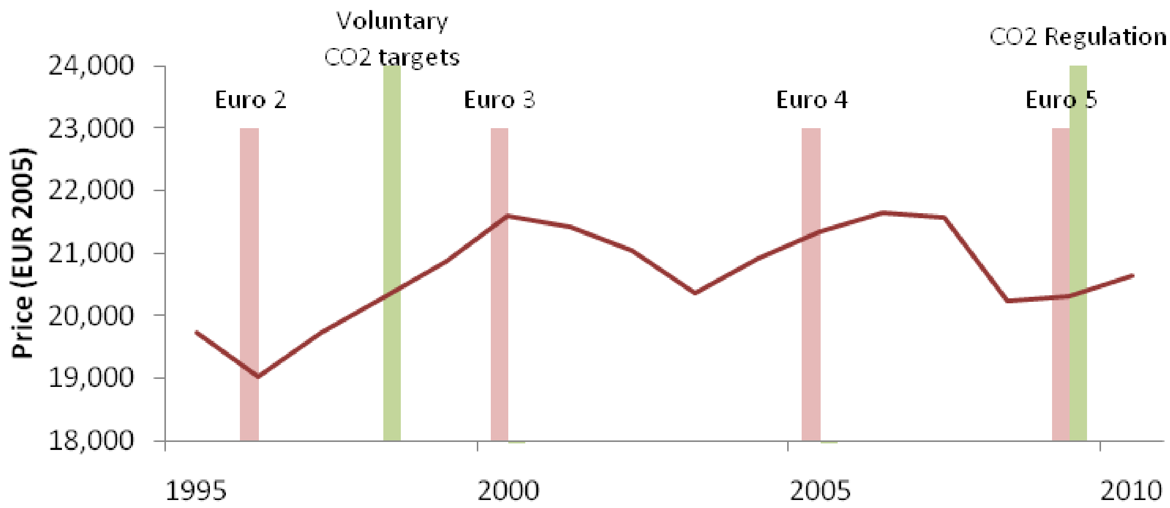
The introduction of Euro 3 in 2000 is the only circumstance where there is an increase in average vehicle prices for all vehicle categories except for 4x4. However at time is the introduction of the single European currency, the EURO, so it is difficult to state whether this price increase (in Euro terms) is a result of the environmental standard, or due to currency changes.

Figure 2-8: Evolution in the average price of cars in the super-mini category (Class B) across six member states (in EUR 2005) with environmental legislation overlaid.



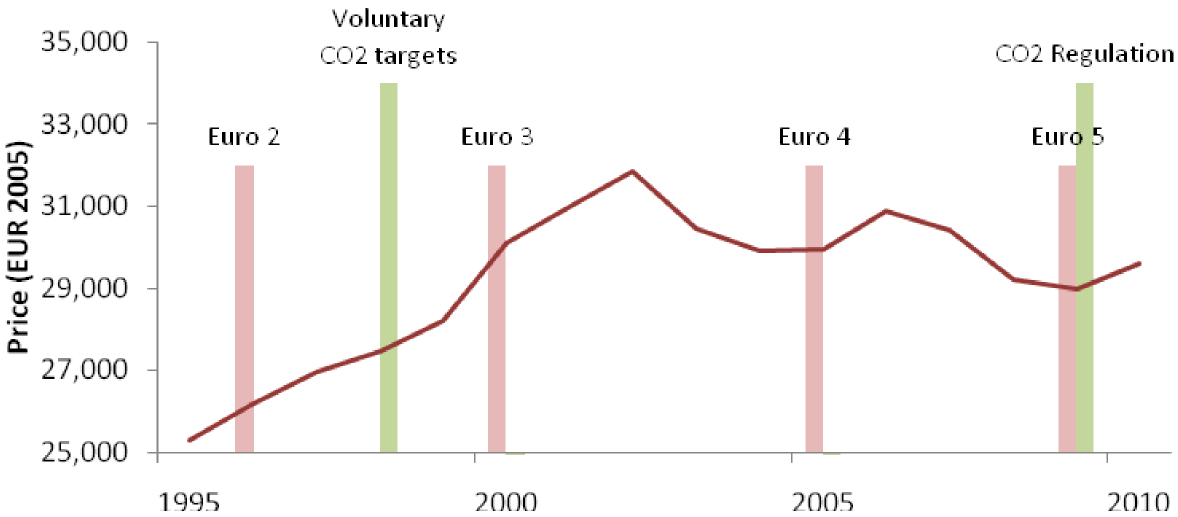
Source: JATO dataset

Figure 2-9: Evolution in the average price of cars in the lower medium category (Class C) across six member states (in EUR 2005) with environmental legislation overlaid.



Source: JATO dataset

Figure 2-10: Evolution in the average price of cars in the upper medium category (Class D) across six member states (in EUR 2005) with environmental legislation overlaid



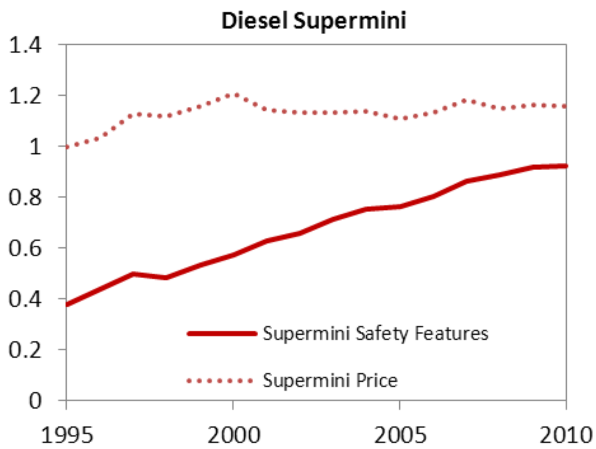
Source: JATO dataset

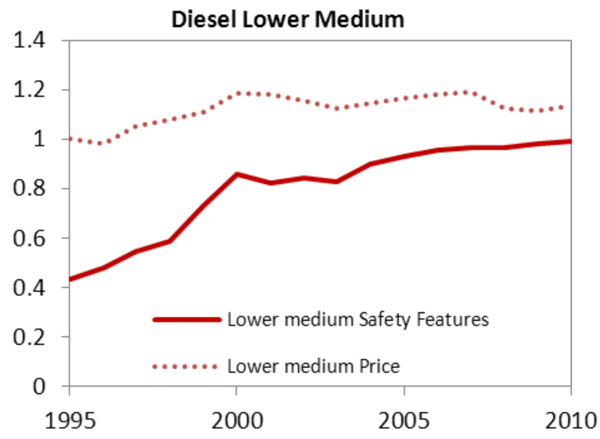
In Europe, Couton et al (1996) modelled the environmental and safety aspects of cars, assessing the impacts of catalytic converters and airbags on vehicle prices in France. The authors modelled the market using technical characteristics including engine type, engine power, environmental characteristics, reliability and market segment. The author found that the environmental and safety characteristics were "highly significant" with the presence of an airbag increasing the hedonic price "by 6% on average and the catalytic converter by 8%", with the latter's hedonic price increasing significantly over the period.

The EuroNCAP safety ratings have provided significant incentives to manufacturers to increase safety features in a "race to the top".

Over the past decade, it could be argued that safety regulations have imposed no additional cost on the vehicle manufacturers as vehicles are engineered to achieve a high Euro NCAP score, which demands significantly higher standards than those defined in the legislation. Evidence from the JATO data shows that the level of safety features have increased at a fast rate while prices have remained relatively constant. Figure 2-11 and Figure 2-12 below illustrate this (with safety features being measured as a fraction of the total options within the dataset, these are: side impact bars, driver/passenger airbag, side airbag, ABS, electronic braking system, stability control). In 1995 both petrol and diesel superminis had only around 40% of the listed safety options installed, whereas by 2010 they were averaging over 90%. This represents a significant improvement on vehicle safety over the period, while petrol and diesel superminis averaged an inflation adjusted price of 6% and 15% respectively.

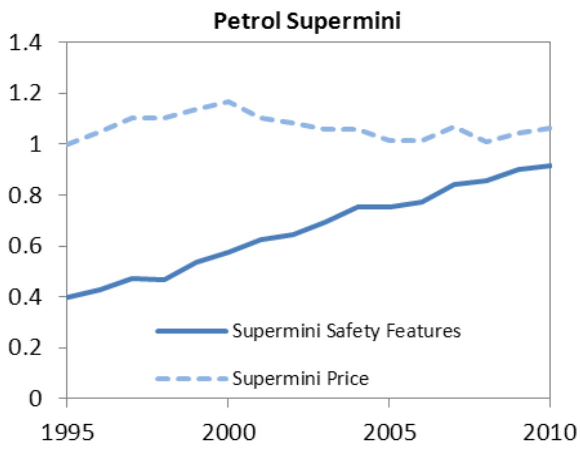
Figure 2-11: Correlation between normalised price (2005 EUR) and level of safety features over time for diesel cars. Normalised price is on the left-hand axis and safety features on the right-hand axis.

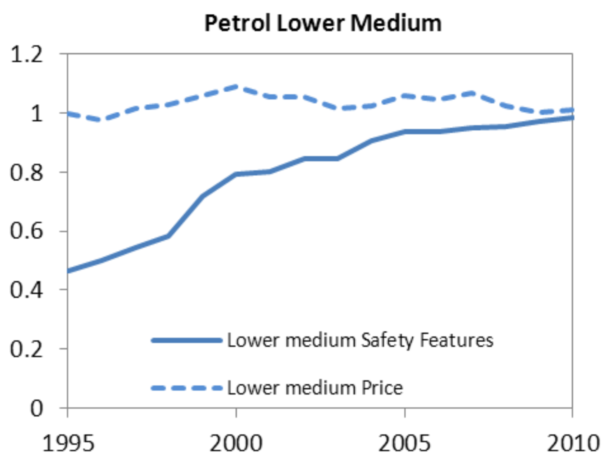




Note: Comparison for all other size categories is available in Annex Section 1.2
Source: JATO dataset

Figure 2-12: Correlation between normalised price (2005 EUR) and level of safety features over time





Note: Comparison for all other size categories is available in Annex Section 1.2
Source: JATO dataset

As expected, the smallest (and cheapest) categories have the lowest levels of safety features installed and are the last to integrate these features. The luxury and executive segments are the first to install these features and by 2002 have all the listed safety features within the JATO dataset installed as standard. This is illustrated in Annex Section 1.2. These high end segments continue to increase their safety levels with supplementary airbags such as knee, side and rear curtain airbags. Other safety packages installed on premium vehicles are pre-crash systems, which can automatically tighten seatbelts, apply the brakes, and adjust the seating position and headrest in anticipation of a crash. However these attributes are not included within this dataset.

It is also worth noting that while the focus of this study is on the European Union, other markets such as North America and Japan have had environmental and safety legislation in place over this time period. Hence in reality costs can often be amortised across markets larger than the European Union and this tends to reinforce the benefits of scale and geographic reach for individual vehicle manufacturers.

2.3.2 Block Exemption

Although competition in the industry had significantly increased, a review of the impacts of Block Exemption found that the causes were mainly external factors

Block Exemption dates back to 1985 when European Original Equipment Manufacturers (OEMs) of vehicles were given a ten year partial exemption from the rules for competition which were drawn up within the treaty establishing the European Community. This allowed vehicle manufacturers to selectively and exclusively control their distribution systems (dealers). Two main reasons were given for this:

1. The new car market was subject to fierce competition and specific franchise regulation was felt necessary to avoid a 'cut-throat' level of competition.

2. Cars require regular maintenance and repair and it was felt this could best be done by an exclusive dealer network to ensure high standards.

In return for this, OEMs committed to move towards EU-wide price harmonisation.[43]

It has been suggested that the original 1985 agreement gave OEMs too much power.[44] By 1995 it was also found that there had been little progress towards price harmonisation, with price differentials for similar vehicles as high as 40% in some markets.[45] As a result when Block Exemption was renewed in 1995, substantial changes were made. These gave more power to dealers, allowing them to engage in different types of selling (e.g. leasing), allowing sale of non-OEM parts provided they were of equivalent quality, and allowing dealers to sell different makes of vehicle (provided it was through separate premises and management). It also introduced rules that gave independent garages access to the technical knowledge and tools needed to repair modern vehicles.[46]

However, in 2000 the European Commission published a report reviewing the changes made in the 1995 Block Exemption which concluded it had failed to achieve some of its aims, with buyers still finding it difficult to purchase vehicles from another member state, independent dealers being denied access to technical information, and the dealers only becoming commercially independent to a limited extent.[47]

In 2002, EC regulation No. 1400/2002[48] updating the details of the Block Exemption was introduced which again attempted to increase competition. This strengthened the ability of dealers to reach customers in different areas or countries, making cross-border sales easier. It allowed them to sell more than one brand of vehicle (multi-franchising) and clarified rules regarding sales via the internet. It also allowed vehicle owners to have their vehicles serviced and repaired by independent garages without affecting the warranty.

A review of the impacts of the 2002 changes published by the EC in 2008 concluded that competition in the industry had significantly increased but that this was primarily due to external factors. It reported that "vigorous and increasing inter-brand competition has translated into falling real prices against a background of increased market integration at EU level".[49] It concluded that those provisions of the 2002 Block Exemption Review which diverged from general European legislation regarding competition appeared to be redundant and that "a more flexible regime... would have ensured an

[43] Automotive retailing in the new millennium - The e-commerce revolution, chapter 12, The Economist Intelligence Unit, 2000
[44] Automotive retailing in the new millennium - The e-commerce revolution, chapter 12, The Economist Intelligence Unit, 2000
[45] Automotive retailing in the new millennium - The e-commerce revolution, chapter 12, The Economist Intelligence Unit, 2000
[46] http://ec.europa.eu/competition/sectors/motor_vehicles/legislation/explanatory_reg_1475_95_en.pdf
[47] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52000DC0743:EN:NOT
[48] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2002:203:0030:0041:en:PDF
[49] http://ec.europa.eu/competition/sectors/motor_vehicles/documents/evaluation_report_en.pdf

equivalent level of protection of competition in the market, while entailing lower compliance costs for companies and a more efficient enforcement system for competition authorities."

In June 2010 a new automotive Block Exemption came into force. This essentially marked a move away from sector specific legislation to application of the general competition rules which are applied to all other sectors of the economy. This was felt to be all that was required to ensure competition in the sale of new vehicles. However for the after-market, it was felt that there was still a need for some sector specific Block Exemption requirements to ensure sufficient competition.

Gaulier (2000) found that both producers and retailers of cars benefited at that time from the exemption regulation, with the distribution system playing "an important role in maintaining price differentials in the EU."

2.4 Business strategy factors

Key points:

- ***Platform sharing and 'commonisation' of parts have been key strategies for manufacturers to reduce costs, meet consumer demand for a greater variety of vehicles and enabled flexible manufacturing plants***
- ***Sharing of powertrains has also enabled manufacturers to keep costs down***
- ***Manufacturers are now focusing on reducing the numbers of different platforms they use***
- ***Manufacturers generally aim to have vehicle production facilities close to markets***
- ***Western European market saturation and strong growth in Eastern Europe and Asia have driven a shift in production location***
- ***Labour costs and the high costs of converting old facilities to more flexible manufacturing have also contributed to shifts in locations***
- ***Both Ford and General Motors attempted to save costs by 'spinning off' parts of their business as separate component suppliers, but with limited success***

Manufacturers have endeavoured to drive costs down to gain competitive advantage and continue to remain profitable. In their paper, *Car firms' strategies and practices in Europe,* Michel Freyssenet and Yannick Lung identify six sources of profit:

- Economies of scale;
- Diverse offerings;
- Guarantee of quality;
- Innovation;
- Productive flexibility; and
- Permanent cost reduction.

They state that no car companies currently employ all six of these strategies, but that in Europe the strategies of different manufacturers can be categorised into one of the following four:

- Volume and diversity;
- Quality;
- Innovation and flexibility; and
- Permanent cost reduction.

In this section we review some of the key business practice changes which have taken place in the car industry over the past two decades.

2.4.1 Platform sharing and architectures

Manufacturers have reduced costs by re-using the same parts, sub-systems and vehicle platforms across different model ranges.

For those manufacturers following a profit strategy based on high volumes and a diversity of different models, a key part of cost reduction in the last 20 years has been a concerted effort to reduce the number of parts they have to conceive, design, develop and manufacture. Instead they have aimed to re-use the same parts, sub-systems and ultimately entire vehicle platforms. As they have acquired other brands they have aimed to share parts across brands.

Over the longer term, the possibility of achieving this has been enhanced by a general convergence on common vehicle architectures. The majority of passenger cars are front-wheel drive and use transverse-mounted engine architectures. This has been applied across small, medium and many larger vehicles and has enabled manufacturers to share engines, gearboxes and drivetrain components between different models.

Within this common architecture, manufacturers have then aimed to reduce the number of different parts used. They have done this primarily by using identical parts, sub-systems and entire vehicle platforms across *different* model ranges. Some manufacturers have also followed a strategy of ensuring that any given model is as close as possible to being identical in all world markets.

This has helped to reduce costs in several ways:

- Reducing design and development costs – rather than designing and developing bespoke parts for every model variant certain parts and technology can be retained from one generation of model to the next, called as ‘carryover’.
- Reducing manufacturing costs through economies of scale: higher volumes result in lower piece prices; reduced numbers of supplier contracts result in greater bargaining power.
- Reducing manufacturing costs through reduced complexity.
- Reducing engine management system calibration development costs – when common engines and exhaust after-treatment systems are used between different vehicles, then the task of engine management calibration to meet emissions regulations can be reduced.

Minimising the number of different parts also allows manufacturers to reduce durability testing costs. The counter point to this is that if a part or system does require an in-service recall then it can simultaneously affect many different model lines and become extremely costly. In 2010, the high profile brake recalls affecting Toyota models involved 12 different models in the US[50] and a further eight in the UK[51] and were reported to involve nine million vehicles.[52] In early 2011 a further problem with fuel pipes affected various Avensis and Lexus models bringing Toyota's total recalls to 12 million vehicles over 18 months.[53]

Convergence of global consumer preferences is enabling manufacturers to harmonise vehicles in different world markets

Manufacturers have continuously struggled to achieve commonality across all world markets, not just due to varying legislation but also customer preferences. In the 1980s, Ford attempted to produce a true world car with the introduction of the Escort Mk.3. However it was reported that when production started, the versions sold in America and Europe shared only two common parts.[54] Over forty years and nine model generations, the Toyota Corolla has become the best-selling car of all time[55] and it is often described as a world car. What is ostensibly the same model is sold in more than 140 countries and regions.[56] It is built in 16 different countries,[57] yet the 2009 version is described as being the first time that it has been designed with all world markets in mind rather than being created for Japan and subsequently adapted for Europe and North America.[58]

According to Lewis Booth, Executive Vice President and Chief Financial Officer at Ford Motor Company, different tastes in different markets made it very difficult to sell an identical vehicle across the world. However he states "customers' tastes are now converging".[59] Despite these difficulties, manufacturers have made significant reductions in the number of different parts they use. For a multi-national manufacturer such as Ford, even a policy to use a limited number of fasteners can have substantial benefits.

Shared platforms are used to produce different models within a brand, or across different brands through joint ventures

As well as harmonising an individual model across the globe, a major focus has been the use of shared platforms. According to Freyssenet and Lung, General Motors invented platform sharing during the inter-war years, producing models for different brands from a common platform[60]. It has been common practice ever since, but in the last twenty years there has been a focus on reducing the numbers of platforms used.

In 1998 the Economist reported that PSA group would make increasing numbers of models from each platform. The platform would comprise "the subframe, engine, transmission, and the wheel, axle and suspension assembly, as well as other equipment such as air conditioning and seat frames" which it estimated would amount to 60% of the vehicle's production cost in the future.[61] In 1999 Ford was reported to be reducing its worldwide platforms from 32 to 16 while simultaneously increasing the number of model derivatives offered.[62] In the same year, Volkswagen was reported to be reducing from sixteen to four platforms,[63] and Fiat to just three.[64]

There are two main ways in which manufacturers use platforms. In the first, an individual manufacturer uses one platform to produce a number of different models either of the same brand, or across

[50] http://pressroom.toyota.com/pr/tms/customer-faqs-regarding-the-sticking-153495.aspx
[51] http://www.autocar.co.uk/News/NewsArticle/Toyota-iQ/247193/
[52] http://abcnews.go.com/Blotter/toyota-recall-toyota-camry-corolla-brake-defects/story?id=9790405
[53] http://www.bbc.co.uk/news/world-asia-pacific-12283732
[54] The Economist (Dec 2010), *Ford: Epiphany in Dearborn* http://www.eiu.com/index.asp?layout=EBArticleVW3&article_id=1347663519&rf=0
[55] http://www.toyota.com/corolla/awards.html
[56] http://www2.toyota.co.jp/en/news/06/1010.html
[57] http://www.toyoland.com/toyota/plants.html
[58] http://www.autoguide.com/manufacturer/toyota/2009-toyota-corolla-1008.html
[59] http://www.eiu.com/index.asp?layout=EBArticleVW3&article_id=1347663519&rf=0
[60] Freyssenet, M., Lung, Y., (2007?), Car firms' strategies and practices in Europe
[61] The Economist (Nov 1998) Peugeot Citroen enters a new era
[62] S. Birch, *Building the Puma*, Automotive Engineering, 106 (5), pp. 107Ð109 (May 1998).
[63] R. Bremner, *Common Knowledge*, FT Automotive World, pp. 42Ð46 (June 1999)
[64] D. Kurylko and L. Ciferri, *Fiat's Three-Platform Strategy Will Help Maker Reduce Costs*, Automotive News, p. 60 (19 July 1999).

different brands within the same manufacturing group. In the second completely separate manufacturers agree to a joint venture using a common platform.

Almost all vehicle manufacturers use this approach to produce several distinctly different vehicles from a common platform. For example, the Ford Puma was a sports coupé derived from the Fiesta platform in the same way that the Opel/Vauxhall Tigra was derived from the Corsa. Small vans are often rebodied versions of cars, for example the original Citroen Berlingo was based on the Citroen ZX/Peugeot 306 Estate and the Opel/Vauxhall Combo van is based on the Corsa. The practice is a common way to create variants within a specific size segment, but it is also possible to achieve across different segment sizes.

The concept of shared platforms has generally been more sophisticated than the ‘badge engineering’ approach in which almost identical vehicles were sold under different brands. However the badge engineering approach is still in use to a certain extent, particularly for smaller vehicles where it is often hardest to make a profit and where individual brands are part of a larger manufacturing group. The 1996 Mazda 121 shared a common production line with the Ford Fiesta Mk4, launched in 1995. They were the same vehicle with very little difference other than badges. At the time Ford owned a controlling share in Mazda.

More commonly while the platform itself is the same, the body styling is distinctly different. In a joint venture between Volvo and Mitsubishi, the 1994 Volvo S40 and the Mitsubishi Carisma shared the same underpinnings while not sharing visual similarities. The S40 was also offered with the Mitsubishi 1.8L gasoline direct injection (GDI) engine.

The strategy has been used for mid-size vehicles too. The Volkswagen Group have been particularly successful using this approach. It owns Skoda, Audi and Seat and used the Golf Mk 4 platform to produce cars as varied as the Skoda Octavia, Seat Toledo, the new VW Beetle and the Audi TT. Dr. Bernd Pischetsrieder, Chairman of Volkswagen from 2002-2006 was reported to have felt that platform sharing had been taken too far, with sales of cheaper Skoda models eroding those of the Golf using the same platform. Volkswagen has since moved to a more modular and flexible approach to their platforms.[65] This allows greater individuality to be introduced to vehicles, but also enables the manufacturer to produce vehicles in different class size segments from a common platform.

The platform with the greatest production volumes currently is the Toyota MC platform at almost three million units. It is used for the Corolla, the RAV4, the Prius and the Lexus HS250h. However the Renault-Nissan X85 platform is expected to be used to produce almost four million units in 2016, being used for the Nissan Micra, Renault Clio and 36 other models.[66] The Volkswagen MQB platform is expected to be used for nearly all of their front wheel drive vehicles in the future, from the Polo to the Golf and Passat[67]. It is expected to be used for Audi, Seat and Skoda vehicles too and is predicted to be the second highest volume platform in the world in 2016 at almost 4 million units. Volkswagen group has also used the platform approach for their larger sport utility vehicle, the Touareg. It shares its entire chassis with the Porsche Cayenne and Audi Q7. All three are built at the Volkswagen factory in Bratislava.

Sometimes platform sharing extends across completely separate brands through a joint venture agreement. The original Ford Galaxy was a joint venture with Volkswagen with the sister models being the VW Sharan and the Seat Alhambra. In current production a joint venture between Toyota, Peugeot and Citroen has resulted in the Aygo, 107 and C1 which have only relatively small styling and interior differences to distinguish between them. A less obvious example is the current production Fiat 500

[65] http://www.economist.com/surveys/PrinterFriendly.cfm?story_id=3127250
[66] http://www.autosavant.com/2010/11/16/platform-sharing-set-to-increase-dramatically/
[67] http://www.autosavant.com/2010/11/16/platform-sharing-set-to-increase-dramatically/

which, in a joint venture with Ford, shares its platform with the second generation Ka. The platform is also used for the second generation Fiat Panda and the 2011 version of the Lancia Ypsilon.

A downside of platform sharing is the potential for products to become homogenised with little distinction between them. However by focusing on differentiating the areas visible to customers such as the body and interior styling and the 'touch points' with which customers interact (for example handles, interior trim, seating, steering wheel) many consumers are unaware of the sharing of parts between models. The fact that fewer customers service their own vehicles has also reduced awareness of part sharing.

Manufacturers are increasingly choosing to share costs by working in partnership

There are examples of manufacturers providing each other with models to complete their ranges in different markets. For example Nissan and Mitsubishi have an agreement under which Nissan will make a small van which will go on sale in Japan as a Mitsubishi. Meanwhile Mitsubishi will manufacture a sports utility vehicle which Nissan will sell in the Middle East.[68]

A further development which has enabled manufacturers to significantly reduce cost is sharing of powertrains (engines, gearboxes etc.). Powertrains have a longer lifecycle than vehicles themselves and require investment in dedicated tooling for manufacture. Research and development of a completely new family of engines is an expensive and time consuming process, particularly with the increasingly complex technologies required to reduce emissions and improve fuel economy. As a result manufacturers who have acquired a number of different brands will use the same engines across a wide variety of vehicles.

For example the Volkswagen 1.9 TDI engine was first introduced in 1994 and marked their first introduction of direct injection diesel technology (although turbo-charged direct injection technology had previously appeared in 1989 in the Audi 100 R5 2.5 TDI). Within VW the 1.9TDI was used in the Polo, Golf (Mk3 & 4), Vento, Jetta, Bora, Beetle, Passat, Sharan, and Caddy. It was also used for the Audi 80, A3, A4, and A6, the Seat Ibiza, Cordoba, Leon, Toledo, and Alhambra, the Ford Galaxy and the Skoda Octavia. It was then upgraded with the introduction of the Pumpe-Düse injection system to meet "the stringent demands for improved performance and cleaner emissions"[69] and used in an even wider range of vehicles, still being available in 2010, sixteen years later.

However manufacturers have also increasingly chosen to share costs by developing new engines in partnership. Ford and Peugeot have an agreement whereby smaller diesel engines used in Ford vehicles have primarily been developed by Peugeot. Nissan and Renault have increasingly shared engines with Renault leading diesel development and Nissan leading gasoline engines. In 2009 it was reported that this arrangement together with increased platform sharing and cooperation in developing electric cars would generate 180 billion yen (US$1 billion) in cash flow.[70]

2.4.2 Reducing production costs through relocation

Manufacturing is increasingly relocating away from Western Europe, due to lower costs and strong market growth in other areas

Over the last twenty years several factors have combined to reduce the volume of vehicle manufacturing required in Western Europe and encourage a shift to Eastern Europe and Asia:

1. Western European markets reaching saturation;

[68] http://www.bbc.co.uk/news/business-11988802
[69] http://www.myarchive.us/richc/VW_TDI_with_PumpeDuse.pdf
[70] http://www.greencarcongress.com/2009/03/renault-and-nis.html

2. Strong market growth in Eastern Europe and Asia;
3. Increasing cost pressures forcing manufacturing to be located in areas with lower labour costs; and
4. Requirements for plants to be more flexible in building different models according to demand.

In an article in 2010, Barclays Capital state that automotive sales in the US and Europe peaked in 1999-2000 and stayed roughly stable to 2007, whereas emerging markets have shown steady growth. They comment that the gradual shift to the "East" will accelerate in the next decade.[71]

Evidence submitted to the UK Government's Trade and Industry Committee by vehicle manufacturers led them to conclude in 2007 *"we believe that the closure of car plants in Western Europe and the opening of up-to-date facilities in Eastern Europe, using cheaper labour, will continue".* This was felt to be due to the industry having a *"regional approach to its markets, expanding or contracting capacity to meet regional demand"*. They went on to state that the fundamental cause of plant closures was "*the excess production capacity in areas of the world (including Western Europe) where demand is stagnant or falling"*.[72] This was despite strong evidence of cost reduction. General Motors stated that since 2002 their UK Ellesmere Port plant had improved quality by 40%, almost halved manpower hours per car and reduced total plant cost per car by 40% and assembly cost per car by 36%. Indeed the UK plants of Nissan, Toyota and Honda have been ranked as the top three most productive in Europe in 2000.[73]

Peugeot closed their UK plant at Ryton which produced the 206 model and moved production of the then new 207 model to the Slovak Republic. The company stated that the costs of converting the plant to allow flexible platform based manufacture were too high given that it was already their most expensive plant. However, trade unions suggested that labour costs in the Czech and Slovak republics were about a third of those in Western Europe. Addressing overcapacity further contributed to the closure of Ryton with the company closing the plant earlier than expected due to fall off in demand for the 206.[74]

Other examples of relocating manufacturing to Eastern Europe include Renault which produces vehicles in Pitesti, Romania having taken over Dacia in 1999,[75] while Ford and Fiat produce the Ford Ka and Fiat 500, which both share the same platform, at a plant in Tichy, Poland.

Elsewhere other manufacturers have also reduced production capacity to cut costs. In 2000, Ford's European capacity was reported as being 2.25 million vehicles a year, yet 1999 sales were 1.7 million units.[76] *The Economist* reported in 2010 that Ford had closed 17 factories including parts-makers and halved its shop-floor workforce in North America since 2006. This had resulted in reductions in annual running costs of about $14 billion. However the article noted that Europe is still 'plagued by overcapacity' due to the reluctance of Peugeot, Renault and Volkswagen to reduce capacity, instead resorting to discounting.[77] Ford did end production of vehicles at its Dagenham UK site in 2002, although the site continues to manufacture diesel engines.

Favourable legislative environments may also encourage the relocation of manufacturing, for example with respect to employment law, taxes and/or state aid

[71] http://www.icis.com/Articles/2010/03/22/9343257/global-chemical-industry-recovers-but-an-automotive-shift-to-asia-will-pose-more.html
[72] Success and failure in the UK car manufacturing industry, Fourth Report of Session 2006–07, House of Commons Trade and Industry Committee, 2007
[73] http://www.touchbriefings.com/pdf/11/auto031_p_ryhs.pdf
[74] Success and failure in the UK car manufacturing industry, Fourth Report of Session 2006–07, House of Commons Trade and Industry Committee, 2007
[75] http://www.renault.com/en/groupe/renault-dans-le-monde/pages/renault-en-roumanie.aspx
[76] Feast, R. (2000), ``Why Ford is rebuilding in Europe'', Automotive World, June, pp. 6-7. (quoted in the paper 'Restructuring Ford Europe').
[77] http://www.economist.com/node/17673258?story_id=17673258

Other factors which have influenced manufacturers' decisions regarding production site locations include variations between different country's regulations both of the labour market and of the automotive industry:

- Costs and complexity of the redundancy process; (statutory minimum redundancy pay can vary by a factor of five between EU countries).[78]
- Availability of state aid for manufacturing;
- Import and export tariffs;
- Protection of indigenous industry.

Manufacturers are also opening production facilities in Asia, recognising the potential for growth in the region. The 2010 version of the Nissan Micra started production in four plants in four different countries, three of which are in Asia: China, India and Thailand. The new plant near Chennai in India cost $990 million and has the capacity to produce 400,000 vehicles a year. The plant is planned to export the Micra model to over 100 countries including Europe, the Middle East and Africa.[79] Exports to Europe started in October 2010.

General Motors has eleven joint ventures in China[80] and has been reported to have plans to export Chinese made vehicles to America.[81] Jaguar Land Rover too has announced plans to build cars in China and India[82], while their three UK plants which had been threatened with closure have for the moment survived.[83]

Volkswagen announced that they will start vehicle production in Malaysia, south-east Asia's second biggest car market, in 2011. Five other foreign vehicle manufacturers have also been reported to be interested in setting up production. The Malaysian government is starting to reduce the restrictions which require foreign companies to work jointly with local Malaysian partners. Malaysian import taxes for vehicles are amongst the highest in the world.[84]

Suppliers are also facing cost pressures, which is leading them to expand production in Eastern Europe and Asia

Suppliers too have been forced to close plants and shift production to areas with a lower cost base. In 1998 Lear, a seating supplier announced 15 of its European plants would face closure as well as one in North America and one in South America. However they expanded production in Portugal, citing a good cost structure and transportation facilities and stated at the time they might also put a second operation somewhere in Eastern Europe.[85] In 2011, they have seating plants in Turkey, Hungary, Slovakia, Poland, and the Czech Republic, as well as Russia, India, China, Thailand and South Korea.[86]

In 1999, the tyre manufacturer, Continental was also reported to be planning to relocate 40% of tyre production to lower cost countries having announced plans for new plants in Slovakia and Romania to add to an existing plant in the Czech Republic. At the end of 2009, Continental opened a new automotive R&D centre at Iasi in Romania, hosting 450 employees and covering chassis and safety,

[78] Success and failure in the UK car manufacturing industry, Fourth Report of Session 2006–07, House of Commons Trade and Industry Committee, 2007
[79] Nissan Motor India announces the start of commercial production of Micra http://www.nissan-global.com/EN/NEWS/2010/_STORY/100524-01-e.html
[80] GM Looks to Rev Up Chinese Exports http://online.wsj.com/article/SB10001424052748703703804576145391695274576.html
[81] GM plans to export cars from China to the US http://www.telegraph.co.uk/finance/newsbysector/transport/general-motors/5323274/GM-plans-to-export-cars-from-China-to-the-US.html
[82] Jaguar Land Rover announces production in China and India as British factory faces the axe http://www.dailymail.co.uk/news/article-1282297/Jaguar-Land-Rover-announces-production-China-India-British-factory-faces-axe.html
[83] Jaguar Land Rover to retain three UK factories http://www.bbc.co.uk/news/uk-england-11549823
[84] http://www.bbc.co.uk/news/business-12050488
[85] Research Report: European automotive components, 2000 Edition, Part 2 The market, Matthew Beecham
[86] Information from http://www.lear.com/

powertrain and interior.[87] In November 2010 they celebrated ten years of automotive business in Romania where they now have 4000 employees in total.[88]

2.4.3 Purchasing strategies

Another area in which manufacturers have reduced costs is in their handling of inventory. 'Just-in-time' parts handling procedures are perhaps the most well-known element of what has become known as the Toyota Production System. This system aims to minimise the parts inventory and hence the resulting costs. However Toyota also emphasises the importance of involving employees and focusing on continuously improving quality and just-in-time is seen as one component of a "lean manufacturing" system. The system relies on having good supplier relationships in order to synchronise delivery of parts with production, often requiring suppliers to be located near the manufacturing plant.

A study by University of Michigan Business School (2002) examining the effectiveness of supply chain collaboration for automotive manufacturers concluded that they can reduce in-house inventory up to 60%, reduce transaction costs by up to 88% and cut lead times by up to 75%.[89]

Vehicle manufacturers have adopted a range of purchasing and supply chain management strategies to drive down the cost of bought-in materials and components. Some of these initiatives are long-term, with the impact on cost reduction unfolding as the new model development programme progresses. Others are short term, and more closely relate to built-in year-on-year cost reductions expected of suppliers as production learning experiences are applied. With respect to the latter, Veloso and Kumar (2002:11) show a typical range of price reductions over time required by individual vehicle manufacturers of their suppliers. In extremis, such annual reductions may also be supplemented by additional one-off demands for price reductions. In terms of purchasing strategy, initiatives such as modular supply, outsourcing of R&D and supply chain co-ordination; Just-In-Time, value engineering, target and supplier parks have all acted to reduce total costs for the vehicle manufacturers, though not necessarily just through the piece price of a component or system (see for example Ibusuki and Kaminski, 2005; Parry and Roehrich, 2009; Jurgens, 2004; Chanaron, 2001).

2.4.4 Spin off of suppliers

Spin-off of suppliers in order to reduce costs has been attempted by Ford and GM, but with little success.

Another method of achieving cost reduction used by both Ford and General Motors has been to 'spin-off' parts of the organisation so that they become separate component supplier companies rather than divisions of the vehicle manufacturer itself. Cost reductions can then be achieved through increased competition with rival component manufacturers and a longer term erosion of pay and conditions terms.

In 1999 General Motors made their in-house parts division, Delphi Automotive Systems a completely separate company. The New York Times reported that "G.M. wants to farm out the business to leaner, cheaper parts makers worldwide, as other auto makers have done for years".[90] It was suggested that Delphi could reduce costs by moving factories overseas.[91]

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[87] *Continental inaugurates new office building of the Research and Development Center in Iasi, Romania,* Continental Press release 3/12/09 http://www.conti-online.com/generator/www/com/en/continental/pressportal/themes/press_releases/2_corporation/locations/pr_2009_12_03_iasi_en.html
[88] http://www.conti-online.com/generator/www/com/en/continental/pressportal/themes/press_releases/2_corporation/locations/pr_2010_06_11_10years_automotive_romania_en.html
[89] http://findarticles.com/p/articles/mi_m0UDO/is_23_15/ai_92001658/
[90] http://www.nytimes.com/1999/05/25/business/gm-is-set-to-spin-off-parts-division.html
[91] http://www.businessweek.com/magazine/content/05_38/b3951115.htm

Ford created their Visteon parts division in September 1997 as a way of reorganising its component business sub systems.[92] Visteon was responsible for the vehicle interior (instrument panel, seating etc.), lighting, powertrain control, chassis, electronic, climate control, and glass. Between 1997 and 2000 Visteon reported that it saved $600m a year and was aiming for a further $450m saving in 2000.[93]

In 2000, Ford followed GM's example in spinning off Visteon. One former Ford executive has commented that 'there was no logic in paying those kinds of wages for parts. It was economic suicide. Once GM did it, we had to'. Both Visteon and Delphi claimed that their spin-offs would enable them to capture new business from other manufacturers; however their high labour costs in comparison to competitors meant that they struggled to achieve this. Delphi's chairman and CEO stated that including benefits their workers cost $65 an hour – more than twice that for competitors. However both spin-offs have resulted in significant further costs for the parent companies. In 2005, Visteon was reported as having lost $3.4 billion since 2002 with Ford having to bail it out for $1.6 billion in 2003 and stating it would book a further $1 billion in restructuring charges in 2005, taking back 24 manufacturing plants.[94]

Ford stated at the time that it hoped to reduce its supply costs by $600-700 million a year by 2010 in the deal, but in May 2009, Visteon's US business filed for Chapter 11 bankruptcy having never posted an annual profit. Visteon's main UK subsidiary also filed for reorganisation earlier that year.[95] Delphi fared little better. In 2005 it hired a turn-around specialist after having lost $608 million in the first half of the year and after having identified that its pension plan was estimated to cost $1.1 billion in 2006.[96] He identified the need to reduce wages and benefits, cut jobs and close 24 factories. Laid-off workers were reportedly costing $400 million a year as they were entitled to 75% of their wages. Again the parent company, GM, was called on to help with the bail out. However in the same year, Delphi filed for Chapter 11 bankruptcy protection. Since then it has sold off or closed most of its plants in the United States and in 2009 its core assets were purchased by a group of private investors to create a new DPH Holdings Corporation.[97]

2.5 Direct cost factors

Key points:

- ***Raw material costs are a major component of direct costs but have remained relatively stable until recently;***
- ***Direct costs may have been increased by 3 – 10% due to a shift in vehicle composition;***
- ***There has been a strong focus on component sharing and supply base consolidation; the number of suppliers per vehicle more than halved, leading to cost reductions through greater volume production;***
- ***Flexible plants enables manufacturers to match supply to demand, thereby avoiding stockpiles of unwanted products;***
- ***Quality improvement initiatives have substantially reduced costs and contributed to profitability;***

[92] http://www.eiu.com/index.asp?layout=displayIssueArticle&article_id=593095659&rf=0
[93] http://www.theengineer.co.uk/in-depth/ford-favours-fast-track-float-for-visteon-to-grab-market-share/282209.article
[94] http://www.businessweek.com/magazine/content/05_38/b3951115.htm
[95] http://www.businesspundit.com/visteon-files-for-chapter-11-bankruptcy-endangers-ford/
[96] http://www.businessweek.com/magazine/content/05_38/b3951115.htm
[97] http://www.dphholdingsdocket.com/dph

- ***Labour costs have been reduced by relocation of manufacturing to Eastern Europe and Asia;***

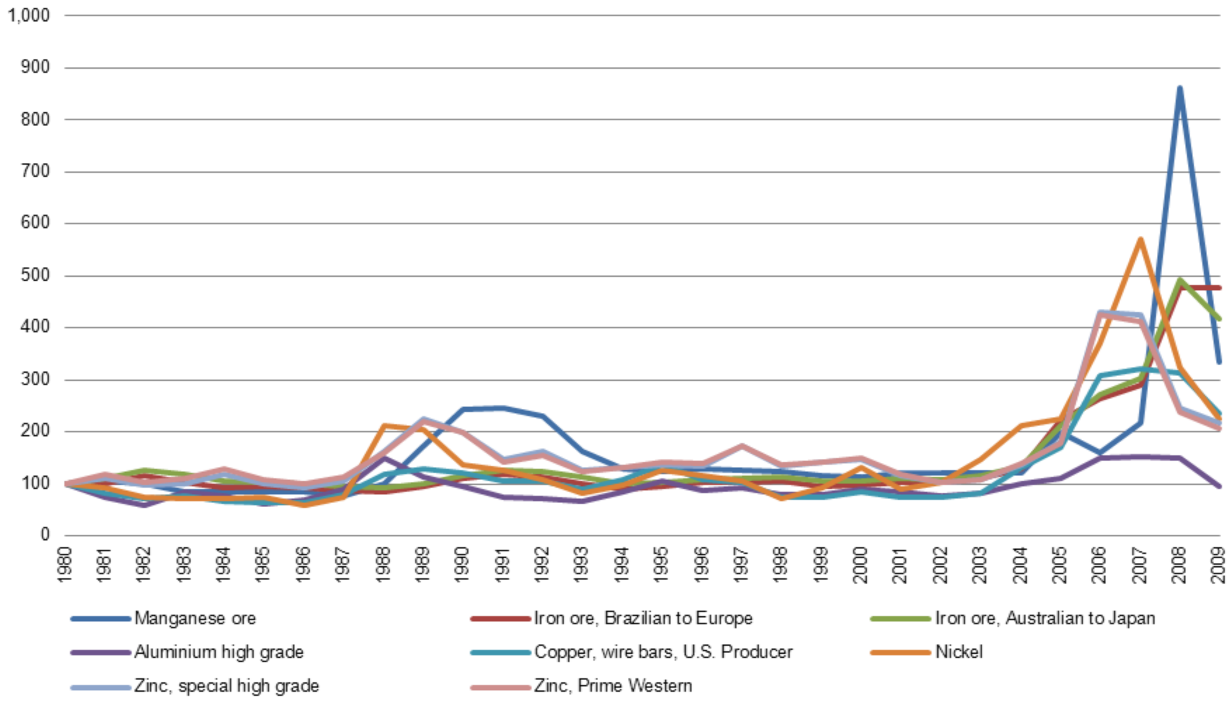
- ***Engine, vehicle and after treatment technology has become much more complex. (driven partly by emissions legislation)***

2.5.1 Resource prices and taxes

Commodity prices for raw materials commonly used in car manufacturing have remained relatively stable until recently.

One of the most significant direct costs for vehicle manufacturers is the cost of the materials and energy which are needed to construct a new car. Figure 2-13 below shows commodity price indices for iron, manganese, copper, aluminium, nickel and zinc, materials commonly found in passenger cars. There have been two notable fluctuations in resource prices over the period under consideration. The first was seen around 1990, when manganese, nickel and zinc prices doubled, while the second is the spike which has been seen in virtually all commodity prices stand which started around 2004 and continued into the credit crunch:

Figure 2-13: Commodity price indices of raw materials for passenger cars (1980 = 100) [98]

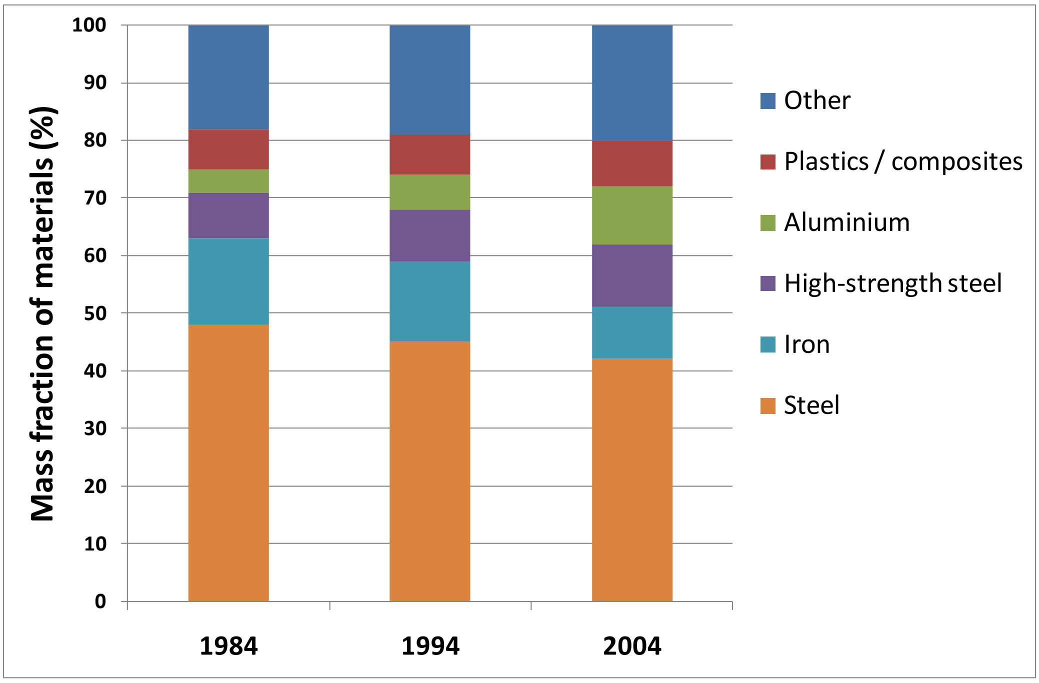


As well as the changes in the costs of materials needed to construct vehicles, the material composition of vehicles has changed

Modern vehicle designs have seen a gradual shift away from mild steel and cast iron, in favour of high strength steels, aluminium, plastics and composites. This has allowed manufacturers to create stiffer, stronger body structures while simultaneously attempting to minimise weight increases.

[98] UNCTADstat, United Nations Conference on Trade and Development. http://unctadstat.unctad.org/ReportFolders/reportFolders.aspx?sRF_ActivePath=P,8&sRF_Expanded=,P,8

Figure 2-14: Changes in vehicle material composition over time



Source: Ward's Motor Vehicle Facts & Figures (2006). New York: Penton Media

Figure 2-14 illustrates how the mass fraction shares of different materials have changed over time for a typical car (in the US market). However these changes have led to increased costs for manufacturers.

It is very difficult to estimate the resulting cost impacts of changes in the overall composition of a vehicle as they can depend on a number of factors. For instance a change to a stronger material may allow a significant reduction in the amount of material required for a given part. Equally improvements in other material properties may allow cost savings to be made elsewhere. For instance a change to a material which has better high temperature resistance may allow a designer to avoid the use of a heat shield and the associated extra material and manufacturing complexity costs. However it is possible to estimate the likely range of part cost increases with change in materials and these are illustrated in Table 2-14.

