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The influence of the  
Diesel scandal on  
traditional car manufacturers  
Electric Vehicle  
development as part of the  
automotive megatrends

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## Abstract

**Title:** The influence of the Diesel scandal on traditional car manufacturers Electric Vehicle development as part of the automotive megatrends

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The automotive industry currently faces four megatrends which are challenging the competitive environment: Connectivity, Autonomous Driving, Shared Services and Electric Vehicles. On top of that, aftermaths from the Diesel scandal are still noticeable.

Therefore, the objective of this work was to find whether the Diesel scandal has an influence on the development of Electric Vehicles of traditional car manufacturers among the other trends.

First, consumers were asked to fill out a survey on the attractiveness of and their attention towards Electric Vehicles before and after the scandal. It was concluded that EV demand didn't change because of the Diesel scandal, even though the attention of consumers increased. A main reason therefore is the dependency of EV demand on financial incentives rather than environmental concerns.

Second, to measure the impact on EV development, selected employees from traditional car manufacturers were interviewed and the results were discussed with an industry expert. After collecting the drivers behind Electric Vehicle development, an indirect influence on EV development was revealed. To meet environmental targets set by governments or political unions, OEMs must focus on new technologies due to the lack of Diesel car sales.

When establishing a connection between the research findings and literature, the dynamic capabilities framework was not found to be applicable as the development and adaptation of Electric Vehicles is mainly dependent from external surroundings. Thus, Industrial Organization as underlying theory was found to be suitable.

**Keywords:** Competitive advantage; dynamic capabilities; resource based theory; superior performance; automotive industry; diesel scandal; Industrial Organization; Environmental targets; OEM; traditional car manufacturers; Electric Vehicles; Electric Vehicle development; Electric Vehicle demand; Automotive megatrends; Connectivity; Autonomous Driving; Shared Services

## Sumário Executivo

**Título:** The influence of the Diesel scandal on traditional car manufacturers Electric Vehicle development as part of the automotive megatrends

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A indústria automóvel enfrenta atualmente quatro macro-tendências que desafiam a envolvente competitiva: Conectividade, Direção Autónoma, Serviços Partilhados e Veículos Elétricos. Além disso, os resultados do escândalo “Diesel” ainda são visíveis.

O objetivo deste trabalho foi descobrir se o escândalo “Diesel” tem influência no desenvolvimento de veículos elétricos de fabricantes dentro da indústria tradicional automóvel, entre outras tendências.

Em primeiro lugar, foi pedido aos consumidores que preenchessem um questionário sobre a atratividade e a atenção destes para com os veículos elétricos antes e depois do escândalo. Concluiu-se que a procura de veículos elétricos não mudou devido ao escândalo “Diesel”, embora a atenção dos consumidores tenha aumentado. Uma das principais razões, portanto, é a dependência de veículos elétricos de incentivos financeiros, em vez de preocupações ambientais.

Em segundo lugar, para medir o impacto no desenvolvimento de veículos elétricos, foram entrevistados funcionários, seleccionados de fabricantes de automóveis tradicionais, e os resultados foram discutidos com um especialista do setor. Depois de recolher os drivers por detrás do desenvolvimento do Veículo Elétrico, uma influência indireta no desenvolvimento de VE foi revelada. Para atingir as metas ambientais estabelecidas pelos governos ou sindicatos políticos, os OEMs devem-se focar em novas tecnologias devido à falta de vendas de carros a “Diesel”.

Ao estabelecer uma conexão entre os resultados da pesquisa e a literatura, a tese das capacidades dinâmicas não se mostrou aplicável ao desenvolvimento e adaptação de veículos elétricos. Assim, a Organização Industrial como teoria subjacente foi considerada adequada.