Table 2-14: Relative part costs with material changes

Material	Relative cost per part
Mild steel	1.0
High strength steel (A606)	1.0 – 1.5
Aluminium (AA6111)	1.3 – 2.0
Composites (carbon fibre / glass fibre)	2.0 – 10.0

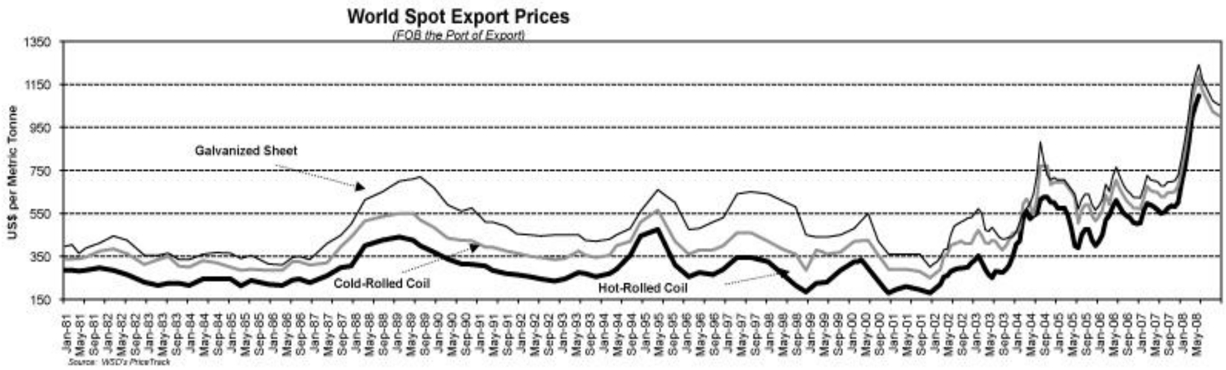
Source: Powers 2000[99]

[99] Powers, W. F. (2000). Automotive Materials in the 21st Century. Advanced Materials & Processes, p 38-41, May 2000.

These figures in combination with the typical changes in material compositions shown in Figure 2-14 suggest that manufacturers may have experienced somewhere between a 3 – 10 % increase in costs between 1984 and 2004 solely due to these changes in composition.

When combined with changes in material costs over this time, the increase is much larger. The price of steel, which has the largest share, has seen similar trends to those for commodity prices as shown in Figure 2-15.

Figure 2-15: Variation in steel prices 1981 - 2008



Source: World Steel Dynamics[100]

This in combination with the price increases that have been seen in the other primary materials used in automotive manufacture has led to estimated overall material cost increases of 50 – 55 %, although this figure excludes any increases due to increasing overall vehicle mass over this time.

2.5.2 Component costs

The last twenty years have seen the automotive parts supply base consolidate in response to demands from manufacturers for lower costs.

The original equipment manufacturers' (OEMs') trend to outsource modules and systems to first tier suppliers while also working to share components across different models and markets has meant that to be a first tier supplier has required a presence in at least two of the major car-producing areas (Europe, North America, South-east Asia/Japan).[101] This in turn means that mergers and acquisitions have occurred amongst component suppliers.

In 1999 The Economist reported that manufacturers' cost-cutting requirements and policies of sourcing equipment and services from a reduced number of direct suppliers were indirectly driving this process. They stated that manufacturers were attempting to reduce the number of components to be assembled in each new model by up to 30% and highlighted Ford's stated aim that the number of direct suppliers per model would gradually be reduced by 50%.[102] In the early 1990s there were 400-500 direct suppliers per model but by the mid-90s this had been reduced to little over 200 and by 1999 to around 100 in mature economies.

An increased focus on parts sharing and platform strategies has also driven a reduction in the number of suppliers. Manufacturers have sought to reduce costs by reducing the number of different components they design and to develop and use them across as many different models as possible.

[100] http://www.worldsteeldynamics.com/matrix/globalexportpricing.html
[101] Research Report: European automotive components, 1998 Edition, Part 1 The Industry
[102] Research Report: European automotive components, 2000 Edition, Part 2 The market, Matthew Beecham, The Economist Intelligence Unit, http://www.eiu.com/report_dl.asp?issue_id=1573094557&mode=pdf

As a result suppliers now compete for fewer, larger volume contracts, enabling OEMs to demand lower piece price margins.

While component sharing and the adoption of platform strategies have been followed by almost all manufacturers, different manufacturers have adopted different strategies regarding the geographic location of suppliers. While some aim to have suppliers close to the assembly plant, others, such as GM, have attempted to centralise as much as possible.[103] The Toyota / PSA Group joint venture which has created a new plant at Kolin in the Czech Republic was reported as being expected to source at least 40% of component suppliers from within the same country.[104] It is not clear what the impact of these different strategies is on overall costs as this will be dependent on local labour rates, shipping costs and any piece-cost reductions achieved through manufacturing in fewer, larger volume plants.

Tighter emission standards have been a key driver behind the increased use of electronic components, which now make up a significant proportion of total vehicle cost.

The share of the total vehicle cost attributable to different types of components has also changed. This has been particularly true for electronic components. In 2000, it was forecast that the total electronic content would increase from 17.5% of the value of a medium-sized car to around 30% by 2005.[105] Progressive tightening of emissions legislation has required ever greater control of combustion system parameters. This has involved greater numbers of sensors as well as increasingly powerful microprocessors in the engine management system. The introduction of systems designed to improve safety and allow the driver to maintain control such as anti-lock braking, electronic stability control, and active suspension have also increased the electronic components' share of the total cost of a vehicle. When interviewed in February 2011, Visteon India's managing director, Vish Viswanathan stated:

"Electronic components are increasingly taking on a larger share of the total cost of the vehicle. The key drivers behind this change are increased consumer expectation for comfort, convenience, seamless connectivity and stricter environmental and safety regulations."[106]

2.5.3 Manufacturing costs

Increased emphasis on flexible manufacturing has allowed manufacturers to quickly respond to market demands, thus avoiding stockpiles of unpopular models.

Manufacturers have also made substantial changes to the manufacturing process in order to reduce costs. Being able to respond quickly to changes in customer demand has been essential in reducing vehicle manufacturers' costs. Inflexible factories that continued to produce large numbers of vehicles which the market no longer demanded had in some cases led to large amounts of stock having to be sold at discount prices. Instead there has been an emphasis on flexible manufacturing. The ultimate expression of this would be only to build vehicles to customer orders. This would avoid the creation of stockpiles of vehicles which do not meet a customers' desired combination of body colour, trim, engine and transmission variant etc. which may then have to be sold at a discount.

In the last twenty years several innovations have dramatically improved the flexibility of vehicle manufacturing:

- Ever greater use of computer controlled machinery and robotic welding arms which can quickly and easily be reprogrammed to produce different models;

[103] Success and failure in the UK car manufacturing industry, Fourth Report of Session 2006–07, House of Commons Trade and Industry Committee, 2007
[104] Bumpy ride is far from over', *Financial Times*, 28 September 2006
[105] Research Report: European automotive components, 2000 Edition, Part 2 The market, Matthew Beecham
[106] http://www.autocarpro.in/contents/peopleDetails.aspx?PeopleID=96

- The use of shared platforms for different model variants allowing several different vehicles to be produced on the same production line;

- Greater use of sub-assemblies supplied to final assembly lines by co-located suppliers.

The greater use of shared platforms has allowed manufacturers to vary which models they produce according to changes in market demand much more quickly than before. With a drive towards a wider variety of models produced from fewer platforms, together with vehicles which are designed for a global market, manufacturers are much better able to react to market "pull" rather than having to "push" vehicles which have been built to keep the manufacturing plant running, but for which there is low demand.

Quality control systems, which minimise parts defects and improve customer satisfaction, have also played a central role in controlling costs and improving competitiveness.

Inspired by the 'continuous improvement' approach of Toyota, Ford Motor Company had introduced in the 1980s the concept of Total Quality Management (TQM) with the slogan "Quality is Job 1". TQM was a process improvement methodology aimed at improving customer satisfaction by reducing vehicle defects.

Japanese manufacturers had also introduced statistical process control techniques to control and reduce manufacturing variability, learning from the American statistician, Dr. W. Edwards Deming who had been invited to Japan after the Second World War by industrial leaders. It was not until 1999 that Ford introduced Six Sigma, a concept which had gained publicity in America through its successful use at General Electric by their then CEO Jack Welch. Six Sigma uses statistical techniques to minimise waste and improve quality. Ford's "consumer-driven six sigma" approach used five stages: define; measure; analyse; improve; and control. Ford chose to use this with three primary objectives: improved customer satisfaction; reduced defects; and cost savings. Ford stated that improving customer satisfaction by one and a half points improved loyalty by one point which in just the North American market was estimated to result in more than $2 billion incremental revenue and $100 million profit. Six Sigma was credited with a $300 million contribution to the bottom line and a two-point increase in customer satisfaction in 2001[107], and having reduced the warranty repair rate by 60% by 2008.[108]

2.5.4 Labour costs

Labour costs have been reduced through relocation of manufacturing activities away from the US and Western Europe.

A major factor in reducing costs for automotive manufacturers over the past twenty years has been addressing the costs of wages. This has been particularly true in the US for Ford, General Motors and Chrysler, each of whom had to address the legacy costs of health care insurance for retirees as well as higher than average wages for their many long tenure employees. In 2005, the health care costs for both active and retired employees per vehicle produced were calculated to be $1,268 for GM and $945 for Ford.[109] As a result in 2007 the Detroit carmakers negotiated a deal with unions to transfer legacy costs to independently administered trusts and introduced 'second-tier' wages for new hires. In 2009, Ford announced a deal with unions with cost savings of $500 million a year, however that still left Ford's wages in the US at $55 per hour (including benefits, pensions and bonuses) compared to $48 per hour paid by foreign competitors with plants in the US.[110]

[107] http://www.qualitydigest.com/sept01/html/ford.html
[108] http://www.brighthub.com/office/project-management/articles/72279.aspx
[109] From tail fins to hybrids: How Detroit lost its dominance of the U.S. auto market - **Thomas H. Klier**
[110] http://www.chicagofed.org/digital_assets/publications/economic_perspectives/2009/ep_2qtr2009_part1_klier.pdf

In Europe, labour costs for manufacturing vary substantially between countries and this has been suggested to be a factor in decisions about plant closures. Giving evidence in 2006 to an investigation for the UK Government, unions stated that it is difficult to make accurate comparisons but gave figures for hourly rates from several sources which suggested the ranges given in Table 2-15.

Table 2-15: Labour costs per hour in a selection of European countries[111]

Country	Labour Cost per hour (€)
Germany	26 - 34
UK	18 - 26
France	22
Slovak Republic	3 - 7
Poland	5
Hungary	5
Czech Republic	4

Irandoust (1998)[112] found that unit labour costs, which are a significant component of vehicle manufacturer's marginal costs, were important in determining actual car prices.

2.5.5 Exchange rates

Manufacturers may absorb exchange rate fluctuations in order to protect their market shares.

Irandoust (1998) notes that local currency prices of imported goods are often found to be notably insensitive to fluctuations in exchange rates. Ginsburgh and Vanhamme (1989)[113] found that between 1984 and 1987, car manufacturers adopted a strategy of 'pricing to market' in Europe, absorbing exchange rate fluctuations and not passing them through into export prices. Manufacturers might do this to protect market shares in a foreign market, even though it means a cut in margin due to the lower real price they are selling the vehicle for. Gaulier (2000) provides an interesting insight into the effects this strategy can have:

> *"For example, Volkswagen Audi Group (VAG) maintained its Lira prices after the depreciation from 1992 to 1994, in order not to lose market shares. This Pricing to Market strategy implies mark-up cuts for makers and lower prices (in their national currency) for European consumers in the Italian market. This led to arbitrage (parallel trade) especially by German and Austrian consumers. In turn, VAG then managed to prevent its dealers from selling cars to non-Italian consumers. VAG was convicted of refusal to sell by The Commission, and had to pay high fines (Euro 102 million, reduced to Euro 90 million in July 2000). This case demonstrates how*

[111] Success and failure in the UK car manufacturing industry, Fourth Report of Session 2006–07, House of Commons Trade and Industry Committee, 2007

[112] Irandoust, M. *Pricing policy in the Swedish Automobile market*, 1998

[113] Ginsburgh, V.and Van Hamme, G. *Price differences in the EC car market: some further results,* 1989

exchange rate fluctuations can be associated with strategic behaviour to generate price heterogeneity."

Irandoust (1998) suggests that this is not a universal phenomenon, but is limited to markets for differentiated products, such as cars. The author investigated to what extent this practice existed in the Swedish new car market and found that car price adjustments were influenced by exchange rates, costs and quality with pricing to market behaviour being "more pronounced in Japanese export pricing than for British, Italian and German exports" while "French prices were insensitive to exchange rate fluctuations." A strategy of being currency neutral is often sought, for example, by purchasing material and components in the currency in which the vehicles are sold.

2.5.6 Shipping costs

Shipping costs can influence manufacturers' decisions regarding plant location and supplier strategy. In evidence to the UK Government, General Motors commented on the costs of shipping associated with production of its Astra model at its Ellesmere Port plant in the UK versus two other plants on mainland Europe. Taking account of the sales splits between domestic and export markets for each plant, they estimated an annual logistical cost disadvantage of €18.7 million for the UK plant.[114]

2.6 Indirect cost factors

Key points:

- ***Indirect costs will be affected by legislation. The extent to which the legislation has an influence depends on the indirect cost.***

- ***The complexity of the technological change required to comply with the legislation and the timeframe also have an impact.***

- ***Improved computing power has helped to offset increased research and development costs and duration.***

The costs to manufacturers of new regulations will be felt both in direct manufacturing costs and indirect costs such as research and development, administration, marketing amongst others. When assessing the impact of potential policies, one tool which is used to estimate the effects of regulations on manufacturer costs is the retail price equivalent multiplier which compares direct manufacturing costs with other factors that influence the price of a vehicle. A weakness in the use of this multiplier is that some indirect cost components (for example pensions or healthcare costs) may not be affected by a vehicle modification applied in order to comply with a regulation.

In Rogozhin and Gallaher (2009)[115], the authors develop what they call an indirect cost multiplier, which evaluates the indirect costs which are likely to be affected by vehicle modifications associated with environmental legislation. A range of multipliers was developed that account for differences in technical complexity of the modification and adjust over time as the technology becomes integrated into the manufacturing process. The authors produce industry average and manufacturer-specific multipliers. While the focus of the study is on the US car industry, the assessed manufacturers include European and Asian companies.

[114] Success and failure in the UK car manufacturing industry, Fourth Report of Session 2006–07, House of Commons Trade and Industry Committee, 2007

[115] Rogozhin, A. and Gallaher, G. *Automobile Industry Retail Price Equivalent and Indirect Cost Multipliers*, Environmental Protection Agency, 2009

Table 2-16: Average Indirect Cost Multipliers for the US Car Market

Cost Category	Cost Contributor	Average	Min	Max
Vehicle Manufacturing	Cost of Sales	1	1	1
Production Overhead	Warranty	0.03	0.01	0.04
	R&D	0.05	0.02	0.07
	Depreciation & Amortisation	0.07	0.05	0.11
	Maintenance, Repair, Operations Cost	0.03	0.03	0.03
	Total	**0.18**	**0.13**	**0.22**
Corporate Overhead	General & Administrative	0.07	0.03	0.12
	Retirement	<0.01	0	0.01
	Health	0.01	<0.01	0.01
	Total	**0.08**	**0.04**	**0.14**
Selling	Transportation	0.04	0.04	0.1
	Marketing	0.04	0.02	0.08
Dealers	Dealer New Vehicle Net Profit	<0.01	<0.01	<0.01
	Dealer New Vehicle Selling Cost	0.06	0.06	0.06
Selling & Dealers	**Total**	**0.14**	**0.12**	**0.18**
All	**Total**	**0.4**	**0.38**	**0.44**
Net Income		0.06	0.02	0.09
Other Costs		0.04	<0.01	0.11
RPE Multiplier		**1.46**	**1.42**	**1.49**

Source: Rogozhin and Gallaher (2009)

2.6.1 Research & development

Improved computing power has helped to offset increased research and development costs and duration.

The increasing complexity of vehicles and the technologies used in them has substantially increased the research and development effort required. However manufacturers have worked hard to refine the product development process to reduce costs during manufacture and improvements in computing power have radically changed the development process. There have also been various strategies which have swept through the industry as it strives to reduce costs.

Computer aided design (CAD) and computer aided manufacturing (CAM) have both helped to speed the research and development process for new models. The rapid improvement in computer modelling over the last 20 years has revolutionised vehicle design. Detailed CAD modelling of body structures has helped designers to achieve stiffer, safer, more crashworthy vehicles, while reducing manufacturers' reliance on expensive crash testing. CAD modelling has also improved the speed and quality of packaging design (ensuring all component parts fit together in three dimensional space with appropriate clearances). This has been a key enabler in reducing the number of different parts and in sharing platforms.

One technique increasingly employed by automotive manufacturers through the 1990s was the concept of 'simultaneous engineering'. There are various definitions of what this means but the overall idea has been defined as *"product development in the lesser possible stated period through the execution of the diverse phases of the engineering activities in parallel, including requirements demanded for all the elements of the product cycle of life*".[116] While the technologies included in vehicles have become more complex, techniques such as this have helped to minimise product development times and improve quality. In fact the combination of strategies employed in 'lean manufacturing' have led to the time taken to bring a new model to market being reduced from six or seven years to just three.[117]

By encouraging product development engineers to work closely with manufacturing engineers, parts can be designed to be easier and cheaper to produce. Design for manufacture (DFM as it is known) has been defined as the "design of product and process specification for cost effective, reliable manufacture to achieve customer satisfaction and business success".[118] Design for assembly (DFA) is defined as "a process for improving product design for easy and low-cost assembly, focusing on functionality and on assimilability concurrently". Both concepts require designers to review part designs against a set of guidelines. Techniques such as these can help to minimise the occurrence of mis-assembly during production. Ensuring that parts are designed so that they are easy and cheap to manufacture and assemble was credited as playing a significant part in helping to reduce Daimler-Chrysler's costs during the first half of the 1990s.[119]

The last 30 years have also seen dramatic changes in the way that engines are controlled. The traditional petrol engine system consisted of a throttle pedal connected by a Bowden cable to a purely mechanical carburettor designed to provide the appropriate mixture of fuel and air, together with a mechanical distributor to determine ignition timing. This has been replaced by electronic controls.

Modern vehicles use an electronic throttle pedal connected to an engine control unit (ECU) which precisely controls the quantity of air and fuel entering the engine, the precise timing of the ignition timing (sometimes using multiple sparks) and the beginning and end of fuel injection (again sometimes featuring multiple injections). Together with this, many engines feature exhaust gas recirculation (EGR) systems to control nitrogen oxide emissions, variable intake manifold geometries, variable valve timing and lift systems, variable boost and geometry turbo-charging, variable exhaust systems and even technologies such as variable engine compression ratio.

The fine control of air/fuel ratio and combustion characteristics has been an enabler for the introduction and improved performance of catalytic converters to reduce hydrocarbon, carbon monoxide and nitrous oxide emissions. Transmission systems have also developed from simple manual and automatic gearboxes, to include developments such as auto-shift manual and dual clutch systems.

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[116] Concurrent Engineering – Process Requirements and Life Cycle Influences on the Development of Automobile Stamped Parts http://www.grima.ufsc.br/cobef4/files/152001022.pdf

[117] Feast, R. (2001), ``What's holding back Uncle Sam?'', Automotive World, February, pp. 30-4.

[118] B L Miles (1989), Design for assembly-a key element within design for manufacture, Institute of Mechanical Engineers

[119] http://www.economist.com/surveys/PrinterFriendly.cfm?story_id=3127250

All of these systems must be calibrated to work together and respond appropriately under all operating conditions. They must also be optimised to meet emissions and fuel economy regulations – a very complex task given the substantial number of degrees of freedom available, resulting in a substantial increase in development costs. However manufacturers have ameliorated these rising costs through increased use of computing power to improve the efficiency of data collection and analysis. Improved test and analysis techniques such as Design of Experiments (DoE) have also reduced development time. In some cases they have been able to use feedback from engine sensors to enable the engine management system itself to perform real-time optimisation[120] or advanced modelling tools to reduce calibration development time by about 50%.[121]

2.7 Market factors

Key points:

- ***Strong competition in the new car market has been the primary driver for the adoption of the cost reduction strategies discussed above.***

- ***In the past market restrictions have an effect on vehicle prices.***

As discussed above, fierce competition has driven dramatic improvements in both the quality and performance of vehicles. One measure of quality which manufacturers use is the average number of defects (or faults) found per vehicle. By the year 2000, across the whole industry, this number had been reduced to an average of just over one defect per vehicle[122] – better than the best company's rating in 1989. Performance qualities such as acceleration, braking and cornering had improved such that some derivatives of small family cars outperform the high performance exotica of the 1970s. Performance differentials between brands substantially diminished as technologies and vehicle architectures became more standardised. At the same time as vehicle performance and styling were becoming more uniform and despite consolidations between some OEMs, there were increasing numbers of brands and increasing numbers of models being offered by each brand.[123] Illustrating this with the JATO dataset, there was a 216% increase in the number of model variants between 1995 and 2010 for a set number of models[124]. Added to this, many of the markets in Europe were starting to approach saturation point, with the numbers of new car registrations across the seven biggest markets starting to decline slightly from 2006 numbers and growth in vehicles per 1000 population in the EU-15 at less than half a percent in 2007/08.

Price differentials across countries are to a large extent due to discriminating practices

Gaulier (2000) found that *"firms operating in several markets determine their optimal price on the basis of the nature and intensity of competition in each market*" and concluded that *"a large part of the price gaps observed between European markets appear to be linked to market segmentation practices of firms"*. Gaulier cites Ginsburgh and Mertens (1985) who "*argue that in an oligopolistic market, prices should reflect the production costs and technical characteristics of products. However, when prices are regressed on the two groups of variables, a sizeable part of variance remains unexplained.*..The authors show that this residual price variation is due to un-measurable vehicle characteristics (degree of comfort of the car, etc.), and anticompetitive behaviour (price discrimination)." Changes to the Block Exemption rules as well as easier access to price information through the internet and an increasingly competitive market have largely addressed this.

[120] http://www.greencarcongress.com/2009/08/dd-mbc-20090805.html
[121] http://www.greencarcongress.com/2010/04/avl-20100413.html
[122] L Ealey, G Mercer and research associates *Automotive retailing in the new millennium - The e-commerce revolution*, *2000*
[123] L Ealey, G Mercer and research associates *Automotive retailing in the new millennium - The e-commerce revolution*, *2000*
[124] Excludes Slovakia and Slovenia data, as this was only available after 2000.

Market openness also has an effect on vehicle prices. In 1993, five European Member States (France, Italy, Spain, Portugal and the United Kingdom) had quotas or voluntary restraints on imports of Japanese vehicles. Gaulier (2000) considered the quotas imposed on imports of Japanese vehicles and found that this had an influence on prices. Japanese cars tended to be cheaper than the average European car, but by 1989, Japanese cars were no longer significantly lower in price than other cars. This coincided with the introduction of the voluntary export restraint agreements negotiated between the EC and Japan. The result of this was to change the Japanese manufacturers' strategy in Europe from driving for volume at the cheap end of the market, to competing on quality, (i.e. getting the greatest value for the limited number of vehicles the Japanese were allowed to import into Europe).

2.8 Consumer factors

Key points:

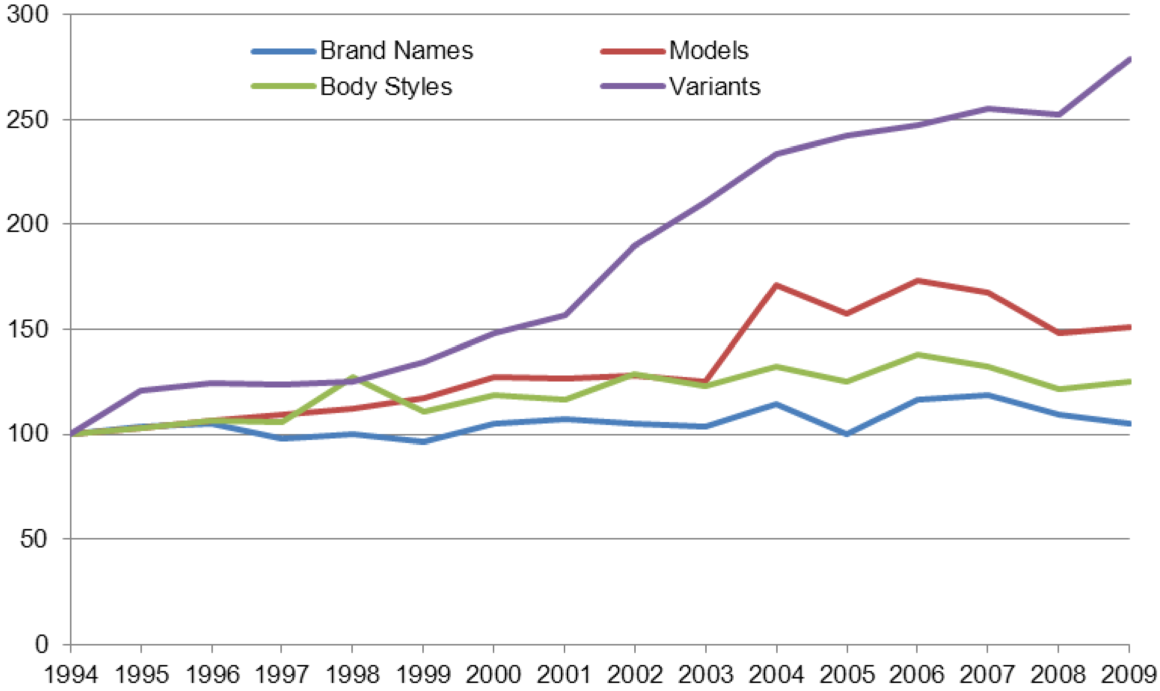
- ***Consumer demands have changed substantially over the past two decades.***
- ***The emphasis has shifted from a need to own a vehicle to the need to own a vehicle of quality and character.***
- ***The specification of vehicles has steadily improved over time, with features which were restricted to the luxury end of the market increasingly being found on more basic vehicles.***
- ***Other factors, such as rising fuel prices are starting to have an influence on consumer choice.***
- ***Vehicle prices are influenced by a domestic market effect, for example French consumers preferring French brands.***

Attempts by manufacturers to differentiate themselves in an increasingly competitive market may have counteracted the cost reductions obtained through platform strategies and commonality.

In the latter half of the research period (2000-2010), manufacturers have offered increasing numbers of vehicle types and variants. Manufacturers have stated this has been in reaction to consumers demanding more choice.[125] However it may also have been due to manufacturers attempting to differentiate themselves in an increasingly competitive market. Whatever the reason, manufacturers had to find ways to offer more distinctive, characterful vehicles for more specific customer segments while continuing to reduce cost and increase reliability. This could be argued to have undermined the cost reduction benefits achieved through platform strategies and commonality. Figure 2-16 below illustrates how the diversity of offerings in the UK new car market has evolved over time: Taking the JATO dataset results for the UK market, this gives a similar picture, with an increase of 211% for model variants of a set number of models for the period of 1995 to 2010.

[125] House of Commons Trade and Industry Committee: Success and failure in the UK car manufacturing industry (2006-7) Evidence from PSA http://www.publications.parliament.uk/pa/cm200607/cmselect/cmtrdind/399/399.pdf

Figure 2-16: Trend in the number of brands, body styles, models and variants in the UK market (Index 1994 = 100)



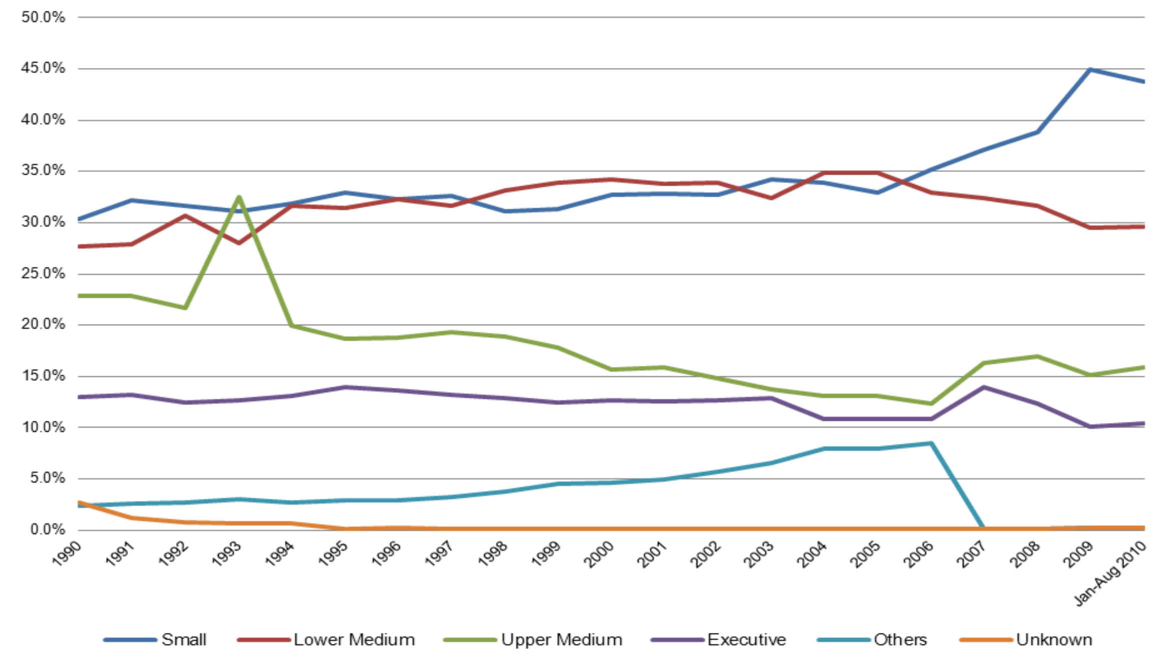
Source: Centre for Automotive Industry Research

Consumer demand has tended toward smaller vehicles which typically have thinner margins.

Figure 2-17 shows that consumer preference has also started to shift towards smaller vehicles[126] which tend to have thinner margins[127], while an increasing focus on reducing fuel consumption has driven the introduction of new technologies. These factors all resulted in a very competitive marketplace in which manufacturers have strived to drive costs down to gain competitive advantage and continue to remain profitable.

[126] It is worth noting that while the trend has been towards the small vehicle market segment, average vehicle sizes within market segments has increased.
[127] "Any colour you like so long as its green" http://www.economist.com/node/8810682

Figure 2-17: Percentage market share of passenger car segments in Western Europe[128]



Source: ACEA. Note: ACEA document states 'In 2007 some vehicles were dispatched from the category "Others" to all the remaining categories'

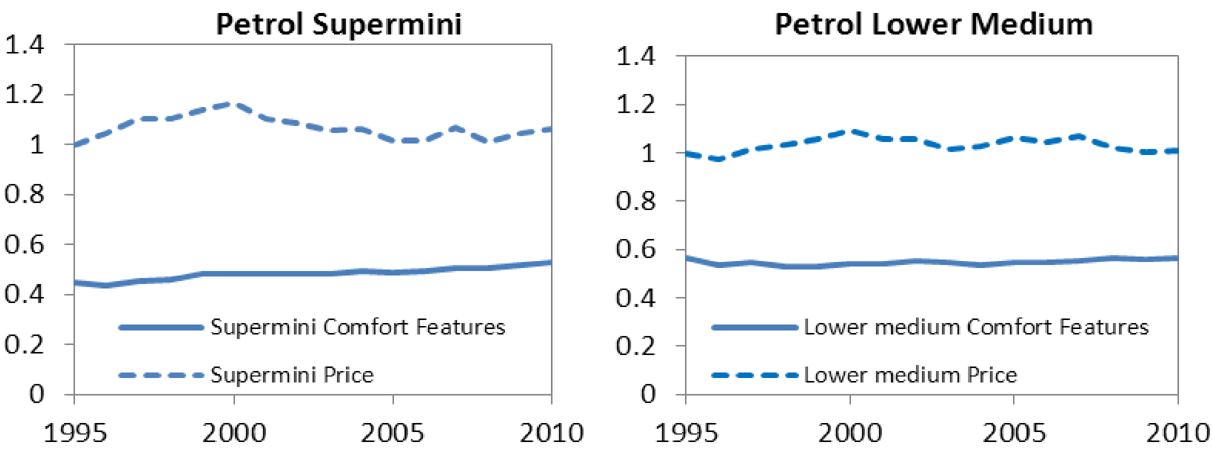
The price differences between models may be explained by variations in characteristics such as quality, comfort and performance.

Factors such as quality, comfort and vehicle features have steadily grown over this period to be valued factors for consumers. Murray (1999) found that "price differences between car models can be explained by variations in individual car characteristics. The strongest influence is exerted by comfort, luxury items, manoeuvrability, economy and performance." Murray also suggested that changes in consumer tastes could affect the implicit prices of car characteristics, a finding which "raises serious doubts about the usual practice of employing pooled cross-section and time-series data in estimations of hedonic price equations." For the UK car market, Murray (1999) estimates that while the real prices of new cars rose at an annual rate of 2.2% between 1977 and 1991, the quality adjusted real price of cars fell at an average rate of about 5.9% over the same period.

Figure 2-18 and Figure 2-19 illustrate the level of comfort features installed on vehicles compared to price over the 15 year period, as taken from the JATO dataset[129]. It can be seen that there is not an appreciable increase in the level of comfort features, as can be compared to the level of safety features discussed in Section 2.3.1. For instance the comfort features reported within the JATO dataset show that the petrol supermini category (Figure 2-18) increase only from 45% to 53%. Similarly, the diesel lower medium category (Figure 2-19) also has a limited change, increasing from 53% to 57%.

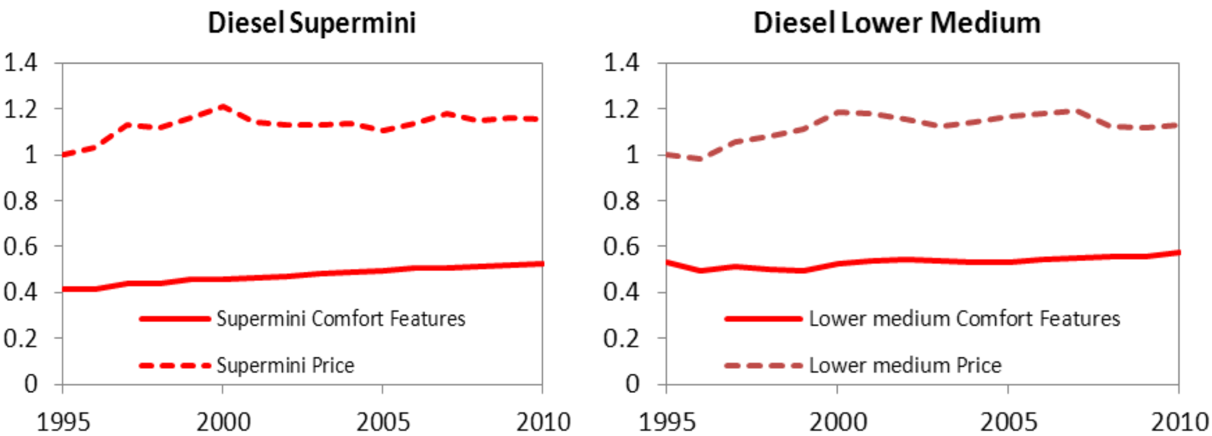
[128] European Automobile Manufacturers' Association (ACEA) http://www.acea.be/images/uploads/files/20101003_Segments__Bodies_1008.pdf
[129] Comfort features are: Luxury Interior upholstery, Cruise control ,Electric front seats, alarm, Immobilizer, Electric front windows, Electric windows front and rear, door mirrors operation, Central door locking operation, Front Fog lights, Allow wheels, Power assisted steering, Air-conditioning On-board computer, Sat-Nav. The comfort feature value is calculated by summing the comfort attributes installed in the car by the total potential comfort feature attributes within the JATO dataset.

Figure 2-18: Changes in the level of comfort features in petrol supermini and lower medium vehicles for the period of 1995 to 2010. (1995 = 1)



Note: This chart is constructed by normalising the price, by dividing each year by 1995. The comfort feature is calculated by summing the comfort attributes installed in the car by the total potential comfort feature attributes within the JATO dataset. Charts of other vehicle categories are available in Annex Section 1.2.
Source: JATO dataset

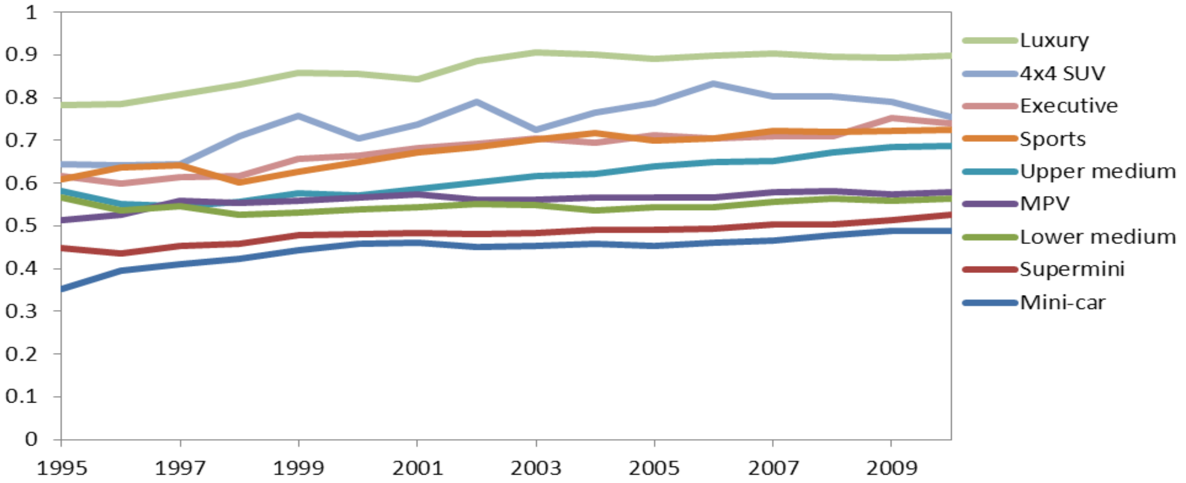
Figure 2-19: Changes in the level of comfort features in diesel supermini and lower medium vehicles for the period of 1995 to 2010. (1995 = 1)



Note: This chart is constructed by normalising the price, by dividing each year by 1995. The comfort feature is calculated by summing the comfort attributes installed in the car by the total potential comfort feature attributes within the JATO dataset. Charts of other vehicle categories are available in Annex Section 1.2.
Source: JATO dataset

The trend in improving vehicle quality can be seen in Figure 2-20 and Annex Section 1.2. The specification of new vehicles has steadily improved, with the luxury end of the market seeing features becoming standard first, but as feature costs reduce, these formerly luxurious features (for example power steering and remote central locking) are increasingly common in lower price market segments.

Figure 2-20: Changes in the level of comfort features for petrol vehicles between 1995 and 2010.



Note: This chart is constructed by normalising the price, by dividing each year by 1995. The comfort feature is calculated by summing the comfort attributes installed in the car by the total potential comfort feature attributes within the JATO dataset.
Source: JATO dataset

Gaulier (2000) notes that the internet has had an influence on vehicle pricing strategies. Thanks to this technological change, today's consumer is better informed regarding the range of vehicles available and the prices that can be expected. Consumer advice, price comparisons and car supermarkets all allow the consumer to shop around for the best price.

In addition to increasing standard features the availability of extra options has influenced transaction prices. Transaction prices can be much higher than list prices due to optional extra equipment and vehicle financing deals – the differences can be significant enough to recoup the additional costs of emissions abatement equipment and still make a profit. Some added options such as satellite navigation and cd-disc changer/MP3 player have significantly higher mark-up compared to a non-OEM aftermarket product. Options developed for high end models can be installed in lower end models at very low marginal cost but with very high mark ups.

Manufacturers may be able to charge higher prices in their home markets, as consumers tend to favour local brands.

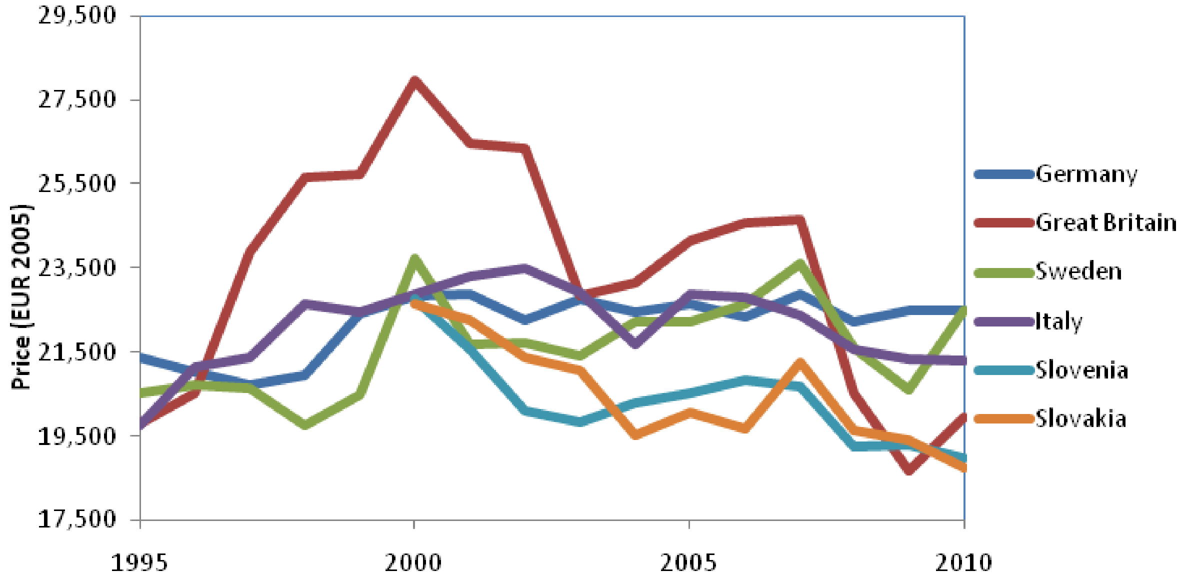
Some assessments of the new car market have detected a domestic market influence on vehicle prices. Couton (1996) investigated the French car market and found that the country of origin of the car manufacturer influenced the price, with cars of both French and German origin increasing the hedonic price by 10% on average, and 18% in the executive market segment. Murray (1999) also noted this effect, finding that UK cars were found to be significantly different in price to the rest of the cars sold in the UK, suggesting that this "might be explained along the lines that 'British is best', (i.e. domestic cars are priced higher than the average car)." The study also notes that a similar result was found by Bajic (1993) for the US. Verboven (1996) also finds that low price elasticities and high domestic market power are seen in France, Germany, the UK and Italy.

The price differences, from the JATO data, for two popular models in the six countries are shown in Figure 2-21 and Figure 2-22 below[130]. The average prices for VW Golf have been historically low in Slovenia and Slovakia relative to the other Member States and an explanation of this is that there less premium range Golf's being sold in Slovakia and Slovenia during the period. For example the GTI is 4% of sample in Slovakia and Slovenia, compared with 5% for the other four countries.

[130] There is no vehicle data for Slovakia and Slovenia prior to 2000, so the price trend can only be shown for 2000 onwards.

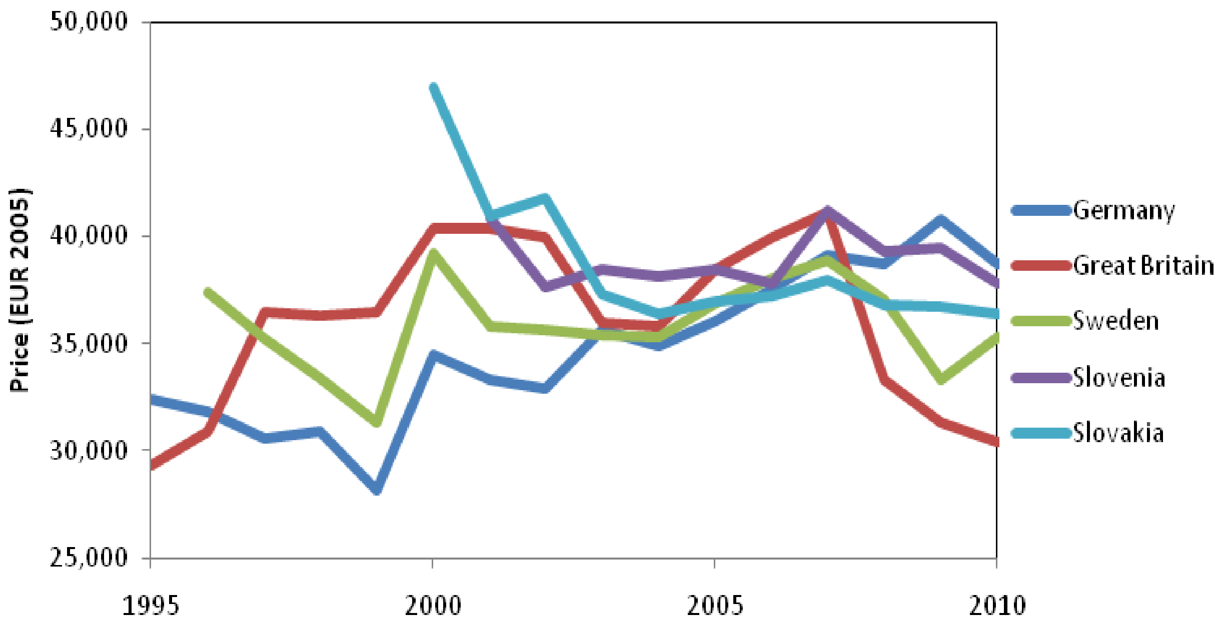
The price of a Golf within the UK prior to 2002 has been more expensive than other nations, and this can be attributed to a higher number of premium brands being sold, for example 12% of the Golf samples in the UK are GTIs.

Figure 2-21: Evolution in the price of VW Golf between 1995 and 2010 across the six Member States (in EUR 2005)



Source: JATO dataset

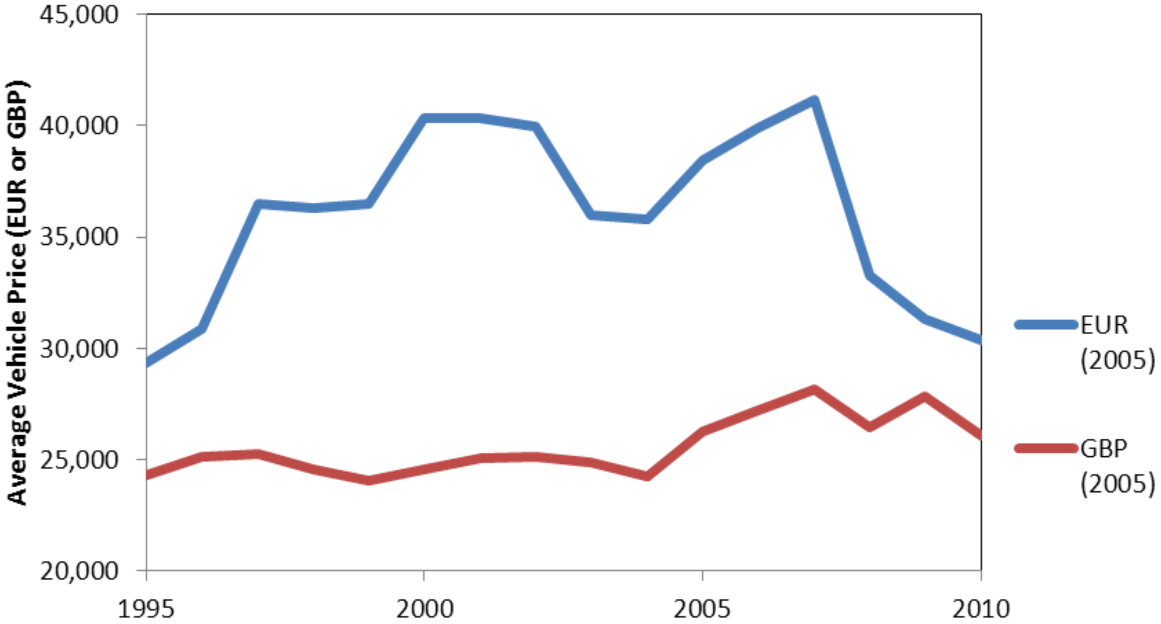
Figure 2-22: Evolution in the price of a BMW 3-Series between 1995 and 2010 across five Member States (in EUR 2005)



Source: JATO dataset

There is significantly more price volatility in the UK and Sweden samples, and this can be attributed to the currency exchange rates. This is illustrated in the sudden decrease in average prices within the UK for Golf's and 3-Series in 2008-2010. This can be attributed to the global financial crisis, where the pound devalued and the GBP-EUR exchange rate decreased from 1.5€/£ to 1.1€/£. This meant that importing vehicles into the UK became more expensive in pounds by 15-20%. Hence it is likely that European vehicle manufacturers such as Volkswagen and BMW cut their margins on these vehicles to stay cost competitive. Figure 2-23 illustrates the average price (in EUR 2005) of a BMW 3 series sold in the UK, both in Euro and Pound terms. This shows that the cars were sold at a similar price in Pounds in 2010 than they were sold in previous years; however the Euro amount has decreased by €10,000, or 25% from the 2008 Euro price.

Figure 2-23: Comparison of the average price of a BMW 3 Series sold in the UK between 1995 and 2010, priced in both Euros and Pounds (Indexed to 2005 prices)



Source: JATO dataset

Baltas and Saridakis (2009)[131] investigated the influence of brand name and market segment differences on US car pricing. They found that beyond the normal price differentiation attributable to vehicle features and performance, the heterogeneity of the market segments allowed discriminatory pricing strategies. The luxury car market segment can be expected to command high price premiums and the authors' model showed that the performance adjusted prices were considerably higher than for other market segments. These higher prices explain why high end brands focus so much attention on this market segment and why mass market brands attempt to enter these markets. However the authors' model shows that brand name is particularly important in this segment and hence mass market brands usually struggle to gain sales in the higher end market segments.

[131] Baltas, G. and Saridakis, C. *Brand-name effects, segment differences, and product characteristics an integrated model of the car market,* 2009

3 Key trends from the JATO dataset

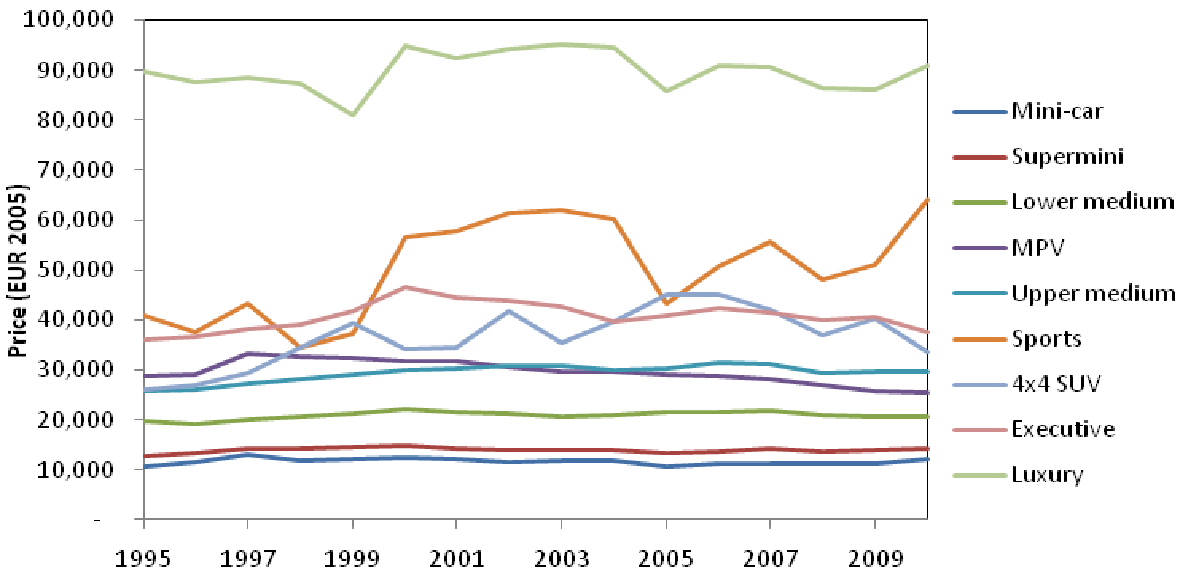
3.1 Introduction

The following section contains basic descriptive and analytic trends from the JATO dataset. . The analysis has been carried out on vehicle split by size categories as well as examining trends for selected individual vehicle models. It is important to note, that the analysis is not volume or sales weighted but uses a simple arithmetic average which is based on each dataset entry. Each dataset entry represents one model variant for one country for one year. Each price if weighted by the market share (in volume) of the corresponding model would provide a more representative and meaningful estimate of the change of the average prices over time. However, we did not have the information to weight the vehicle data by sales.

3.1.1 Price evolution between size categories

Figure 3-1 illustrates the average vehicle list price (indexed for inflation and exchange rates) for each of the size categories within the dataset. It can be seen that on the whole, vehicle prices have remained relatively consistent over the period 1995 to 2010. The exceptions are sports and 4x4 categories, which have more significant price increases.

Figure 3-1: Evolution in the average prices of passenger cars in each size category over the period 1995 to 2010 (in EUR 2005)



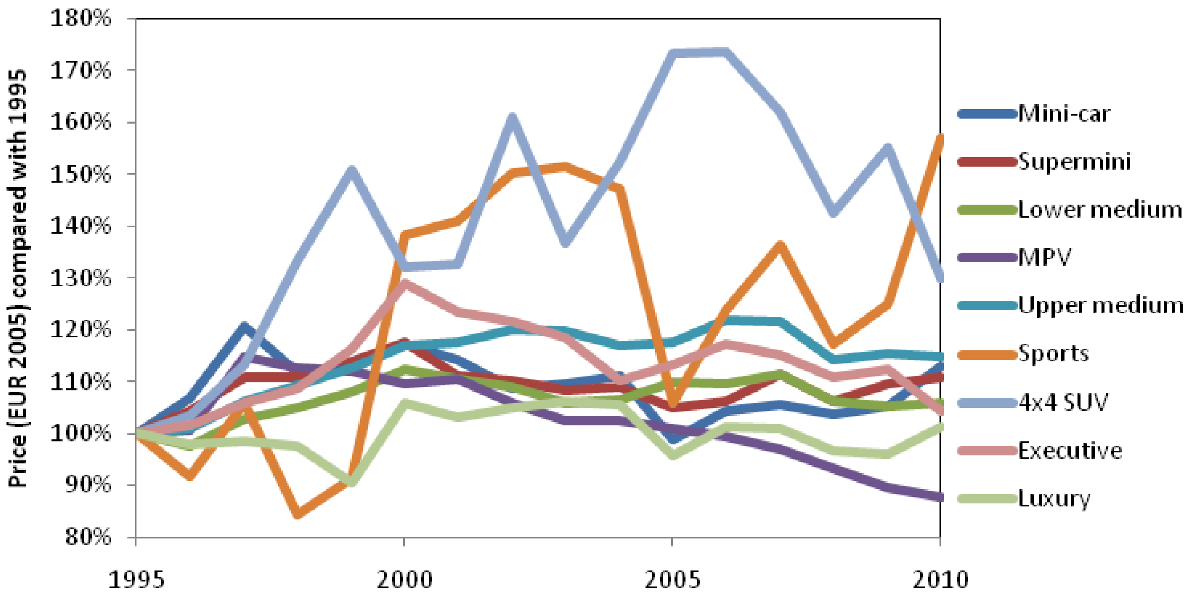
Source: JATO Dataset

To enable a comparison between each vehicle size category, Figure 3-2 illustrates the trend in vehicle prices relative to 1995 (with 1995 = 100%), and all subsequent years are shown relative to 1995. Here the vehicle category price trends for mini-car, lower medium, and supermini, can be seen to follow a very similar trend with minimal volatility and change in average prices throughout the period.

The trends of sports and 4x4 SUV are more erratic due to the smaller datasets and a larger number of premium vehicles, which produces more price volatility. For example, the sports category contains Porsche which has high variation in price from the Boxster to the 911 GT2, (from €43,000 to €262,000). Hence small variations in the composition of these datasets can appreciably alter the average price for that year.

The MPV category is the only size category which has an average inflation adjusted price decrease during the 15 year period. This is attributed to the increasing share of compact MPVs entering the marketplace, such as the Opel Zafira, Renault Scénic and the Volkswagen Touran. These vehicles are smaller and cheaper than the more traditional large MPV's such as the Renault Espace or Volkswagen Sharan.

Figure 3-2: Differential in car price for each vehicle size category compared to 1995 (all with EUR 2005 prices)



Source: JATO Dataset

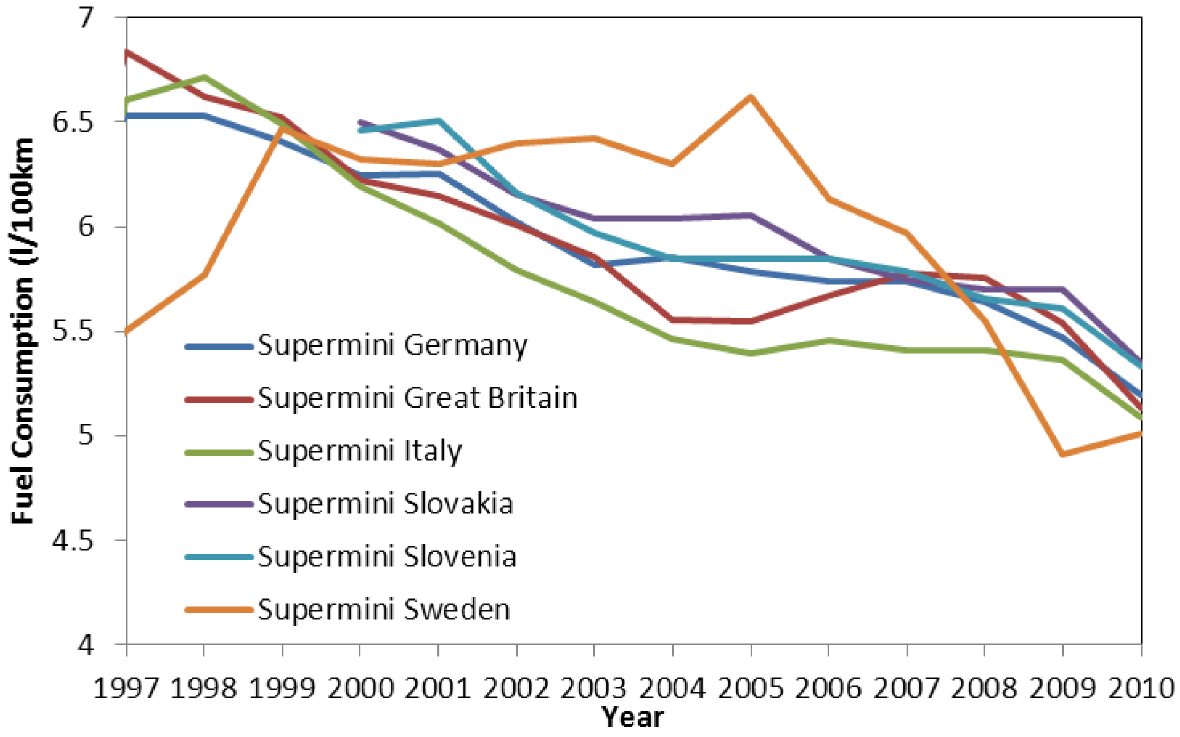
3.1.2 Fuel Consumption change for common vehicle categories

Figure 3-3 to Figure 3-5 chart the change in fuel consumption for supermini, lower medium and upper medium for all six countries within the dataset. The years 1995 and 1996 have been excluded from the charts as they present a misleading picture of fuel consumption. This is due to the combined fuel consumption reporting only being consistent for the years 1997 onwards.

There is a clear downward trend with fuel consumption decreasing for all countries for all three of the vehicle size categories. The only anomaly is the Swedish Supermini vehicle category, but this is attributed to a small dataset which can produce more volatile and less reliable averages.

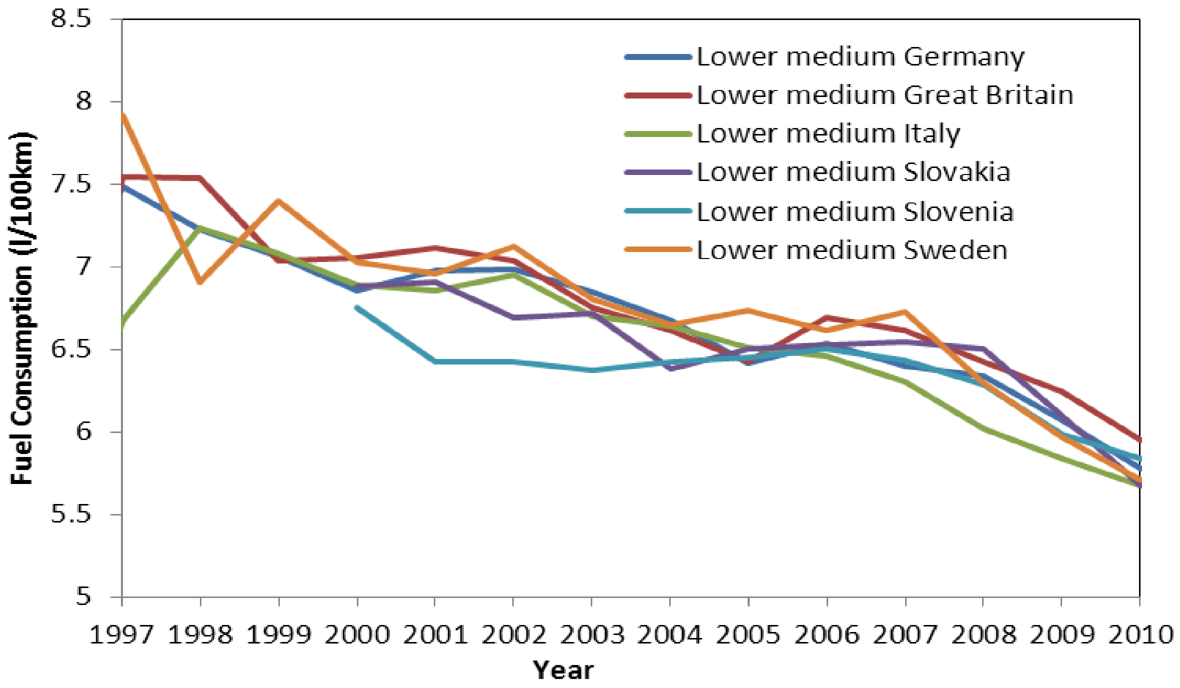
The average fuel consumption for Superminis between 1997 and 2010 has decreased by 25% in the UK and 20% in Germany. Lower medium sized vehicles have had a similar decrease in average fuel consumption, with UK and German vehicles decreasing by 21% and 23% respectively. However the Upper Medium vehicles category did not experience such reductions in average fuel consumption, with only 15% and 18% fall for UK and German vehicles respectively.

Figure 3-3: Average fuel consumption across the six member states for Supermini size category. The years 1995 and 1996 have been excluded due to fuel consumption measurement standards.



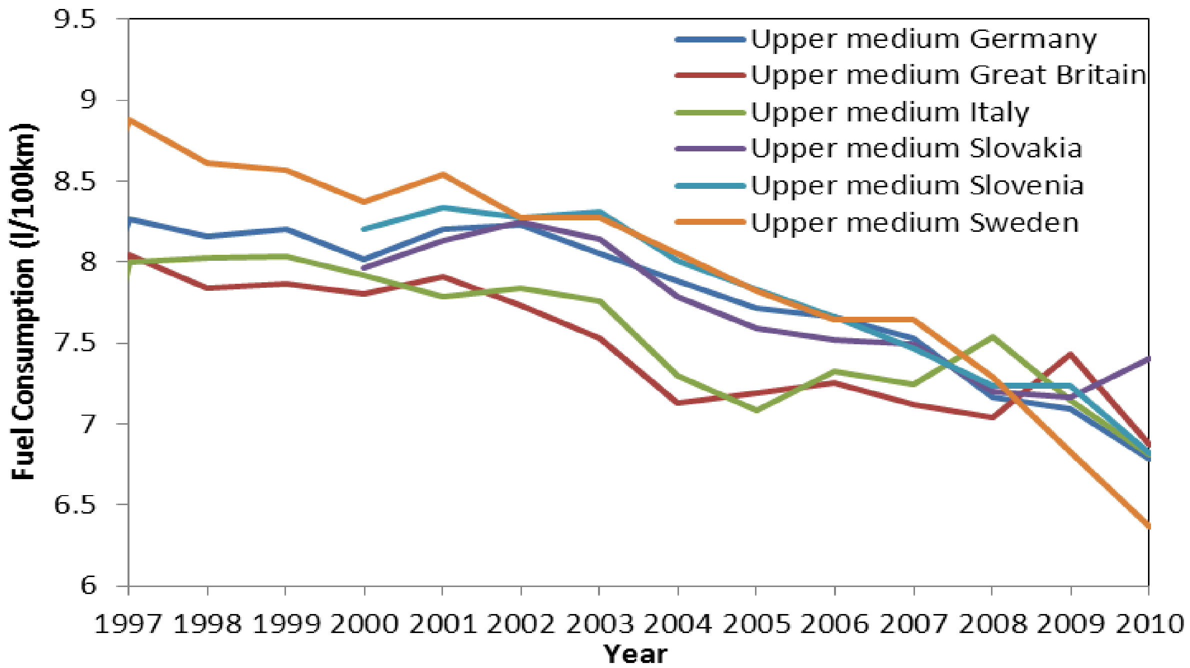
Source: JATO Dataset

Figure 3-4: Average Fuel consumption for lower medium sized vehicles in the six member states. The years 1995 and 1996 have been removed due to consumption measurement standards.



Source: JATO Dataset

Figure 3-5: Average fuel consumption for upper medium sized vehicles in the six member states. The years 1995 and 1996 have been removed due to consumption measurement standards.



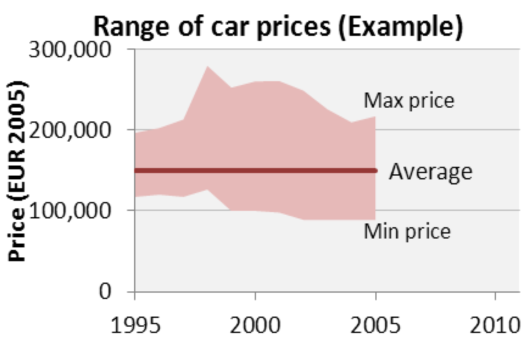
Source: JATO Dataset

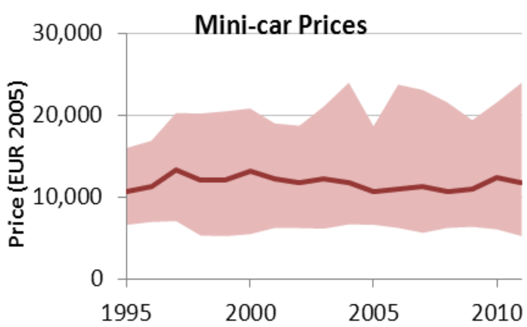
3.1.3 Range of car prices for all different size categories

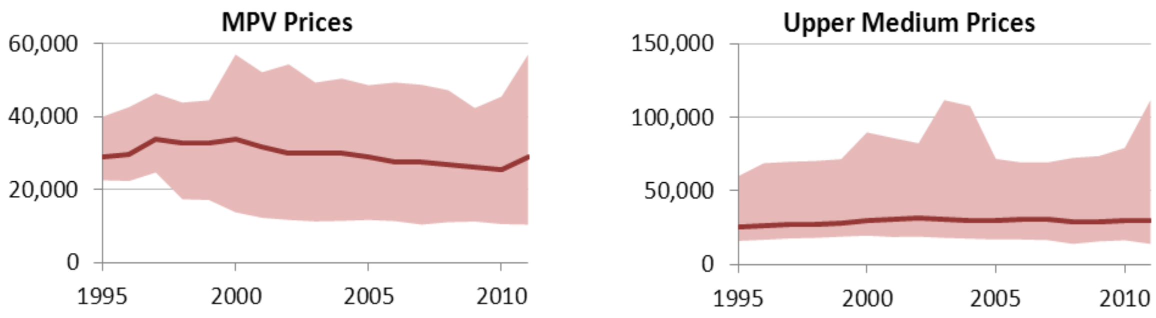
Figure 3-6 below provides further analysis on the range of vehicle prices for some vehicle categories, illustrating the minimum, average and maximum price for each year. All prices have been adjusted to 2005 Euro prices, with the arithmetic mean (or average) shown with the narrow dark line. The lighter band shows the vehicle range between the minimum and maximum prices.

It can be seen that for the selected vehicle categories, the mean is skewed such that it is closer to the minimum price than the maximum. This is due to the fact that the majority of vehicles being sold are of a standard range, with only a few 'top of the range' vehicles being sold. The only categories which have a more symmetrical distribution of prices are mini and MPV. This implies that these vehicles do not have expensive and high powered models, which fits with the type of vehicles in these categories. This can be compared to other categories, such as the upper medium, which have vehicles with high power and more expensive models such as the BMW M3 or Audi RS4.

Figure 3-6: Minimum, mean, and maximum car prices for different size categories for the six Member States (all in EUR 2005).







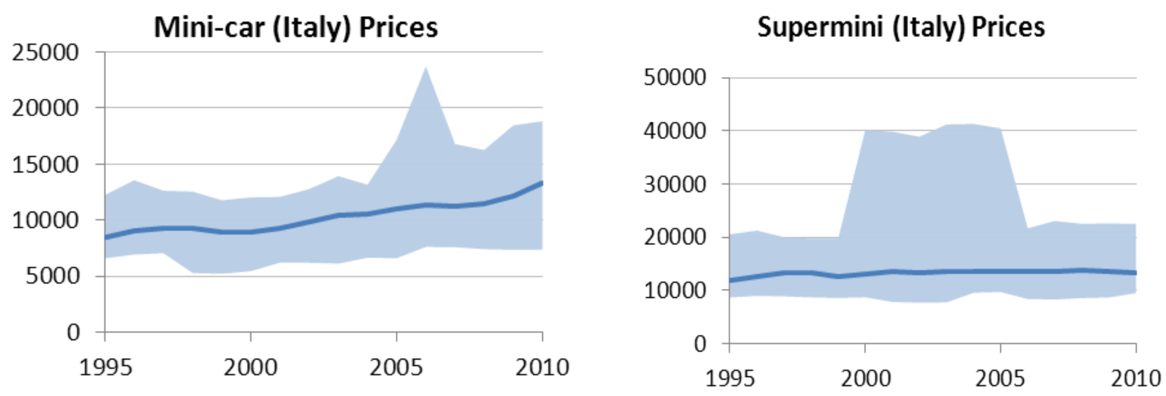
Source: JATO Dataset

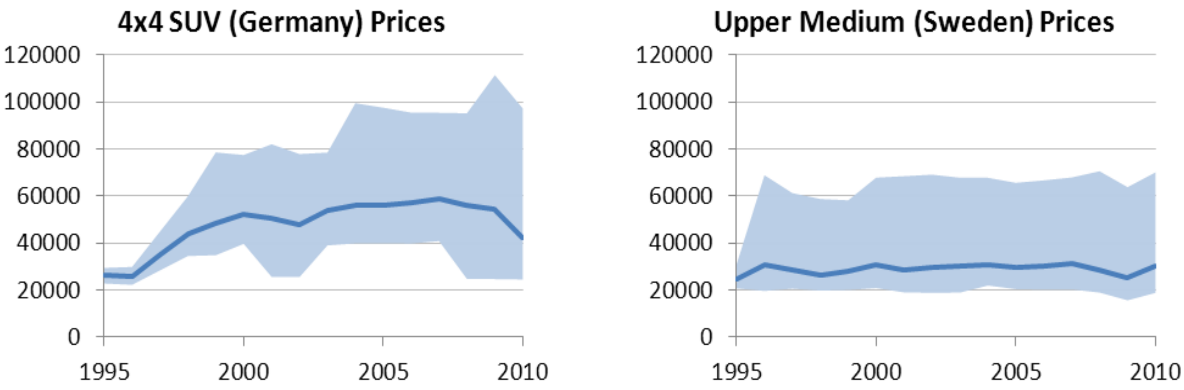
3.1.4 Range of car prices for selected member states and size categories

Figure 3-7 shows examples of vehicle prices for specific vehicle categories within countries. Not all category/country combinations have been illustrated due to the large number of charts that could be presented. These charts illustrate the variation of the vehicle markets over time due to various reasons.

In the Mini-car (Italy) chart, there is a maximum price spike in 2006, as a powerful limited edition version of the Fiat Panda is released for just one year. In the Supermini (Italy) chart there is a significant increase in the maximum price for 2000-2005, as Renault released a special Sport Clio which contained a 3.0 litre V6 engine. The 4x4 SUV (Germany) illustrates the changes in consumer choices. With 4x4 SUV vehicles becoming more popular amongst consumers, the range of models has increased which brings a wider price variation. For example the high performance Range Rover Sport was introduced in 2005, which contained a 4.4 litre V8.

Figure 3-7: Range of car prices for a selection of different size categories from individual member states (in EUR 2005)



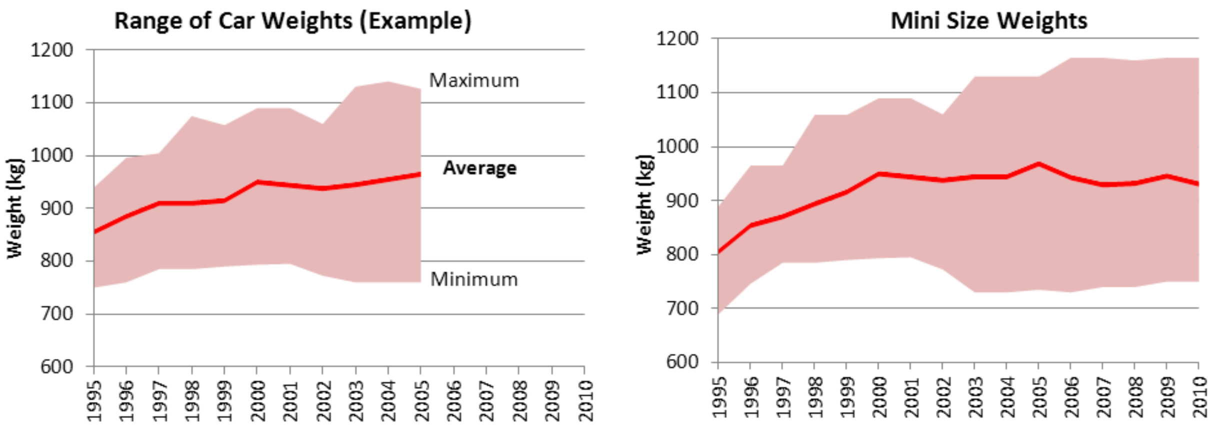


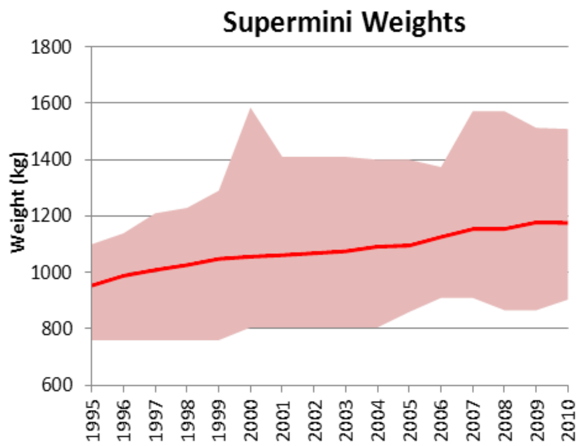
Source: JATO Dataset

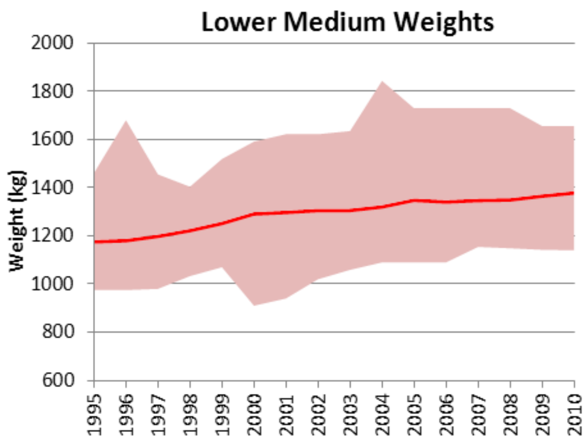
3.1.5 Range of vehicle weights for all member states

Vehicle weight is a key factor for determining fuel consumption (Figure 3-8). It can be seen that the mean (average) price is not skewed to the minimum range. There is an overall upward trend for nearly all vehicle categories, for example, the average weight of supermini vehicles increasing by 23% between 1995 and 2010. The distribution of the vehicle weight is more symmetrical than the prices, as expensive high performance vehicles are not necessarily any heavier than the low end options. These vehicles can even sometimes weigh less due to the use of lighter materials such as aluminium or carbon fibre.

Figure 3-8: Range of Vehicle Weights for given vehicle size categories for all the six member states







Source: JATO Dataset

3.2 Key trends – analysis

Building on from the analysis in Section 3.1 where a single vehicle attribute is evaluated over time, in this section multiple attributes are evaluated over time to enable visual comparison. However due to the different data ranges of the attributes, it is not possible to compare these adjacent to one another within the same graph. Hence these values have been normalised with the first year of the sample having the value of 1. This is achieved by dividing all the values by the first year, which is 1995. The exception to this is fuel consumption, which has 1997 equalling 1 due to the changes in the fuel consumption reporting that took place during 1995-1997. Subsequent charts are illustrated in Annex Section 1.2.

3.2.1 Average price and HC & NO_x limit – normalised

As discussed in Section 2.2, the EURO Standards include HC & NO_x emissions limits. While it is not possible to chart the average HC & NO_x emissions for each vehicle category due to the lack of information within the dataset, it is possible to chart the HC & NO_x emissions limits set by the EURO Standards versus price. Figure 3-9 and Figure 3-10 illustrate the relationship between the between average vehicle price and HC & NO_x limits. To enable a direct comparison, both levels have also been normalised, with the 1995 prices set to 1, and all subsequent prices relative to that. It can be seen that the diesel limits are gradually reduced over the 15 year period, whereas the petrol limits are heavily reduced in 1996 due to the introduction of the EURO 2 standard.

Figure 3-9: Correlation between the normalised average price (2005 EURO) and the HC & NO_x emissions limit for each vehicle size category

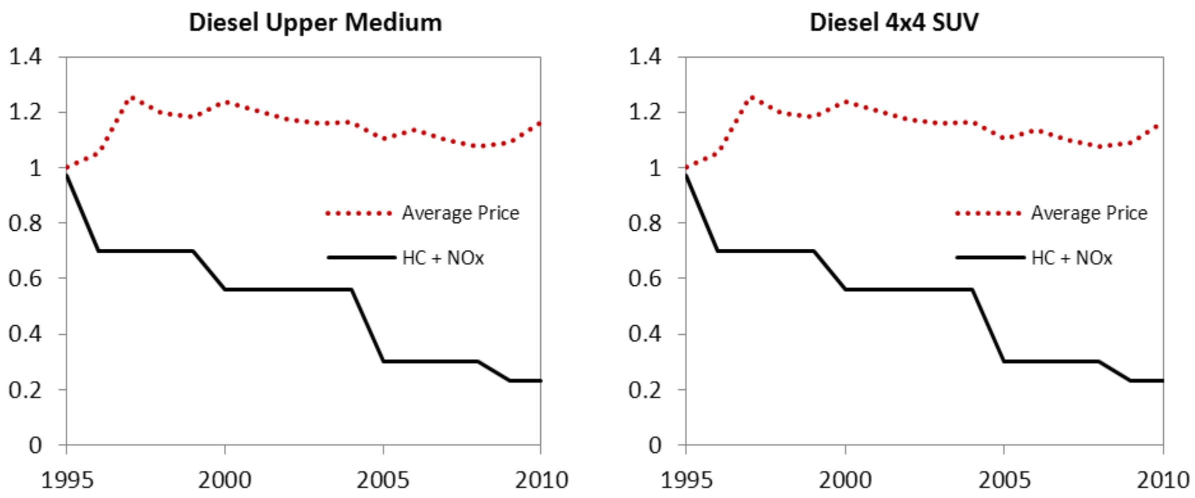
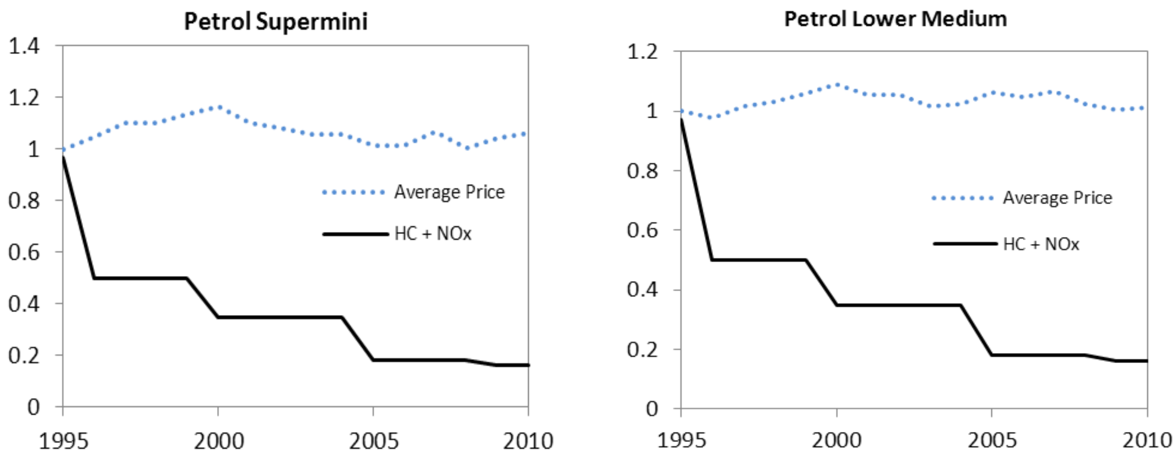


Figure 3-10: Correlation between the normalised average price (2005 EURO) and the normalised HC & NO_x emissions limit for each vehicle size category



Source: JATO Dataset

3.2.2 Cross attribute analytics

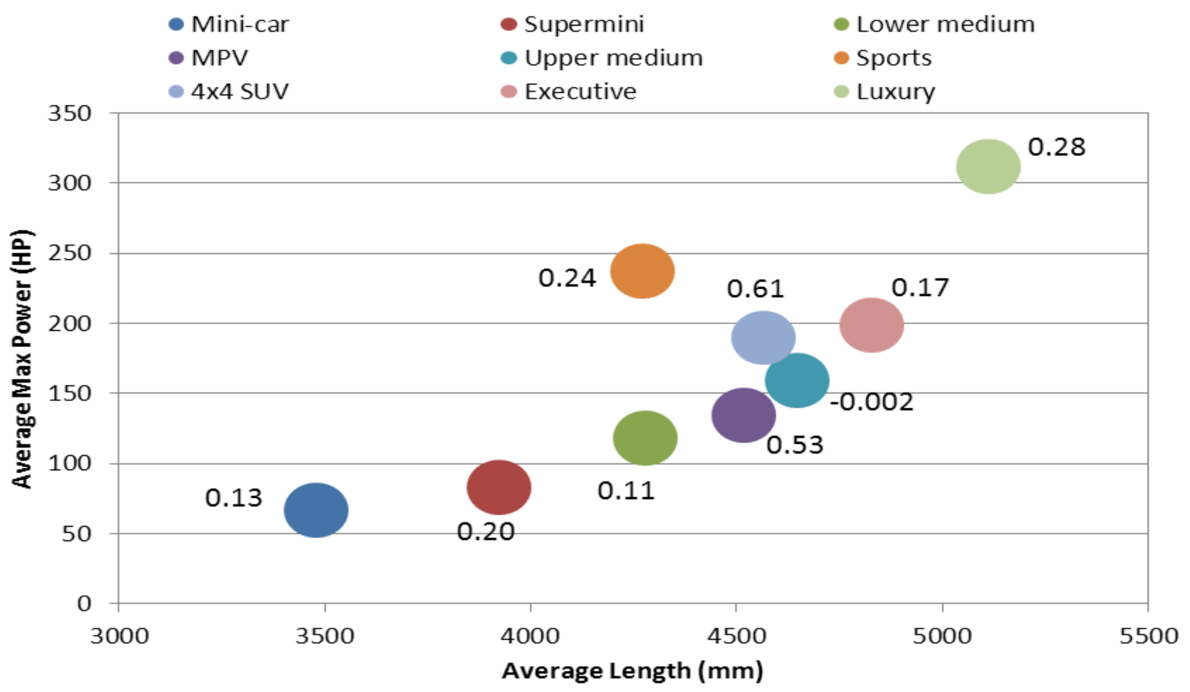
This section contains 'bubble charts', which compare all vehicle size categories relative to two vehicle attributes. These charts do not include a time dimension, with the data being the average of the 15 year time period. Also included for each size category 'bubble', is the correlation coefficient[132] between the two attributes on the x and y-axes.

The following graphs enable the reader not only to understand the correlation between price and the vehicle attribute given in the x-axis, but also illustrates where the average of each vehicle category sits within that space. For example the vehicle size categories combined together form a very obvious relationship, with the outliers being the sports and the 4x4 categories due to their unique attributes.

[132] A measure of the strength of the linear relationship between two variables that is defined in terms of the (sample) covariance of the variables divided by their (sample) standard deviations. Covariance is a measure of how much two variables change together.

As can be seen below in Figure 3-11 to Figure 3-15, there are strong relationships between the vehicle price and the attributes of power, weight, CO_2 Emissions (or Fuel Consumption) and engine capacity. When running regressions for the whole dataset, these strong trends will produce a strong correlation between price and these vehicle attributes. By selecting a single vehicle category this trend is not so strong, this is illustrated in the below charts, where the correlation coefficient[133] for each vehicle category is displayed adjacent to the bubble. For instance, there is a strong correlation of 0.84 between max power and price (Figure 3-12), however when selecting just the supermini category, this correlation drops to just 0.55.

Figure 3-11: Comparison of Average Car Length vs. Average Max Power for all vehicle categories (correlation coefficient is given adjacent to bubble)



[133] A measure of the strength of the linear relationship between two variables that is defined in terms of the (sample) covariance of the variables divided by their (sample) standard deviations.

Figure 3-12: Comparison of Average Price vs. Average Max Power for all vehicle categories (regression correlation coefficient is given adjacent to bubble)

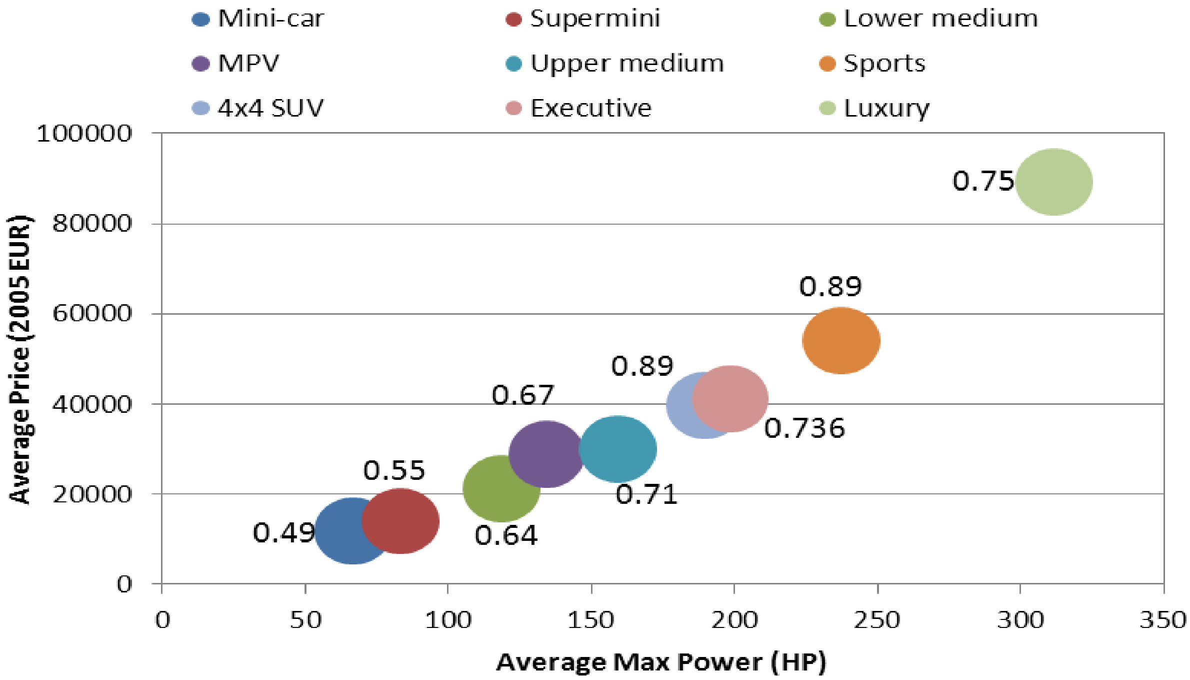


Figure 3-13: Comparison of Average Price vs. Average CO_2 Emissions for all vehicle categories (correlation coefficient is given adjacent to bubble)

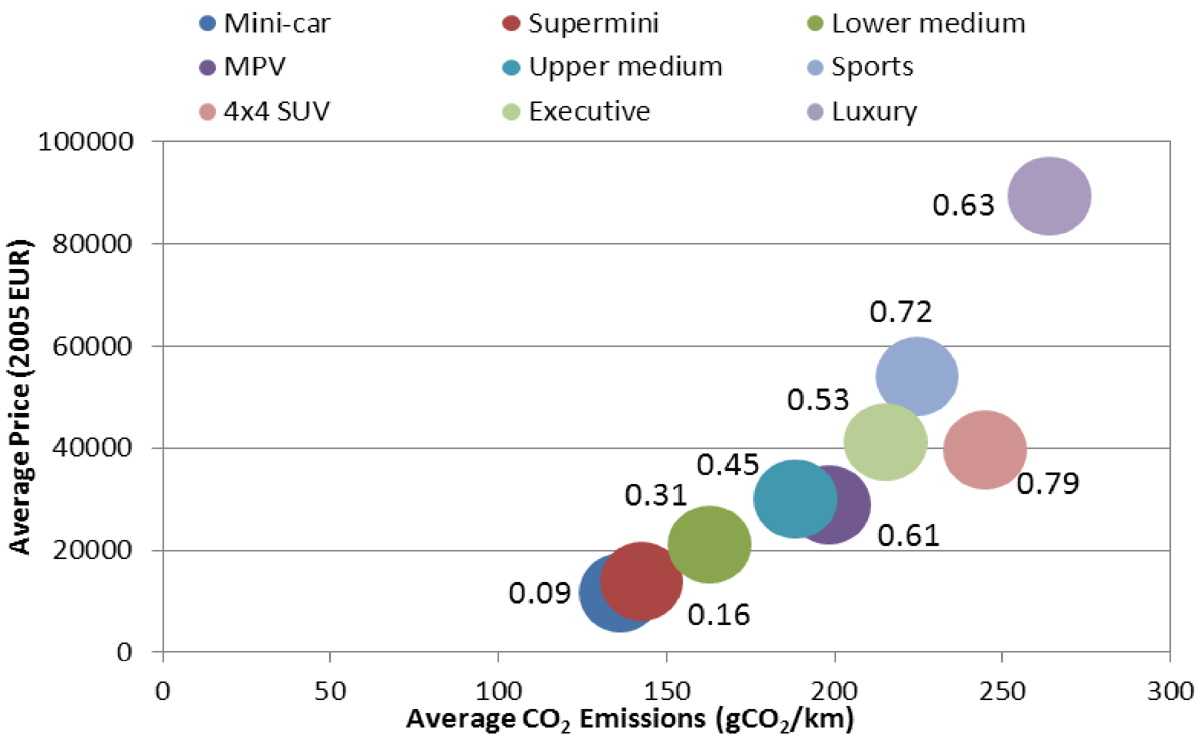


Figure 3-14 : Comparison of Average Price vs. Average Engine Capacity for all vehicle categories (correlation coefficient is given adjacent to bubble)

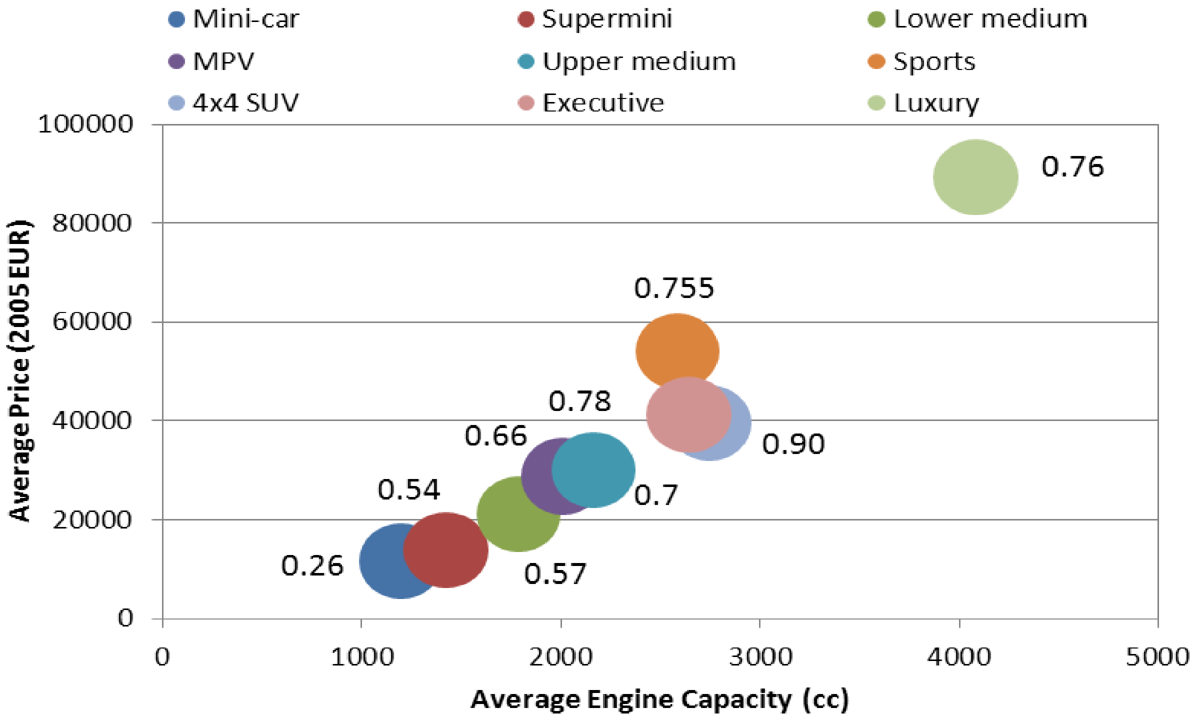
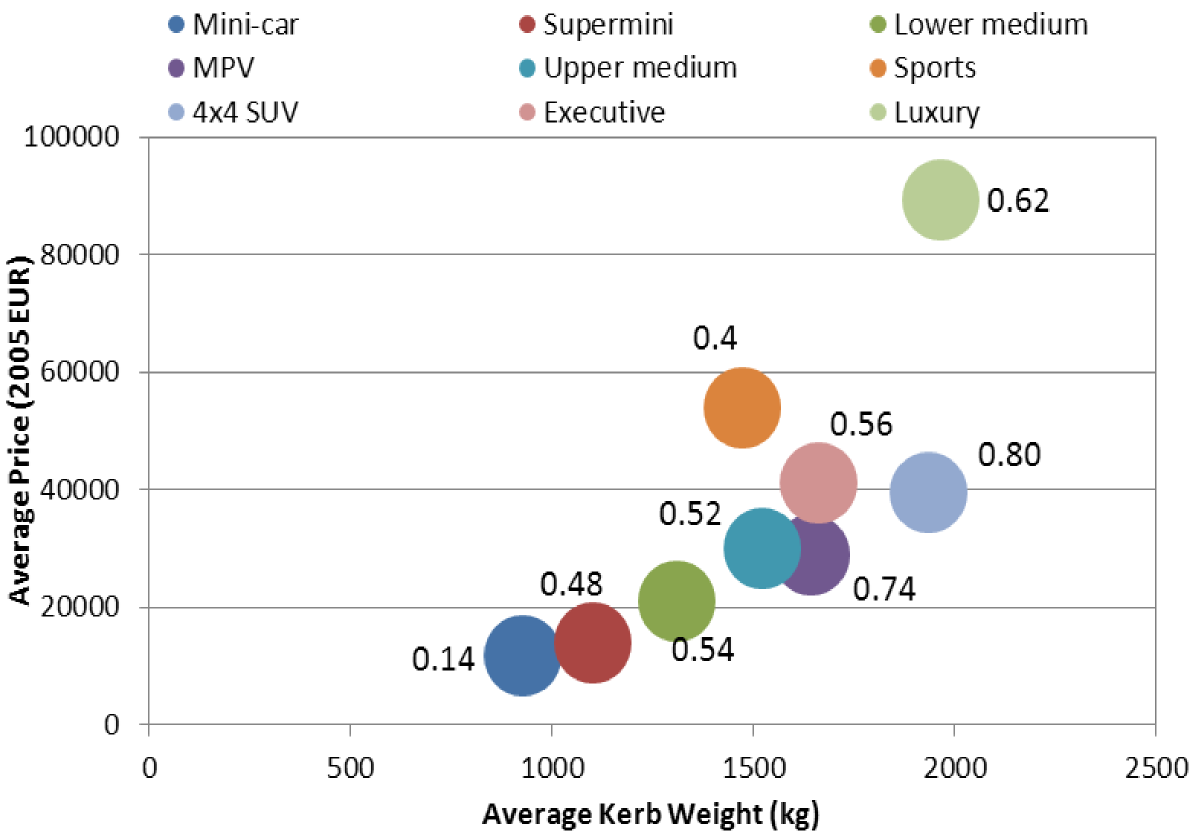


Figure 3-15: Comparison of Average Price vs. Average Kerb Weight for all vehicle categories (correlation coefficient is given adjacent to bubble)



4 Background on hedonic regression modelling

4.1 Introduction

The findings and discussions in the literature review section (Section 2) indicate that many factors influence vehicle production costs and consequently it may be very difficult to decompose vehicle production costs (or possibly end-user prices) into its various components. In this chapter, we briefly summarise methods used in the past to analyse the impact of environmental regulation on vehicle prices. We then outline our proposed quantitative model based on the hedonic pricing approach.