**Palavras-chave:** Vantagem Competitiva; Capacidades Dinâmicas; Teoria Baseada nos Recursos; performance superior; indústria automobilística; escândalo de diesel; Organização industrial; Metas ambientais; equipamento original dos fabricantes; fabricantes de carros tradicionais; Veículos elétricos; Desenvolvimento de veículos elétricos; Demanda de veículos elétricos; Megatendências automotivas; Conectividade; Direção Autónoma; Serviços Partilhados

# Content

Abstract .....	II
Sumário Executivo .....	III
Acknowledgments .....	VI
List of figures .....	VII
Index of abbreviations .....	VIII
1. Introduction .....	1
1.1 Topic Presentation and relevance .....	1
1.2 Problem statement definition and research questions.....	3
1.3 Structure.....	3
2. Literature Review .....	5
2.1 Industrial Organization .....	5
2.2 Resource Based Theory .....	6
2.3 Dynamic Capabilities .....	7
2.4 Selected drivers of the automotive industry .....	9
2.4.1 The Diesel gate and the Environment.....	9
2.4.2 Automotive Product R&D .....	11
2.4.3 The four automotive megatrends .....	13
2.4.3.1 Connectivity and Autonomous Driving .....	13
2.4.3.2 Shared Services .....	14
2.4.3.3 Electric Vehicles .....	15
3. Conceptual Framework and Hypotheses.....	17
4. Methodology and Data Collection .....	18
4.1 Research Method .....	18
4.1.1 Consumer research method.....	18
4.1.2 Company research method.....	19
4.2 Sampling.....	20
4.2.1 Consumer survey sampling.....	20
4.2.2 Company survey and interview sampling.....	20
4.3 Research Instruments.....	21
4.4 Design and Procedure.....	21
4.4.1 Consumer survey design and procedure .....	22

4.4.2 Company survey and interview design and procedure .....	23
5. Results Analysis .....	24
5.1 Consumer Research .....	24
5.1.1 Descriptive Analysis .....	24
5.1.2 Main Results .....	26
5.2 Company Research .....	28
5.2.1 Descriptive Analysis .....	28
5.2.2 Main Results .....	28
5.3 Conclusion of the Results .....	30
6. Limitations and future research.....	34
6.1 Limitations.....	34
6.2 Future Research Implications .....	35
6.2.1 Academic Research Implications.....	35
6.2.2 Practical Research Implications .....	37
Appendix .....	IX
References .....	XXIII

## Acknowledgments

The automotive industry fascinates me since I can remember. With family members working in that industry, I enjoyed my past internships at an OEM, Tier 1 and a Tier 2 company. Especially the upcoming years will be exciting due to the automotive megatrends and the resulting new business opportunities.

Therefore, I want to thank my supervisor professor João Flório for keeping pushing me to find a topic that really interests me personally. With his extensive knowledge in the field of competitive advantage and his friendly attitude and direct feedback, he has a share in the success of this dissertation.

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## List of figures

Figure 1: Extended automotive industry revenue in the US 2014 (Source: Corwin et al., 2015)	1
Figure 2: Structure of the thesis (Source: Own Image)	4
Figure 3: Internal and external product complexity (Source: Sørensen, 2006; Clark and Fujimoto, 1991)	12
Figure 4: EV types (Source: Underwood, 2015)	15
Figure 5: Conceptual framework (Source: Own Image)	17
Figure 6: Average fleet emissions by fuel type 2016 (Source: Klug, 2017)	32
Figure 7: Drivers of EV development (Source: Own Image)	37
Table 1: R&D expenses 2016 of top 10 OEMs ranked by revenue (Source: Own Illustration based on 2016 business reports of OEMs)	3
Table 2: Consumer responds by continent and country (Source: Own Illustration)	25
Table 3: Consumer Survey Dependent Variables (Source: Own Illustration)	XV
Table 4: Consumer Survey Independent Variables (Source: Own Illustration)	XVI
Table 5: Company online survey Dependent Variables (Source: Own Illustration)	XVII
Table 6: Company online survey Independent Variables (Source: Own Illustration)	XVIII
Table 7: Cronbach's alpha of consumer attention and awareness scales (Source: Own Illustration)	XIX