4.2 Review of methods of quantifying the effects of legislation on vehicle prices.

4.2.1 Review of studies on the effect of environmental legislation on vehicle prices/costs

Extensive research has been conducted on analysing the effects of environmental legislation on US vehicle manufacturers. A significant proportion of this research is focused on the 1970s and 1980s when CAFE standards were introduced. Much of this analysis examined the ex-ante and ex-post costs associated with this legislation. For example, Goldberg (1998) studied the effect of this legislation and concluded that the 1989 CAFE standard resulted in profit reductions for domestic manufacturers of approximately $210 million, with consumers not facing large increases in car prices. While the prices of large cars increased as a result of CAFE, the prices of small cars actually decreased. Hence CAFE standards seemed to function as a set of internal taxes within car firms where fuel inefficient cards subsidised fuel efficient ones.

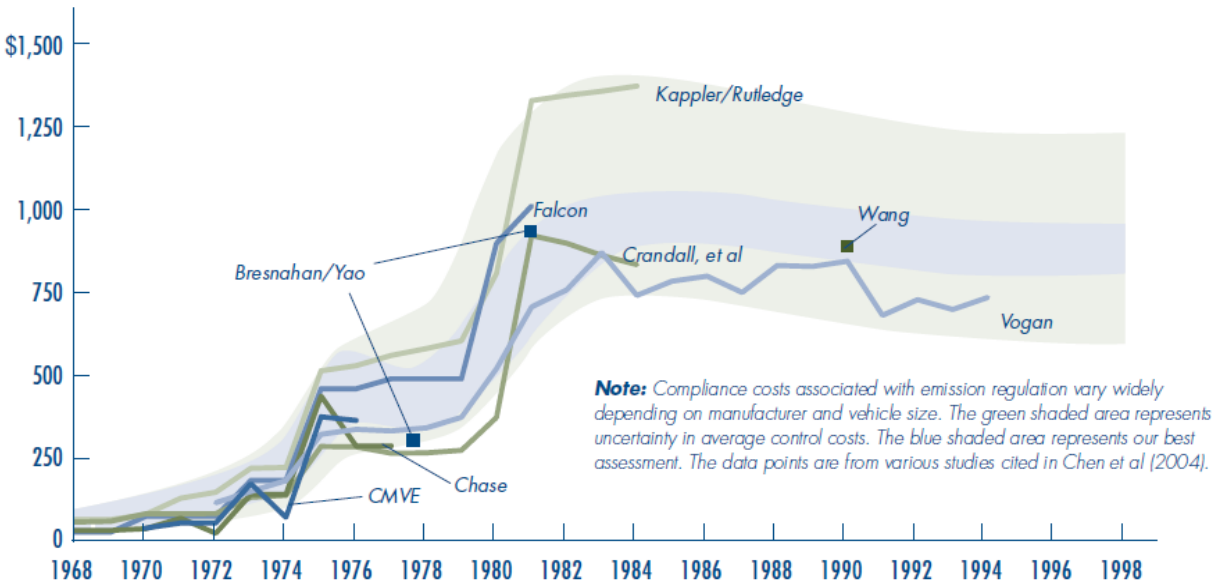
Hwang & Peak (2006) also investigated cost predictions for regulations in the USA, and stated that there is a history of the motor industry and its allies overestimating costs by a factor of between two and ten times the actual costs. Regulators also overestimated costs, but to a lesser extent. The primary reason for this overestimation was given as being due to unanticipated technological innovation.

Chen (2004) has produced one of the most comprehensive reports on the effect or regulation on vehicle prices, but this is based only on the US market. Here a comprehensive database for 1972-2002 of vehicle attributes at the make, model and series level was compiled to analyse the effect of regulations on US vehicle costs. This concluded that compliance costs were not fully passed onto consumers in the form of increased vehicle prices, at least immediately. For some years when emission control costs increased substantially, average vehicle prices actually declined, confirming that other more important factors are at play such as the desire to smooth sales over time and across models, helping to balance planned production volumes with shifting demand. They also include myriad smaller goals, such as using pricing to boost sales of vehicles with high fuel economy so as to achieve the company's CAFE standards, or making entry-level cars attractive to first-time buyers. Automakers use other non-pricing tactics to respond to regulatory changes and market shifts including advertising and financing incentives.

4.2.2 Analytical methods for assessing the costs of complying with vehicle regulations

Findings by Chen et al (2004)[134], suggest that there is considerable uncertainty in estimating average control costs (see shaded bands in Figure 4-1), which is a function of the analytical methods used and the complex pricing behaviour of car manufacturers. Although Chen (2004) produced a comprehensive US-centric report, it is not explained how the data were manipulated to produce the results, and it is very unlikely that any hedonic model was created given the lack of explanation in the methodology.

Figure 4-1: Emission control equipment costs, 1968–1998 (In 2002 US Dollars)



Source: Chen et. al (2004)

There have been a number of hedonic models created to analyse car features and price indices in the European market. Izquierdo et al. (2001) studied the Spanish new car market for the period of 1997 to 2000. This study used a semi-log hedonic model to test price against a number of quality indicators, such as horsepower, acceleration, air-conditioning, anti-lock braking systems (ABS), driver airbag and ten others vehicle attributes. However, the aim of this piece was to measure quality improvements and to estimate the quality bias in the car price index. The semi-log hedonic model was also employed by van Dalen (2004) with a similar objective of estimating the quality-corrected price indices of new passenger cars.

Much of the literature on the subject of regulations and standards on vehicle prices has been written on the introduction of the US CAFE standards, with the analysis being aimed at identifying the difference between the predicted costs and the actual costs of meeting these standards.

The more recent studies analysing vehicle prices in Europe have only investigated quality/price indices on an individual nation basis, with no studies found that look to create hedonic models for cars in many nations.

Hedonic regression and probit/logit regression models have been predominantly used to model the impact of regulation and quality factors on vehicle prices. These models are especially favoured for analysing quality changes of new or used cars in explaining their prices. A summary of some of the

[134] Belinda Chen, Ethan Abeles, Andrew Burke, and Daniel Sperling. Effect of Emissions Regulation on Vehicle Attributes, Cost, and Price. Prepared for CARB under contract 02-310. 2004. http://www.its.ucdavis.edu/pubs/pub2004.htm

papers relevant for this study is given in Box 4.1. The literature on the use of hedonic regressions on car prices either focuses on the estimated coefficients[135] of the product characteristics in the hedonic regressions or the proportion of the price that is explained by the characteristics. A number of papers on hedonic pricing, with a theoretical focus on examining the relationships between price and characteristics exist[136]: from the demand point of view (Muellbauer, 1974)[137] and from the supply point of view (Ohta, 1975)[138]. Some relevant papers in the EU context are by Mertens and Ginsburgh (1985)[139] and Ginsburgh and Vanhamme (1989)[140]. Both papers analysed product differentiation and price discrimination in the European car market using hedonic functions.

Hedonic price functions reflect changes in prices caused by changes in product characteristics. This can be misclassified as changes in productivity or technological progress. Vehicle characteristics have been changing very rapidly over time. An important reason (as discussed in Section 4.2.2-4.2.4) for prices to remain constant even though vehicle features have been constantly changing is attributed to the changes in production processes. Barry et. al (1996)[16] estimated a hedonic cost function that combined plant-level cost data and information on which products were produced at each plant together with a model of the relationship between production costs and product characteristics. They importantly mapped production data with product quality data to analyse the implications on plant level costs. They also included a productivity shock parameter to capture changes in underlying technology and in the regulatory environment. This allowed them to analyse whether changes in automobile characteristics and the rate of patenting are related to regulations and gas prices.

Theoretically, using a hedonic cost function would be ideal for the purposes of this study. It is the production counterpart of the hedonic price function. A cost function would reflect the evolution and trend in production costs and the impact of production inputs and nature of technology on total costs. However, it is nearly impossible to obtain plant level production and cost data for vehicle manufacturers. It would be very onerous, time consuming and expensive to collect the required data to estimate a hedonic cost function. In many cases, plant level data in Europe is confidential and not available in the public domain.

Box 4.1: Hedonic regressions for car prices

Silva and Reis (2006) evaluated the effects of quality change on the price index for new passenger cars in Portugal for the years 1997–2001. Hedonic regression models were used, giving particular emphasis to the relation between the form of the price index and the econometric techniques used for inference. The results of the empirical part of the paper indicate that during this period the changes in the quality of new cars sold in Portugal are responsible for price increases averaging 4.8% per year.

Goldberg (1998) analysed the effects of Corporate Average Fuel Economy (CAFE) standards in the US on automobile sales, prices, and fuel consumption. They developed a discrete choice model of auto demand and a continuous model of vehicle utilization from the Consumer Expenditure Survey (1984-1990). The paper considers the pros and cons of CAFE regulations and their effectiveness. It also argues that nested logit models are better to use for modelling automobile demand than simple multinomial logit models. This is because the nested logit models consider the possibility that the consumer forgoes the purchase and includes information on past purchases. Moreover, this paper

[135] Agarwal and Ratchford (1980), Atkinson and Halvorsen (1984), Bajic (1988, 1993), Arguea and Hsiao (1993) and Arguea, Hsiao and Taylor (1994)
[136] Berry et al (1996), Kroonenberg Nellie and J. S. Cramer (2005) and Boskin et al, (1996)
[137] Muellbauer, J. (1974). Household production theory, quality, and the hedonic technique. The American Economic Review, 64(6), 977-994.

[138] Ohta, M. (1975). Production technologies for the US boiler and turbo generator industries and hedonic prices indexes for their products: a cost-function approach. The Journal of Political Economy, 83(1), 1-26.

[139] Mertens, Y., Ginsburgh, V., 1985. Product differentiation and price discrimination in the European community: the case of automobiles. The Journal of Industrial Economics 35, 151–166.
[140] Ginsburgh, V., Vanhamme, G., 1989. Price differences in the EC car market. Annales d'Economie et de Statistique 15/16, 137–149.

includes equations derived to find the profit and penalties associated with not meeting regulations, whatever they may be. It can be concluded from this method of analysis that CAFE regulations are not enough of an incentive for consumers to purchase more fuel efficient vehicles, since the regulations are a “set of internal taxes (on fuel inefficiency) and subsidies (on fuel efficient vehicles) within each firm”.

Berry et al (1996) looked at changes in the economic and regulatory environment on production costs and product characteristics in the automobile industry. They estimated a “hedonic cost function” that relate product-level costs to their characteristics. They examined how this cost surface has changed over time and how these changes relate to changes in gas prices and in emission standard regulations. They also briefly consider the related questions of how changes in automobile characteristics, and in the rate of patenting, are related to regulations and gas prices.

Boyd & Mellman (1980) wrote one of the first papers exploring how government regulations, namely CAFE regulations and rising fuel prices are forcing auto manufacturers to improve fuel economy. Boyd & Mellman utilise the hedonic demand model, also known as the “random coefficients logit model”, which is an extension of the multinomial logit probability choice model. This model incorporates the variation in consumer tastes and preferences. The paper compares the accuracy of the hedonic model’s predictions of market shares to the accuracy of the logit model’s predictions. It argues that the hedonic model is often a better fit to the data than the logit model, but not necessarily all the time. This study also reveals that consumers do value improvements in fuel economy, but these improvements will also eventually change other vehicle attributes. Boyd & Mellman conclude that the shift in market shares from less to more fuel efficient cars in response to feasible changes in new car prices or gasoline prices are likely to have only modest short-run impacts on fleet average fuel economy.

5 Hedonic regression analysis

5.1 Introduction

As discussed in Chapter 4, a hedonic regression modelling approach is the most suitable way to analyse the effect of environmental regulation on vehicle prices. Hedonic price functions implicitly capture changes in prices caused by changes in product characteristics. Although the characteristics of the product are neither sold nor priced in isolation, the overall price of the good reflects the bundle of embodied characteristics valued by some implicit or shadow prices. These implicit characteristic prices can be seen as parameters that associate the dependent variable and the independent variables of the hedonic model. The estimation of a hedonic price equation makes it possible to distinguish between the variation in prices explained by a change in the characteristics and the variation that can be attributed to a pure price effect.

However, to make the link between changes in vehicle prices caused by changes in vehicle attributes is not straight forward. This can be misclassified as changes in productivity or technological progress. Vehicle characteristics have been changing very rapidly over time. An important reason for prices to remain constant even though vehicle features have been constantly changing is attributed to the changes in production processes, marketing strategies, platform sharing, etc. Automakers also use other non-pricing tactics to respond to regulatory changes and market shifts including advertising and financing incentives. These effects cannot be captured under a hedonic approach as they are partially or completely hidden. Thus, in order to understand the boundaries of the hedonic modelling approach it will be helpful to first outline the key assumptions and findings from the literature review under which the analysis of the hedonic regression should be considered.

5.2 Key findings and assumptions from the literature review as a basis for hedonic modelling

Hedonic methods are based on the assumption that price differences among products stem from differences in their characteristics. The hedonic framework is particularly well suited for analysing high-technology industrial products, such as motor vehicles, because performance characteristics may determine the price structure of the market. Nevertheless, the structure of such markets may not be explained so simply. Passenger cars have number of different categories and applications ranging from city minis to large SUVs. Producers choose segmentation strategies to exploit this large variation in demand. In particular, these segments exhibit considerably diverse price sensitivities. In such a case, OEMs implement implicit price discrimination strategies to exploit the less price-sensitive segments (See section 2.7 and 2.8).

Hedonic models can be specified to capture technology adjusted price change by using year-specific intercepts. Even after the “dynamisation” of the hedonic function (e.g. equation 1 in Model 2 below), there are further issues to be dealt with. Although one might expect that technical performance and intersegment differences explain the bulk of price variation, it is clear from literature review that a number of factors might have a significant effect on the determination of equilibrium prices. Some of the main factors are:

- Platform sharing and commonality (section 2.4.1) - re-use the same parts, sub-systems and ultimately entire vehicle platforms;
- Purchasing strategies (section 2.4.3) – ‘Just-in-time’ parts handling procedures;

- Numerous strategies to reduce manufacturing costs such relocation, sub-assemblies, computer controlled machinery, etc. (section 2.4.2, 2.5.2, 2.5.3);
- Complexity of complying with environmental regulations as the costs to manufacturers of new regulations impacts on direct manufacturing costs and indirect costs such as research and development, administration and marketing (section 2.6); and
- Fast changing consumer tastes and real time access to consumer advice, price comparisons and car supermarkets could affect the implicit prices of car characteristics (section 2.8).

Thus various aspects of a car company's offer that are difficult to quantify may have an impact on price variation. For instance, different manufacturers offer different after-sales support, warranties, financing terms, etc. In addition, more often than not, the reputation of the supplier "brand effect" is an important determinant of purchase decisions (see section 2.8). Therefore, we expect a significant amount of cross-sectional and over time variance in car prices to be explained by inter firm differences in the above mentioned factors.

To investigate the above questions, we can extend the dynamic hedonic function to accommodate segment specific and firm-specific factors. This can be either done by segment-specific dummy variables whose coefficients are segment-specific intercepts, which allow for differences among segments. The other and more reliable option is to define the dataset based on key data attributes. The empirical hedonic regression modelling was undertaken for the following groups:

1. **Diesel/Petrol** – car prices and attributes including environmental performance differ by fuel.
2. **Countries** – purchasing behaviour, car markets and availability, popularity of make/models, fuel taxation, sales taxes, differ by country. This grouping is probably the most important of all the others, because of the reasons above.
3. **Size Categories** (A,B,C, etc.) – brand effect, cost associated to size of vehicles, car attributes such as engine power, fuel efficiency, and environmental performance all differ by car size categories.
4. **Particular make or model** – e.g. VW Golf, which is sold across most car markets in Europe. This would allow us to analyse the price effect on the EU as a whole.
5. **Time** – consumer trends, car make/model choice, environmental and safety regulation, and standard vehicle features are sensitive to time period.
6. **Manufacturer (Brand)** – certain make/models have a premium price effect that can override rational consumer behaviour based solely on car attributes.

We undertook over 40 regressions based on the above categories to analyse the variance in car prices as a function of selected vehicle features. The results provided important lessons to estimate the hedonic regression and improve the specification of the equation to provide robust coefficient estimates.

5.3 Estimation issues

5.3.1 Functional form

The first issue to be considered is the functional form for the hedonic regression. Given that economic theory does not restrict the functional form for hedonic functions, we proceeded by choosing the semi-log formulation.

A semi-log model can reflect the variation in vehicle prices due to each explanatory variable. The slope coefficient (β_is) measures the constant relative change in vehicle prices for a given absolute change in the explanatory variables. A relative change multiplied by 100 becomes a percentage change. For example, an absolute change in gCO_2/km can be associated with a ± relative change (%) in vehicle price.

$$\beta_1 = \frac{\text{Relative change in vehicle prices}}{\text{Absolute change in env indicator}}$$

Thus, it is possible to analyse the share of the vehicle price that is explained by various explanatory variables.

5.3.2 Weighted or un-weighted

An important issue when using hedonic regressions is whether the regressions should be weighted or not. A distinction should be made between weighting the hedonic regression and weighting the hedonic price index. The literature is divided over the benefits of weighting. Generally, decisions on weights are made based on the availability of data and testing results of appropriate functional forms[141] and econometric tests. If transaction prices are available, then price indexes can be computed without using weights since the probability that the price of a given model is included in the sample is proportional to its market share (in volume); that is, the sample is self-weighted.

However, list prices as we have used for this study should be used to construct price indexes by weighting each price by the corresponding market share. However, market share data for the JATO dataset was not available.

Our preferred option has been not to weight. In fact, as Deaton (1997)[142] remarks under the standard assumptions of the linear regression model, weighting leads to a loss of efficiency. Even if those assumptions are not satisfied, weighting will not generally be the appropriate solution.

5.3.3 Multicollinearity

Multicollinearity is the undesirable situation where the correlations among the independent variables are strong, (i.e. individual variables are strongly related to each other and it becomes difficult to isolate the significance of any one indicator).

All models where tested for multicollinearity and variables that contributed to high multicollinearity were removed from the model. There are a number of circumstances where high multicollinearity can occur in our analysis, these are:

[141] Linear, Logarithmic, Log-linear, exponential, etc.

[142] Deaton, A. (1997) The analysis of households surveys: A micro-econometric approach to development policy. The John Hopkins University Press.

- CO_2 Emissions (g/km) and Fuel Consumption (l/100km)

  - Here there is an almost 1:1 correlation within the dataset, such that only one of these attributes can be included in the analysis. For regressions, the fuel consumption attribute has been selected.

- Power, weight, engine capacity, fuel consumption, length, width, acceleration, and top speed.

  - When all vehicle categories are selected in a regression, there can be a high level of multicollinearity between the listed attributes. The similar correlations of these attributes with price can be seen in the graphs of Section 0. Hence there is a need to remove some of these attributes. The specific removals will be on a case by case basis depending on the Variance Inflation Factor that is identified.

See section 2.5 in the Annex document for more discussion on multicollinearity.

5.4 Limitations of hedonic modelling

Hedonic models have a number of limitations. In general, hedonic modelling is relatively complex to interpret and requires a high level of statistical knowledge and expertise. The model suffers from two main data problems:

1. **Measurement error**: There will be errors in the observed values of the dependent and explanatory variables. The statistical model also depends on the choice of (and any weights attached to) significant indicators. There can be a number of other variables, such as other car features and macro-economic variables that could add to the robustness of the model.

2. **Multicollinearity:** Multicollinearity is a serious problem in hedonic models and arises when the effects of several variables are closely linked. If mulitcollinearity exists, it becomes hard to determine which correlated variables are truly influential. An example of multicollinearity occurs when car features such as acceleration, engine size and top speed may be closely correlated with the levels of another.

Some other key limitations are:

- **Data requirements** - The amount of data that needs to be collected and worked with is very large. The availability and accessibility of data directly affects the amount of time and the expense that will be undertaken to carry out an application of the model.

- **Non-linear relationship** - Some variables may not be linearly related to car prices. Taking squares of these variables can remove the bias but then it becomes difficult to interpret the data. Moreover, given the large number of degrees of freedom, this does not cause significant problems with the heterogeneity of the variances.

- **Market failure** - The car market could suffer from market failure because of government intervention in the form of taxes and subsidies on certain models.

- **Limited scope** - Hedonic pricing models do not estimate non-monetary benefits of cars. For example, any vintage or brand effects are not measured.

- **Information bias with willingness to pay** - This method estimates people's willingness to pay for various car attributes. However, if the people are unaware of the relation between the car attributes and their benefits to them, then the value will not be reflected in the price of the car.

- **Price Changes** - Another assumption is that prices in the market will automatically adjust to any changes in the attributes. In reality, there may be a lag for certain attributes if their availability is limited or exclusive.

5.5 Empirical hedonic model specifications

We interpret the hedonic equation as an instrument to approximate the evolution of price indexes, taking into account the variation in product characteristics. Some of the variation in product characteristics is a direct impact of regulation where as others are indirectly affected. For example, engine after treatment technology has become much more complex, partly driven by emissions legislation. Regression coefficients can be interpreted as implicit prices for vehicle characteristics or can be interpreted as the results of the interaction of the supply and demand curves for characteristics. A shift in any curve might cause a change in the estimated coefficients over time. Thus in empirical implementation, the stability of the parameters over time has to be tested. The most obvious alternative consists of estimating year by year equations and testing equality restrictions among coefficients.

For the empirical hedonic modelling, four alternative specifications have been used for estimating the hedonic equations (Table 5-1). Model 1 can directly capture the Euro standards effect in the form of an announcement and permanent effect. To analyse the impact of the regulation we also have to consider the changes in car attributes to comply with environmental regulations. Hence, models 2-4 have been designed to indirectly analyse the impact of regulation on car prices by looking at variables such as fuel efficiency, engine capacity and size. The literature review shows that these car features were substantially affected by stringent environmental regulations (see section 2.3.1).

Table 5-1: Empirical hedonic models

Models	Description
Model 1	Panel data analysis - Single time variable and individual environmental time dummies for all years. This method assumes constant coefficients over the years. Here the time dummy attribute the base year 1995=1, 1996=2 etc., with 2010=16. The announcement effect dummy variable takes the value '1' for all the years from the announcement of the Euro standard to year it came into effect, and '0' otherwise. The effective date dummy variable takes the value '1' for only the year the regulation was enforced, and '0' otherwise. Further information on how these dummy variables are inserted can be found in Section 2.3.1 of the Annex. $$\ln P_{it} = \beta_o + \beta_D D_{it} + \sum_{i=1}^{n} \beta_i x_{it} + \beta_{Ay} A_y + \beta_{Ey} E_y + \varepsilon_{it}$$ Where P_{it} is the price of the car of model *i* in period *t*; β is a vector of unknown parameters to be estimated, x_{it} is the vector of car characteristics, D_{it} is the vector of car brands, Ay is the environmental standard announcement effect time dummy, for the standard in

	the y years (E.g. if the announcement date is 1998 and the effective date is 2000, then the Ay variable takes the value 1 from 1998 to 1999 and 0 elsewhere), and Ey is the environmental standard effective date time dummy for the yth year. (e.g. if the effective date is 2000, then Ey will only take the value of 1 for the year 2000 and 0 elsewhere)
Model 2	Panel data analysis – Annual time dummy variable method. This method assumes constant coefficients for the vehicle attributes over the full period. Here time dummy variables for each of the years are inserted, and there are no individual environmental regulation dummy variables (this would cause multicollinearity with the time dummy variables). The regression equation is as follows: $\ln P_{it} = \beta_o + \beta_D D_{it} + \sum_{i=1}^{n} \beta_i x_{it} + \beta_t t + \varepsilon_{it}$ Where β_t is the annual time dummy variables The main problem with the time dummy variable method is that parameter stability over time is assumed. This assumption can be relaxed by using an unconstrained approach, i.e. by specifying separate equations for each time period.
Model 3	Period by period (single period equations) – Individual one year period with no time or environmental dummy variables. In this case, the coefficients of the regressions are assumed to vary from one year to the next. $\ln P_{it} = \beta_0 + \beta_{Dt} D_{it} + \beta_t x_{it} + \varepsilon_{it}$ The problem with single year equations is that the estimated coefficients tend to be a bit erratic due to the reduced sample size, reduced number of degrees of freedom along with a high level of multicollinearity among characteristics. An alternative solution to this is to introduce a moving average based on a small period, i.e. two or three years (method 4 and 5 below).
Model 4a and 4b	Moving sample of order h. The regression equation is estimated for a centred moving sample of order *h*. A different vector of coefficients is estimated for each moving sample. Two samples were estimated based on a 2 and 3 year moving sample. $\ln P_{ih} = \beta_{0h} + \beta_D D_{ih} + \sum_{i=1}^{n} \beta_{ih} x_{ih} + \beta_h + \varepsilon_{ih}$ a) Adjacent 2 year periods. Completing a regression for two contiguous years, t and t-1. In this case the coefficients of the regression are assumed to be constant for each pair, but variable from one pair of periods to the next. This has the same equation as (2), but only one the years will have a time dummy value of 1. b) Adjacent 3 year periods - Completing a regression for three contiguous years, t, t-1 and t-2. In this case the coefficients of the regression are assumed to be constant for each pair of periods, but variable from one set of periods to the next. This has the same equation as (2), but with two of the three years having a time dummy value of 1.

5.6 Results

The empirical hedonic models were estimated for four specific datasets:

1. All ***diesel*** vehicles across six Member States from 1997 to 2010,

2. All ***petrol*** vehicles across six Member States from 1997 to 2010,

3. All ***diesel*** vehicles in the supermini and lower medium categories combined (vehicles with extreme power/weight ratios i.e. the highest and lowest 10% of the dataset were removed to show the effects for a similar size car with comparable performance over the time period).

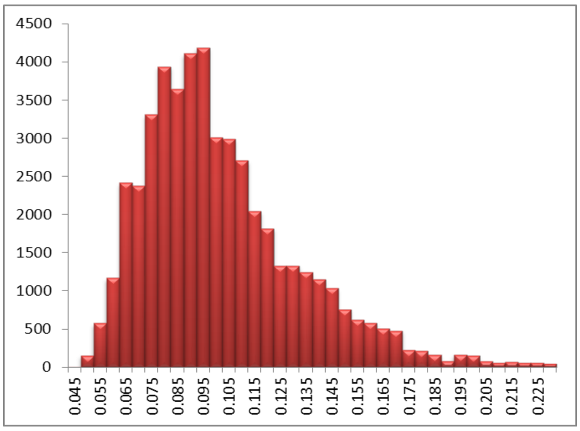
4. All ***petrol*** vehicles in the supermini and lower medium categories combined (vehicles with extreme power/weight ratios i.e. the highest and lowest 10% of the dataset were removed to show the effects for a similar size car with comparable performance over the time period),

In dataset 3 and 4, we are covering a more homogenous sample by removing the low power to weight ratio that occurred during the early years of the sample and the high power to weight ratios in the later part of the sample. As in the literature review section (

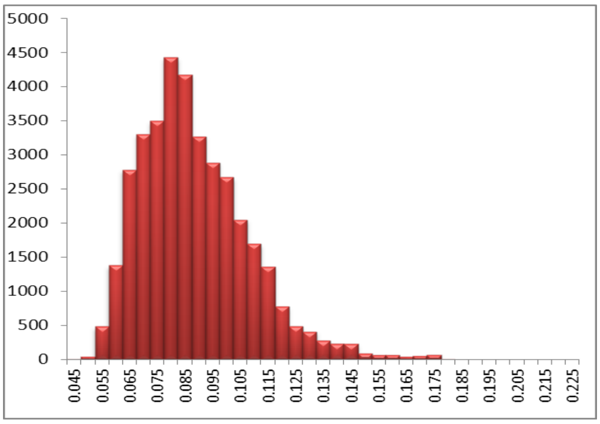
Figure 2-5**)**, the power/weight ratio of both diesel and petrol vehicles has been increasing over time. By selecting this restrictive sample we are able to avoid any premium brand or other related effects that might influence the relationship between specific attributes and price (Figure 5-1).

Figure 5-1: Histograms of vehicle power/weight ratios for all 4 datasets

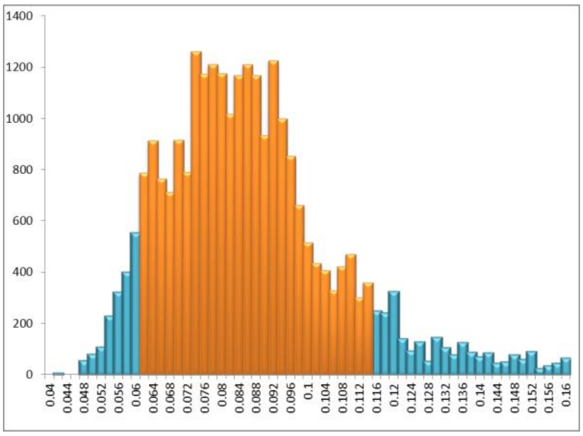
Dataset 1: Petrol - all size categories power/weight ratio



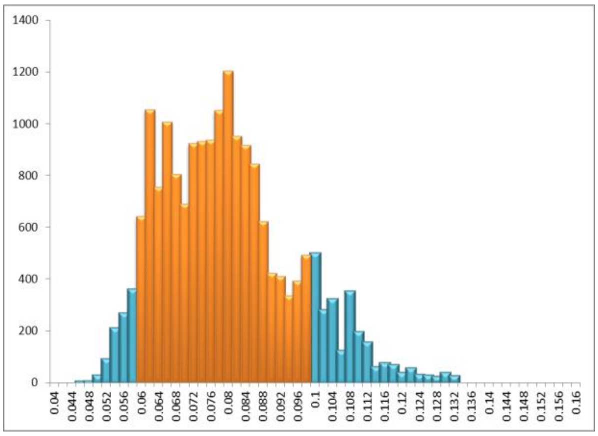
Dataset 2: Diesel - all size categories power/weight ratio



Dataset 3: Petrol – Supermini and Lower medium vehicles power/weight ratio (Blue bars represent the 10% extremes of the dataset which were removed from the regressions)



Dataset 4: Diesel – Supermini and Lower medium vehicles power/weight ratio (Blue bars represent the 10% extremes of the dataset which were removed from the regressions)



5.7 Dataset 1 - All diesel vehicles across six Member States

5.7.1 Model 1 findings

Model 1 is based on a semi-log regression equation, for diesel vehicles across six Member States.

R	R Squared	Adjusted R Squared	Standard error of the estimate
0.965960	0.933079	0.932966	0.00

R (0.97), the multiple correlation coefficient[143], shows a strong correlation between the observed and predicted values of the dependent variable, the ln(car price)[144].

R^2 (0.93), the coefficient of determination[145], is the squared value of the multiple correlation coefficient. It shows that about 93% of the variation in the ln(car prices) is explained by model 1. It is very difficult to lower the R^2 below 0.9 without removing nearly all of the attributes within the dataset. A higher value indicates a stronger relationship among the variables, with a value of one indicating that all data points fall exactly on a line in multidimensional space and a value of zero indicating no relationship at all between the independent variables collectively and the dependent variable.

Table 5-2 Analysis of variance for all diesel vehicles for model 1

	Sum of Squares	df	Mean Square	F	Sig.
Regression	4919.676	62	79.34962	8255.174	0.00
Residual	352.8412	36708	0.009612		

The significance value of the F statistic is less than 0.05 and highly significant. The null hypothesis that car price is not linearly related to all the explanatory variables can be rejected. The F statistic is the regression mean square (MSR) 79.349 divided by the residual mean square (MSE) 0.009612. The regression sum of squares (RSS)[146] 4919.676 is significantly larger than the error sum of squares (ESS)[147] 352.8412, indicating model 1 accounts for most of the variation in car prices (dependent variable).

The estimation results for the pooled regression model show a good fit. In addition, the estimated coefficients take the expected sign and are statistically significant.

The estimated coefficients for the dummy variables can be interpreted as the percentage increase in car price derived from the introduction of a new attribute.[148] The attributes indicated by binary data whether the feature exists or not (i.e. indicated by dummy variable), can be interpreted, for example, as (holding the rest of the characteristics constant):

- Those cars with ABS and stability control are 11.6% more expensive
- Those cars with luxury interior upholstery are 5.5% more expensive.
- Those cars with cruise control are 2% more expensive.
- Those cars with front fog lights are 2.7% more expensive.

[143] Multiple correlation coefficient is an estimate of the combined influence of two or more variables on the observed (dependent) variable.
[144] ln(car price) is the natural log of the car price, i.e using Log to the base of e, the exponential.
[145] Multiple correlation is a linear relationship among more than two variables. It is measured by the coefficient of multiple determination, denoted as R^2, which is a measure of the fit of a linear regression. A regression's R^2 falls somewhere between zero and one (assuming a constant term has been included in the regression).
[146] The regression (or explained) sum of squares (ESS) is a quantity used in describing how well a model, often a regression model, represents the data being modelled. In particular, the explained sum of squares measures how much variation there is in the modelled values and this is compared to the total sum of squares, which measures how much variation there is in the observed data, and to the residual sum of squares, which measures the variation in the modelling errors.
[147] The residual sum of squares (RSS) is the sum of squares of residuals. It is also known as the sum of squared residuals (SSR) or the sum of squared errors of prediction (SSE). It is a measure of the discrepancy between the data and an estimation model. A small RSS indicates a tight fit of the model to the data. In general, total sum of squares = regression (or explained) sum of squares + residual sum of squares.
[148] The formula used is to calculate % change in vehicle price as a result of parameter $\beta t = [\exp(\beta t) - 1] \times 100\%$

- Those cars in the year when the Euro 3 regulation was enforced were 3.3% more expensive (i.e. just for year 2000).
- Those cars in the year when the Euro 4 regulation was enforced were 0.6% more expensive (i.e. just for year 2005).
- Those cars in the year when the voluntary agreement was enforced were 2.8% cheaper (i.e. just for year 2008)
- Those cars in the year when the Euro 5 regulation was enforced were 1.8% more expensive (i.e. just for year 2009)

There are some caveats for using the Euro time dummies to capture the effect of environmental regulations on car prices. The time dummies can be influenced by many other factors in a particular year, such as exchange rates, interest rates, etc. In addition, cars will be under old and new standards in one particular year. However, since the JATO dataset does not have environmental parameters using Euro time dummies is an indicative way of showing the relationship between environmental regulation and car prices.

Table 5-3: Parameter Estimates for All diesel vehicles using Model 1

Parameter	Unstandardised Coefficients		Standardised Coefficients		Ln Car Price (t)	Ln Car Price (p)
	Ln Car Prices (Param.)	Ln Car Price (Std.Err)	Ln Car Price (Beta (ß))	Ln Car Price (St.Err.ß)		
Intercept	8.630	0.075			114.719	0.000
Year, 1997=1	-0.017	0.000	-0.148	0.004	-36.907	0.000
Shared Platform	0.013	0.002	0.013	0.002	7.394	0.000
Euro NCAP Rating	-0.016	0.001	-0.054	0.002	-27.590	0.000
Number of doors	0.005	0.001	0.012	0.002	6.576	0.000
Max. power (cv)	0.002	0.000	0.240	0.003	75.888	0.000
Kerb weight (kg)	0.0006	0.000	0.407	0.004	102.761	0.000
Overall Height (mm)	-0.0001	0.000	-0.023	0.002	-10.505	0.000
ABS	0.059	0.004	0.034	0.002	15.386	0.000
Passenger Airbag	0.071	0.070	0.001	0.001	1.020	0.308
Stability Control	0.052	0.002	0.067	0.002	32.872	0.000
Electronic brake distribution	-0.044	0.003	-0.035	0.003	-12.887	0.000
Combined fuel consumption (l/100km)	0.028	0.001	0.086	0.004	23.305	0.000
Driven wheels	-0.016	0.001	-0.030	0.002	-16.447	0.000
Automatic?	0.008	0.002	0.007	0.002	4.004	0.000
Side airbag	0.016	0.002	0.014	0.002	7.457	0.000
Luxury Interior upholstery	0.054	0.002	0.045	0.002	28.566	0.000
Cruise Control	0.020	0.001	0.025	0.002	14.323	0.000
Electric front seats	0.047	0.002	0.049	0.002	28.070	0.000
Alarm	-0.014	0.002	-0.014	0.002	-8.240	0.000
Immobiliser	0.100	0.024	0.006	0.001	4.222	0.000
Electric front windows	0.020	0.006	0.005	0.001	3.493	0.000
Electric windows front and rear binary	0.024	0.002	0.030	0.002	15.040	0.000

Parameter	Unstandardised Coefficients		Standardised Coefficients		Ln Car Price (t)	Ln Car Price (p)
	Ln Car Prices (Param.)	Ln Car Price (Std.Err)	Ln Car Price (Beta (ß))	Ln Car Price (St.Err.ß)		
Central door locking operation	0.022	0.002	0.019	0.002	11.204	0.000
Fog Lights	0.027	0.001	0.035	0.002	18.655	0.000
Alloy Wheels	0.037	0.001	0.047	0.002	25.340	0.000
Power assisted steering	0.059	0.012	0.009	0.002	4.977	0.000
Air-conditioning	0.077	0.002	0.079	0.002	45.159	0.000
On-board computer	0.011	0.002	0.014	0.002	6.981	0.000
Sat-Nav Binary	0.045	0.003	0.025	0.002	16.832	0.000
Convertible	0.074	0.005	0.021	0.002	13.865	0.000
Euro 3 Announcement Effect (A_y)	-0.010	0.003	-0.005	0.002	-2.874	0.004
Euro 3	0.033	0.003	0.017	0.002	11.368	0.000
Euro 4 Announcement Effect	0.010	0.002	0.012	0.003	4.229	0.000
Euro 4	0.006	0.002	0.004	0.002	2.396	0.017
Voluntary Agreement Announcement Effect	0.018	0.003	0.023	0.003	7.142	0.000
Voluntary Agreement	-0.028	0.003	-0.031	0.004	-8.790	0.000
Euro 5 Announcement	0.015	0.002	0.017	0.003	6.626	0.000
Euro 5	0.018	0.003	0.015	0.003	5.704	0.000
Audi	0.128	0.002	0.104	0.002	51.177	0.000
Mercedes	0.115	0.004	0.049	0.002	32.003	0.000
Ford	-0.059	0.002	-0.046	0.002	-27.845	0.000
BMW	0.126	0.003	0.076	0.002	40.614	0.000
Opel	-0.088	0.002	-0.074	0.002	-41.506	0.000
Vauxhall	-0.054	0.003	-0.038	0.002	-20.763	0.000
Fiat	-0.129	0.004	-0.046	0.002	-29.718	0.000
Citroen	-0.120	0.004	-0.045	0.002	-28.349	0.000
Renault	-0.138	0.003	-0.070	0.002	-41.832	0.000
Peugeot	-0.154	0.004	-0.053	0.002	-35.118	0.000
Saab	-0.051	0.007	-0.011	0.001	-7.825	0.000
Hyundai	-0.298	0.008	-0.055	0.001	-39.207	0.000
Toyota	-0.100	0.006	-0.025	0.001	-17.337	0.000
Skoda	-0.159	0.003	-0.103	0.002	-59.431	0.000
Volvo	-0.036	0.004	-0.014	0.002	-9.109	0.000
Alfa Romeo	-0.019	0.005	-0.006	0.002	-4.092	0.000
Suzuki	-0.052	0.009	-0.008	0.001	-5.656	0.000
Jaguar	-0.062	0.014	-0.006	0.001	-4.535	0.000
Lancia	-0.072	0.009	-0.011	0.001	-8.046	0.000
Land Rover	-0.381	0.014	-0.040	0.001	-27.952	0.000
Seat	-0.191	0.006	-0.049	0.001	-33.820	0.000
Smart	0.227	0.019	0.022	0.002	12.243	0.000
Kia	-0.309	0.007	-0.070	0.002	-45.162	0.000
Mini	-0.002	0.020	0.000	0.001	-0.124	0.901

Note: 1997 is the default year and VW is the default brand. The shading shows the significance of the coefficients with dark green showing the strongest but negatively related coefficients and dark red showing the strongest but positively related coefficients to car prices.

For attributes with actual performance data, an absolute change in the attribute can be associated with a relative change in price. The regression analysis shows that a unit increase in fuel consumption (l/100 km) relates to a 2.8 per cent increase in average car prices. A one kg increase in kerb weight can be associated with a 0.06% increase in price. A one CV increase in maximum power is associated with a 0.2% increase in price.

5.7.2 Model 2 findings

Model 2 is based on a semi-log regression equation, for diesel vehicles across six Member States.

R	R Squared	Adjusted R Squared	Standard error of the estimate
0.96	0.92	0.93	0.002835

R (0.96), the multiple correlation coefficient, shows a strong correlation between the observed and predicted values of the dependent variable, the ln(car price).

R^2 (0.92), the coefficient of determination, is the squared value of the multiple correlation coefficient. It shows that about 92% of the variation in ln(car prices) is explained by model 1.

Table 5-4: Analysis of variance of all diesel vehicles using model 2

	Sum of Squares	df	Mean Square	F	Sig.
Regression	4900.651	67	73.14405	7219.276	0.00
Residual	371.8664	36703	0.010132		

The significance value of the F statistic is less than 0.05 and highly significant. The null hypothesis that car price is not linearly related to all the explanatory variables can be rejected. The F statistic is the regression mean square (MSR) divided by the residual mean square (MSE). The regression sum of squares (RSS) is significantly larger than the error sum of squares (ESS), indicating model 1 accounts for most of the variation in car prices (dependent variable).

The estimation results for the pooled regression model, presented in Table 5-5 below, show a good fit. In addition, the estimated coefficients take the expected sign and are statistically significant.

The estimated coefficients for the dummy variables can be interpreted as the percentage increase in car price derived from the introduction of a new attribute. The attributes indicated by binary data whether the feature exists or not (i.e. indicated by dummy variable), can be interpreted, for example, as:

- those cars with ABS and stability control are 5.1% more expensive, holding the rest of the characteristics constant;

- those cars with luxury interior upholstery are 6.2% more expensive, holding the rest of the characteristics constant;
- those cars with cruise control are 1.4% more expensive, holding the rest of the characteristics constant; and
- those cars with front fog lights are 3% more expensive, holding the rest of the characteristics constant.

For attributes with actual performance data, an absolute change in the attribute can be associated with a relative change in price. In Table 5-5, the regression analysis shows that a unit increase in fuel consumption (l/100 km) relates to a 3.8 per cent increase in average car prices. Increase in length by 10cm can be associated with a 3% increase in price. A unit increase in engine max. power (cv) can be associated with a 0.3% increase in price.

Table 5-5: Parameter estimates of all diesel vehicles using Model 2

	Unstandardised Coefficients		Standardised Coefficients			
Parameter	Ln Car Prices (Param.)	Ln Car Price (Std.Err)	Ln Car Price (Beta (ß))	Ln Car Price (St.Err.ß)	Ln Car Price (t)	Ln Car Price (p)
Intercept	7.134	0.072			98.707	0
Shared Platform	0.029	0.002	0.028	0.002	16.8	0
Euro NCAP Rating	-0.015	0.001	-0.052	0.002	-27.631	0
Number of doors	0.008	0.001	0.018	0.002	10.555	0
Overall Length (mm)	0.0003	0.000	0.314	0.003	122.886	0
Overall Height (mm)	0.0004	0.000	0.083	0.002	43.789	0
Max. power (cv)	0.003	0.000	0.291	0.003	101.249	0
ABS	0.052	0.004	0.03	0.002	14.065	0
Passenger Airbag	0.102	0.066	0.002	0.001	1.533	0.125
Stability Control	0.051	0.002	0.066	0.002	33.957	0
Electronic brake distribution	-0.033	0.003	-0.026	0.003	-9.857	0
Combined fuel consumption (l/100km)	0.038	0.001	0.117	0.003	34.536	0
Driven wheels	0.013	0.001	0.023	0.002	13.338	0
Automatic transmission	0.018	0.002	0.017	0.002	9.905	0
Side airbag	0.013	0.002	0.012	0.002	6.569	0
Luxury interior upholstery	0.06	0.002	0.05	0.002	33.051	0
Cruise Control	0.014	0.001	0.018	0.002	11.013	0
Electric front seats	0.02	0.002	0.021	0.002	12.119	0
Alarm	-0.017	0.002	-0.018	0.002	-10.752	0
Immobiliser	0.037	0.023	0.002	0.001	1.649	0.099
Electric front windows	0.022	0.005	0.006	0.001	4.177	0
Electric windows front and rear binary	0.004	0.002	0.004	0.002	2.321	0.02

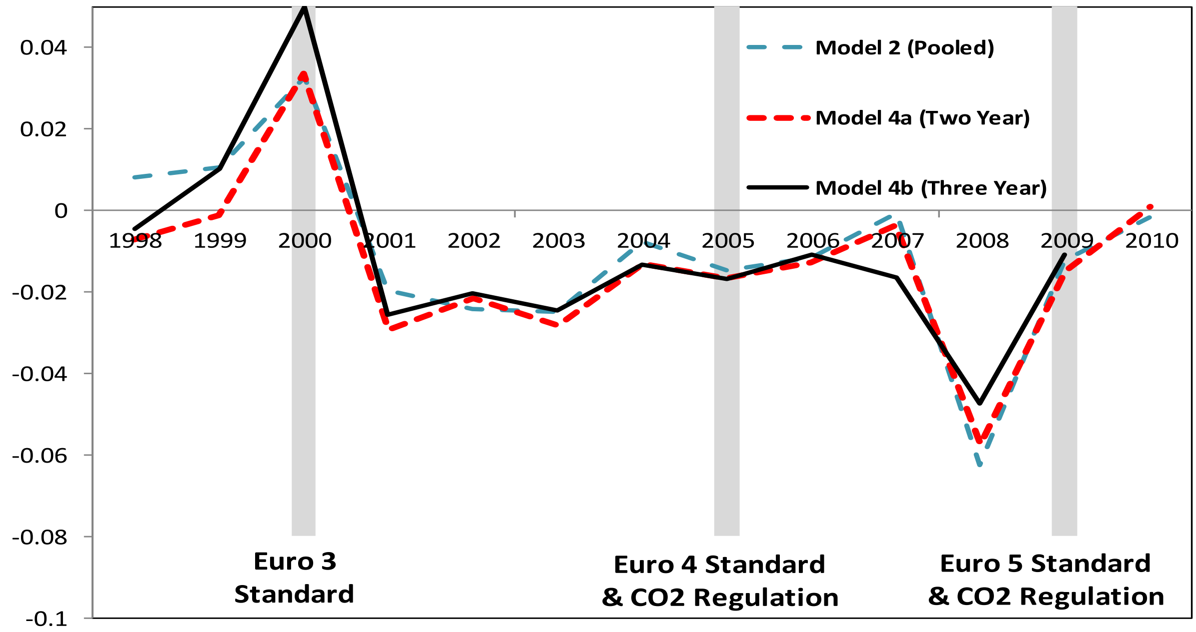
	Unstandardised Coefficients		Standardised Coefficients			
Parameter	Ln Car Prices (Param.)	Ln Car Price (Std.Err)	Ln Car Price (Beta (ß))	Ln Car Price (St.Err.ß)	Ln Car Price (t)	Ln Car Price (p)
Central door locking operation	0.023	0.002	0.02	0.002	12.449	0
Fog Lights	0.031	0.001	0.039	0.002	22.189	0
Alloy Wheels	0.048	0.001	0.061	0.002	34.053	0
Power assisted steering	0.072	0.011	0.011	0.002	6.407	0
Air-conditioning	0.056	0.002	0.058	0.002	34.08	0
On-board computer	0.018	0.001	0.023	0.002	12.268	0
Sat-Nav Binary	0.05	0.003	0.028	0.001	19.677	0
Convertible	0.204	0.005	0.059	0.001	40.479	0
1998	0.006	0.005	0.002	0.002	1.076	0.282
1999	0.011	0.005	0.004	0.002	2.067	0.039
2000	0.034	0.005	0.018	0.003	6.597	0
2001	0.004	0.005	0.002	0.003	0.82	0.412
2002	-0.022	0.005	-0.013	0.003	-4.112	0
2003	-0.054	0.005	-0.037	0.004	-10.315	0
2004	-0.075	0.005	-0.055	0.004	-13.95	0
2005	-0.099	0.005	-0.076	0.004	-18.107	0
2006	-0.119	0.006	-0.094	0.004	-21.538	0
2007	-0.124	0.006	-0.101	0.005	-22.216	0
2008	-0.187	0.006	-0.157	0.005	-33.189	0
2009	-0.201	0.006	-0.167	0.005	-34.875	0
2010	-0.203	0.006	-0.172	0.005	-34.484	0
Audi	0.15	0.002	0.121	0.002	63.608	0
Mercedes	0.19	0.003	0.081	0.001	54.695	0
Ford	-0.063	0.002	-0.049	0.002	-31.124	0
BMW	0.179	0.003	0.108	0.002	61.298	0
Opel	-0.058	0.002	-0.049	0.002	-29.073	0
Vauxhall	-0.06	0.002	-0.042	0.002	-24.075	0
Fiat	-0.145	0.004	-0.051	0.001	-35.155	0
Citroen	-0.163	0.004	-0.062	0.001	-41.103	0
Renault	-0.127	0.003	-0.064	0.002	-40.198	0
Peugeot	-0.121	0.004	-0.042	0.001	-28.963	0
Saab	-0.005	0.006	-0.001	0.001	-0.737	0.461
Hyundai	-0.267	0.007	-0.05	0.001	-36.882	0
Toyota	-0.036	0.006	-0.009	0.001	-6.42	0
Skoda	-0.184	0.003	-0.118	0.002	-71.683	0
Volvo	-0.005	0.004	-0.002	0.001	-1.193	0.233

	Unstandardised Coefficients		Standardised Coefficients			
Parameter	Ln Car Prices (Param.)	Ln Car Price (Std.Err)	Ln Car Price (Beta (ß))	Ln Car Price (St.Err.ß)	Ln Car Price (t)	Ln Car Price (p)
Alfa Romeo	-0.003	0.004	-0.001	0.001	-0.595	0.552
Suzuki	-0.074	0.009	-0.011	0.001	-8.491	0
Jaguar	-0.057	0.013	-0.006	0.001	-4.425	0
Lancia	-0.062	0.009	-0.01	0.001	-7.317	0
Land Rover	-0.147	0.013	-0.015	0.001	-11.43	0
Seat	-0.171	0.005	-0.044	0.001	-31.806	0
Smart	0.365	0.018	0.036	0.002	20.478	0
Kia	-0.269	0.007	-0.061	0.001	-41.221	0
Mini	0.129	0.019	0.009	0.001	6.716	0

Note: 1997 is the default year and VW is the default brand. The shading shows the significance of the coefficients with dark green showing the strongest but negatively related coefficients and dark red showing the strongest but positively related coefficients to car prices.

In the semi-log formulation, the coefficient for the time dummy variables reveals the variation in the log of the price adjusted by quality or technological change. The technological change effect is indicated by the coefficient β_t in the hedonic equation (1) above. We notice that the values of period intercepts fall over time, as expected, reflecting a decline in performance-corrected prices due to technological change. This suggests that technological progress allows the same bundle of attributes to be produced at a lower cost and bought at a lower price. For example, in 2010, the year intercept is roughly 10 times lower than it was in 2002. The time trend for the coefficients for the time dummy variables for three alternative specifications is given in Figure 5-2.

Figure 5-2: Coefficients estimates for time dummy variables for three alternative specifications (all diesel vehicles)



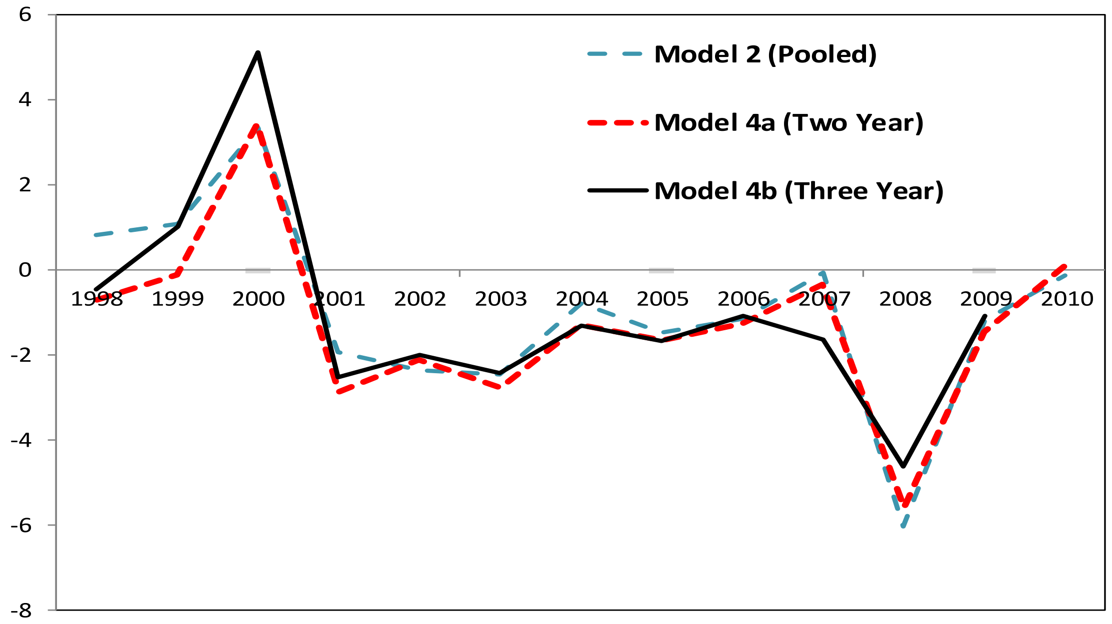
In order to interpret brand effects, it should be noted that the reference brand is VW. The significance of the estimated coefficients shows that there is a brand-quality effect over and above the included car attributes. BMW and Mercedes cars appear as the most expensive brand, once the characteristics have been controlled for. It appears that significant price premiums were being charged by these manufacturers. These premiums are charged over performance-adjusted prices and therefore can be interpreted as implicit price discrimination schemes that exploit differences among car segments.

The time variable 't' can also be used to calculate the technology (quality/features) adjusted price index,(i.e. the price increase or decrease compared with the previous year when technology-related shifts are excluded). In a logarithmic function the technology adjusted percentage of price change over the previous year is calculated from the coefficients of the time dummy variables based on the formula: Technology (Quality) adjusted price change = [exp (β_t) – 1] x100 (Figure 5-3). The index demonstrates variations in year on year changes.

Although the marginal prices for characteristics differ substantially depending on the methodology employed, the rate of variation of the technology (quality) adjusted price index is very similar for all three alternative formulations. The reason for this apparent paradox is that the multicollinearity and the reduced degrees of freedom distort the yearly regression coefficients. However, when adding up the contributions of all explanatory variables, the differences cancel out, so that the behaviour of quality adjusted prices is very similar, irrespective of the formulation employed to estimate the characteristics.

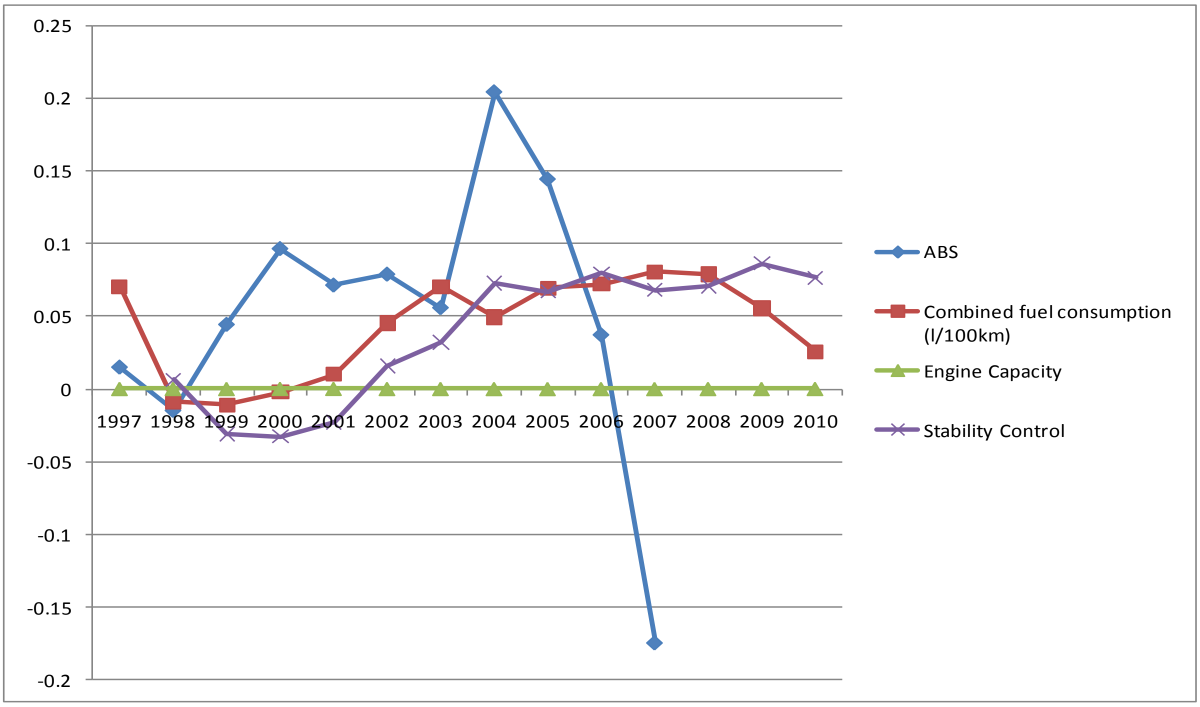
The year on year changes in Figure 5-3 can partially be ascribed to annual fluctuations, but may also reflect specific impacts such as business cycles and trends in fuel prices. The steep fall in prices in 2000 and sustained low prices are mainly due to due to both increasing tax rates on transport fuels and, more recently, rising world crude oil prices. The economic recession in 2008-2009 had an impact on vehicle prices, with the pound devaluation causing vehicles sold in the UK to be worth around 20% less in Euro terms than before the crisis. Another likely effect of the economic recession is a decrease in vehicle prices as a result of a decrease in consumer demand due to the tighter credit conditions and economic uncertainty.

Figure 5-3: Technology adjusted price change (%) (all diesel vehicles)



The estimated coefficients in the single year regressions varied considerably for some variables from one year to another, and showed more systematic behaviour for others. (Figure 5-4)

Figure 5-4: Estimated coefficients for selected attributes (Model 3) (all diesel vehicles)



However, the estimations using order 2 and 3 year moving samples smoothed out the changes in the estimated coefficients. To illustrate this, in Figure 5-5 we plotted the estimated coefficients from three alternative model specifications for three car attributes: fuel consumption, kerb weight and car length. The coefficients also show the trend in magnitude and significance of car attributes for explaining the variation in car prices. The main observations are:

- Model 1 and 2 provided average coefficient estimates for the variation in price explained by the variation in fuel consumption. However the annual coefficient estimates shows that a unit increase in fuel consumption (l/100 km) was associated with a:

    - negative impact on car prices in 1998 and 1999,
    - 7% increase in average car prices in 2007, and
    - 3% increase in average car prices in 2010.

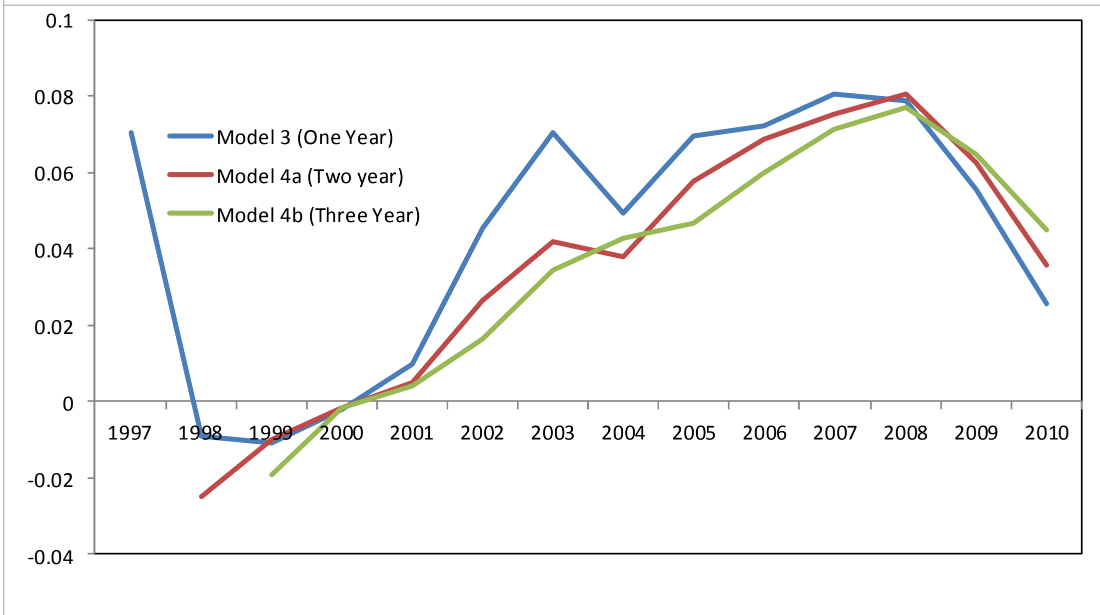
  This indicates that increase in fuel consumption led to greater price premium for all diesel vehicles across the six Member States between 1999 and 2007 and then the price penalty started to fall again. This makes sense as larger, heavier and better performance cars will have higher prices and will in general use more fuel. However, the increase in price premium could be due to higher specifications of cars that consume more fuel and possible brand effects. Hence, to understand the link between fuel consumption and price one essentially needs to look at a narrow band of the data to show the effects for a similar size car with comparable performance over the time period. Section 5.7 looks at a supermini and lower medium size category thus capturing a small sample of certain vehicle size and engine power.

- Per unit increase in weight was associated with a 0.01% increase in price in 2001-2002. After which weight of the car slowly started to account for a larger share of price increase over the whole period (0.05% in 2010).

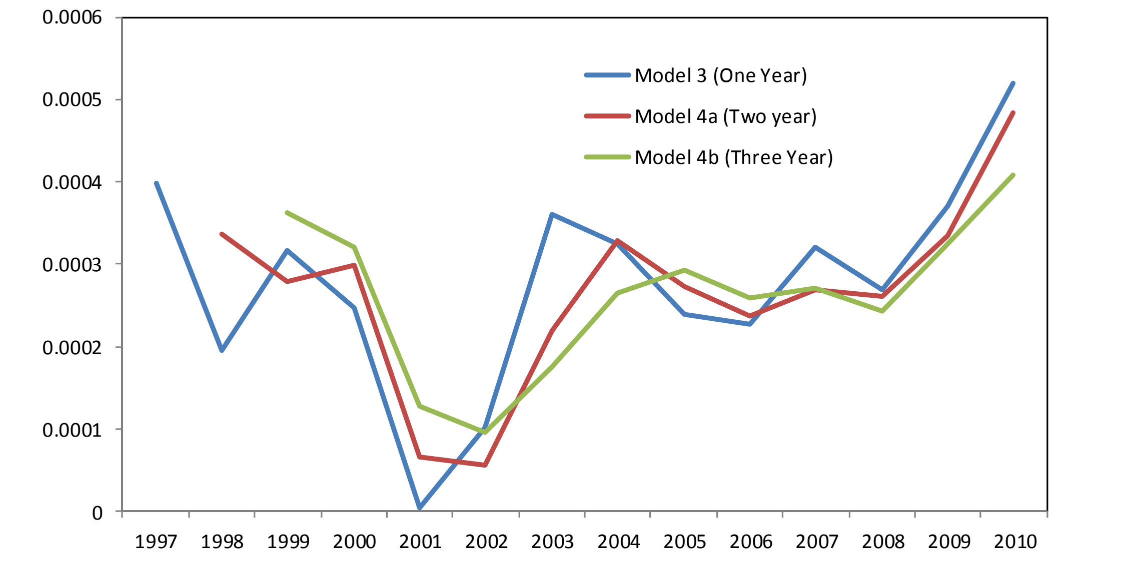
- The significance of length in explaining car prices has been declining over time. In 2000, a 10 cam increase in the length of the car was associated with around 3-3.5% increase in price. This association fell to around 1.5-2% in 2010.

Figure 5-5: Estimated coefficients for three alternative regressions specifications (all diesel vehicles)

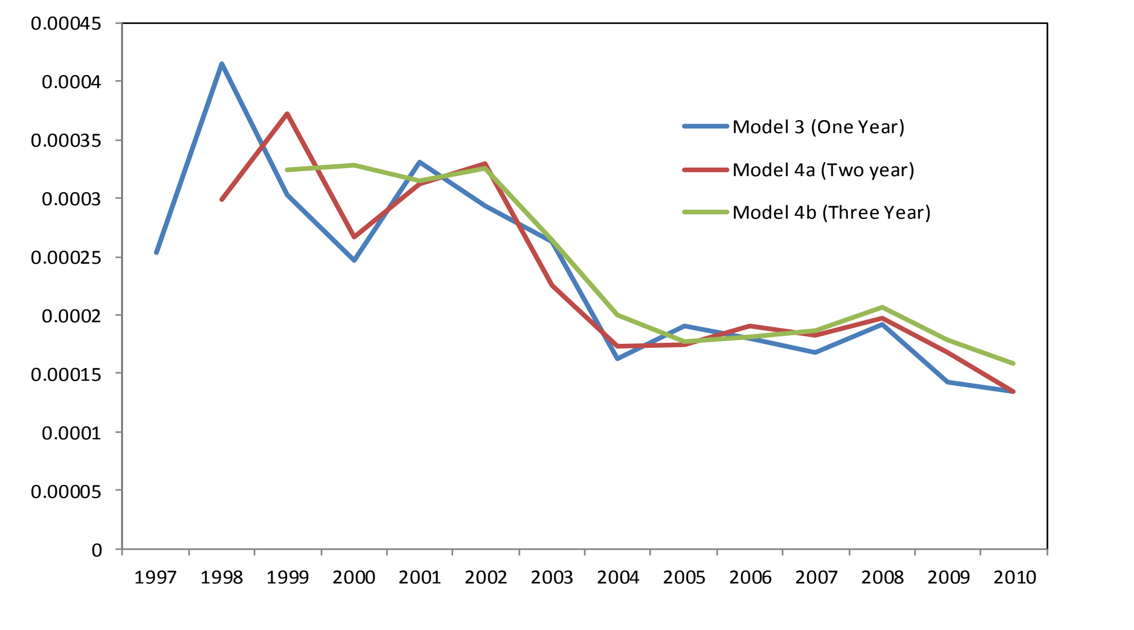
a) Parameter estimate - Combined fuel consumption (l/100km)



b) Parameter estimate – kerb weight (kg)



Parameter estimate - Overall Length for 3 different regression techniques



5.8 Dataset 2 - All petrol vehicles across six Member States

5.8.1 Model 1 findings

Model 1 is based on a semi-log regression equation, for petrol vehicles across six Member States.

R	R Squared	Adjusted R Squared	Standard error of the estimate
0.97	0.95	0.95	0.00

R (0.97), the multiple correlation coefficient, shows a strong correlation between the observed and predicted values of the dependent variable, ln (car prices).

R^2 (0.95), the coefficient of determination, is the squared value of the multiple correlation coefficient. It shows that about 95% of the variation in ln (car prices) is explained by model 1.

Table 5-6: Analysis of variance of petrol vehicles subset using model 1

	Sum of Squares	df	Mean Square	F	Sig.
Regression	12401.1	66	187.9	14105	0.00
Residual	653.1	49028	0.013		

The significance value of the F statistic is less than 0.05 and highly significant. The null hypothesis that car price is not linearly related to all the explanatory variables can be rejected. The F statistic is the regression mean square (MSR) divided by the residual mean square (MSE). The regression sum of squares (RSS) is significantly larger than the error sum of squares (ESS), indicating model 1 accounts for most of the variation in ln (car prices).

The estimation results for the pooled regression model show a good fit. In addition, the estimated coefficients take the expected sign and are statistically significant.

The estimated coefficients for the dummy variables can be interpreted as the percentage increase in car price derived from the introduction of a new attribute. The attributes indicated by binary data whether the feature exists or not (i.e. indicated by dummy variable), can be interpreted, for example, as (holding the rest of the characteristics constant):

- Those cars with ABS and stability control are 3.6% more expensive.
- Those cars with luxury interior upholstery are 5.7% more expensive.
- Those cars with cruise control are 1.7% more expensive.
- Those cars with front fog lights are 3.3% more expensive.
- Those cars in the year when the Euro 3 regulation was enforced were 6.4% more expensive (i.e. just for year 2000)
- Those cars in the year when the Euro 4 regulation was enforced were -3.4% more expensive (i.e. just for year 2005)
- Those cars in the year when the Euro 5 regulation was enforced were 2.8% more expensive (i.e. just for year 2009)

Table 5-7: Parameter estimates of all petrol vehicles using model 1

Parameter	Unstandardised Coefficients		Standardised coefficients			
	Ln (Price) (Param.)	Ln (Price) (Std.Err)	Ln (Price) (Beta (ß))	Ln (Price) (St.Err.ß)	Ln (Price) (t)	Ln (Price) (p)
Intercept	8.73171	0.03227			270.595	0.0000
Shared Platform	0.02178	0.00217	0.01228	0.00122	10.034	0.0000
Euro NCAP Rating	-0.02457	0.00049	-0.07504	0.00149	-50.393	0.0000
Number of doors	0.00672	0.00077	0.01226	0.00141	8.713	0.0000
Max. power (cv)	0.00164	0.00002	0.22425	0.00273	82.011	0.0000
Kerb weight (kg)	0.00070	0.00001	0.35472	0.00320	110.977	0.0000
Overall Height (mm)	-0.00033	0.00001	-0.04647	0.00144	-32.333	0.0000
ABS	0.03635	0.00287	0.02006	0.00158	12.672	0.0000
Driver Airbag	0.22037	0.02877	0.00862	0.00113	7.661	0.0000
Passenger Airbag	-0.11309	0.01048	-0.01315	0.00122	-10.792	0.0000
Stability Control	0.04068	0.00170	0.03881	0.00162	23.931	0.0000
Electronic brake distribution	-0.07309	0.00245	-0.05555	0.00187	-29.775	0.0000
Combined fuel consumption (l/100km)	0.03406	0.00082	0.11717	0.00283	41.378	0.0000
Driven wheels	-0.02599	0.00112	-0.03313	0.00142	-23.287	0.0000
Automatic?	0.03644	0.00153	0.02885	0.00121	23.772	0.0000
Side airbag	0.01316	0.00189	0.01047	0.00150	6.970	0.0000
Luxury interior upholstery	0.05706	0.00189	0.03736	0.00124	30.213	0.0000
Cruise Control	0.01684	0.00152	0.01489	0.00135	11.059	0.0000
Electric front seats	0.04148	0.00182	0.03081	0.00135	22.845	0.0000
Alarm	0.01119	0.00172	0.00844	0.00130	6.503	0.0000
Immobiliser	-0.03366	0.01224	-0.00291	0.00106	-2.751	0.0059
Electric front windows	0.01923	0.00440	0.00485	0.00111	4.370	0.0000
Electric windows front and rear binary	0.03140	0.00161	0.02975	0.00152	19.532	0.0000
Central door locking operation	0.01330	0.00177	0.00944	0.00126	7.512	0.0000
Fog Lights	0.03343	0.00148	0.03151	0.00139	22.657	0.0000
Alloy Wheels	0.03989	0.00153	0.03737	0.00144	26.042	0.0000
Power assisted steering	0.12188	0.00524	0.02942	0.00126	23.268	0.0000
Air-conditioning	0.06581	0.00160	0.05432	0.00132	41.152	0.0000
On-board computer	0.00689	0.00158	0.00651	0.00149	4.364	0.0000
Sat-nav Binary	0.04034	0.00297	0.01591	0.00117	13.570	0.0000
Convertible	0.09443	0.00355	0.03375	0.00127	26.571	0.0000
Side impact bars	0.03691	0.02117	0.00192	0.00110	1.744	0.0812

Parameter	Unstandardised Coefficients		Standardised coefficients			
	Ln (Price) (Param.)	Ln (Price) (Std.Err)	Ln (Price) (Beta (ß))	Ln (Price) (St.Err.ß)	Ln (Price) (t)	Ln (Price) (p)
Euro 3 Announcement effect	0.00166	0.00256	0.00084	0.00129	0.651	0.5150
Euro 3	0.06427	0.00248	0.02842	0.00110	25.914	0.0000
Euro 4 Announcement effect	0.03842	0.00206	0.03724	0.00200	18.624	0.0000
Euro 4	-0.03387	0.00205	-0.01863	0.00113	-16.537	0.0000
Euro 5 Announcement effect	-0.05971	0.00247	-0.04435	0.00183	-24.191	0.0000
Euro 5	0.02793	0.00341	0.01537	0.00188	8.189	0.0000
Voluntary Agreement Announcement	0.03855	0.00239	0.03067	0.00190	16.146	0.0000
CO_2 Regulation Announcement	-0.00286	0.00245	-0.00246	0.00210	-1.168	0.2427
Audi	0.14079	0.00260	0.08146	0.00151	54.110	0.0000
Mercedes	0.15409	0.00339	0.05686	0.00125	45.517	0.0000
Ford	-0.07532	0.00223	-0.04322	0.00128	-33.758	0.0000
Porsche	0.60438	0.00889	0.07934	0.00117	67.989	0.0000
BMW	0.17941	0.00297	0.09011	0.00149	60.374	0.0000
Opel	-0.06799	0.00227	-0.04215	0.00141	-29.981	0.0000
Vauxhall	-0.04265	0.00259	-0.02331	0.00142	-16.438	0.0000
Fiat	-0.14726	0.00442	-0.03932	0.00118	-33.332	0.0000
Citroen	-0.16806	0.00436	-0.04602	0.00119	-38.550	0.0000
Renault	-0.17506	0.00340	-0.06500	0.00126	-51.498	0.0000
Peugeot	-0.18472	0.00378	-0.05799	0.00119	-48.827	0.0000
Saab	-0.04773	0.00505	-0.01055	0.00112	-9.457	0.0000
Hyundai	-0.26819	0.00554	-0.05729	0.00118	-48.390	0.0000
Toyota	-0.08293	0.00431	-0.02181	0.00113	-19.229	0.0000
Skoda	-0.22424	0.00287	-0.10079	0.00129	-78.252	0.0000
Volvo	-0.08616	0.00382	-0.02613	0.00116	-22.567	0.0000
Alfa Romeo	-0.06549	0.00498	-0.01521	0.00116	-13.143	0.0000
Suzuki	-0.09284	0.00736	-0.01341	0.00106	-12.611	0.0000
Chevrolet	-0.47387	0.00498	-0.11182	0.00117	-95.236	0.0000
Jaguar	-0.07399	0.01105	-0.00703	0.00105	-6.699	0.0000
Lancia	-0.06520	0.00755	-0.00926	0.00107	-8.633	0.0000
Lexus	0.06050	0.01204	0.00526	0.00105	5.026	0.0000
Land Rover	-0.45416	0.02847	-0.01639	0.00103	-15.953	0.0000
Seat	-0.26730	0.00626	-0.04619	0.00108	-42.731	0.0000
Smart	0.32784	0.01258	0.03100	0.00119	26.070	0.0000

Parameter	Unstandardised Coefficients		Standardised coefficients			
	Ln (Price) (Param.)	Ln (Price) (Std.Err)	Ln (Price) (Beta (ß))	Ln (Price) (St.Err.ß)	Ln (Price) (t)	Ln (Price) (p)
Kia	-0.36308	0.00667	-0.06057	0.00111	-54.451	0.0000
Mini	-0.02827	0.01137	-0.00257	0.00103	-2.487	0.0129

Note: 1997 is the default year and VW is the default brand. The shading shows the significance of the coefficients with dark green showing the strongest but negatively related coefficients and dark red showing the strongest but positively related coefficients to car prices.

5.8.2 Model 2 findings

Model 2 is based on a semi-log regression equation, for petrol vehicles across six Member States.

R	R Squared	Adjusted R Squared	Standard error of the estimate
0.97	0.95	0.95	0.002835

R (0.97), the multiple correlation coefficient, shows a strong correlation between the observed and predicted values of the dependent variable (car sale price).

R^2 (0.95), the coefficient of determination, is the squared value of the multiple correlation coefficient. It shows that about 95% of the variation in car prices is explained by model 2.

Table 5-8: Analysis of variance of petrol vehicles subset using model 2

	Sum of Squares	df	Mean Square	F	Sig.
Regression	12430.75	60	73.14405	7219.276	0.00
Residual	623.4344	49034	0.012714		

The significance value of the F statistic is less than 0.05 and highly significant. The null hypothesis that car price is not linearly related to all the explanatory variables can be rejected. The F statistic is the regression mean square (MSR) divided by the residual mean square (MSE). The regression sum of squares (RSS) is significantly larger than the error sum of squares (ESS), indicating model 2 accounts for most of the variation in car prices (dependent variable).

The estimation results for the pooled regression model, presented in Table 5-9 below, show a good fit. In addition, the estimated coefficients take the expected sign and are statistically significant.

The estimated coefficients for the dummy variables can be interpreted as the percentage increase in car price derived from the introduction of a new attribute. For instance, those cars with luxury interior upholstery and stability control are 7.2% and 6.2% more expensive respectively, holding the rest of the characteristics constant. In order to interpret brand effects, it should be noted that the reference brand is VW. The significance of the estimated coefficients shows that there is a brand-quality effect over and above the included car attributes. Porsche, BMW and Mercedes cars appear as the most expensive brand, once the characteristics have been controlled for.

Table 5-9: Parameter estimates of all petrol vehicles using model 2

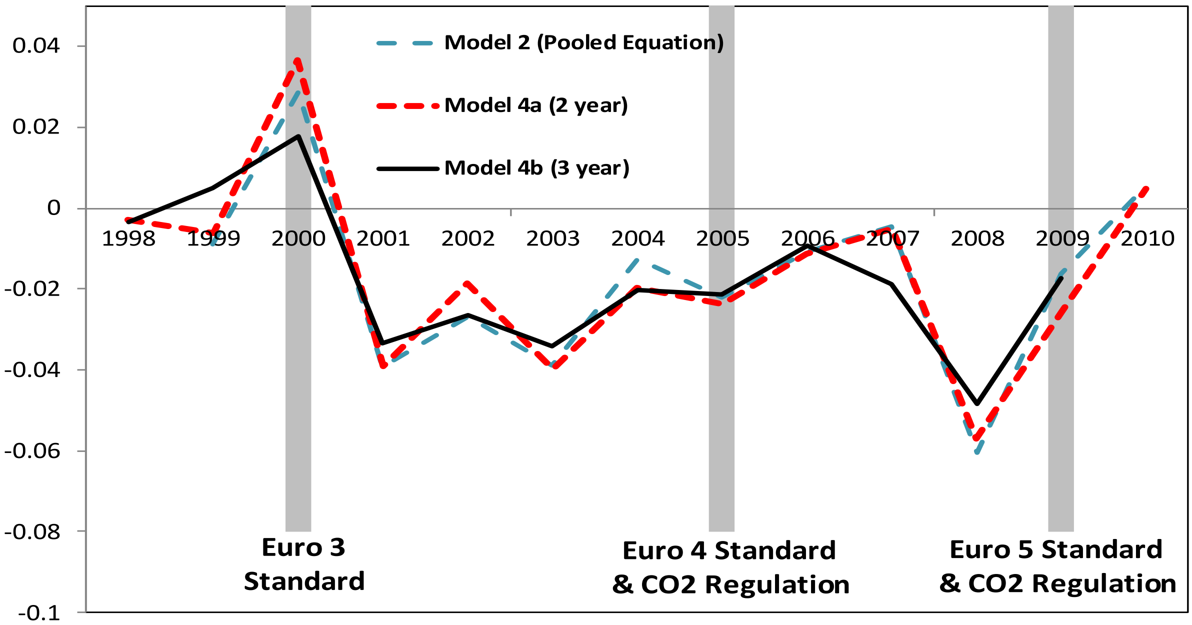
	Unstandardised Coefficients		Standardised coefficients			
Parameter	ln car prices (Param.)	ln car prices (Std.Err)	ln car prices (Beta (ß))	ln car prices (St.Err.ß)	ln car prices (t)	ln car prices (p)
Intercept	7.0793	0.0360			196.68	0.0000
Shared Platform	0.0056	0.0021	0.0012	0.0009	2.7214	0.0065
Euro NCAP Rating	-0.0166	0.0005	0.0014	-0.0535	-36.40	0.0000
Number of doors	0.0098	0.0007	0.0013	0.0154	14.188	0.0000
Max. power (cv)	0.0023	0.0000	0.0026	0.3120	121.11	0.0000
Kerb weight (kg)	0.0002	0.0000	0.0041	0.0944	25.125	0.0000
Overall Length (mm)	0.0002	0.0000	0.0029	0.1738	62.196	0.0000
Overall Width (mm)	0.0005	0.0000	0.0026	0.0687	28.847	0.0000
Overall Height (mm)	0.0001	0.0000	0.0015	0.0051	5.4092	0.0000
ABS	0.0173	0.0026	0.0014	0.0067	6.6462	0.0000
Driver Airbag	0.1029	0.0258	0.0010	0.0021	3.9942	0.0001
Passenger Airbag	-0.0767	0.0094	0.0011	-0.0111	-8.150	0.0000
Stability Control	0.0549	0.0016	0.0015	0.0494	35.279	0.0000
Electronic brake distribution	-0.0146	0.0024	0.0018	-0.0147	-6.111	0.0000
Combined fuel consumption (l/100km)	0.0104	0.0008	0.0028	0.0301	12.658	0.0000
Driven wheels	0.0108	0.0011	0.0013	0.0111	10.231	0.0000
Automatic?	0.0612	0.0014	0.0011	0.0463	43.873	0.0000
Side airbag	0.0104	0.0017	0.0013	0.0057	6.1625	0.0000
Luxury interior upholstery	0.0615	0.0017	0.0011	0.0381	36.268	0.0000
Cruise Control	0.0163	0.0014	0.0012	0.0120	11.864	0.0000
Electric front seats	0.0192	0.0017	0.0012	0.0118	11.596	0.0000
Alarm	0.0035	0.0015	0.0012	0.0004	2.2900	0.0220
Immobiliser	0.0421	0.0110	0.0010	0.0018	3.8132	0.0001
Electric front windows	0.0243	0.0039	0.0010	0.0042	6.1755	0.0000
Electric windows front and rear binary	-0.0024	0.0015	0.0014	-0.0050	-1.604	0.1086
Central door locking operation	0.0213	0.0016	0.0011	0.0129	13.396	0.0000
Fog Lights	0.0357	0.0013	0.0012	0.0312	27.033	0.0000
Alloy Wheels	0.0492	0.0014	0.0013	0.0435	35.641	0.0000
Power assisted steering	0.1101	0.0047	0.0011	0.0243	23.435	0.0000
Air-conditioning	0.0647	0.0014	0.0012	0.0510	44.767	0.0000
On-board computer	0.0148	0.0014	0.0013	0.0114	10.459	0.0000
Sat-Nav Binary	0.0531	0.0027	0.0010	0.0189	19.942	0.0000
Convertible	0.1939	0.0033	0.0012	0.0670	58.183	0.0000
Side impact bars	-0.0006	0.0189	0.0010	-0.0020	-0.033	0.9736
1998	-0.0039	0.0035	0.0013	-0.0039	-1.135	0.2562

1999	-0.0161	0.0036	0.0013	-0.0085	-4.531	0.0000
2000	0.0067	0.0036	0.0016	-0.0002	1.8627	0.0625
2001	-0.0353	0.0037	0.0017	-0.0201	-9.653	0.0000
2002	-0.0670	0.0038	0.0018	-0.0358	-17.68	0.0000
2003	-0.1084	0.0038	0.0020	-0.0609	-28.54	0.0000
2004	-0.1293	0.0039	0.0021	-0.0748	-33.08	0.0000
2005	-0.1615	0.0040	0.0022	-0.0932	-40.20	0.0000
2006	-0.1809	0.0041	0.0023	-0.1064	-43.84	0.0000
2007	-0.1936	0.0042	0.0023	-0.1120	-45.81	0.0000
2008	-0.2631	0.0043	0.0024	-0.1509	-60.57	0.0000
2009	-0.2893	0.0045	0.0025	-0.1641	-64.70	0.0000
2010	-0.2927	0.0046	0.0025	-0.1647	-63.81	0.0000
Audi	0.1284	0.0024	0.0014	0.0715	53.47	0.0000
Mercedes	0.1837	0.0031	0.0011	0.0656	59.88	0.0000
Ford	-0.0832	0.0021	0.0012	-0.0501	-39.58	0.0000
Porsche	0.6151	0.0081	0.0011	0.0787	75.57	0.0000
BMW	0.1783	0.0027	0.0014	0.0869	65.90	0.0000
Opel	-0.0686	0.0020	0.0013	-0.0450	-33.62	0.0000
Vauxhall	-0.0583	0.0024	0.0013	-0.0344	-24.50	0.0000
Fiat	-0.1447	0.0040	0.0011	-0.0407	-36.41	0.0000
Citroen	-0.1742	0.0039	0.0011	-0.0498	-44.27	0.0000
Renault	-0.1675	0.0031	0.0011	-0.0644	-54.80	0.0000
Peugeot	-0.1486	0.0035	0.0011	-0.0488	-42.89	0.0000
Saab	-0.0454	0.0045	0.0010	-0.0120	-10.05	0.0000
Hyundai	-0.2444	0.0050	0.0011	-0.0543	-48.94	0.0000
Toyota	-0.0799	0.0039	0.0010	-0.0230	-20.61	0.0000
Skoda	-0.2010	0.0027	0.0012	-0.0927	-74.82	0.0000
Volvo	-0.0578	0.0035	0.0010	-0.0196	-16.76	0.0000
Alfa Romeo	-0.0224	0.0046	0.0011	-0.0073	-4.87	0.0000
Suzuki	-0.1116	0.0066	0.0010	-0.0180	-16.84	0.0000
Chevrolet	-0.4231	0.0047	0.0011	-0.1020	-89.62	0.0000
Jaguar	-0.0816	0.0099	0.0009	-0.0096	-8.25	0.0000
Lancia	-0.0397	0.0068	0.0010	-0.0076	-5.80	0.0000
Lexus	0.0802	0.0108	0.0009	0.0051	7.4555	0.0000
Land Rover	-0.2490	0.0255	0.0009	-0.0108	-9.74	0.0000
Seat	-0.2318	0.0057	0.0010	-0.0420	-41.00	0.0000
Smart	0.4450	0.0114	0.0011	0.0400	39.133	0.0000
Kia	-0.3221	0.0060	0.0010	-0.0557	-53.24	0.0000
Mini	0.0916	0.0103	0.0009	0.0065	8.9279	0.0000

Note: 1997 is the default year and VW is the default brand. The shading shows the significance of the coefficients with dark green showing the strongest but negatively related coefficients and dark red showing the strongest but positively related coefficients to car prices.

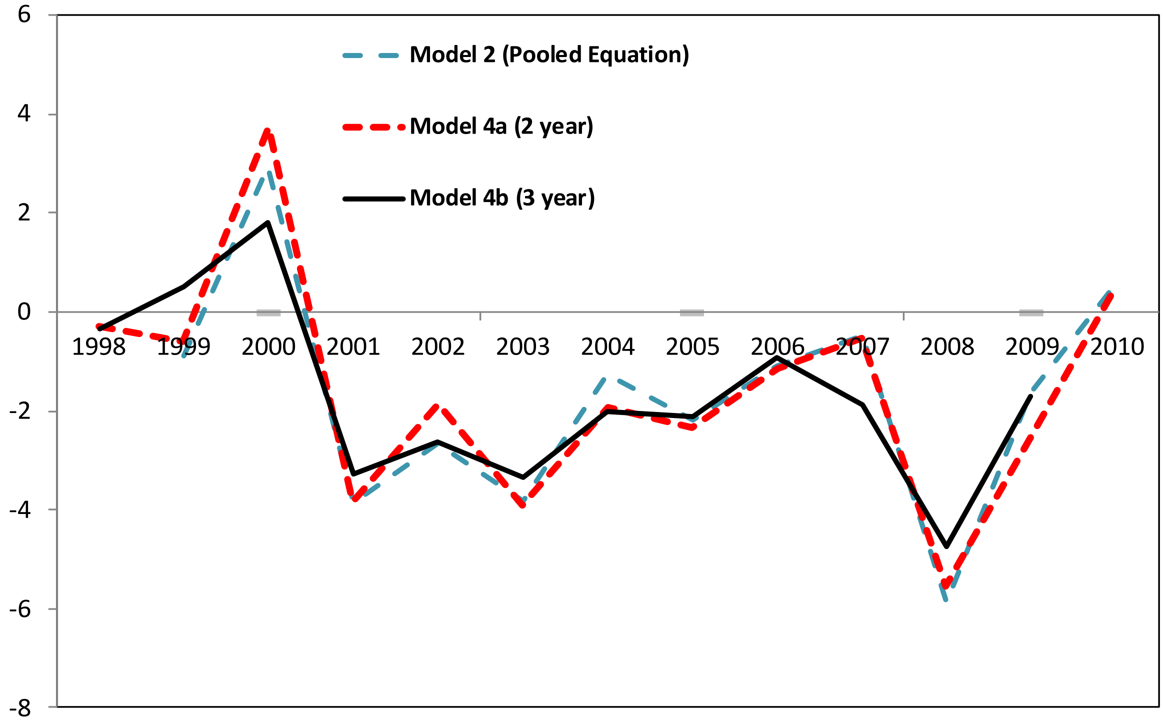
In the semi-log formulation, the coefficient for the time dummy variables reveals the variation in the log of the price adjusted by quality or technological change. The technological change effect is indicated by the coefficient β_t in the hedonic equation (1) above. The time trend for the coefficients for the time dummy variables for three alternative specifications is given in Figure 5-6.

Figure 5-6: Coefficients estimates for time dummy variables for three alternative specifications (all petrol vehicles)



As in the previous section, the time variable 't' can also be used to calculate the technology (quality/features) adjusted index, (i.e. the price increase or decrease compared with the previous year when technology-related shifts are excluded). In a logarithmic function the technology adjusted percentage of price change over the previous year is calculated from the coefficients of the time dummy variables based on the formula: Technology (Quality) adjusted price change = [exp (β_t) – 1] x100 (Figure 5-7). As can be observed in Figure 5-7, our findings are that all indexes are remarkably close across alternative methodologies. The technology adjusted index follows a very similar trend to the Model 1 – diesel dataset.

Figure 5-7: Technology adjusted price change for all petrol vehicles (%)



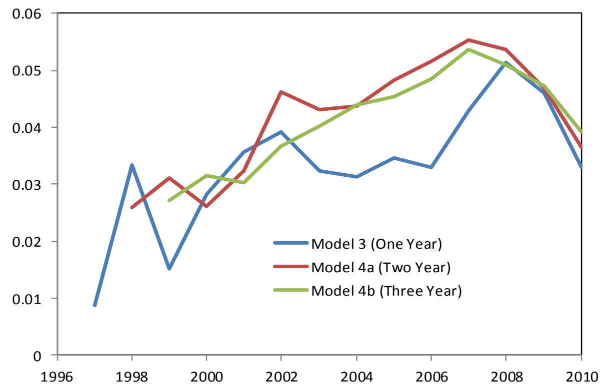
The estimated coefficients in the single year regressions varied considerably for some variables from one year to another[149], and showed more systematic behaviour for others. However, the estimations using order 2 and 3 year moving samples smoothed out the changes in the estimated coefficients. To illustrate this, in Figure 5-8, we plotted the estimated coefficients from three alternative specifications for three car attributes: engine capacity, fuel consumption and car length. The coefficients also show the trend in magnitude and significance of car attributes for explaining the variation in car prices. The main observations are:

- The significance of fuel consumption in explaining car prices increased from 1999 to 2008 and then fell sharply to 2010. This can be attributed to environmental regulations though the exact share of environmental regulations in explaining this trend is not obvious.
- As expected, the significance of engine capacity (correlates inversely with fuel consumption to a large extent) fell from 2000 to 2007, and then started to increase again.
- The size of the car, (using length as a proxy) became less and less significant in explaining car prices. A 10cm increase in length was associated with a 3% increase in price in 2000. This association fell to around 2.5% in 2010.

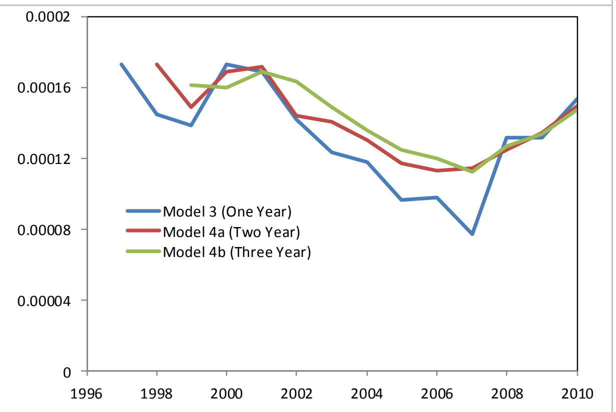
[149] See excel sheets provided as part of the annexes for all parameter estimates for each year.

Figure 5-8: Estimated coefficients for three alternative regressions specifications (all petrol vehicles)

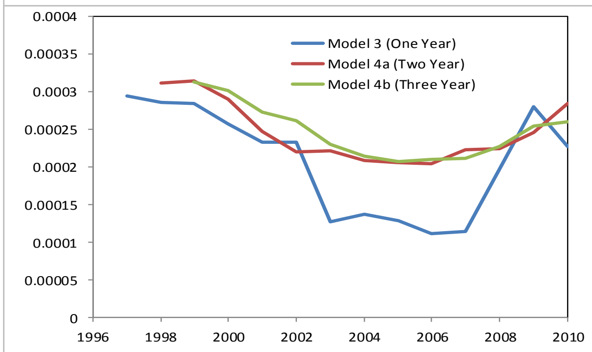
Parameter estimate – Combined fuel consumption (l/100km)



Parameter estimate – Engine capacity (cc)



Parameter estimate – Overall length (mm)



5.9 Dataset 3 - All *diesel* vehicles in the supermini and lower medium categories combined

This dataset contains the ***diesel*** vehicles in the supermini and lower medium categories combined. This dataset has stripped out cars with extreme power/weight ratios. This was achieved by removing the cars with the highest and lowest 10% values within the subset. The aim of this is to remove the underlying correlation that cars with high fuel consumption (e.g.. luxury, heavy, powerful cars) are more expensive.