## Index of abbreviations

AD	Autonomous Driving
BEV(s)	Battery Electric Vehicle(s)
CA	Competitive Advantage
DC	Dynamic Capabilities
DS	Diesel Scandal
EPA	Environmental Protection Agency
EV(s)	Electric Vehicle(s)
FCEV(s)	Fuel-cell Electric Vehicle(s)
GWP	Global warming potential
HEV(s)	Hybrid Electric Vehicle(s)
HOV	High-occupancy vehicle
HR	Human Resources
HSD	Honestly Significant Difference
ICEV(s)	Internal combustion engine vehicle(s)
OEM(s)	Original Equipment Manufacturer(s)
PHEV(s)	Plug-in hybrid Electric Vehicle(s)
R&D	Research and Development
SAE	Society of Automotive Engineers
SME(s)	Small and Medium Enterprise(s)



# 1. Introduction

## 1.1 Topic Presentation and relevance

It is no surprise that the automotive industry is targeted by researchers worldwide resulting in a wide variety of existing papers: The extended value chain is essential to global economic growth. In the United States alone, the industry generated \$2 trillion in 2014 (see Figure 1) (Corwin *et al.*, 2015).

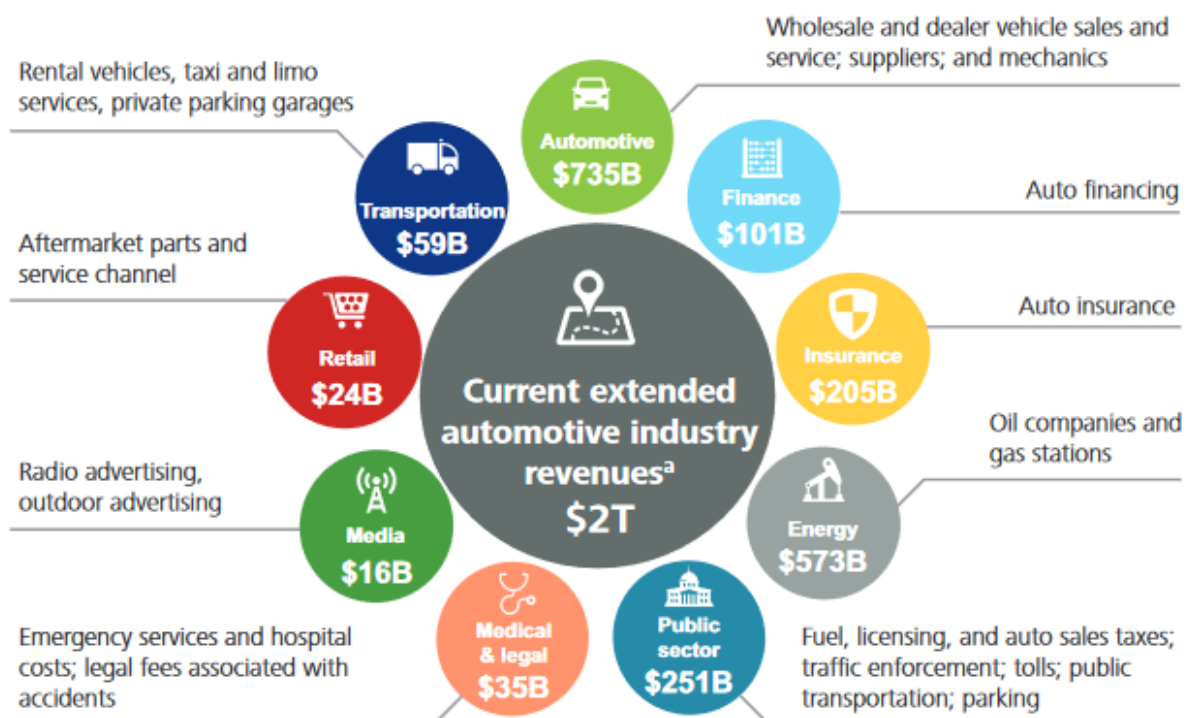


Figure 1: Extended automotive industry revenue in the US 2014

Due to changing consumer preferences, shorter product life cycles and innovation pressure, the automotive industry currently faces a revolution in multiple ways (Fojcik and Proff, 2017). Daimler uses the shortcut *CASE* for the megatrends Connectivity, Autonomous driving (AD), Shared Services and E-mobility (Daimler, 2018). While Connectivity features enable a car to communicate with the environment as requirement for self-driving cars, the trend of car sharing proves popular especially by the younger generation (Viereckl *et al.*, 2016). Regarding E-mobility, Volvo announced recently to change their business strategy to be a pure electric car provider only (Vaughan, 2017), while the market of Electric Vehicles (EVs) grew by 60 percent in

2016 and is expected to reach a 30 percent overall market penetration by 2030 (International Energy Agency, 2017).