5.9.1 Model 1 findings

Model 1 is based on a semi-log regression equation, for petrol vehicles across six Member States, and does not contain time dummy variables, but does contain dummy variables for the EURO Standards.

R	R Squared	Adjusted R Squared	Standard error of the estimate
0.85	0.72	0.72	0.00

R (0.72), the multiple correlation coefficient, shows a correlation between the observed and predicted values of the dependent variable (ln (car sale) price).

R^2 (0.72), the coefficient of determination, is the squared value of the multiple correlation coefficient. It shows that about 72% of the variation in ln (car prices) is explained by model 1.

Table 5-10: Analysis of variance of diesel subset using model 1

	Sum of Squares	df	Mean Square	F	Sig.
Regression	123.6485	48	2.576010	473.9956	0.00
Residual	48.68921	8959	0.005435		

The significance value of the F statistic is less than 0.05 and highly significant. The null hypothesis that ln(car price) is not linearly related to all the explanatory variables can be rejected. The F statistic is the regression mean square (MSR) divided by the residual mean square (MSE). The regression sum of squares (RSS) is significantly larger than the error sum of squares (ESS), indicating model 1 accounts for most of the variation in car prices (dependent variable).

The estimation results for the pooled regression model, as presented in Table 5-11 can be interpreted as the percentage increase in car price derived from the introduction of a new attribute. The attributes indicated by binary data whether the feature exists or not (i.e. indicated by dummy variable), can be interpreted, for example, as:

- those cars with stability control are 2.3% more expensive, holding the rest of the characteristics constant;
- those cars with luxury interior upholstery are 3.3% more expensive, holding the rest of the characteristics constant;
- those cars with electric front seats are 8% more expensive, holding the rest of the characteristics constant;
- convertibles are nearly 15% more expensive once all the other characteristics are controlled for.

For attributes with actual performance data and not dummy variables, an absolute change in the attribute can be associated with a relative change in price. In the regression analysis shows that a unit increase in fuel consumption (l/100 km) relates to a 3.2% per cent increase in average car prices. A one CV increase in max power can be associated with a 0.2% increase in price. A per unit increase in weight (kg) can be associated with a 0.02% increase in price

Table 5-11: Estimated parameter coefficients for the diesel subset using model 1.

Parameter	Unstandardised Coefficients		Standardised coefficients			
	Ln (Price) (Param.)	Ln (Price) (Std.Err)	Ln (Price) (Beta (ß))	Ln (Price) (St.Err.ß)	Log (Price) (t)	Log (Price) (p)
Intercept	8.568079	0.0908			94.397	0.000
Shared Platform	-0.013727	0.0040	-0.0496	0.0145	-3.427	0.001
Euro NCAP Rating	-0.016877	0.0014	-0.1177	0.0099	- 11.918	0.000
Number of doors	0.012382	0.0015	0.0884	0.0107	8.285	0.000
Engine Capacity	-0.000075	0.0000	-0.0866	0.0092	-9.411	0.000
Max. power (cv)	0.002358	0.0001	0.2798	0.0084	33.151	0.000
Kerb weight (kg)	0.000215	0.0000	0.1282	0.0111	11.539	0.000
Overall Length (mm)	0.000091	0.0000	0.0918	0.0111	8.281	0.000
Overall Width (mm)	0.000240	0.0000	0.0665	0.0111	5.997	0.000
Overall Height (mm)	-0.000155	0.0000	-0.0355	0.0109	-3.257	0.001
ABS	-0.069470	0.0073	-0.0754	0.0079	-9.569	0.000
Stability Control	0.023838	0.0023	0.0829	0.0080	10.417	0.000
Electronic brake distribution	-0.030443	0.0055	-0.0539	0.0097	-5.569	0.000
Combined fuel consumption (l/100km)	0.032221	0.0027	0.1402	0.0119	11.764	0.000
Driven wheels	0.007666	0.0018	0.0366	0.0086	4.256	0.000
Automatic?	0.022060	0.0042	0.0457	0.0086	5.297	0.000
Side airbag	0.020517	0.0032	0.0503	0.0079	6.327	0.000
Luxury Interior upholstery	0.033805	0.0037	0.0585	0.0064	9.162	0.000
Cruise Control	0.008363	0.0022	0.0273	0.0072	3.788	0.000
Electric front seats	0.077750	0.0048	0.1038	0.0064	16.224	0.000
Alarm	-0.002898	0.0026	-0.0076	0.0068	-1.106	0.269
Immobiliser	0.148581	0.0376	0.0226	0.0057	3.947	0.000
Electric front windows	0.053039	0.0221	0.0137	0.0057	2.397	0.017
Electric windows front and rear binary	0.003738	0.0029	0.0130	0.0100	1.305	0.192
Central door locking operation	-0.012998	0.0028	-0.0357	0.0077	-4.644	0.000
Fog Lights	0.037086	0.0022	0.1324	0.0078	16.949	0.000
Alloy Wheels	0.055743	0.0022	0.1977	0.0077	25.524	0.000
Air-conditioning	0.024294	0.0026	0.0784	0.0083	9.388	0.000
On-board computer	0.024226	0.0026	0.0842	0.0090	9.392	0.000
Sat-Nav Binary	0.029113	0.0068	0.0263	0.0061	4.285	0.000
Convertible	0.140414	0.0077	0.1510	0.0082	18.341	0.000
Euro 3 Announcement Effect	0.002394	0.0058	0.0029	0.0069	0.413	0.679

Parameter	Unstandardised Coefficients		Standardised coefficients			
	Ln (Price) (Param.)	Ln (Price) (Std.Err)	Ln (Price) (Beta (ß))	Ln (Price) (St.Err.ß)	Log (Price) (t)	Log (Price) (p)
Euro 3	0.042078	0.0041	0.0651	0.0063	10.329	0.000
Euro 4 Announcement Effect	0.025968	0.0035	0.0902	0.0120	7.496	0.000
Euro 4	0.011466	0.0038	0.0228	0.0075	3.033	0.002
Euro 5 Announcement Effect	0.014448	0.0050	0.0445	0.0155	2.868	0.004
Euro 5	-0.010672	0.0033	-0.0242	0.0076	-3.205	0.001
Voluntary Agreement Announcement	0.076313	0.0040	0.2629	0.0137	19.156	0.000
CO_2 Regulation Announcement	-0.002518	0.0035	-0.0087	0.0120	-0.723	0.470
Audi	0.077319	0.0059	0.1538	0.0117	13.147	0.000
Ford	-0.077033	0.0037	-0.2062	0.0100	-20.689	0.000
Opel	-0.060149	0.0051	-0.1331	0.0114	-11.698	0.000
Vauxhall	-0.061347	0.0058	-0.1077	0.0102	-10.536	0.000
Fiat	-0.226710	0.0080	-0.2403	0.0085	-28.232	0.000
Citroen	-0.148330	0.0066	-0.1812	0.0081	-22.378	0.000
Hyundai	-0.338006	0.0119	-0.1779	0.0062	-28.509	0.000
Skoda	-0.156298	0.0061	-0.2991	0.0118	-25.434	0.000
Alfa Romeo	-0.103696	0.0090	-0.0805	0.0069	-11.585	0.000
Suzuki	-0.247612	0.0160	-0.0997	0.0064	-15.500	0.000

Note: 1997 is the default year and VW is the default brand. The shading shows the significance of the coefficients with dark green showing the strongest but negatively related coefficients and dark red showing the strongest but positively related coefficients to car prices.

The Euro emission standards, both the announcement effects and the time effect, allow us to check whether the announcement effect on price was a one-off or permanent effect. These are all significant at the 5% level.

'Euro 3 announcement effect', 'Euro 3', 'Euro 4 announcement effect', 'Euro 4' and 'Euro 5 announcement effect' are all positively related to price indicating that the Euro standards had a permanent effect on cost. However, we notice that the values of Euro standard intercepts fall over time, as car manufacturers are better prepared to comply with these standards. Since the Euro standards are essentially time dummies (Model 2 below) the declining values of the Euro standards intercepts also reflect a decline in performance-corrected prices due to technological change.

5.9.2 Model 2 findings

Model 2 is based on a semi-log regression equation, for petrol vehicles across six Member States.

R	R Squared	Adjusted R Squared	Standard error of the estimate
0.9376	0.879	0.878	

R (0.94), the multiple correlation coefficient, shows a strong correlation between the observed and predicted values of the dependent variable (car sale price).

R^2 (0.88), the coefficient of determination, is the squared value of the multiple correlation coefficient. It shows that about 88% of the variation in car prices is explained by model 2.

Table 5-12: Analysis of variance for diesel subset using model 2

	Sum of Squares	df	Mean Square	F	Sig.
Regression	711.2190	59	12.05456	1832.020	0.00
Residual	97.78431	14861	0.006580		

The significance value of the F statistic is less than 0.05 and highly significant. The null hypothesis that car price is not linearly related to all the explanatory variables can be rejected. The F statistic is the regression mean square (MSR) divided by the residual mean square (MSE). The regression sum of squares (RSS) is significantly larger than the error sum of squares (ESS), indicating model 2 accounts for most of the variation in car prices (dependent variable).

The estimation results for the pooled regression model, presented in below, show a good fit. In addition, the estimated coefficients take the expected sign and are statistically significant.

For attributes with actual performance data, an absolute change in the attribute can be associated with a relative change in price. Table 5-13 shows the regression analysis for a unit increase in fuel consumption (l/100 km) relates to a 2.1% per cent increase in average car prices. This suggests that cars with higher fuel consumption in this category are subject to a price penalty. A one CV increase in max power can be associated with a 0.15% increase in price. A per unit decrease in acceleration was associated with a 0.9% increase in price. Size related parameters did not have any discernible impact on car prices. This is not surprising as we are looking at more focussed car segment.

Table 5-13: Estimated parameter coefficients for the diesel subset using model 2

Parameter	Unstandardised Coefficients		Standardised coefficients			
	ln car prices (Param.)	ln car prices (Std.Err)	ln car prices (Beta (ß))	ln car prices (St.Err.ß)	ln car prices (t)	ln car prices (p)
Intercept	7.8674	0.0615			128.0159	0.0000

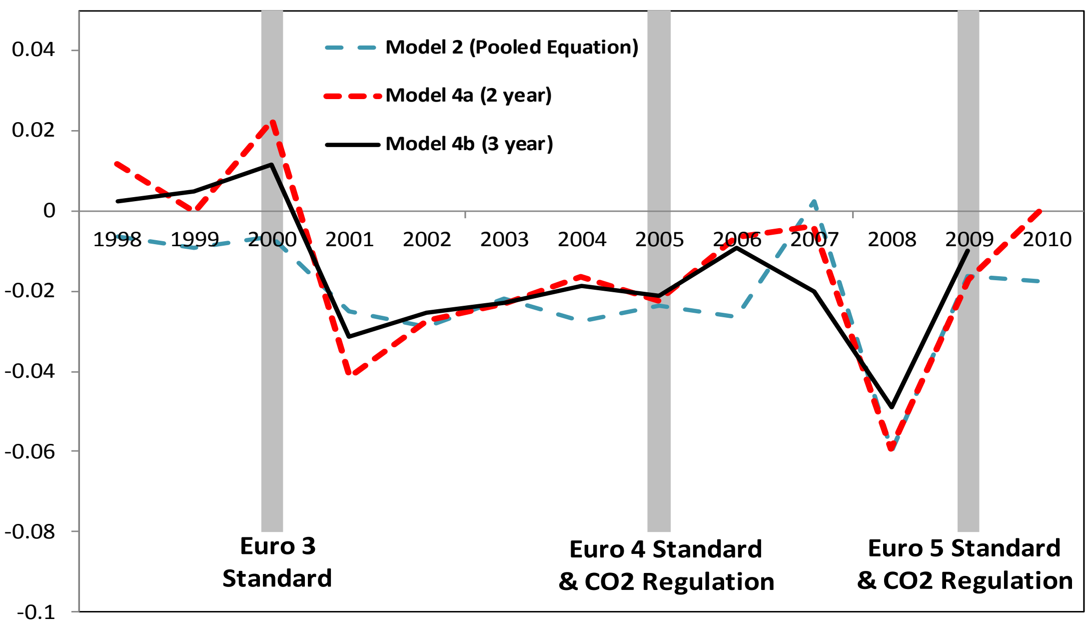
Parameter	Unstandardised Coefficients		Standardised coefficients			
	In car prices (Param.)	In car prices (Std.Err)	In car prices (Beta (ß))	In car prices (St.Err.ß)	In car prices (t)	In car prices (p)
Shared Platform	-0.0223	0.0030	-0.0441	0.0059	-7.4243	0.0000
Number of doors	0.0145	0.0008	0.0609	0.0033	18.2046	0.0000
Max. power (cv)	0.0015	0.0001	0.1244	0.0108	11.4734	0.0000
Kerb weight (kg)	0.0003	0.0000	0.1955	0.0086	22.8048	0.0000
Overall Length (mm)	0.0002	0.0000	0.1817	0.0068	26.8035	0.0000
Overall Width (mm)	0.0005	0.0000	0.1164	0.0069	16.8833	0.0000
Overall Height (mm)	-0.0002	0.0000	-0.0389	0.0048	-8.0384	0.0000
ABS	-0.0280	0.0049	-0.0314	0.0055	-5.6676	0.0000
Stability Control	0.0463	0.0020	0.0977	0.0041	23.7320	0.0000
Electronic brake distribution	0.0163	0.0047	0.0219	0.0064	3.4321	0.0006
Combined fuel consumption (l/100km)	0.0209	0.0020	0.0601	0.0057	10.5274	0.0000
Driven wheels	0.0109	0.0017	0.0250	0.0039	6.4438	0.0000
Automatic?	0.0283	0.0038	0.0284	0.0038	7.4461	0.0000
acceleration 0-100 km/h	-0.0092	0.0012	-0.0667	0.0085	-7.8380	0.0000
Side airbag	0.0241	0.0023	0.0430	0.0041	10.3552	0.0000
Luxury interior upholstery	0.0498	0.0038	0.0410	0.0031	13.1054	0.0000
Cruise Control	0.0232	0.0020	0.0418	0.0035	11.7915	0.0000
Electric front seats	0.0894	0.0052	0.0541	0.0031	17.3577	0.0000
Immobiliser	0.0810	0.0289	0.0083	0.0030	2.8054	0.0050
Electric front windows	0.0350	0.0069	0.0156	0.0031	5.0483	0.0000
Central door locking operation	0.0070	0.0023	0.0109	0.0036	3.0404	0.0024
Fog Lights	0.0323	0.0018	0.0686	0.0039	17.6833	0.0000
Alloy Wheels	0.0426	0.0018	0.0907	0.0038	23.7432	0.0000
Power assisted steering	0.0666	0.0148	0.0139	0.0031	4.5122	0.0000
Air-conditioning	0.0422	0.0020	0.0824	0.0038	21.5412	0.0000
On-board computer	0.0243	0.0021	0.0512	0.0043	11.8244	0.0000
Sat-Nav Binary	0.0368	0.0059	0.0189	0.0030	6.2691	0.0000
Convertible	0.1333	0.0066	0.0699	0.0034	20.2687	0.0000
1998	-0.0063	0.0075	-0.0033	0.0040	-0.8410	0.4003
1999	-0.0154	0.0074	-0.0087	0.0042	-2.0711	0.0384
2000	-0.0216	0.0069	-0.0191	0.0061	-3.1376	0.0017
2001	-0.0468	0.0068	-0.0486	0.0071	-6.8805	0.0000
2002	-0.0755	0.0069	-0.0762	0.0070	-10.9270	0.0000
2003	-0.0973	0.0069	-0.1090	0.0077	-14.1777	0.0000
2004	-0.1247	0.0070	-0.1430	0.0080	-17.8084	0.0000
2005	-0.1483	0.0071	-0.1839	0.0088	-20.9240	0.0000
2006	-0.1749	0.0071	-0.2190	0.0089	-24.5441	0.0000
2007	-0.1726	0.0071	-0.2328	0.0096	-24.1429	0.0000
2008	-0.2326	0.0072	-0.3240	0.0100	-32.4361	0.0000
2009	-0.2489	0.0074	-0.3344	0.0099	-33.8209	0.0000
2010	-0.2664	0.0076	-0.3542	0.0101	-35.2271	0.0000
Audi	0.0928	0.0048	0.0819	0.0042	19.3183	0.0000
Mercedes	0.1920	0.0077	0.1016	0.0040	25.0950	0.0000

Parameter	Unstandardised Coefficients In car prices (Param.)	In car prices (Std.Err)	Standardised coefficients In car prices (Beta (ß))	In car prices (St.Err.ß)	In car prices (t)	In car prices (p)
Ford	-0.0765	0.0029	-0.1090	0.0041	-26.3191	0.0000
Opel	-0.0715	0.0034	-0.0969	0.0046	-20.9959	0.0000
Vauxhall	-0.0429	0.0037	-0.0506	0.0044	-11.4735	0.0000
Fiat	-0.1517	0.0052	-0.1055	0.0036	-29.3922	0.0000
Citroen	-0.1289	0.0047	-0.1048	0.0038	-27.6239	0.0000
Renault	-0.1901	0.0042	-0.1756	0.0039	-45.3993	0.0000
Peugeot	-0.1597	0.0048	-0.1253	0.0037	-33.4897	0.0000
Hyundai	-0.3051	0.0097	-0.0951	0.0030	-31.5581	0.0000
Toyota	-0.0627	0.0075	-0.0293	0.0035	-8.4124	0.0000
Skoda	-0.1786	0.0037	-0.2271	0.0046	-48.8452	0.0000
Alfa Romeo	-0.0771	0.0089	-0.0272	0.0031	-8.6778	0.0000
Suzuki	-0.1702	0.0164	-0.0311	0.0030	-10.3598	0.0000
Lancia	-0.0317	0.0101	-0.0102	0.0033	-3.1295	0.0018
Seat	-0.2023	0.0057	-0.1197	0.0034	-35.4244	0.0000
Kia	-0.2921	0.0069	-0.1396	0.0033	-42.0809	0.0000
Mini	0.0268	0.0170	0.0046	0.0029	1.5746	0.1154

(Note – 1997 is the default year, and VW is the default brand)

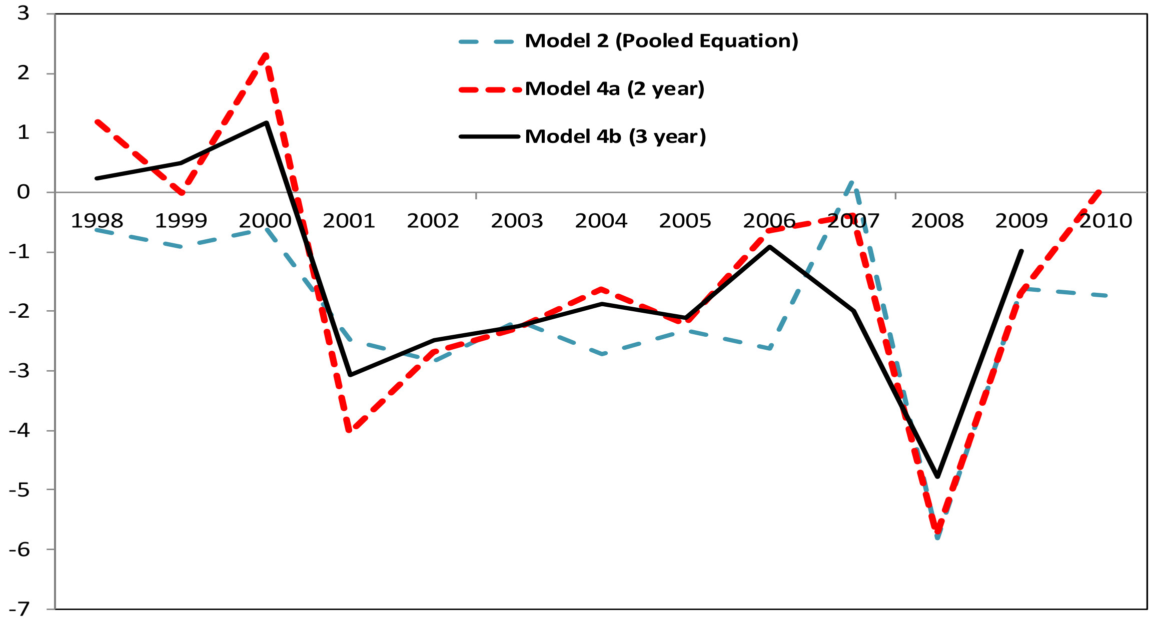
We notice that the values of period intercepts fall over time, as expected, reflecting a decline in performance-corrected prices due to technological change. This suggests that technological progress allows the same bundle of attributes to be produced at a lower cost and bought at a lower price. For example, in 2010, the year intercept is roughly 12 times lower than it was in 2000. The time trend for the coefficients for the time dummy variables for three alternative specifications is given in Figure 5-9.

Figure 5-9: The Coefficient estimates for time dummy variables for three alternative specifications for the diesel subset



The time variable ‘t’ can also be used to calculate the technology (quality/features) adjusted price index, (i.e. the price increase or decrease compared with the previous year when technology-related shifts are excluded). In a logarithmic function the technology adjusted percentage of price change over the previous year is calculated from the coefficients of the time dummy variables based on the formula: Technology (Quality) adjusted price change = [exp (β_t) – 1] x100 (Figure 5-10)

Figure 5-10: Technology adjusted price change (%) of the diesel subset



The estimations using order 2 and 3 year moving samples smoothed out the changes in the estimated coefficients. However, given the relatively small dataset for diesel vehicles in the two vehicle categories, there is more coefficient volatility than in the previous regressions.

Figure 5-11 to

Figure 5-14 illustrates the estimated coefficients from three alternative model specifications for four car attributes: power, fuel consumption, kerb weight and car length. The coefficients show the trend in magnitude and significance of car attributes for explaining the variation in car prices. The main findings are:

- A unit increase in fuel consumption prior to 2001 was associated with a decrease in prices whereas after 2001 it was associated with an increase in prices. This suggests that in the diesel supermini and lower medium segment cars with higher fuel consumption commanded a price premium presumably because larger engine variants are associated high feature content and thus price. This is expected as diesel engines are more expensive than petrol variants. Particularly in recent times as after treatment technologies for diesel engines have been needed to meet increasingly stringent exhaust emission standards.

- A unit change in power (cv) was associated with small impact on price, on average around 0.3%. There was slight downward trend in this relationship.

- An increase in weight by 1kg was associated with a negative impact on price prior to 2003. However, after 2003 heavier cars were associated with higher prices. In 2010, a 100 kg increase was associated with a 3% increase in price.

- The significance of size in explaining car prices slowly declined over time. In 2000, a 10cm increase in the length of the car was associated with 2% increase in car prices, which fell to around 0.5% in 2010.

Figure 5-11 Parameter Estimate – Fuel Consumption (l/100km) for diesel subset

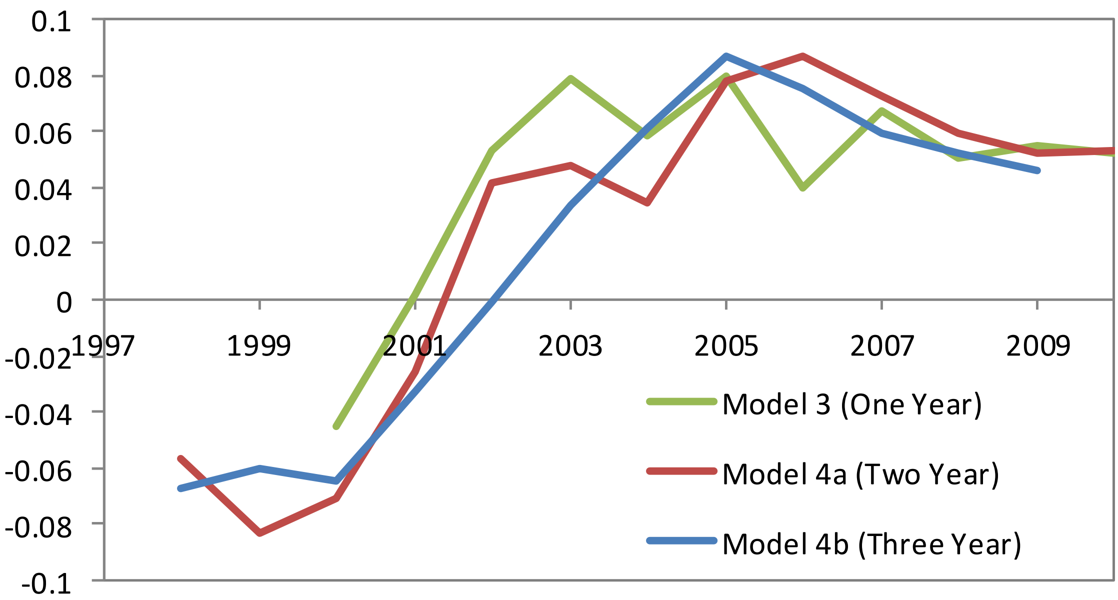


Figure 5-12: Parameter Estimate - Power (CV) for diesel subset

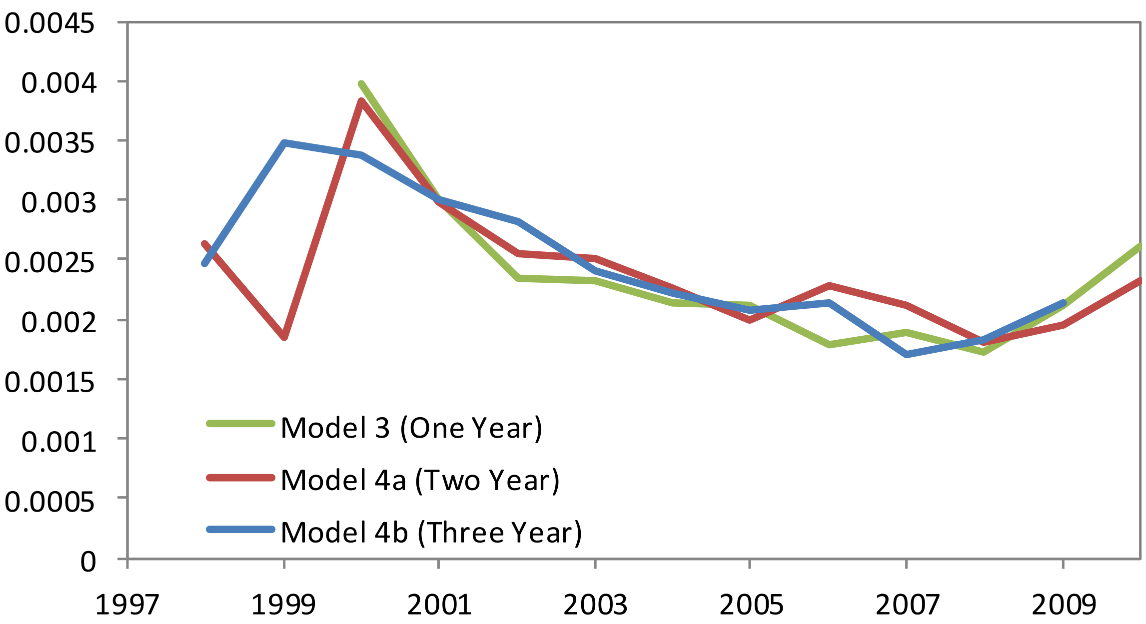


Figure 5-13: Parameter Estimate – Kerb Weight (kg) for diesel subset

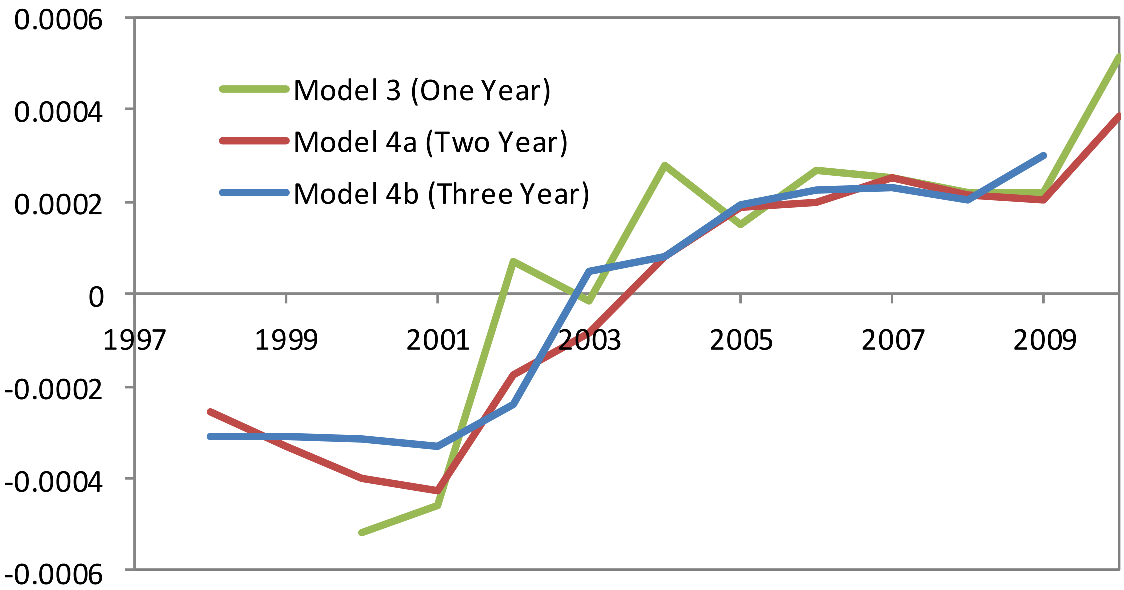
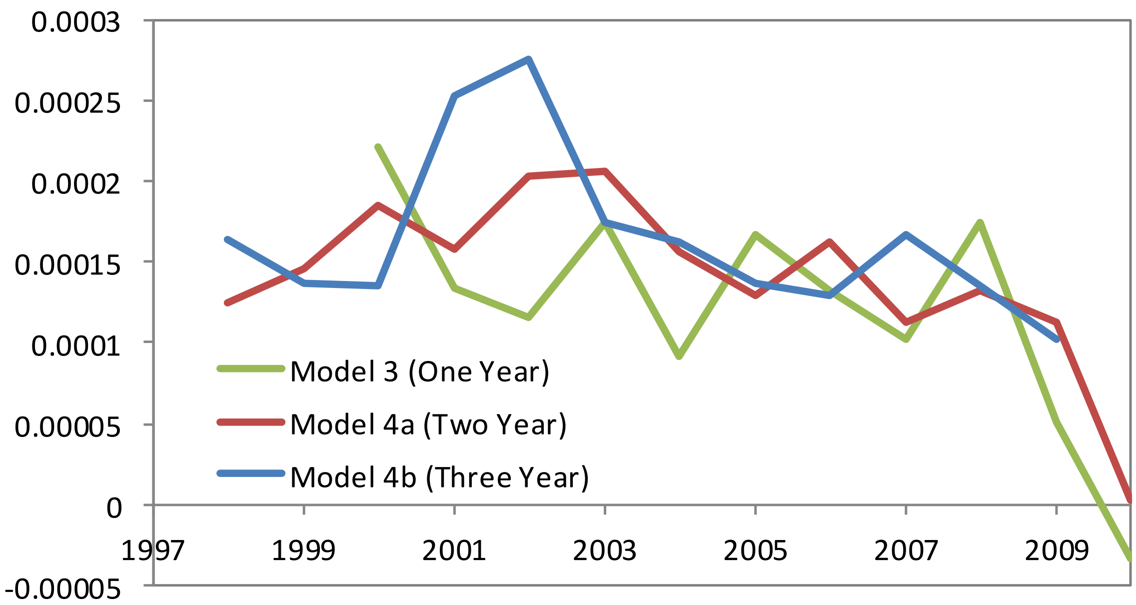


Figure 5-14: Parameter Estimate – Length (mm) for diesel subset



5.10 Dataset 4 – All *petrol* vehicles in the supermini and lower medium categories combined

This dataset contains the ***petrol*** vehicles in the supermini and lower medium categories combined. This dataset has stripped out cars with extreme power/weight ratios. This was achieved by removing the cars with the highest and lowest 10% values within the subset. The aim of this is to remove the underlying correlation that cars with high fuel consumption (i.e. luxury, heavy, powerful cars) are more expensive

5.10.1 Model 1 findings

Model 1 is based on a semi-log regression equation, for petrol vehicles across six Member States.

R	R Squared	Adjusted R Squared	Standard error of the estimate
0.938483	0.880751	0.880428	0.00

R (0.94), the multiple correlation coefficient, shows a strong correlation between the observed and predicted values of the dependent variable (car sale price).

R^2 (0.88), the coefficient of determination, is the squared value of the multiple correlation coefficient. It shows that about 88% of the variation in car prices is explained by model 1.

Table 5-14: Analysis of variance of all petrol vehicles using model 1

	Sum of Squares	df	Mean Square	F	Sig.
Regression	1390.458	57	24.39400	2730.675	0.00
Residual	188.2608	21074	0.008933		

The significance value of the F statistic is less than 0.05 and highly significant. The null hypothesis that car price is not linearly related to all the explanatory variables can be rejected. The F statistic is the regression mean square (MSR) divided by the residual mean square (MSE). The regression sum of squares (RSS) is significantly larger than the error sum of squares (ESS), indicating model 1 accounts for most of the variation in car prices (dependent variable).

The estimation results for the pooled regression model, as presented in Table 5-15 can be interpreted as the percentage increase in car price derived from the introduction of a new attribute. The attributes indicated by binary data whether the feature exists or not, (i.e. indicated by dummy variable), can be interpreted, for example, as:

- those cars with stability control are 4.8% more expensive, holding the rest of the characteristics constant,
- those cars with luxury interior upholstery are 8% more expensive, holding the rest of the characteristics constant,
- those cars with electric front seats are 5.5% more expensive, holding the rest of the characteristics constant,
- those cars with power assisted steering are 11% more expensive, holding the rest of the characteristics constant, and
- convertibles are nearly 24.9% more expensive once all the other characteristics are controlled for.

For attributes with actual performance data and not dummy variables, an absolute change in the attribute can be associated with a relative change in price. In the regression analysis shows that a unit increase in fuel consumption (l/100 km) relates to a 1.3% per cent increase in average car prices. A one CV increase in max power can be associated with a 0.3% increase in price. A per unit increase in acceleration was associated with a 0.4% decrease in price.

Table 5-15: Parameter estimates of petrol subset using model 1

	Unstandardised Coefficients		Standardised coefficients			
	ln car prices (Param.) (ß)	ln car prices (Std.Err)	ln car prices (Beta (ß))	ln car prices (St.Err.ß)	ln car prices (t)	ln car prices (p)
Intercept	7.820	0.051			153.473	0.000
Shared Platform	-0.021	0.003	-0.028	0.004	-6.755	0.000
Euro NCAP Rating	-0.017	0.001	-0.085	0.004	-20.929	0.000
Number of doors	0.019	0.001	0.069	0.003	21.397	0.000
Max. power (cv)	0.003	0.000	0.205	0.008	25.668	0.000
Kerb weight (kg)	0.000	0.000	0.069	0.007	9.948	0.000
Overall Length (mm)	0.000	0.000	0.188	0.006	33.897	0.000
Overall Width (mm)	0.001	0.000	0.104	0.006	17.468	0.000
Overall Height (mm)	0.000	0.000	-0.056	0.004	-13.071	0.000
ABS	-0.011	0.003	-0.014	0.004	-3.316	0.001
Stability Control	0.047	0.002	0.078	0.004	21.699	0.000
Electronic brake distribution	-0.043	0.003	-0.064	0.005	-13.365	0.000
Combined fuel consumption (l/100km)	0.013	0.001	0.043	0.005	8.967	0.000
Driven wheels	0.030	0.003	0.032	0.003	11.506	0.000
Automatic?	0.074	0.003	0.101	0.003	28.787	0.000
acceleration 0-100 km/h	-0.004	0.001	-0.024	0.006	-4.113	0.000
Side airbag	0.031	0.002	0.053	0.004	14.713	0.000
Luxury interior upholstery	0.077	0.004	0.056	0.003	21.852	0.000
Cruise Control	0.024	0.002	0.032	0.003	10.999	0.000
Electric front seats	0.054	0.005	0.026	0.003	10.229	0.000
Alarm	0.029	0.003	0.032	0.003	11.300	0.000
Immobiliser	-0.009	0.015	-0.001	0.002	-0.607	0.544
Electric front windows	0.036	0.005	0.019	0.003	7.456	0.000
Electric windows front and rear binary	0.005	0.002	0.008	0.004	2.346	0.019
Central door locking operation	0.003	0.002	0.005	0.003	1.617	0.106
Front Fog Lights	0.032	0.002	0.058	0.003	18.375	0.000
Alloy Wheels	0.049	0.002	0.088	0.003	27.843	0.000
Power assisted steering	0.105	0.006	0.043	0.003	16.306	0.000
Air-conditioning	0.046	0.002	0.078	0.003	25.554	0.000
On-board computer	0.016	0.002	0.028	0.004	7.769	0.000

	Unstandardised Coefficients		Standardised coefficients			
	In car prices (Param.) (ß)	In car prices (Std.Err)	In car prices (Beta (ß))	In car prices (St.Err.ß)	In car prices (t)	In car prices (p)
Sat-Nav Binary	0.047	0.006	0.019	0.002	7.668	0.000
Convertible	0.215	0.005	0.144	0.003	41.602	0.000
Euro 3 Announcement Effect	0.028	0.003	0.026	0.003	8.731	0.000
Euro 3	0.072	0.003	0.058	0.003	22.575	0.000
Euro 4 Announcement Effect	0.054	0.002	0.098	0.004	25.175	0.000
Euro 4	0.002	0.003	0.002	0.003	0.752	0.452
Euro 5 Announcement	-0.004	0.002	-0.006	0.003	-1.958	0.050
Euro 5	-0.006	0.003	-0.006	0.003	-1.955	0.051
CO_2 Regulation Announcement	-0.093	0.002	-0.150	0.004	-41.075	0.000
Audi	0.087	0.005	0.053	0.003	16.679	0.000
Mercedes	0.217	0.007	0.111	0.003	32.183	0.000
Ford	-0.078	0.003	-0.100	0.004	-27.754	0.000
Opel	-0.066	0.003	-0.079	0.004	-20.268	0.000
Vauxhall	-0.044	0.004	-0.050	0.004	-12.434	0.000
Fiat	-0.170	0.005	-0.097	0.003	-32.259	0.000
Citroen	-0.197	0.005	-0.129	0.003	-41.794	0.000
Renault	-0.247	0.004	-0.215	0.003	-63.267	0.000
Peugeot	-0.195	0.004	-0.148	0.003	-45.756	0.000
Hyundai	-0.281	0.005	-0.144	0.003	-51.216	0.000
Toyota	-0.089	0.006	-0.052	0.003	-15.927	0.000
Skoda	-0.236	0.004	-0.243	0.004	-64.026	0.000
Alfa Romeo	-0.122	0.009	-0.037	0.003	-13.807	0.000
Suzuki	-0.173	0.008	-0.059	0.003	-21.560	0.000
Chevrolet	-0.463	0.005	-0.311	0.003	-89.644	0.000
Lancia	-0.093	0.010	-0.027	0.003	-9.506	0.000
Seat	-0.289	0.006	-0.128	0.003	-46.757	0.000
Kia	-0.405	0.008	-0.155	0.003	-50.497	0.000
Mini	-0.012	0.012	-0.002	0.003	-0.992	0.321

Note: 1997 is the default year and VW is the default brand. The shading shows the significance of the coefficients with dark green showing the strongest but negatively related coefficients and dark red showing the strongest but positively related coefficients to car prices.

The Euro emission standards, both the announcement effects and the time effect, allow us to check whether the announcement effect on price was a one-off or permanent effect. Euro 4, Euro 5 announcement effect and Euro 5 dummies all are not significant at the 5% level.

'Euro 3 announcement effect', 'Euro 4 announcement effect' and Euro 3 are all positively related to price indicating that the Euro standards had a permanent effect on cost. However, we notice that the values of Euro standard intercepts fall over time, as car manufacturers are better prepared to comply with these standards. Since the Euro standards are essentially time dummies (Model 2 below) the declining values of the Euro standards intercepts also reflect a decline in performance-corrected prices due to technological change.

5.10.2 Model 2 findings

Model 2 is based on a semi-log regression equation, for petrol vehicles across six Member States.

R	R Squared	Adjusted R Squared	Standard error of the estimate
0.944820	0.892685	0.892359	0.00

R (0.94), the multiple correlation coefficient, shows a strong correlation between the observed and predicted values of the dependent variable (car sale price).

R^2 (0.89), the coefficient of determination, is the squared value of the multiple correlation coefficient. It shows that about 89% of the variation in car prices is explained by model 2.

Table 5-16: Analysis of variance

	Sum of Squares	df	Mean Square	F	Sig.
Regression	1409.298	64	22.02028	2738.158	0.00
Residual	169.4209	21067	0.008042		

The significance value of the F statistic is less than 0.05 and highly significant. The null hypothesis that car price is not linearly related to all the explanatory variables can be rejected. The F statistic is the regression mean square (MSR) divided by the residual mean square (MSE). The regression sum of squares (RSS) is significantly larger than the error sum of squares (ESS), indicating model 2 accounts for most of the variation in car prices (dependent variable).

The estimation results for the pooled regression model, presented in Table 5-17 below, show a good fit. In addition, the estimated coefficients take the expected sign and are statistically significant.

For attributes with actual performance data, an absolute change in the attribute can be associated with a relative change in price. In Table 5-17, the regression analysis shows that a one CV increase in max power can be associated with a 0.2% increase in price. A per unit increase in acceleration was associated with a 0.3% decrease in price. Size related parameters did not have any discernible impact on car prices. This is not surprising as we are looking at more focussed car segment.

The estimation results for the pooled regression model, presented in Table 5-17 below, show a good fit. In addition, the estimated coefficients take the expected sign and are statistically significant.

The estimated coefficients for the dummy variables can be interpreted as the percentage increase in car price derived from the introduction of a new attribute. The attributes indicated by binary data whether the feature exists or not (i.e. indicated by dummy variable), can be interpreted, for example, as:

- those cars with stability control are 6.2% more expensive, holding the rest of the characteristics constant;
- those cars with luxury interior upholstery are 7.2% more expensive, holding the rest of the characteristics constant;
- those cars with electric front seats are 6% more expensive, holding the rest of the characteristics constant;
- those cars with shared platforms were 2.4% less expensive, holding the rest of the characteristics constant;
- those cars with power assisted steering are 9.9% more expensive, holding the rest of the characteristics constant; and
- convertibles are nearly 24.6% more expensive once all the other characteristics are controlled.

For attributes with actual performance data an absolute change in the attribute can be associated with a relative change in price. In Table 5-17, the regression analysis shows that a unit increase in fuel consumption (l/100 km) relates to a 2.2% per cent decrease in average car prices. This suggests that cars with higher fuel consumption in this category are subject to a price penalty. A one CV increase in max power can be associated with a 0.2% increase in price. A per unit increase in acceleration was associated with a 0.3% decrease in price.

Table 5-17: Parameter estimates of petrol subset using Model 2

	Unstandardised Coefficients		Standardised coefficients			
Parameter	ln car prices (Param.) (ß	ln car prices (Std.Err)	ln car prices (Beta (ß))	ln car prices (St.Err.ß)	ln car prices (t)	ln car prices (p)
Intercept	7.709	0.05			157.88	0.00
Shared Platform	-0.024	0.00	-0.03	0.00	-8.13	0.00
Euro NCAP Rating	0.0004	0.00	0.00	0.00	0.45	0.65
Number of doors	0.019	0.00	0.07	0.00	23.00	0.00
Engine Capacity	0.00095	0.00	0.08	0.01	14.77	0.00
Max. power (cv)	0.00234	0.00	0.19	0.01	23.09	0.00
Kerb weight (kg)	0.00013	0.00	0.06	0.01	9.53	0.00
Overall Length (mm)	0.00023	0.00	0.21	0.01	38.89	0.00
Overall Width (mm)	0.00047	0.00	0.10	0.01	17.07	0.00
Overall Height (mm)	-0.0002	0.00	-0.03	0.00	-8.17	0.00
ABS	-0.022	0.00	-0.03	0.00	-6.94	0.00
Stability Control	0.059	0.00	0.10	0.00	28.12	0.00
Electronic brake distribution	0.002	0.00	0.00	0.00	0.74	0.46
Combined fuel consumption (l/100km)	-0.022	0.00	-0.07	0.01	-12.50	0.00
Driven wheels	0.038	0.00	0.04	0.00	15.02	0.00
Automatic?	0.095	0.00	0.13	0.00	37.22	0.00
acceleration 0-100 km/h	-0.003	0.00	-0.02	0.01	-3.52	0.00

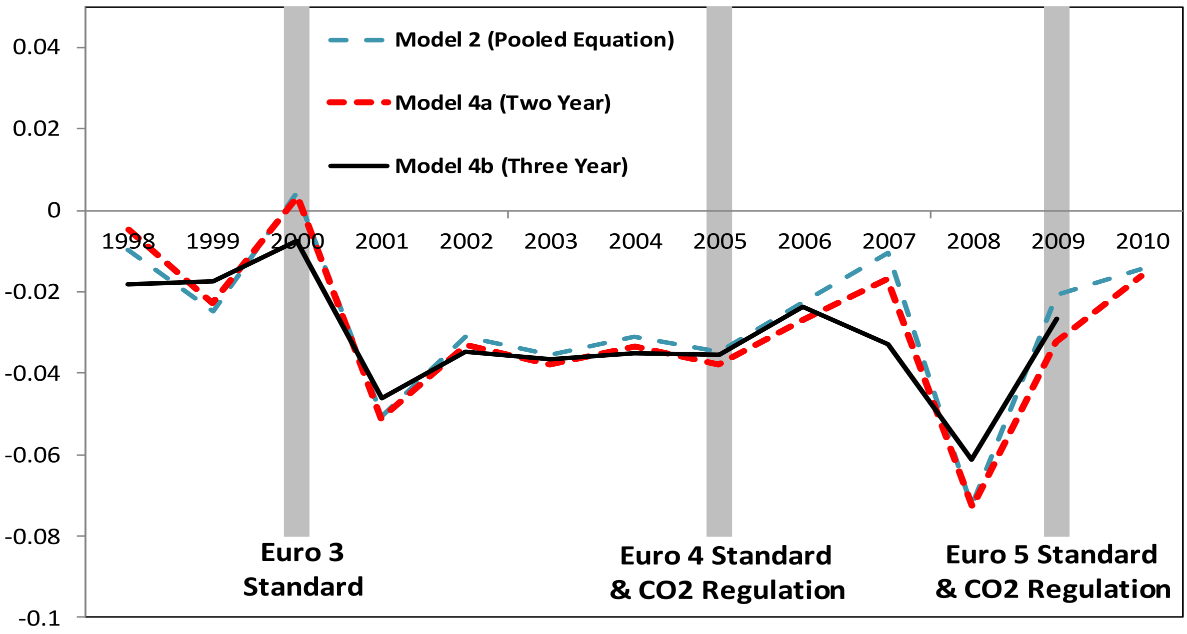
Side airbag	0.032	0.00	0.05	0.00	15.87	0.00
Luxury interior upholstery	0.069	0.00	0.05	0.00	20.53	0.00
Cruise Control	0.030	0.00	0.04	0.00	14.68	0.00
Electric front seats	0.058	0.01	0.03	0.00	11.57	0.00
Alarm	0.021	0.00	0.02	0.00	8.66	0.00
Immobiliser	0.076	0.01	0.01	0.00	5.24	0.00
Electric front windows	0.036	0.00	0.02	0.00	7.78	0.00
Electric windows front and rear binary	0.001	0.00	0.00	0.00	0.50	0.62
Central door locking operation	0.014	0.00	0.02	0.00	7.24	0.00
Front Fog Lights	0.033	0.00	0.06	0.00	19.81	0.00
Alloy Wheels	0.046	0.00	0.08	0.00	27.22	0.00
Power assisted steering	0.095	0.01	0.04	0.00	15.64	0.00
Air-conditioning	0.051	0.00	0.09	0.00	29.95	0.00
On-board computer	0.020	0.00	0.04	0.00	10.20	0.00
Sat-Nav Binary	0.044	0.01	0.02	0.00	7.64	0.00
Convertible	0.225	0.00	0.15	0.00	45.82	0.00
1998	-0.010	0.00	-0.01	0.00	-1.93	0.05
1999	-0.034	0.01	-0.02	0.00	-6.50	0.00
2000	-0.030	0.01	-0.02	0.00	-5.63	0.00
2001	-0.081	0.01	-0.07	0.01	-14.97	0.00
2002	-0.112	0.01	-0.10	0.01	-20.06	0.00
2003	-0.147	0.01	-0.15	0.01	-26.30	0.00
2004	-0.178	0.01	-0.18	0.01	-30.16	0.00
2005	-0.212	0.01	-0.21	0.01	-34.89	0.00
2006	-0.235	0.01	-0.26	0.01	-37.55	0.00
2007	-0.246	0.01	-0.27	0.01	-38.51	0.00
2008	-0.318	0.01	-0.34	0.01	-48.95	0.00
2009	-0.339	0.01	-0.35	0.01	-50.87	0.00
2010	-0.353	0.01	-0.36	0.01	-51.68	0.00
Audi	0.107	0.00	0.06	0.00	21.35	0.00
Mercedes	0.194	0.01	0.10	0.00	30.33	0.00
Ford	-0.069	0.00	-0.09	0.00	-25.62	0.00
Opel	-0.072	0.00	-0.09	0.00	-23.17	0.00
Vauxhall	-0.035	0.00	-0.04	0.00	-10.12	0.00
Fiat	-0.150	0.01	-0.09	0.00	-29.64	0.00
Citroen	-0.181	0.00	-0.12	0.00	-40.25	0.00
Renault	-0.230	0.00	-0.20	0.00	-60.81	0.00
Peugeot	-0.177	0.00	-0.13	0.00	-43.17	0.00
Hyundai	-0.248	0.01	-0.13	0.00	-46.70	0.00
Toyota	-0.094	0.01	-0.05	0.00	-17.40	0.00
Skoda	-0.204	0.00	-0.21	0.00	-57.04	0.00
Alfa Romeo	-0.054	0.01	-0.02	0.00	-6.32	0.00
Suzuki	-0.134	0.01	-0.05	0.00	-17.38	0.00

Chevrolet	-0.350	0.01	-0.24	0.00	-62.04	0.00
Lancia	-0.041	0.01	-0.01	0.00	-4.33	0.00
Seat	-0.262	0.01	-0.12	0.00	-44.22	0.00
Kia	-0.317	0.01	-0.12	0.00	-39.46	0.00
Mini	0.007	0.01	0.00	0.00	0.58	0.56

Note: 1997 is the default year and VW is the default brand. The shading shows the significance of the coefficients with dark green showing the strongest but negatively related coefficients and dark red showing the strongest but positively related coefficients to car prices.