Even though Volkswagen posted its first quarterly loss for 15 years in October 2015 due to the Diesel scandal (DS), they became the best-selling car manufacturer worldwide in 2016 (Müller, 2017). On the other hand, bans on Diesel vehicles in major cities can cause serious problems for consumers, forcing them to react (Hoster, 2015; Reuters, 2017). Toyota announced the time has come for the fuel cell technology in reaction to the Diesel scandal (Toyota, 2018).

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*“The Dieselpgate is the wake-up call to look seriously at  
alternative car technologies”*

*– Harry Hoster, Lancaster University (Hoster, 2015)*

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In this research, only traditional car manufacturers are taken into consideration because pure EV manufacturers would profit from a possible shift in demand without the need to change their business.

Following the business reports of the top Original Equipment Manufacturers (OEMs) ranked by sales in 2016 (MBA Skool, 2017), there was an increase in Research and Development (R&D) budget after the crisis at every company except BMW. The data shown includes write-offs and investments:

OEM	R&D '16 (MIO.)	R&D '15 (MIO.)	CHANGE (%)
<b>FIAT CHRYSLER</b>	€ 3.274	€ 2.864	+14,3
<b>BMW GROUP</b>	€ 5.164	€ 5.169	-0,1
<b>FORD</b>	\$ 7.300	\$ 6.700	+9,0
<b>DAIMLER</b>	€ 7.572	€ 6.564	+15,4
<b>GENERAL MOTORS</b>	\$ 8.100	\$ 7.500	+8,0
<b>NISSAN</b>	¥ 560.000	¥ 531.900	+5,3
<b>HONDA</b>	¥ 719.800	¥ 670.205	+7,4
<b>HYUNDAI-KIA</b>	₩ 1.646,4	₩ 1.523,5	+8,1

<b>TOYOTA</b>	¥ 923.400	¥ 886.200	+4,2
<b>VW GROUP</b>	€ 13.672	€ 13.612	+0,4

Table 1: R&amp;D expenses 2016 of top 10 OEMs ranked by revenue

This R&D development is confirmed by a recent report, which states that car manufacturers from China, South Korea or India will significantly raise their R&D expenditures while those coming from Western countries will likely stay at the same level (Dannenberg and Burgard, 2007). Thus, the question that arises is if these increases in R&D investments are related to the DS and a shift towards EV development.

## 1.2 Problem statement definition and research questions

So far, the influence of scandals on R&D fields of car manufacturers is not given much attention in the world of automotive research. Therefore, this research aims to get a deep understanding of the decision making of the players inside, forwarding the academic research with consumer research, OEM manager consultation and the interpretation of their answers (Glaser and Strauss, 1967).

In the first place, the goal of this thesis is to elaborate the influence of the Diesel scandal on Electric Vehicle demand. Therefore, the first research question is defined:

**Research question 1:** Is the Diesel scandal a driver of increased demand of Electric Vehicles?

Afterwards, the impact on traditional car manufacturers' Electric Vehicle development as part of the four industry megatrends including Connectivity, Autonomous Driving and Shared Services is investigated. This leads to the second research question:

**Research question 2:** Did traditional car manufacturers change their R&D regarding Electric Vehicles more than the other industry megatrends Connectivity, Autonomous Driving and Shared Services as a reaction to the Diesel scandal?

## 1.3 Structure

The dissertation is structured as follows: After this introduction chapter, existing literature of the topic is reviewed. The third chapter contains the methodology used and how data is collected. The analysis of the results is followed by the research conclusion. Finally, limitations as

well as theoretical and practical implications for further research on this topic area are presented.

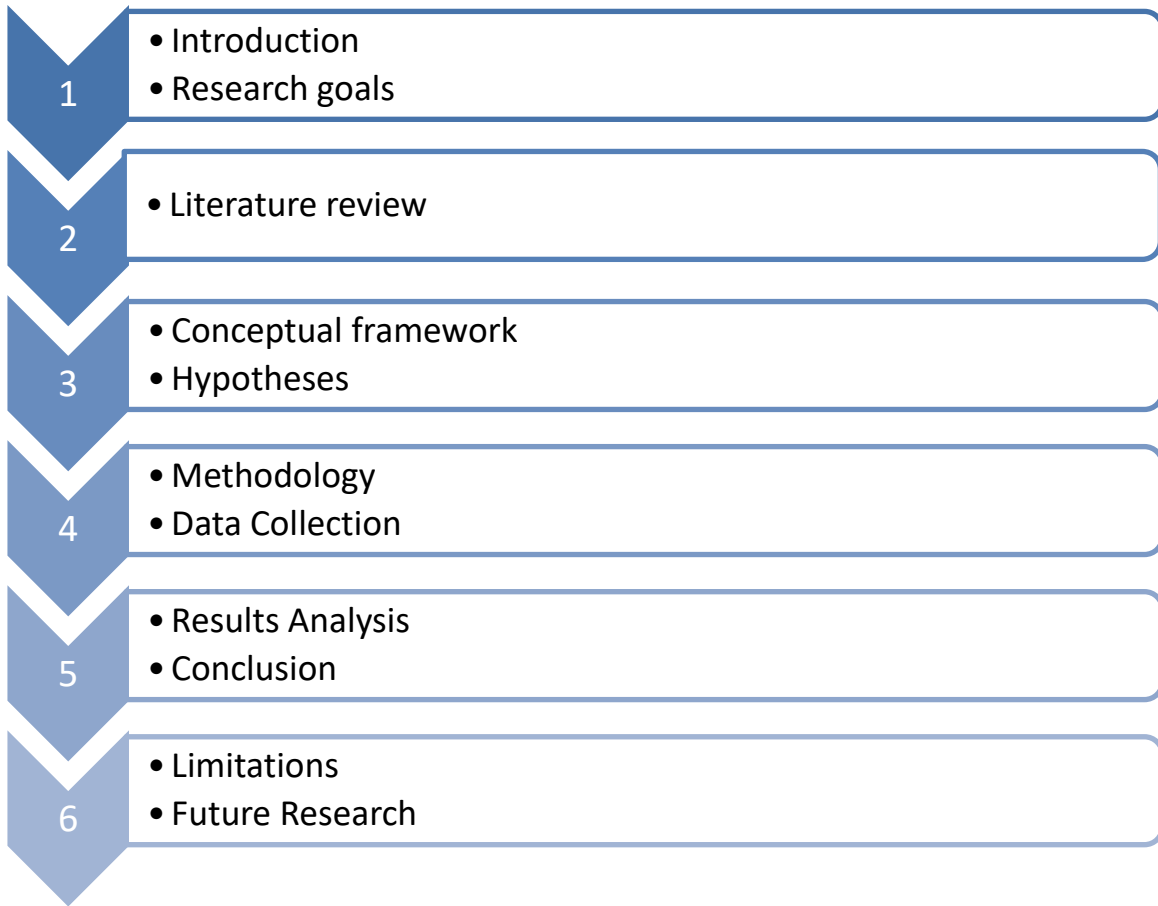


Figure 2: Structure of the thesis

## 2. Literature Review

Because the scope of this work is a very innovative field, suitable literature about the Diesel scandal and its impact on the competitive environment is rare. However, this was not a reason to decline and focus on matured study areas, but rather exploiting something innovative.

Before presenting literature about selected drivers of the automotive industry, general literature of the debate about whether the industry or the firm is the base of superior performance (Henderson and Mitchell, 1997) is presented with a link to this thesis.

### 2.1 Industrial Organization

Regarding industry as the driver for success, the Industrial Organization (I/O) model targets the difference in industry factors as source of the performances among firms. The approach is external with focus on the environment of the business as well as the different behaviors of firms and consumers of a specific type of industry (Bain, 1968). Within the research, strategy is defined as the way a firm tries to compete within its environment, enclosing choices about their operating market, marketing, production and business goals, among others, while the goals can be both defined as economic or noneconomic. Furthermore, the internal competences and values must be matched with the external environment. With the help of consistency tests, a firm can assess the relation of the strategy and the environmental elements while simultaneously it must ensure that all functional areas are interrelated (Andrews, 1971).