We notice that the values of period intercepts fall over time, as expected, reflecting a decline in performance-corrected prices due to technological change. This suggests that technological progress allows the same bundle of attributes to be produced at a lower cost and bought at a lower price. For example, in 2010, the year intercept is roughly 12 times lower than it was in 2000. The time trend for the coefficients for the time dummy variables for three alternative specifications is given in Figure 5-15.

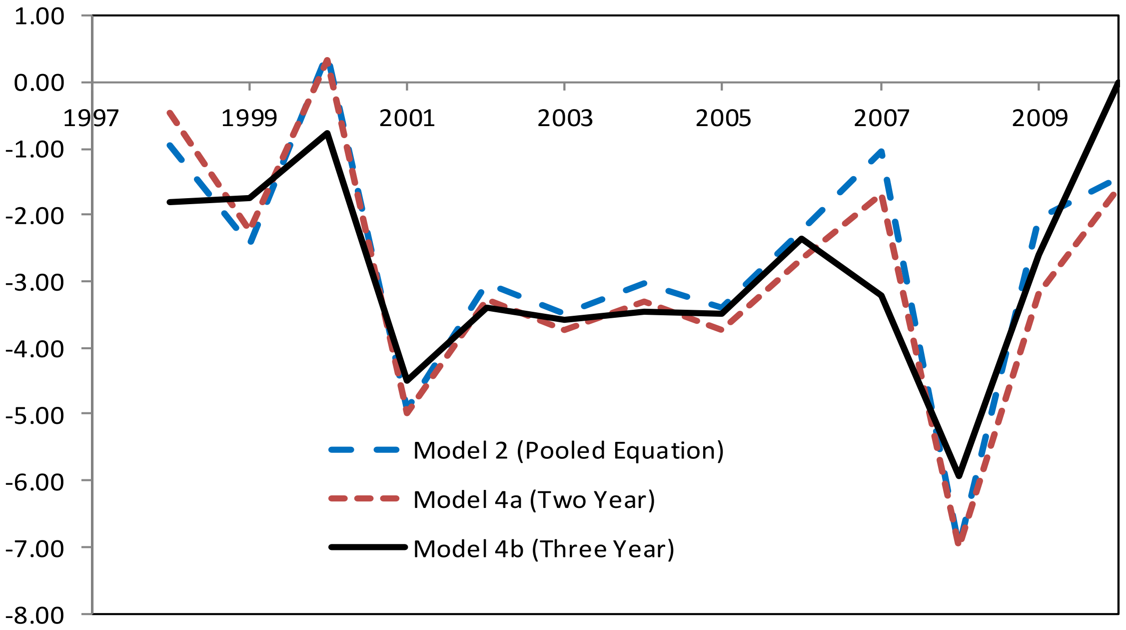
Figure 5-15: Coefficients estimates for time dummy variables for three alternative specifications – (petrol subset)



The time variable ‘t’ can also be used to calculate the technology (quality/features) adjusted price index,(i.e. the price increase or decrease compared with the previous year when technology-related shifts are excluded). In a logarithmic function the technology adjusted percentage of price change over the previous year is calculated from the coefficients of the time dummy variables based on the formula: Technology (Quality) adjusted price change = [exp (β_t) – 1] x100 (Figure 5-16). The fall in price for petrol vehicles in the supermini and lower medium categories is much higher than all diesel and petrol vehicles. This can be attributed to the fact that this is a fiercely price competitive segment. Also, by removing the 10% extremes) we are effectively removing low and high performance models to achieve a more representative price trend.

In dataset 3 and 4, we are covering a more homogenous sample by removing the low power to weight ratio that occurred during the early years of the sample and the high power to weight ratios in the later part of the sample. As can be seen in Figure 2 5, the power/weight ratio of both diesel and petrol vehicles has been increasing over time. By selecting this restrictive sample we are able to avoid any premium brand or other related effects that might influence the relationship between specific attributes and price.

Figure 5-16: Technology adjusted price change for petrol subset (%)



The hedonic regressions using order 2 and 3 year moving samples smoothed out the changes in the estimated coefficients. The estimated coefficients from three alternative model specifications for four car attributes: engine capacity, fuel consumption, kerb weight and car length are given in Figure 5-17 to Figure 5-20. The coefficients also show the trend in magnitude and significance of car attributes for explaining the variation in car prices.

Model 1 and 2 above provided average coefficient estimates for the variation in price explained by the variation in fuel consumption for the entire time period. However the annual coefficient estimates from Model 3 and 4 shows that the variation in price explained by the variation in fuel consumption was more volatile. A per unit change in fuel consumption (l/100 km) was associated with a:

- 2% decrease in average car prices in 1999 and 2000;
- 1% increase in average car prices in 2001-2002; and
- 2.5% decrease in average car prices in 2006.

This indicates that a unit decease in fuel consumption (increase in efficiency) between 2001 and 2006 was associated with an increase in prices. Unlike *"All diesel and petrol dataset" there* is no price premium for cars with greater fuel consumption. This is expected because we have adjusted for the effects of certain features such as brand and size influencing the impact on price. Petrol variants in this size category are generally cheaper than diesel and tend to cover the more price competitive variants. This segment may also be shrinking due to dieselisation and subsequent growth in larger engine vehicles. Hence, parameter estimate for fuel consumption is less likely to have multicollinearity effects from other attributes (e.g. brand effect and performance models). Selecting this narrow dataset has ensured that the relationship between price and fuel performance is accurately captured by the regression and not adulterated by brand effects.

Figure 5-17: Parameter estimate - Combined fuel consumption (l/100km) for 3 different regression techniques for petrol subset

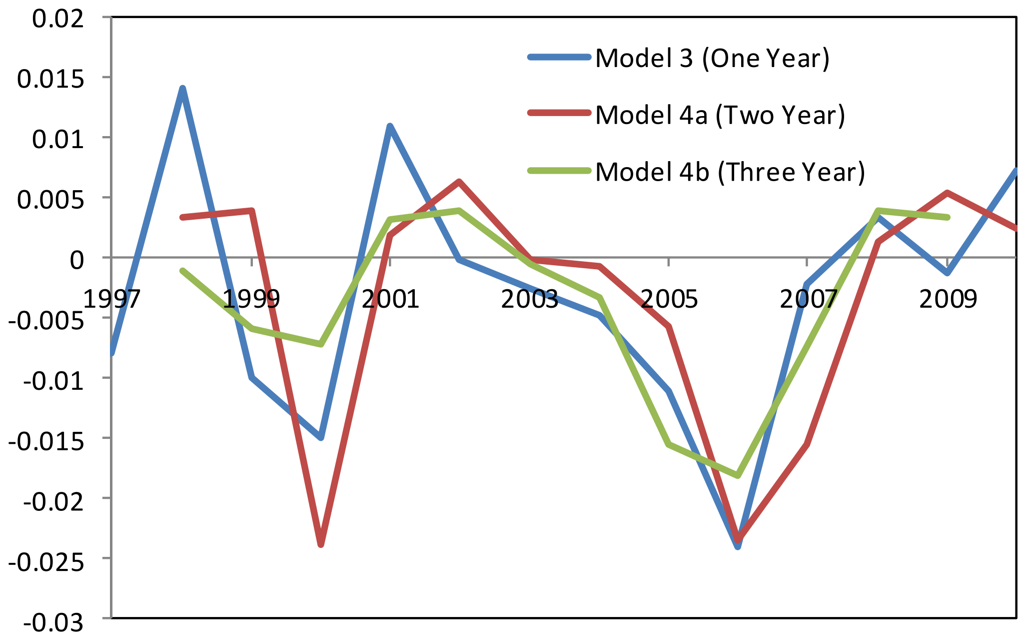


Figure **5-18** shows that a per unit in engine power (CV) was associated with a 0.45% change in car prices and by 2009 this associations was down to 0.25%.

Figure 5-18: Parameter Estimate - Power (CV) for 3 different regression techniques for petrol subset

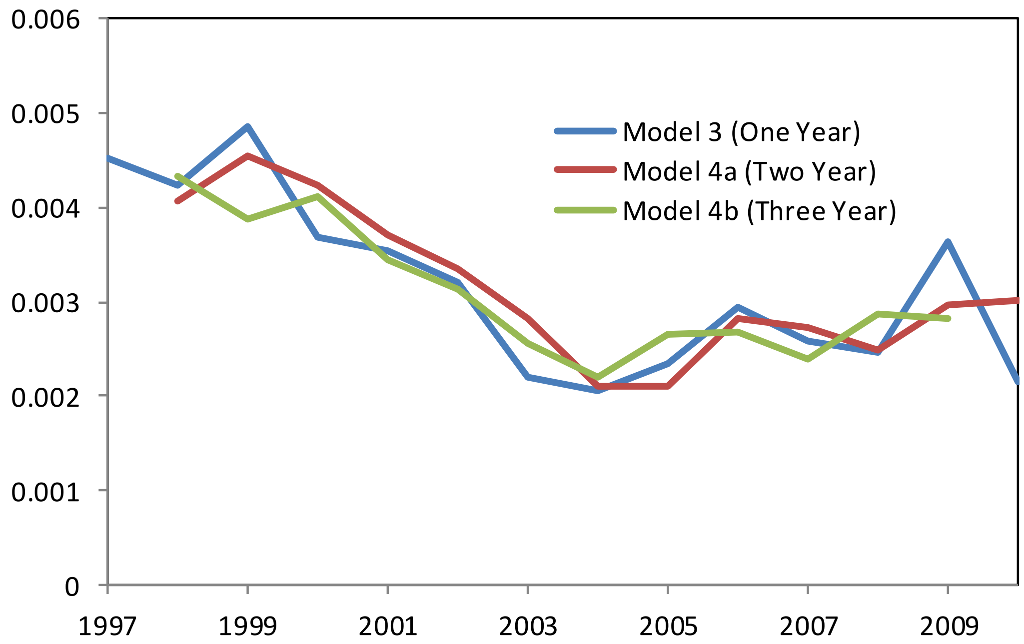


Figure 5-19: Parameter Estimate - Length (mm) for 3 different regression techniques for petrol subset

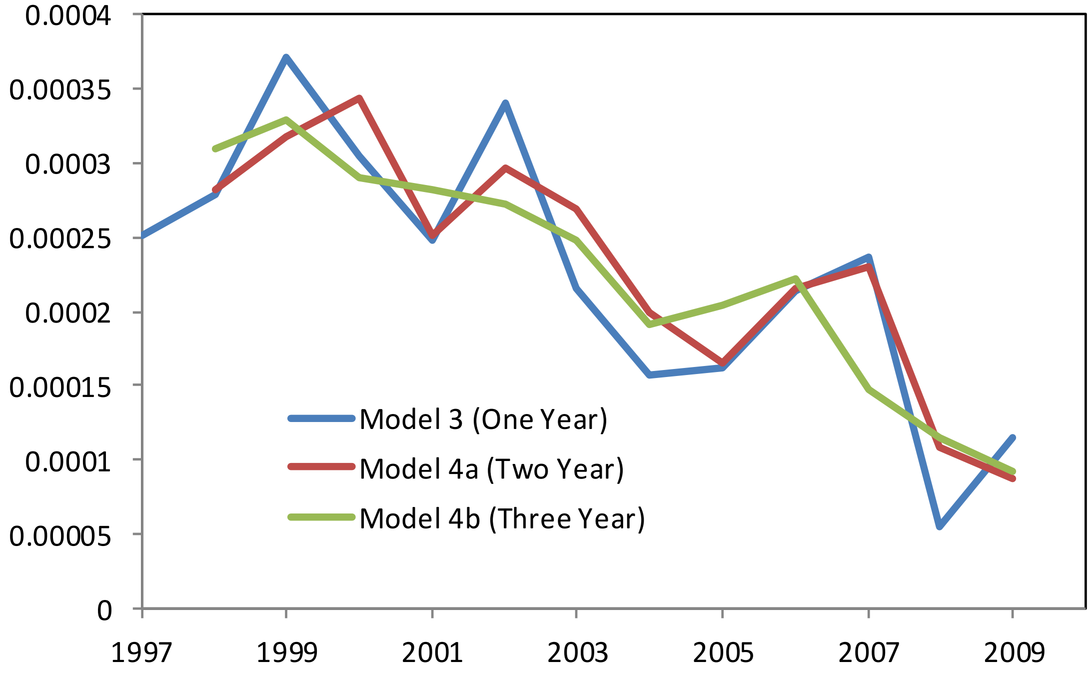
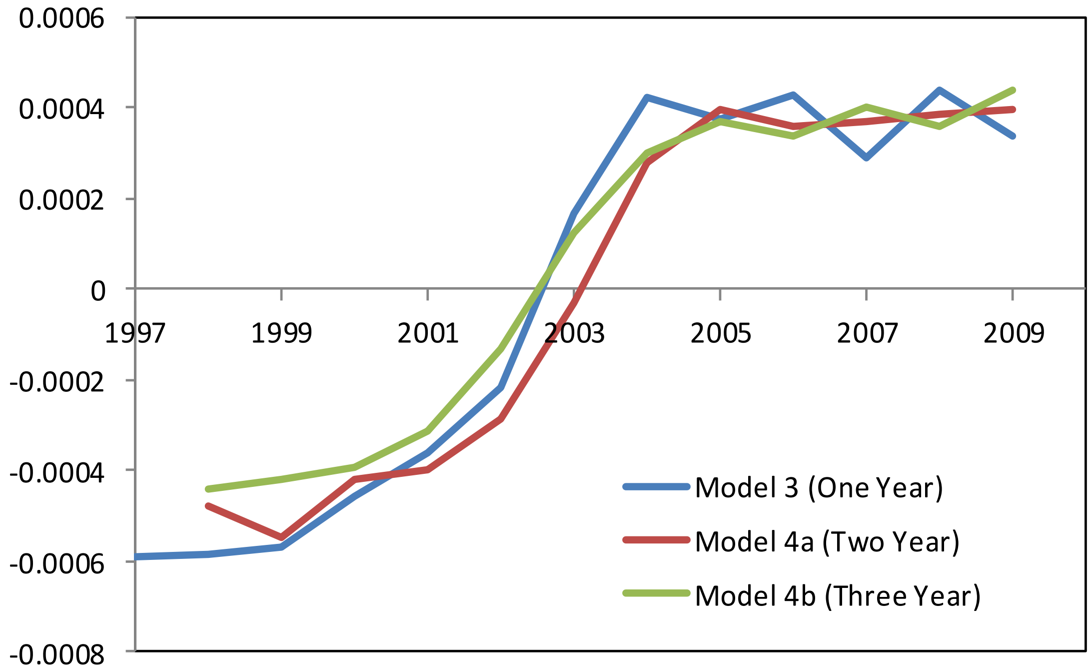


Figure 5-20: Parameter Estimate – Kerb Weight (kg) for 3 different regression techniques for Petrol subset



6 Interviews with stakeholders

6.1 Introduction

The stakeholder interviews were considered as an important method to understand the complexity of the relationship between regulation and vehicle prices. The findings from the interviews in this section should be used together with the findings of the literature review (Chapter 2) and the hedonic model (Chapter 5) in order to come to conclusions for the project as a whole. Interviews with key stakeholders were potentially an important element of this project, as they enabled expertise and experience that would not otherwise be available, (e.g. in the literature, to be used in the project). This improved the credibility of the report's conclusions. The list of stakeholders contacted is given in Table 6-1.

Table 6-1: List of stakeholders contacted as part of the project

Type of stakeholder	Organisations contacted
EU level stakeholders	Association for Emissions Control by Catalyst (AECC) European Association of Automotive Suppliers (CLEPA) European Automobile Manufacturers' Association (ACEA) European Consumers' Organisation (BEUC) European Council for Motor Trades and Repairers (CECRA) Euro NCAP Transport and the Environment (T&E)
Manufacturers	BMW, Daimler, Fiat, Ford, GM, Hyundai, Jaguar Land Rover, Nissan, PSA, Renault, Toyota, Volkswagen, Volvo, Delphi

The set of questions that were used as the basis of the interviews can be found in Section 5 of the Annex document. The questions were developed in order to complement some of the findings of the literature review and to explore these in more detail.

The initial phase of interviewing was undertaken in May and June 2011, during which a response was received from all but one of the EU level stakeholders, although three of those contacted declined to be interviewed. ACEA provided a written response, while two interviews with EU level stakeholders were held. In the course of the initial phase of interviews, one manufacturer was interviewed and another provided a written response, but in many other cases it was difficult to identify someone who was willing to be interviewed for the project, or who had sufficient expertise to cover the questions on the questionnaire. After consultation with The Commission, a renewed effort was made to talk to manufacturers using different contacts in August 2011. No interviews were held as a result of this second round of contact. Those manufacturers who responded declined to be interviewed. Instead, four manufacturers responded that they either supported the written response from ACEA or referred us to ACEA, while a fifth manufacturer provided a written response. Several manufacturers did not respond to this second round of contact, even after chased follow up after the first email.

Hence, the summary of the views from the interviews in Section 6.2 is based on the written response from ACEA, as well as the three interviews (one of which was with a manufacturer) and two written responses from manufacturers.

6.2 Summary of views

The questions that were asked in the course of the interviews covered three broad areas, as follows:

1. Factors influencing car prices;
2. The impact of environmental and safety legislation on prices; and
3. Future impacts and implications.

The discussion of the findings of the three interviews and two written responses is presented below according to these three areas.

6.2.1 Factors influencing car prices

The literature review had identified a number of factors that influence car prices. Instead of asking interviewees to list the factors that influence car prices without a prompt, the list in Table 6-2 was presented to the interviewees.

Table 6-2: Factors that influence prices

Regulatory Factors	Direct safety standards
	Direct environmental standards
	Block Exemption
	Indirect safety standards (e.g. Euro NCAP)
	Indirect environmental standards (e.g. Voluntary agreement)
Business Strategy Factors	Cost pass through
	Spin off of supplier
	Financing offers
	Import share / trends
	Shared platforms / collaboration
	Relocation of production
	Purchasing strategies
	Manufacturer margin
	Dealer and distributor margin
	Cross subsidising across brands / across divisions
Direct Cost Factors	Resource prices (raw materials, energy)
	Resource taxes
	Component costs
	Labour costs
	Exchange rates
	Shipping costs

Indirect Cost Factors	Research & development Plant maintenance & depreciation Marketing Warranty Administration (including pensions & healthcare)
Market Factors	Market competition Market conditions and openness
Consumer Factors	Model choice Option choice Quality

Most of the respondents agreed that these were the main factors that influenced price. Two interviewees suggested that two other regulatory factors were missing,

- Vehicle taxation and incentives (mentioned once); and
- New Free Trade Agreements that favour imported cars over those manufactured in Europe. This was mentioned by two manufacturers with one giving the example of agreements with third countries with significant car industries, such as South Korea, India and Japan.

The most important factors, according to those who answered the question, were environmental standards (mentioned by four of the six), market conditions and competition (mentioned by three) and financing offers (two). Another respondent noted that, of the categories in the list in Table 6-2, the most important categories of factor were regulatory, direct cost, indirect cost and market factors. Additionally, the price of raw materials, exchange rates and consumers demand for improved safety were all noted by one respondent as being important factors.

The least important factors were considered to be the block exemption (by two respondents). Another respondent questioned the importance of margins, as they argued that these are determined by the market, and some indirect cost factors, as plants needed to be maintained and depreciation was decided by tax laws.

When asked whether they agreed with Gaulier (2000) that manufacturers *"operating in several markets determine their optimal price on the basis of the nature and competition in each market"* (see Section 2.7), the five respondents who answered the question agreed. In support of their view, a number noted that in different countries, there were different tax levels (both for private and commercial purchasers), that consumers had different purchasing powers and that the level of competition would be different.

Three of the respondents also agreed with Murray (1999) that *"price differences between car models can be explained by variations in individual car characteristics"* (see Section 2.8), while another mostly agreed adding that brand, vehicle image and attractiveness also influenced price. It was noted that in some EU countries, cars have to be sold with features, which could be environmental, safety or comfort, that are not necessarily demanded by consumers in other countries, (e.g. particulate filters on diesels in Germany). Additionally, a couple of the respondents noted that it was often not possible to change prices to reflect the costs of environmental improvements, as these were not considered to bring added value to the consumer. On the other hand, it was possible to increase prices for features that brought added value, or more appeal, to the consumer, such as air conditioning, ABS, etc. It was also noted that enforced environmental improvements can force changes that enable improved performance, as was the case with the introduction of catalysts enabling direct injection.

Three respondents stated that the most important factor that affected a manufacturer's decision on the extent to which changes in cost are reflected in the price of a car is competition and market conditions. Another suggested that the most important factor was whether the additional characteristics were more appealing (or not) to the customer, although they noted that eventually all increased costs would have to be passed on. Three respondents agreed that these factors varied by brand and the type of vehicle being sold, while the fourth suggested that there was probably little difference for regular cars (i.e. excluding the most expensive models). Four respondents agreed that the factors varied according to the market in which the vehicle is being sold, with one noting that the European market was the most competitive in the world.

More generally, it was noted that manufacturers have reduced prices due to improvements and innovation, as well as engaging with their supply chain and relocation.

6.2.2 The impact of environmental and safety legislation on prices

Most respondents argued that there was always an increase in price resulting from environmental and safety legislation, although in some cases not as much as expected or perhaps immediately. It was also noted that there are occasionally positive impacts (see Section 6.2.1). Two respondents suggested that it was not always the case that environmental or safety legislation increased prices. However, one noted that this was sometimes due to manufacturers not being able to pass on increased costs to consumers due to market conditions, while another argued that some safety improvements might have no impact on prices due to their low costs.

When asked what determines whether environmental and safety legislation leads to increase prices, two respondents suggested that it was competition, while one noted that it was also dependent on the extent and nature of the necessary changes. Euro 4, 5 and 6 were all suggested as examples of legislation that had increased prices, while another argued that all emissions control legislation has increased car prices. On the hand, some felt that some safety legislation would not have had much impact on price.

It was suggested that a means of minimising the impact of improved environmental and safety standards on costs was to redesign models to coincide with improved regulatory standards. Additionally, improved economies of scale, increased productivity and additional action to reduce costs that are within the control of the manufacturer, such as on some of those factors in Table 6-2, could reduce costs and offset increases resulting from improved environmental and safety standards. Otherwise, where costs cannot be reduced or reflected in increases in prices, manufacturers' margins, and potentially those of suppliers, are reduced. One respondent noted that, as it was important to maintain some degree of profitability in order to be able to invest in future improvements, all increases in costs would eventually be passed on to consumers. However, as noted above, sometimes innovation inspired by regulation delivers benefits, as for example the application of some new technologies, such start-stop, enables improved power without the need for larger engines.

More generally, it was noted that the regulatory framework and individual pieces of safety and environmental legislation will increase the costs and prices of cars sold in the EU, but that the impact would vary between models and segments. Each manufacturer will determine how its costs are transferred to the final price of its vehicles without sharing its pricing policy with its competitors. It was argued by several respondents that car prices, both within the EU and for exports, would have been even lower if it had not been for the costs imposed by unilateral European legislation.

One correspondent noted that the information and data on vehicle prices that is publicly available is not necessarily an accurate reflection of the prices paid by consumers, and therefore complicates the understanding of the way in which regulatory costs are passed on to consumers. The prices published by the European Commission are catalogue prices and not those paid by the consumer, which can vary from the catalogue price in ways that are dependent on market segment, brand and the age of the model. Additionally, a vehicle is often sold by a retailer as part of a package, which can include a trade-in and financing package. Different elements of the package can have different margins, and the margins on the car might be the lowest of all.

6.2.3 Future impacts and implications

When asked what factors will have the most impact on reducing real car prices in the next 10 years, two respondents suggested that it would be competition, while further economies of scale was also mentioned. One respondent suggested that it was unlikely that historic rates of improvements in productivity could be maintained, as the strategies with the most potential have already been adopted. On the other hand, CO_2 legislation and the increasing cost of raw materials, including rare earth metals, would act to increase prices. Another correspondent argued that consumers' relationship with cars is changing and that people will not be prepared to pay as much for additional features as they used to and that people are beginning to drive less and learn to drive later in some EU countries. Additionally, one respondent felt that regulatory pressure will lead to smaller, electric cars, which (once the costs of batteries come down) will be cheaper. On the other hand, two respondents noted that regulatory pressure is requiring more expensive hybridisation, which will increase prices. While most respondents argued that it was not possible to identify the net impact on prices of the various trends, one felt that the net pressure will towards lower prices for cars sold in Europe, while another felt that there was no doubt that prices would increase.

In relation to the future development of policy, it was noted it was often difficult for any part of the supply chain to provide information on comprehensive costs, as suppliers and manufacturers understand their respective costs, but not each other's. Hence while suppliers can provide the unit cost of accessories, the cost implications of this for the wider vehicle are only understood by manufacturers. Unit costs will also decline if significant numbers of any particular accessory are required.

Another respondent considered that, in addition to the assessment of costs to industry, consumers and society, it would be important to undertake a competitiveness impact assessment as part of future policy impact assessments. It was also suggested that any savings in fuel duty should be excluded from a cost assessment, as countries would find alternative revenue streams; hence assessments should be undertaken on a revenue-neutral basis. This respondent also noted that the public support that manufacturers received in other markets, (e.g. the USA and Japan), was an effective subsidy for non-European manufacturers, which distorted the European market.

More generally, one respondent suggested that when developing policy in the future it would be important to consider the wider transport system, as it might be cheaper to deliver CO_2 reductions elsewhere, as we are approaching the limit of the reductions that could be achieved from an internal combustion engine. Additionally, a couple of respondents noted that some vehicles in use are clearly much less efficient than new cars, so it was suggested that it might be worth looking at reducing CO_2 emissions by targeting these vehicles, including considering the promotion of fleet renewable as an option in the impact assessment.

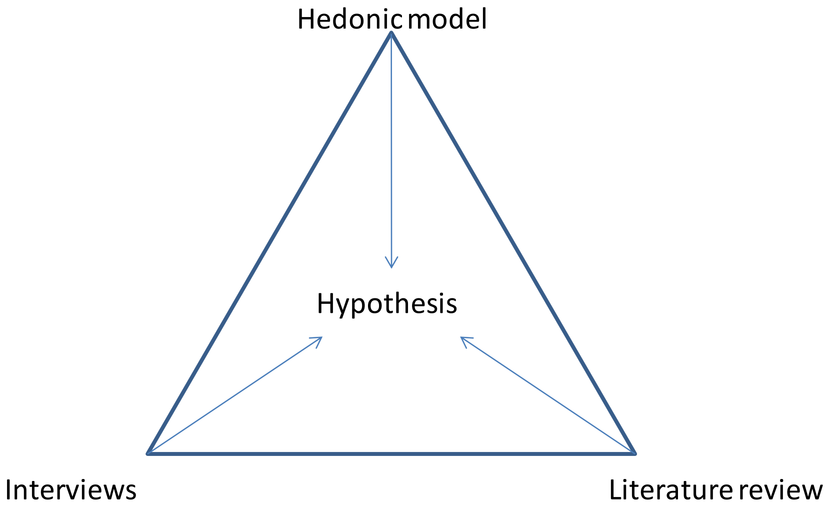
7 Hypotheses

7.1 Introduction

The terms of reference outlined a set of hypotheses to analyse the extent to which, the cost related to various regulations and standards can be separated from the costs of increased vehicle comfort (on-board gadgets and the increase in power of vehicles).

We elaborated on the hypotheses in the terms of reference by **triangulating** our findings from the hedonic regression model, literature review and stakeholder interviews. Triangulating the findings from the hedonic model with findings from the literature review and interviews enabled us to test the validity of all of the hypotheses.

Figure 7-1: Triangulating our findings to meet research objectives



7.2 Validity of study hypotheses

The validity of each hypothesis is discussed below based on the findings from all three study methods. As a general conclusion, the direct and causal link implied in most hypotheses does not hold true. This is particularly the case for hypothesis 3, 4 and 6.

Where possible, findings from the JATO dataset and hedonic model were used as the main method for carrying out this analysis. However, it was not be possible in all cases to use the hedonic approach and analysis of some hypotheses was heavily dependent on the outputs from the qualitative analysis and literature review. The ability of each method in explaining the hypothesis is indicated in Table 7-1

Table 7-1: Strength of research methods in validating the study hypotheses

	Hypothesis	Statistical Analysis	Literature review	Interviews
1	New regulations and standards did not cause (from the end-user perspective) a significant vehicle price increases (if any price increase in real terms at all)			
2	New vehicles are mostly priced according to buyer's ability to pay and not according to production costs (cost of manufacturing)			
3	The addition of extra features helps to maintain the market prices of new vehicles in roughly the same range, otherwise the prices would drop substantially			
4	Improvements in regulated safety, efficiency and environmental parameters is implemented at the expense of the quality of non-regulated vehicle components, or Use of integrated measures and technologies has jointly led to improvement in safety, environmental parameters, performance and comfort levels <change this>			
5	The manufacturer absorbs the higher cost (which is only substantially higher in an initial phase) by lowering their net profits			
6	As a consequence of new regulations and standard, manufacturers postpone the market introduction of comfort features as standard elements that would otherwise have been introduced earlier			
7	The time period of the analysis and type of dataset (time series or cross-sectional) affects the sensitivity of the modelling results			
8	The ability to pass cost of complying with regulation differs by brand and type of vehicle			
9	Cost reductions resulting from changes in production processes have played an important role in offsetting compliance cost			

Strong contribution
Medium contribution
Weak contribution

1. **New regulations and standards did not cause (from the end-user perspective) significant vehicle price increases (if any price increase in real terms at all)**

Outcome: Statistical trends indicate that there is no discernable link between environmental regulation and car prices. On the other hand industry stakeholder argued that car prices would have been lower if it had not been for environmental legislation. Hence, new regulations and standards have not led to real increases in prices, but this does not mean that they did not increase manufacturers' costs.

All of the three study methods have concluded that it has now become increasingly difficult to distil regulatory compliance costs from car retail prices. In the 1980s and early 1990s, the cause and effect of regulation on compliance cost was easier to capture. This relationship has changed dramatically in recent years. Technology related change because of regulation has been overwhelmed by other factors, such as comfort, performance and safety features. Massive fragmentation in the choice of models and variants has led to complex pricing, marketing and production methods.

The price of vehicles did not increase in step with the introduction of environmental regulations and standards. The price trends show slight peaks around Euro 3 for the selected vehicle sizes. However, this could be due a multitude of factors and the figures below do not provide a definitive answer. It is difficult to visually deduce if there has been an increase in prices as a result of the environmental standards. While there are circumstances where the introduction of standards does coincide with an increase in vehicle prices, such as Euro 4 introduction on 4x4 vehicles, there are situations where prices decrease during Euro 4 introduction, such as in luxury cars.

Indicative correlations can be made between emission trends and car prices. Average fleet emissions have been declining over time. List prices for an homogenous model from the JATO dataset (e.g. VW golf, Figure 7-2), real prices from EC Competition Directorate[150] and the technology adjusted price index from the regression analysis all indicate that car prices have fallen more quickly since legally binding CO_2 reductions were announced in 2007 (Table 7-2)

Table 7-2: Key trends in CO_2 emissions and car prices between 2002 and 2010

	Trends 2002-2010	Trends before announcement of legally binding CO_2 targets (2002-2006)	Trends since legally binding CO_2 reduction targets were announced (2007-2010)
	Overall % change	Average annual change (%)	Average annual change (%)
CO_2 emissions from cars	-15	-0.7	-3.0
EC Competition directorate real car prices	-13	-0.6	-2.5
JATO dataset VW Golf list price	-12	-1.4	-1.5
JATO data set technology adjusted price (all diesel)	-22	-1.8	-3.6

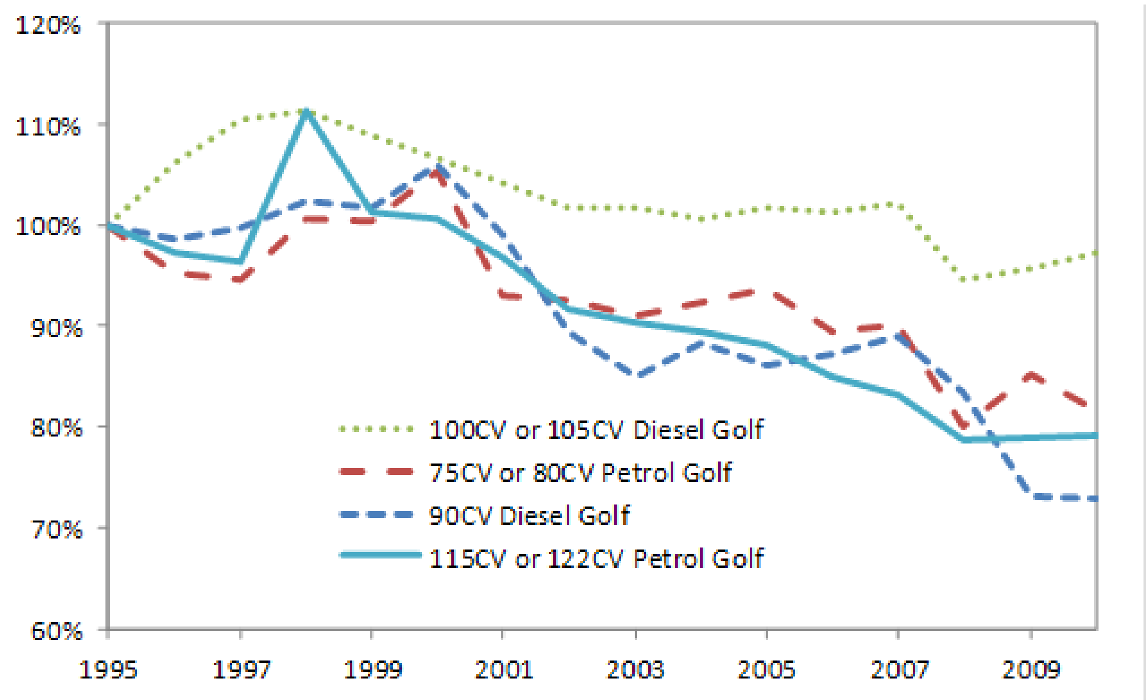
[150] http://ec.europa.eu/competition/sectors/motor_vehicles/prices/report.html

JATO data set technology adjusted price (all petrol)	-16	-3.1	-0.4

Note: All prices are adjusted for inflation and exchange rates

Overall cars have become 12% to 22% cheaper – after inflation – in the eight years from late 2002 to late 2010. Before the CO_2 regulation started to have an impact on the CO_2 emissions from cars, the annual average reduction of car prices was slower compared to the period after the CO_2 regulation was announced in 2007. The average annual reduction in CO_2 emissions was 0.7% and 2.5% in 2002-2006 and 2006-2010 respectively.

Figure 7-2: VW Golf price trends



Source: JATO data set
Note: Similar variants have been used to ensure like for like comparison over the entire time period. Prices have been corrected for exchange rates and inflation.

On the other hand, most industry correspondents believed that legislation that introduces new requirements in relation to the environmental and safety performance of vehicles increases costs, which in turn would generally, at least eventually, be passed on to consumers. In this respect, the argument was that car prices would have been lower if it had not been for such legislation.

2. **New vehicles are mostly priced according to buyer's ability to pay and not according to production costs. (cost of manufacturing)**

Outcome: This is true to some extent, however pricing strategies are very complex and optimal pricing is sensitive to car segment and competition in each market.

The study has concluded that even though one might expect that technical performance and intersegment differences to explain the bulk of price variation in list prices; it is clear from literature review that a number of factors might have an impact on end user prices.

The cost and profit associated with different models and variants are very different and identifying these is even more complex. It is true that over time manufacturers are less able to determine price and usually establish a ceiling price to design cars. This ceiling price is determined by buyer's ability to pay amongst many other factors. A strong illustration of this is described in the consumer factors section (2.8) in the literature review. In Figure 2-22, even though the pound devalued significantly during the 2008, there was not an increase in the price of a BMW 3 series in the UK. Hence manufacturers priced the vehicle at what the consumer can pay, rather than a fixed 'mark-up' on manufacturing costs. This type of pricing behaviour can be seen when currencies fluctuate but prices remain constant in the country of sale. Irandoust (1998) noted that local currency prices of imported goods are insensitive to currency fluctuations. Ginsburgh and Vanhamme (1989) found that car manufacturers had previously adopted a price to market in Europe, and not passing on exchange rate fluctuations to consumers. A Citigroup report (2009)[151] has stated that as a result of the devaluation of the pound, European car manufacturers lost $2.1 billion in profit, as they have absorbed the exchange rate loss.

The literature review suggested that rather than simply linking the price of a particular car to the costs associated with its development, manufacture and distribution, manufacturers price their cars according to the markets in which the cars operate and the wider competitive environment. For example Gaulier (2000) concluded that "firms operating in several markets determine their optimal price on the basis of the nature and intensity of competition in each market"[152], while a 2008 Commission evaluation concluded that "vigorous and increasing inter-brand competition has translated into falling real prices against a background of increased market integration at EU level"[153]. In the US, authors have reached similar conclusions on manufacturers' responses to changes in CAFE and other emission control standards, {e.g. Falvey (1986)[154], Goldberg (1998)[155] and Chen *et al* (2004)[156] (see Section 2.3.1)}.

Most interview respondents agreed with Gaulier (2000; see above) that manufacturers operating in several different markets determined optimal prices on the basis and nature of the car segment and competition in each market. Pricing is heavily dependent on consumer preference and feature content of the car and this can vary significantly by car segment and national markets.

3. **The addition of extra features helps to maintain the market prices of new vehicles in roughly the same range, otherwise the prices would drop substantially.**

Outcome: The implied causal link suggested in the hypothesis does not hold true. Extra features do enable higher mark-ups which can cover any additional costs of complying with regulation. It was not possible to identify the extent (or not) to which this approach maintains market prices at similar levels.

An important reason that prices do not increase even though vehicle features have been constantly changing is changes to other factors, such as consumer demand, production processes, marketing strategies, platform sharing, etc. Automakers also use other non-pricing tactics to respond to regulatory changes and market shifts including advertising and financing incentives.

Study findings have shown that regulation has led to technology improvements to reduce fuel consumption. However, it has also led to other attributes such as better acceleration, stability and top speed for which the consumer is willing to pay.

The level of safety features on a vehicle has increased significantly from 1995-2010, with side impact bars, stability control, ABS, side and front airbags becoming standard equipment on cars by 2010. The

[151] http://www.wintonsworld.com/cars/carnews/carnews-2009/Weak_Pound.html
[152] Gaulier, G. *Convergence of Car prices in the EU - an Empirical Analysis for the Period 1993-1999*, 2000
[153] http://ec.europa.eu/competition/sectors/motor_vehicles/documents/evaluation_report_en.pdf
[154] Falvey, R. *Fuel Economy Standards and Automobile Prices,* 1986
[155] Goldberg, P. *The Effects of the Corporate Average Fuel Efficiency standards in the US,* 1998
[156] For example, Chen B, Abeles E, Burke A and Sperling D (2004) *Effect of Emissions Regulation on Vehicle Attributes Cost and Price.* They found that

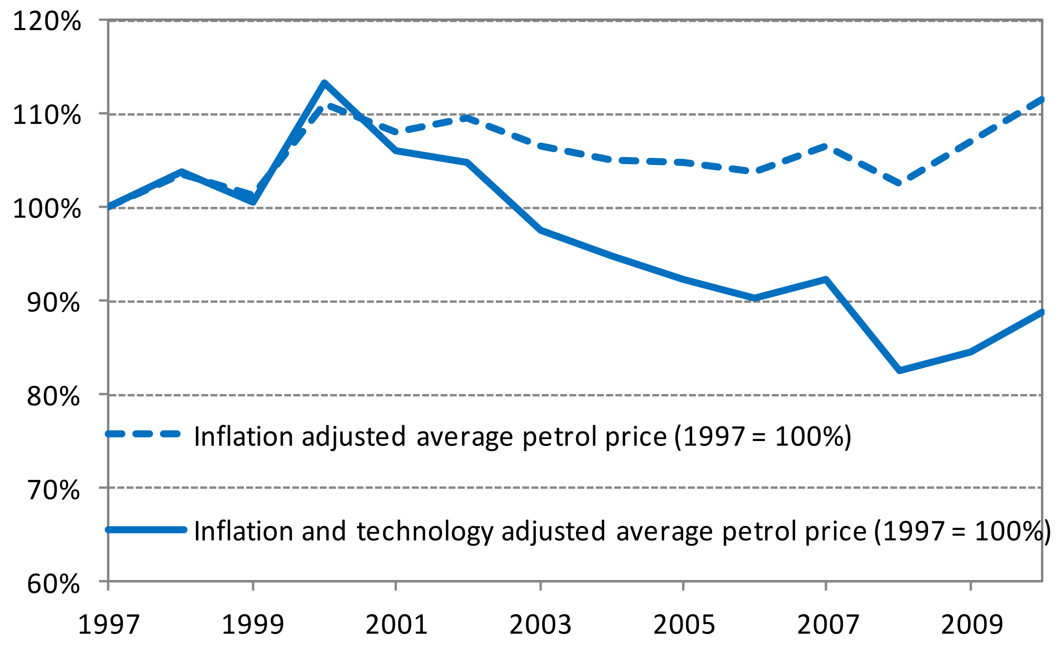
performance of vehicles has improved, as a result of incremental improvements in power and additional features (such as turbo/supercharger and direct injection technologies). The power/weight ratio of vehicles has increased significantly over the 15 year period, with petrol and diesel vehicles increasing by 19% and 31% respectively. The level of comfort features within the vehicle, such as leather upholstery and alloy wheels has improved, with comfort features increasing by 18% for petrol and 8% for diesel. All of the above have been achieved with declining real and technology adjusted prices over time.

From the responses reviewed in Section 6.2.1, it can be concluded that car prices can be increased – and therefore margins increased – for additional features that provide consumers with added value or which made a car more appealing. On the other hand, it was not as straightforward to increase prices in response to features introduced for environmental and safety purposes, as often these do not bring any added value to the consumer. The extent (or not) to which this approach maintains market prices at similar levels cannot be clearly identified. The mark up on price competitive segments is very small but car companies have a range of different methods to increase mark ups. This could be through finance deals, servicing plans and increasing price of premium models.

The regression coefficients showed that a number of comfort, performance and safety features were associated positively with prices. The safety measures are easier to identify due to the binary nature of their implementation (e.g.. a car has/hasn't got a side airbag). For example, for all diesel dataset, cars with ABS and stability control were 5% more expensive, holding the rest of the characteristics constant.

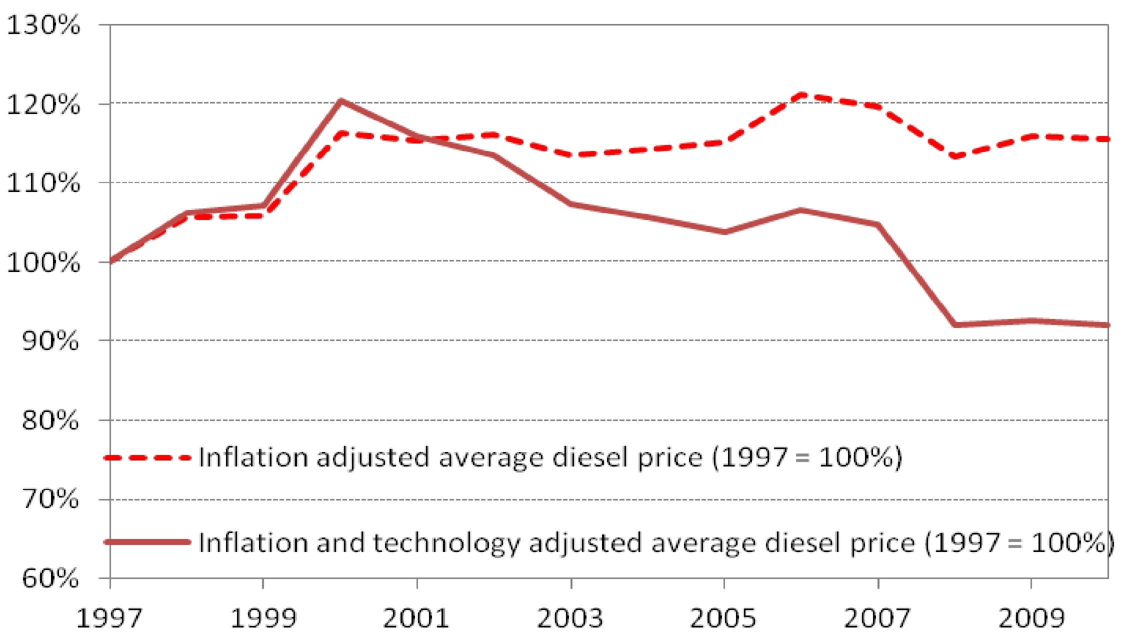
The technology (quality/features) adjusted price index, (i.e. the price increase or decrease compared with the previous year when technology-related shifts are excluded shows a decline in performance-corrected prices due to technological change) (Figure 7-3 and Figure 7-4). This suggests that technological progress allows the same bundle of attributes to be produced at a lower cost and bought at a lower price.

Figure 7-3: Inflation and technology adjusted price index (all petrol vehicles)



Note: This chart is calculated by using the average inflation adjusted price for each year and factoring in the technology adjusted price change parameter found in model 2.

Figure 7-4: Inflation and technology adjusted price index (all diesel vehicles)



Note: This chart is calculated by using the average inflation adjusted price for each year and factoring in the technology adjusted price change parameter found in Model 2

4. **Improvements in regulated safety, efficiency and environmental parameters is implemented at the expense of the quality of non-regulated vehicle components.**

Outcome: The implied causal link suggested in the first part of the hypothesis does not hold true. There are numerous examples where technologies that improve safety, efficiency and environmental features have all led to additional features of high value to consumers.

The discussion in hypothesis 3 is relevant for this hypothesis as well. A key point to be made in relation to the objectives of this study is that the cause and effect between regulation and prices is not a simple linear relationship. This relationship is inherently complex as a number of factors (Table 2-1) affect vehicle costs, while manufacturers set vehicle prices on the basis of other considerations, as noted above. Environmental and safety regulation is a sub-set of all the factors that affect costs and which, potentially indirectly, influence car prices. The net impact of all these factors in balance will determine how these costs translate into prices. While, additional features introduced as a result of regulatory requirements increase costs, the inclusion of additional features that improve performance levels and comfort can lead to improved margins (and higher prices), where these bring added value to the consumer. For example, the introduction of catalysts, the fitting of which was effectively required to meet EU air pollutant emissions legislation, forced changes that have enabled improved performance of cars, (e.g. direct injection). However, there was no evidence to suggest that improvements in regulated safety, efficiency and environmental parameters occur at the expense of the quality of non-regulated vehicle components.

5. **The manufacturer absorbs the higher cost (which is only substantially higher in an initial phase) by lowering their net profits.**

Outcome: This is a possible outcome, but difficult to identify the extent to which it occurs, as a result of the diverse cost base and wide range of pricing options. The temporal dimension is also important, as costs could be absorbed initially and then passed on over time. Additionally, the factors that determine costs and prices can vary significantly by segment, market and manufacturer.

The discussion in hypothesis 2 is also relevant here. Absorbing higher costs will only be an option when increased costs cannot be passed on to the consumer, i.e. when there is a particularly competitive market. However, car makers understandably would not divulge compliance costs or competitive advantages from stringent environmental regulation, as this could provide proprietary information to rival companies. Toyota, for example, was the first company to mass-produce hybrid power. However the company would not want to share the real production costs of its technology – because that would have been, and still is, a closely guarded commercial secret.

Cost pass through rates are relevant in many areas of economic analysis, for example to understand whether an increase in tax on petrol will yield more or less revenue for a government, how far exchange rate changes will be passed on to consumers, or to understand how far carbon trading systems might result in higher prices for consumers, or reduced output from producers, or possibly the relocation of producers (Alexeeva-Talebi, 2010). In principle, depending upon the shape of supply and demand curves, pass through rates can vary from 100% to 0%, or anywhere in between. Equally, in theory the producer may absorb some or all of the extra cost, but in so doing will experience lower profitability and / or reduced volumes. Additionally, pass-through of costs may occur over the short or the long term, and again do so differentially. In an industry with multiple actors in the value chain, the pass through from one level to the next (component / material supplier; manufacturer; wholesale distributor; retailer) is also of significance in understanding where extra costs are absorbed rather than passed on to consumers (Nakamura and Zerom, 2009). The car market is regarded as a structured oligopoly with differentiated products that compete along multiple variables other than (but of course including) price. Where an entire industry faces a cost increase then there is a stronger probability that the cost increase will be passed on, compared with the situation where a single company or model faces a cost increase. In general terms, this is the situation faced in the market for cars. While regions outside the European Union may have regulated on safety and environmental issues in a different way, and to different degrees of stringency, all firms that wished to compete in the European market for new cars faced the same mandatory requirements at the same time – although in some cases (e.g. very low volume producers) exceptions were allowed. Domestic incumbents with a larger market share are more likely to pass on 100% of additional costs (Gron and Swenson, 2000), which suggests that stronger brands are able to pass on a higher proportion of costs than weaker brands such as imported brands with a small market share. Interestingly, this suggests that regulations that do impose additional costs may act to protect the market share of domestic incumbents over imported products that perforce must absorb a higher proportion of the additional costs.

Studies into the operation of the European single market and the imposition of quotas concluded that protectionist measures resulted in enduring price differentials between national markets within the European Union, and in particular resulted in higher prices in protected markets such as Italy (Goldberg and Verboven, 2001). This is interesting because it suggests that any price effect of safety and environmental regulation may have been outweighed by the price effects of industrial policy, at least in the earlier period of the study during the 1970s and 1980s. Moreover, the relative stability of prices in the more recent periods of the study may be attributable in part to the slow but observable creation of a genuine single market for new cars in Europe (Andera, undated). Studies from the US, also showed that manufacturers absorbed the compliance cost of regulation in immediate years following the regulations but were passed on in the subsequent years.

There is evidence from the late 1990s and early 2000s that manufacturers were charging higher prices in their home markets, as consumers tend to favour local brands. However, in recent times even these car companies with secure national markets (e.g. Fiat in Italy) have lost market share and the ability to pass on costs due to increased competition and market fragmentation.

The ultimate impact on profits is not necessarily directly proportional to the extent to which costs can or are passed through. If 100% of costs are passed through, however, and there is no loss of volume then theoretically there is no impact on profits. For vehicle manufacturers the main concern is to retain planned manufacturing volume, as reduced volumes mean fewer vehicles over which to amortise all costs. In view of this, non-price factors may be used to ensure volumes are retained, or price increases may be spread over a longer time period (Chen et al., 2004).

Hence, it is possible that manufacturers absorb the higher cost associated with environmental and safety legislation by lowering their net profits, particularly where these increased costs cannot be passed on to the consumer, i.e. when there is a particularly competitive market. However, as a result of the wide of costs that manufacturers face, and the wide range of pricing strategies adopted, it is very difficult to identify the extent to which manufacturers adopt this approach.

6. **As a consequence of new regulations and standards, manufacturers postpone the market introduction of comfort features as standard elements that would otherwise have been introduced earlier.**

Outcome: There is no evidence to support this hypothesis. The list of standard features has been increasing over time without any discernable impact on prices. Consumers' willingness to pay extra for certain additional features (e.g. metallic paints, alloy wheels) is a bigger factor for not standardising certain features.

The discussion in hypothesis 3 suggests that this is not the case. Comfort features have been increasing over time without any discernible impact on real prices. There is also evidence that features cascade from higher end models to lower models in a very short space of time. These optional features can be installed in smaller models at very low marginal costs once developed and introduced for larger models.

Moreover, this is a 'what if' hypothesis that cannot be adequately tested as it speculates on what might have happened in the absence of an event occurring. It is possible, in theory, that in seeking to adjust for the cost-increasing impact of a regulation that certain features or attributes may be deleted from a model as a compensating adjustment. However, in a structured oligopoly it is already the case that differentiated competition on the basis of brands and features is characteristic; with price only one of many factors relevant in the purchasing decision. In this case, the ability of a manufacturer to withhold features in the name of cost reduction is more limited. The practice of value engineering combined with more flexible manufacturing operations may make feature deletion or non-inclusion more possible in recent years than in the past, but in general terms once a manufacturing system and supply chain is established in order to fit a particular feature into a vehicle, then the cost savings from not doing so are somewhat limited. Of course offering features as optional extras, as part of style / performance packs, or as part of certain trim levels is all part of the marketing of vehicles along with appropriate pricing strategies. Hence there is considerable flexibility in how features are brought to the market, and indeed when.

The willingness of consumers to pay extra for relatively aesthetic features such as metallic paint and alloy wheels, which have scant contribution to either safety, environmental performance or indeed comfort, suggests that there is scope for manufacturers to adjust feature content relative to standard or optional choices with a view to revenue maximization. Rather more likely is that cost reduction pressures have been faced in other areas of the supply chain for those parts of the car that have become standard fitments. In effect, these are much more 'commodity' items. A good example is the steel body of the car. In the earlier period covered by this study the steel body accounted for a much higher proportion of the total finished ex-works cost of the vehicle. Over time features such as rust-proofing or good panel gap fits or the quality of an A class paint finish became important qualifiers for vehicles. Now however it is taken as given, and steel producers have to contend with relentless pressures to reduce the weight of the steel body with simultaneous cost reduction demands. The battle for differentiation has moved on.

7. The time period of the analysis and type of dataset (time series or cross-sectional) affects the sensitivity of the modelling results.

Outcome: The association between car features and prices are sensitive to a number of modelling parameters and the nature of the dataset.

This can be seen by comparing the full diesel or petrol datasets with the dataset which contains the lower medium and supermini vehicles. These smaller datasets produce differing parameter values By analysing the parameter values on a one, two or three year subset, these parameter values for the same segment change through the years. The regression analysis can be undertaken for a combination of more than one of the data groups below, all of which could lead to different conclusions. For example, the results would be sensitive to a particular size category for petrol vehicles in one country.

- **Diesel/Petrol** – car prices and attributes including environmental performance differ by fuel.
- **Countries** – purchasing behaviour, car markets and availability, popularity of make/models, fuel taxation, sales taxes, differ by country. This grouping is probably the most important of all the others, because of the reasons above.

- **Size Categories** (A,B,C, etc.) – brand effect, cost associated to size of vehicles, car attributes such as engine power, fuel efficiency, and environmental performance all differ by car size categories.

- **Particular make or model** – (e.g. VW Golf), which is sold across most car markets in Europe. This would allow us to analyse the price effect on the EU as a whole.

- **Time** – consumer trends, car make/model choice, environmental and safety regulation, and standard vehicle features are sensitive to time period.

- **Manufacturer (Brand)** – certain make/models have a premium price effect that can override rational consumer behaviour based solely on car attributes.

Additionally, as noted above, the complexity of the industry has increased, so it is more difficult to identify any cause and effect relating to the introduction of environmental standards and price increases (see the discussion under hypothesis 1).

8. The ability to pass cost of complying with regulation differs by brand and type of vehicle.

Outcome: Many factors affect manufacturers' costs and manufacturers adopt pricing strategies depending on the car segment and market in which they are selling their vehicles.

The discussion in hypothesis 5 is relevant for this hypothesis as well. As discussed above, many factors affect manufacturers' costs and manufacturers adopt pricing strategies depending on the market in which they are selling their vehicles. From the perspective of their costs, actions within the control of manufacturers, (e.g. to improve productivity and increase economies of scale), can offset cost increases resulting from environmental and safety legislation. However, any increases in costs will generally be passed on to consumers – industry argues that prices would be lower without environmental and safety legislation. The extent to which increased costs can be passed on to consumers depends on competition and market conditions. Of the respondents that had a view on this, most agreed that the ability to pass on costs varied by brand and the type of vehicle being sold (as well as the market) and exposure to foreign brands.

9. Cost reductions resulting from changes in production processes have played an important role in offsetting compliance costs.

Outcome: Regulatory requirements generally increase costs amongst many other factors. Changes in production processes and other actions to improve productivity benefit from economies of scale act to reduce costs.

Manufacturers have had to balance production costs while ensuring that they comply with environmental regulation and meet the high standards of quality and performance that the market demands. This has led to the growth of practices such as platform sharing, parts 'commonisation' and sharing of powertrains, all of which have been key to cost reductions in the industry. Manufacturers have shifted production of vehicles away from Western Europe to Eastern Europe and Asia, in a bid not only to drive down costs through lower labour rates, but also to satisfy rapidly growing new markets.

In the regression analysis, the use of dummy variables for shared platform produces conflicting results. For the full diesel and petrol datasets, the shared platform attribute is associated with an increase in price, whereas it is associated with a decrease in price for the subset regressions.

While regulatory requirements generally increase costs, changes in production processes and other actions to improve productivity and benefit from economies of scale act to reduce costs. However, saying that cost reductions keep compliance costs down is not correct, as these costs are separate; rather reduced costs can offset the impact of increased compliance costs on prices.

8 Conclusion

The three different methods complimented each other well to tackle the main research questions. The literature review provided a good understanding of the boundaries to analyse the relationship between regulation and car prices. The hedonic model provided the statistical rigour to capture changes in prices caused by changes in product characteristics. The stakeholder interviews were very helpful to test our findings from the literature review and hedonic modelling and address any gaps. The main findings from each of the three study methods are discussed below.

Literature review

A wide range of academic literature and industry intelligence were consolidated to summarise the factors which influence new car pricing in Europe. The research investigated regulatory and business strategy factors, direct and indirect costs as well as market and consumer factors (Table 8-1). In general the available literature focuses on more readily quantifiable factors (for example comfort features, safety etc.), but does not tend to cover the more indirect or strategic elements of the car manufacturing industry. While industry media reports help to bridge some of these gaps, there is limited quantitative information on many aspects of the passenger car market.

Table 8-1 Factors that influence car prices

Regulatory Factors	Direct Safety Standards
	Direct Environmental Standards
	Block Exemption
	Indirect Safety Standards (e.g. Euro NCAP)
	Indirect Environmental Standards (e.g. Voluntary agreement)
Business Strategy Factors	Cost Pass Through
	Spin off of supplier
	Financing Offers
	Import share / trends
	Shared platforms / collaboration
	Relocation of production
	Purchasing strategies
	Manufacturer margin
	Dealer and distributor margin
	Cross Subsidising Across Brands / Across Divisions
Direct Cost Factors	Resource Prices (raw materials, energy)
	Resource Taxes
	Component Costs
	Labour Costs
	Exchange Rates
	Shipping Costs
Indirect Cost Factors	Research & Development
	Plant maintenance & Depreciation
	Marketing

	Warranty
	Administration (including pensions & healthcare)
Market Factors	Market competition
	Market conditions and openness
Consumer Factors	Model Choice
	Option Choice
	Quality

Growth in environmental, safety and product regulation has led a wide range of strategies and practices by manufacturers to balance production costs and regulatory compliance.

The last fifteen to twenty years has seen a significant increase in regulation to reduce the environmental and health impacts of car emissions. Manufacturers have had to balance production costs while ensuring that they comply with environmental regulation and meet the high standards of quality and performance that the market demands. This has led to the growth of practices such as platform sharing, parts 'commonisation' and sharing of powertrains, all of which have been key to cost reductions in the industry. Manufacturers have shifted production of vehicles away from Western Europe to Eastern Europe and Asia, in a bid not only to drive down costs through lower labour rates, but also to satisfy rapidly growing new markets.

Massive fragmentation on choice of models and variants makes it very difficult to link cost and profit margins

The car manufacturing business has seen huge changes over the past three decades. The car markets these days feature a far greater range of models, variants and options. Cost and profit margins can vary significantly depending on the model and/or variant. Quantifying this is even more problematic. As the market has become more competitive, manufacturers are less able to determine prices for the vehicles they offer. Thus, automakers have adopted other non-pricing tactics, including advertising and financing incentives, to respond to regulatory changes and market shifts. Manufacturers now favour a "price minus" instead of "cost plus" pricing strategy. This essentially means that designers are given a price to design the car and then explore how much they are able to undercut this price.

Most studies (and interview respondents) indicated that manufacturers operating in several different markets determined optimal prices on the basis and nature of the car segment and competition in each market. Pricing is heavily dependent on consumer preference and feature content of the car and this can vary significantly by car segment and national markets.

Direct costs (manufacturing costs) are managed by new technologies such as platform sharing, quality control systems and statistical process control techniques (e.g. six sigma).

Direct costs have been managed through reducing the number of vehicle parts and the number of component suppliers. Flexible manufacturing techniques allow manufacturers to more closely match supply to demand, while quality improvements have reduced costs and contributed to profitability. The extent to which indirect costs are affected by legislation depends both on the technological complexity of complying with the legislation and the timeframe, with costs reducing over time.

The difficulty in isolating the impact of car attributes on prices stems from the complexity of vehicle production technology, pricing strategies and compliance with regulations.

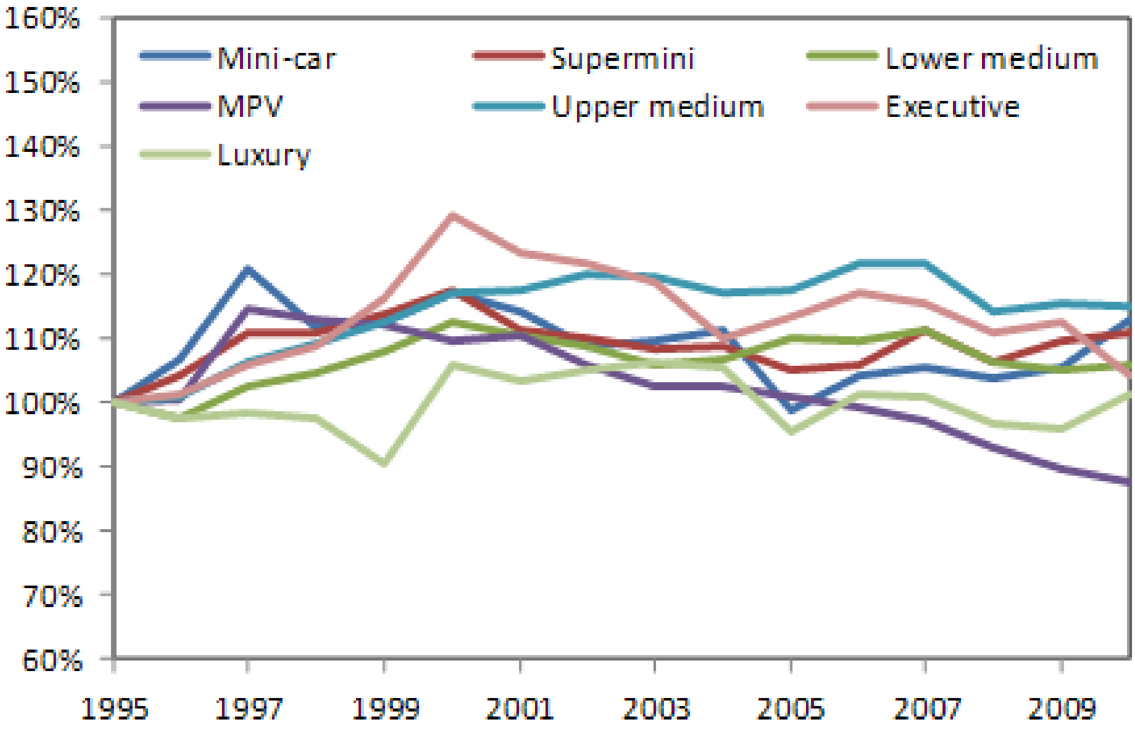
The findings of our literature review show that it has now become more difficult to isolate the impact of various car attributes - such as performance, environmental and safety features - on car prices compared to ten to fifteen years ago. The temporal dimension of cost and profit is separate. The cost of compliance, for example R&D investment or factor development, could be spread over anything between 5 to 20 years. Pricing, servicing and finance plans are also designed to spread the cost of ownership over a number of years.

Only a handful of studies have attempted to isolate the impact of car attributes on prices in the last five years. The majority of the literature is based on the US market, in particular covering the late 1970s and early 1980s. These studies did find notable increases in vehicle prices correlating with new emissions regulations, but they note that the picture varies depending on whether a sales-weighted average or an unweighted average is used. Studies also showed that manufactured absorbed the compliance cost of regulation in immediate years following the regulations but were passed on in the subsequent years.

Evidence from the JATO dataset does not provide any definite relationship between Euro standards and car prices.

Price trends from the JATO dataset suggest that vehicle prices have remained relatively stable over the period 1995 to 2010 (Figure 8-1).

Figure 8-1 Differential in car price for each vehicle size category compared to 1995 (all with EUR 2005 prices)



All price related analysis in this study is based on list price data and not transaction price data. Transaction prices can be much higher than list prices due to optional extra equipment and vehicle financing deals – the differences can be significant enough to recoup the additional costs of emissions abatement equipment and still make a profit.

The price trends indicated slight peaks around Euro 3 for the selected vehicle sizes (Figure 8-2 to Figure 8-4). However, this could be due a multitude of factors and the figures below do not provide a definitive answer. It is difficult to visually deduce if there was an increase in prices as a result of the environmental standards. While there were circumstances where the introduction of standards coincided with an increase in vehicle prices, such as Euro 4 introduction on 4x4 vehicles, there were situations where prices decreased when the Euro 4 introduction, such as in luxury cars. Hence it is not possible to provide a conclusive analysis on the link between Euro standards and prices.

The introduction of Euro 3 in 2000 was the only circumstance where there was an increase in average vehicle prices for all vehicle categories except for 4x4. However, at the same time the single European currency, the EURO, was introduced so it is difficult to state whether this price increase (in Euro terms) is a result of the environmental standard, or due to currency changes. Another possible reason could be that the 4x4 market, which has been expanding rapidly in recent years, at the point of Euro 3 introduction may have been expanding downwards into new price segments which would have reduced average list prices.

Figure 8-2: Evolution in the average price of cars in the super-mini category (Class B) across six member states (in EUR 2005) with environmental legislation overlaid.

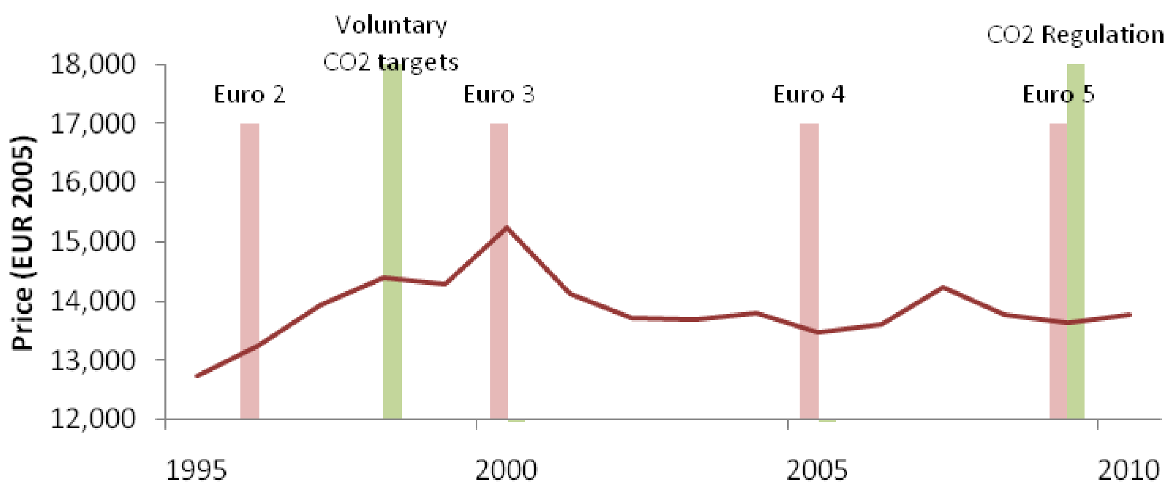


Figure 8-3: Evolution in the average price of cars in the lower medium category (Class C) across six member states (in EUR 2005) with environmental legislation overlaid.

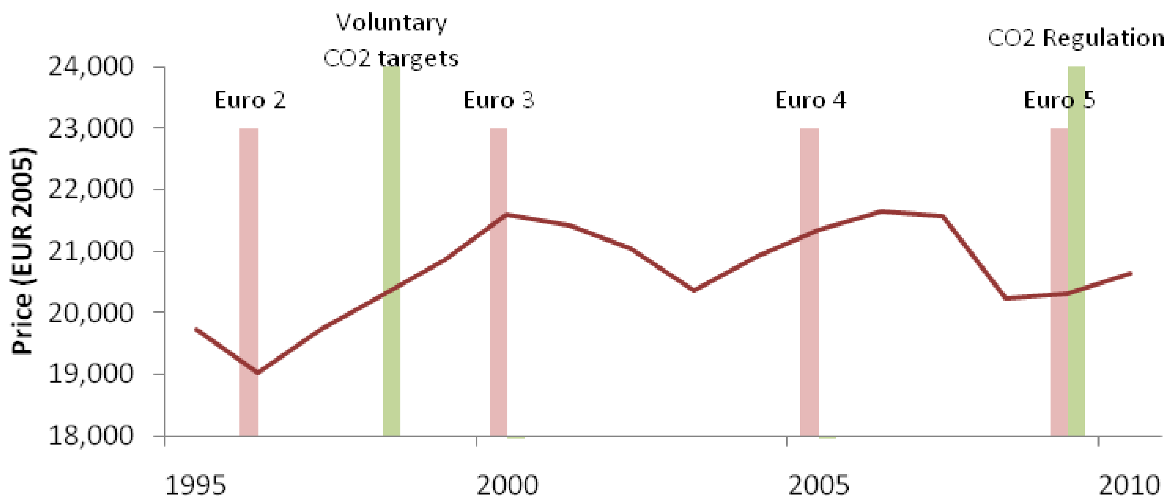
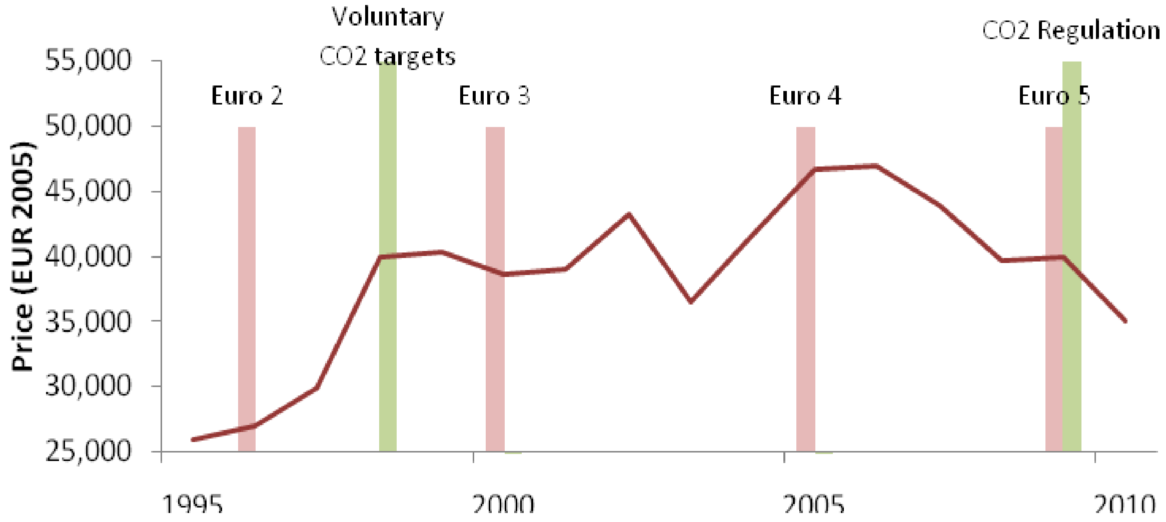


Figure 8-4: Evolution in the average price of cars in the 4x4 category (Class H) across six member states (in EUR 2005) with environmental legislation overlaid



In general only indicative correlations can be made between emission trends and car prices. Average fleet emissions have been declining over time. List price for homogenous model from the JATO dataset (e.g. VW golf, real prices from EC Competition Directorate[157]) and technology adjusted price index from the regression analysis indicate that car prices have fallen more quickly since legally binding CO_2 reductions were announced n 2007 (Table 8-2).

Table 8-2: Key trends in CO_2 emissions and car prices between 2002 and 2010

	Trends 2002-2010	Trends before announcement of legally binding CO_2 targets (2002-2006)	Trends since legally binding CO_2 reduction targets were announced (2007-2010)
	Overall % change	Average annual change (%)	Average annual change (%)
CO_2 emissions from cars	-15	-0.7	-3.0
EC Competition directorate real car prices	-13	-0.6	-2.5
JATO dataset VW Golf list price	-12	-1.4	-1.5
JATO data set technology adjusted price (all diesel)	-22	-1.8	-3.6
JATO data set technology adjusted price (all petrol)	-16	-3.1	-0.4

Note: All prices are adjusted for inflation and exchange rates

[157] http://ec.europa.eu/competition/sectors/motor_vehicles/prices/report.html

Overall cars have become 12% to 22% cheaper – after inflation – in the eight years from late 2002 to late 2010. Before the CO_2 regulation started to have an impact on the CO_2 emissions from cars, the annual average reduction of car prices was slower compared to the period after the CO_2 regulation was announced in 2007. The average annual reduction in CO_2 emissions was 0.7% and 2.5% in 2002-2006 and 2002-2010 respectively.

In the EU, studies looking at impact of regulation on manufacturer costs and vehicle prices are primarily *ex-ante* impact assessments, whereas *ex-post* evaluations of the European market are limited. The main reasons for the difficulty in isolating the impact of car attributes on prices are:

- ***Engine, vehicle and after-treatment technology have become much more complex*** in the last two decades (partly driven by legislation); however improved computing power coupled with techniques such as simultaneous engineering have helped to reduce research and development costs and product development times.

- ***Environmental improvements have been complemented with performance improvements also demanded by the consumer.*** Manufacturers have been able to meet environmental legislation with technologies that also provide improvements in comfort, power and safety features. The JATO dataset showed that from 1995-2010 the average vehicle power has increased by around 40% while the average fuel consumption fell by around 20% for lower medium and supermini vehicles. The study findings showed that car prices can be increased – and therefore margins increased – for additional features that provide consumers with added value or which made a car more appealing. On the other hand, it was not as straightforward to increase prices in response to features introduced for environmental and safety purposes, as often these do not bring any added value to the consumer. The extent (or not) to which this approach maintains market prices at similar levels cannot be clearly identified. The mark up on price competitive segments is very small but car companies have a range of different methods to increase mark ups. This could be through finance deals, servicing plans and increasing price of premium models.

- ***The sector has implemented a range of business strategies aimed at maintaining market share and profitability in an increasingly competitive and liberalised market.*** Consumer demands have evolved substantially over this period, with the emphasis shifting from a desire simply to own a vehicle, to the desire to own a characterful and distinctive vehicle of high quality and specification. Rising fuel prices, and to some extent environmental concerns, are driving a shift in consumer preference towards relatively more economical models; a sector which has traditionally generated thinner margins for the manufacturers.

- ***Compliance with safety and environmental regulations introduced since the late 1980s has forced car manufacturers to improve their designs by adopting a systems engineering approach.*** Early on during this period, these regulations targeted specific aspects of vehicle performance. This led directly to increases in car prices due to the requirement for manufacturers to incorporate new technologies such as catalytic converters. However, in the last decade the emphasis has shifted to incremental safety and environmental legislation which require manufacturers to respond through a diverse combination of measures, including engine modifications, drivetrain improvements and better power to weight ratio. Many car manufacturers are starting to invest in carbon fibre technology which will start being used from 2013. More aluminium in car production is starting to help reduce weight.

Quantitative regression modelling

A hedonic regression modelling approach is a suitable method to analyse the effect of environmental regulation on vehicle prices. Hedonic price functions implicitly capture changes in prices caused by changes in product characteristics. The estimation of a hedonic price equation makes it possible to distinguish between the variation in prices explained by a change in the characteristics and the variation that can be attributed to a pure price effect. However, findings from the literature review suggest that the link between changes in vehicle prices caused by changes in vehicle attributes is not straightforward. Vehicle characteristics have been changing very rapidly over time. Passenger cars have number of different categories and applications ranging from city minis to large SUVs. Producers choose segmentation strategies to exploit this large variation in demand. In particular, these segments exhibit considerably diverse price sensitivities. In such a case, OEMs implement implicit price discrimination strategies to exploit the less price-sensitive segments.

Although one might expect that features, technical performance and intersegment differences would explain the bulk of price variation, it is clear from literature review that a number of other factors have a significant effect on equilibrium prices. These factors include: brand effect; after-sales service; changes in production processes; marketing strategies and platform sharing.

The hedonic equations were specified to isolate some of the above factors as much as possible. Four alternative hedonic model specifications were used to estimate the regression. Model 1 was specified to directly capture the Euro standards effect in the form of an announcement and permanent effect. Models 2-4 were specified to indirectly analyse the impact of regulation on car prices by looking at variables such as fuel efficiency, engine capacity and size. The empirical hedonic models were estimated for four specific datasets:

1. All ***diesel*** vehicles across six Member States from 1997 to 2010;
2. All ***petrol*** vehicles across six Member States from 1997 to 2010;
3. All ***diesel*** vehicles in the supermini and lower medium categories combined across six Member States from 1997 to 2010; and
4. All ***petrol*** vehicles in the supermini and lower medium categories combined across six Member States from 1997 to 2010.

For datasets 3 and 4, the vehicles with extreme power/weight ratios (i.e. the highest and lowest 10% of the dataset) were removed to show the effects for a similar size car with comparable performance over the time period.

The main findings are stated in Table 8-3.

Table 8-3: Findings from quantitative regressions on the four datasets:

Euro standard effects (Using model 1)	Datasets			
	1	**2**	**3**	**4**
Those cars in the year when the Euro 3 regulation was enforced were ***more*** expensive by:	3.3%	6.4%	4.2%	7.2%
Those cars in the year when the Euro 4 regulation was enforced were ***more*** expensive by:	0.6%	-3.4%	1.1%	0.2%
Those cars in the year when the Euro 5 regulation was enforced were ***more*** expensive by:	1.8%	2.8%	-1.1%	-0.6%
Car attributes (comfort) (Using model 2)				
Those cars with ABS are ***more*** expensive by:	5.2%	1.7%	-2.8%	-2.2%
Those cars with luxury interior upholstery are ***more*** expensive by:	6.5%	6.2%	5%	6.9%
Those cars with cruise control are ***more*** expensive by	1.4%	1.6%	2.3%	3%
Those cars with front fog lights are ***more*** expensive by	3.1%	3.6%	3.2%	3.3%
Those cars with air conditioning are ***more*** expensive by	5.6%	6.4%	4.2%	5.1%
Car attributes (performance) (Using model 2)				
A unit increase in fuel consumption (l/100 km) relates to an increase in average car prices by	3.8%	1%	2.1%	-2.2%
A 100 kg increase in kerb weight can be associated with an increase in price by	*	2%	3%	1.3%
An increase in length by 10cm can be associated with an increase in price by	3%	2%	2%	2%
A unit increase in engine power (cv) can be associated with an increase in price by	0.3%	0.2%	0.15%	0.2%

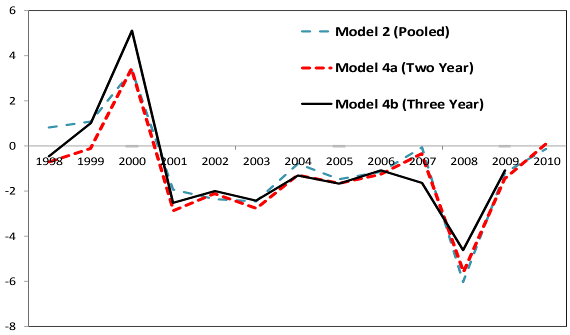
* The kerb weight attribute was removed from regression 1 due to multicollinearity.

Another feature of the hedonic modelling approach is that the coefficient for the time dummy variables reveals the variation in the price adjusted by quality or technological change. This provides preliminary evidence on the impacts of regulation, fuel prices and other exogenous factors on prices and technology change. The time coefficients fall over time for all four datasets, reflecting a decline in performance-corrected prices due to technological change. This suggests that technological progress allows the same bundle of attributes to be produced at a lower cost and bought at a lower price. In other words we find that after controlling for product characteristics, car prices fell during the years 1995-2010 even during rapidly changing fuel prices and increasing emission controls.

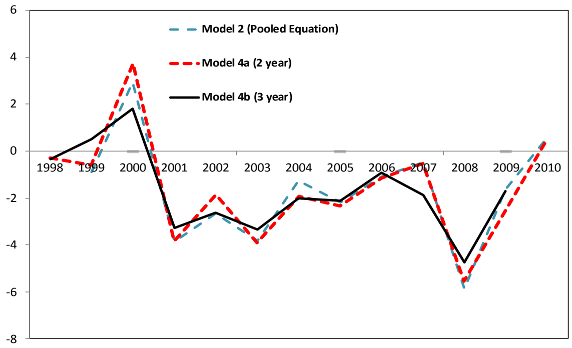
The time variable ‘t’ can also be used to calculate the technology (quality/features) adjusted price index,(i.e. the price increase or decrease compared with the previous year when technology-related shifts are excluded) (Figure 8-5). The year on year changes in the index can partially be ascribed to annual fluctuations, but may also reflect specific impacts such as business cycles and trends in fuel prices. The steep fall in prices in 2000 and sustained low prices are mainly due to both increasing tax rates on transport fuels and, more recently, rising world crude oil prices. The economic recession in 2008-2009 had an impact on vehicle prices, with the pound devaluation causing vehicles sold in the UK to be worth around 20% less in Euro terms than before the crisis. Another likely effect of the economic recession is a decrease in vehicle prices as a result of a decrease in consumer demand due to the tighter credit conditions and economic uncertainty. The fall in price for petrol vehicles in the supermini and lower medium categories (Dataset 4) is much higher than all diesel and petrol vehicles. This can be attributed to the fact that this is a fiercely price competitive segment.

Figure 8-5: Technology adjusted price change (%)

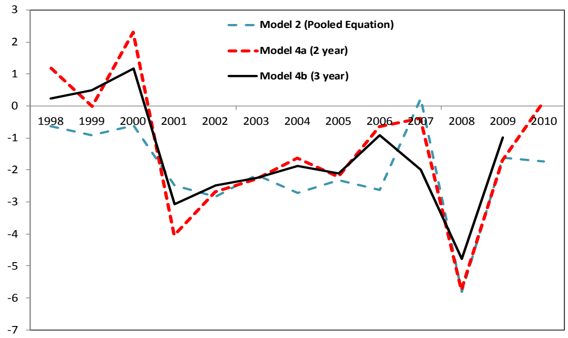
Dataset 1 – All Diesel Vehicles



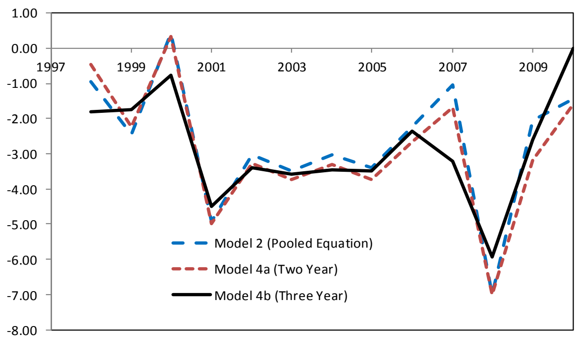
Dataset 2 – All Petrol Vehicles



Dataset 3 – Diesel Subset

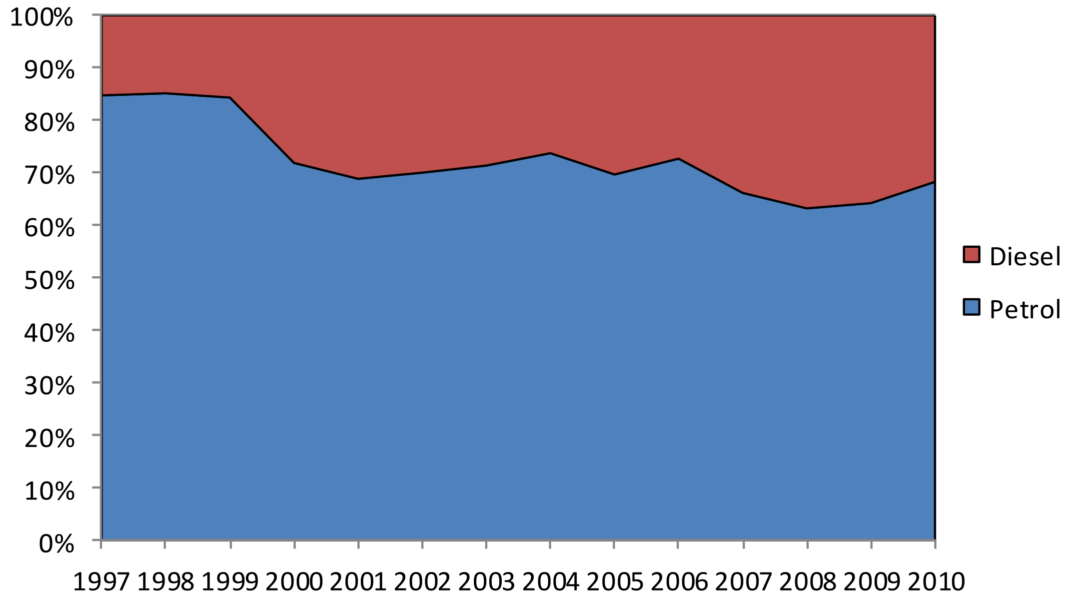


Dataset 4 – Petrol Subset



Lastly, Model 3 and 4, provide annual coefficient estimates to analyse the variation in price due to variation in attributes. This provided key trends in the significance and size of attributes in explaining the variation in car prices. As one can expect this can generate a wealth of information and for convenience only the relationship between price and fuel consumption is discussed here (Figure 8-7).

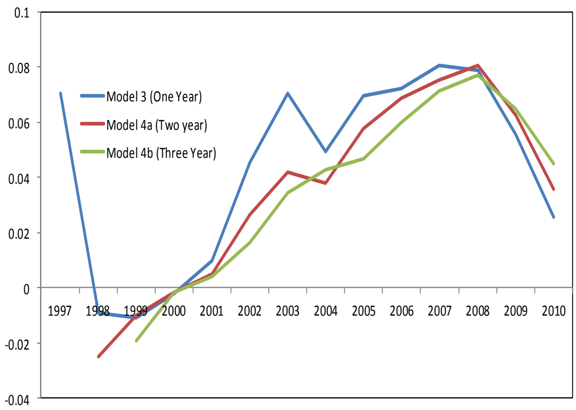
Figure 8-6: Breakdown of diesel and petrol model variants within the JATO dataset.



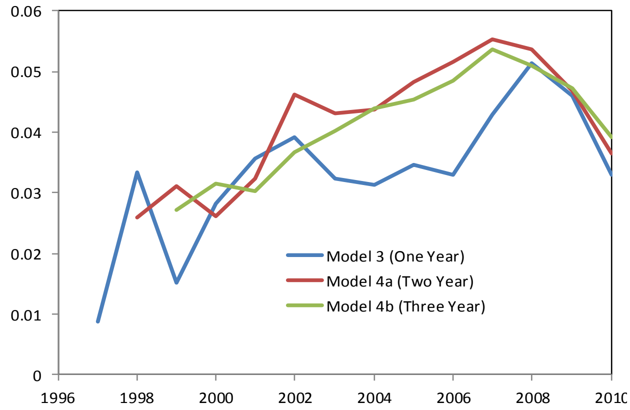
In dataset 1 and 2, an increase in fuel consumption was associated with an increasing price premium for all diesel and petrol vehicles over time. This makes sense as larger, heavier and high performance cars will have higher prices and will in general use more fuel. However, the increase in price premium over time could be due to higher specifications of cars that consume more fuel and possible brand effects. Dataset 3 and 4, by virtue of a narrow and more comparable dataset can demonstrate the link between fuel consumption and price more accurately. Dataset 4 shows that the relationship between fuel consumption and price was volatile compared to Dataset 1, 2 and 3. The graph below for Dataset 4 shows that a unit decease in fuel consumption (increase in efficiency) between 2001 and 2006 was associated with an increase in prices. Unlike “All diesel and petrol dataset” there is no price premium for cars with greater fuel consumption. This is expected because we have adjusted for the effects of certain features such as brand and size influencing the impact on price. Petrol variants in this size category are generally cheaper than diesel and tend to cover the more price competitive variants. However, the figure for Dataset 3, suggests that in the diesel supermini and lower medium segment cars with higher fuel consumption commanded a price premium presumably because larger engine variants are associated high feature content and thus price. This is expected as diesel engines are more expensive than petrol variants. Particularly in recent times as after treatment technologies for diesel engines have been needed to meet increasingly stringent exhaust emission standards.

Figure 8-7: Parameter estimate - Combined fuel consumption (l/100km)

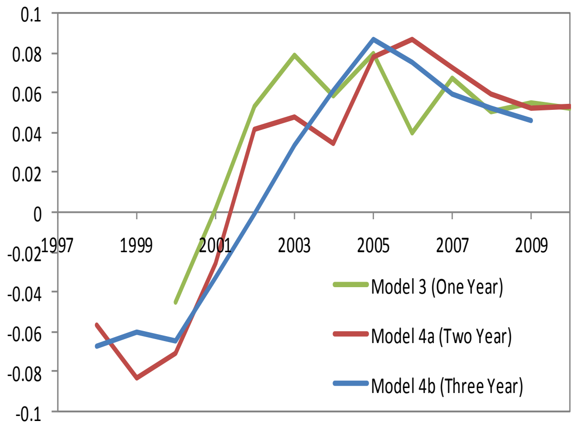
Dataset 1 – All Diesel Vehicles



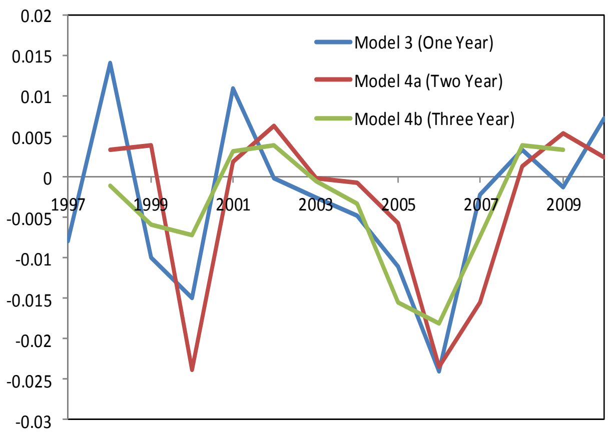
Dataset 2 – All Petrol Vehicles



Dataset 3 – Diesel Subset



Dataset 4 – Petrol Subset



Findings from stakeholder interviews

Seven EU level stakeholders and 14 manufacturers were contacted for interview. Due to the wide scope of the project, and the limited experience of some of the stakeholders contacted, it was challenging to identify representatives of the organisations contacted who were prepared to be interviewed for the project. In the end, two EU level stakeholders were interviewed, along with one manufacturer, while a written response was received from two manufacturers and from ACEA, whose response was supported by several other manufacturers.

The most important factors that influenced car prices and, including the extent to which these costs were passed through to consumers, were environmental standards, market conditions (e.g. tax levels for public and private users, consumers' purchasing power) and competition.

Most of the respondents agreed that the factors identified in the literature review (see list in Table 6-2) were the main factors that influenced costs and car prices. Other regulatory factors, including vehicle taxes and incentives and free trade agreements with third countries with significant car industries, were also mentioned. The most important factors were considered to be environmental standards, market conditions (such as tax levels for public and private users, consumers' purchasing power, etc.) and competition.

Respondents generally agreed that manufacturers operating in several different markets determined optimal prices on the basis and nature of the competition in each market. They also generally agreed that price differences between different models could be explained to some extent by variations in individual car characteristics, particularly where these characteristics brought added value to the consumer, although it was noted that brand, image and attractiveness were also important. The most important factors that explained the extent to which increased costs were passed on to consumers were considered to be competition and market conditions, as well as the extent to which the additional features could be considered to bring added value to consumers. It was generally considered that these factors varied by brand, vehicle type and market.

Whether the increased costs of complying with environmental and safety legislation lead to increases in prices depends on *inter alia* the extent to which these costs are offset by cost reductions resulting from economies of scale and improved productivity and whether prices any cost increases can be passed on to consumers.

Generally, it was felt that environmental and safety legislation would always lead to increased costs, although some considered that the requirements of some pieces of safety legislation did not necessarily increase costs. Where such increased costs did not subsequently lead to increased prices, it was argued that this was due to competition in the markets concerned. Reduced costs resulting from, for example, economies of scale or improved productivity (for the reasons identified in the literature review; see above), could offset the increased costs of regulation. However, where net cost increases could not be passed on to consumers, then the margins of manufacturers and/or their suppliers would be reduced. More generally, if environmental and safety legislation had not increased costs, car prices would be lower than current levels. The extent to which increased costs can be passed on to consumers depends on competition and market conditions. Of the respondents that had a view on this, most agreed that the ability to pass on costs varied by brand and the type of vehicle being sold (as well as the market) and exposure to foreign brands.

Respondents provided mixed messages on the future impact of regulation and impact on costs.

Looking forward, it was considered that competition and further economies of scale would be the most important factors that would lead to reductions in car prices over the next 10 years, although it was noted that the latter factor might play less of a role than it has historically as the strategies with the most potential have already been taken up. Some felt that regulatory pressures would reduce costs, as cars would be smaller, while others felt that costs would subsequently increase, e.g. as hybridisation would be required more widely. There was no agreement as to what the net effect on prices would be: some felt that it was impossible to say, while one respondent felt that competition would continue to drive down prices, while another felt that increases in car prices were inevitable.

Respondents suggested regulatory impacts assessments should be broadened in Europe to better reflect the impact on the industry's competitiveness and other options for reducing transport's CO_2 emissions.

There were few suggestions as to how to improve the assessment of future proposals for EU environmental legislation. Two respondents suggested the need for the consideration of wider options in the impact assessment process, including other means of reducing emissions from vehicles such as stimulating fleet replacement. Another suggestion was for a competitiveness impact assessment to be undertaken along with the impact assessment focusing on costs, and for such assessments to be undertaken on revenue-neutral basis, as governments will find a means to replace any lost revenue stream.

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