Among others, the choice of a competitive strategy is determined by the attractiveness of industries for long-term profitability and the competitive position a firm is planning to take. Competitive advantage can be achieved as a result of differentiation or cost leadership relative to competitors, whereby the first creates brand loyalty, reputation and the possibility of premium pricing, whilst the second targets high sales volume via aggressive pricing (Porter, 1985).

First mover advantages are usually enhanced by large scale economies as markets are finite and competitors may fear reaching a bigger size because they might exceed the demand afterwards which results in losses for everyone in the industry. These fast and large scale movements can also set higher standards or gaining limited access to crucial and scarce resources to potential entrants (Ghemawat, 1986; Lieberman and Montgomery, 1988).

Firms must not only concern with the present situation and growth in near future, but also examine the long-term positioning and its source of competitive advantage. This will especially

help them when their current strategies are either becoming outdated or copied (Hamel and Prahalad, 1994).

For this work, the I/O model is found to be insufficient as it explains firm's behavior just by environmental conditions of the sector it is operating. Even though there might be differences in reaction to the Diesel scandal dependent on the country of origin of the OEMs, internal conditions of firms should be considered rather than the whole industry as timely decision making (Barreto, 2010) to adopt new technologies is also found important beforehand. Hence, literature about the RBT as well as the Dynamic Capabilities (DC) framework are presented in the following subchapters.

### 2.2 Resource Based Theory

Contrary to the I/O model, the Resource Based Theory (RBT) assumes the firm as the base of superior performance (Barney, Wright and Ketchen, 2001). It defines a company as a set of its resources, while the growth of a firm represents the capacity of exploring external opportunities with given internal resources. Hereby, external opportunities can be a source of the firm, as the firm is part of the environment and therefore has an influence on it (Penrose, 1959). To exploit and follow a certain strategy, specific investment decisions, organizational structures or even cultures are implied (Teece, 1984). Moreover, when a company follows a strategy, which is suitable to create value and is not followed by other firms in the industry or potential competitors because of the impossibility of duplication, it is possible to gain sustainable competitive advantage. To explain differences in performances among firms, internal attributes are therefore an important factor.

Within the RBT, there are three key types of resources: *Tangible resources* include all physical, organizational, financial and technological assets. For example, these include plants, patents, processes and systems. *Intangible resources* include firm's reputation, innovation potential and creativity as well as human resources. *Organizational capabilities* represent the skills and competencies inside a firm to convert inputs to outputs and the ability to combine tangible and intangible resources (Ketchen and Eisner, 2008).

To be difficult to imitate, resources must possess at least one of the following characteristics: *Physical uniqueness*, which for example represents exclusive mineral rights, patents or a superior location; *Path dependency*, which describes resources that are built over time and cannot be bought right away such as brand reputation (Ketchen and Eisner, 2008); *Causal ambiguity*,

which represents tacit and invisible assets which can't be identified by competitors (Polanyi, 1962; Itami and Roehl, 1987; Winter, 1987; Ketchen and Eisner, 2008); or *Social complexity*, which refers to the coordinated and bundled knowledge of teams with a sufficient breadth, including culture and interpersonal manager relations (Reed and DeFillippi, 1990; Barney, 1991; Ketchen and Eisner, 2008).

Scale economies, patents or brand reputation serve as an important resource of firms in terms of their market power and generating profits, as they also represent entry barriers for potential competitors (Grant, 1991). However, it is not enough to possess distinct resources. They must be suitable to generate products or services which are wanted by the market (Collis, 1996). This leads to a shift in competition from products to a competition between resources and competences (Hamel and Prahalad, 1994; Sanchez and Heene, 1996), while both together have the potential to describe superior performance of a company (Grant, 2013).

To examine a firm's integration of resources, one of the most prominent methods is the VRIO model, which measures the integration of resources in a company according to the value, rareness, inimitability and organization of these assets (Barney, 2002). Within the RBT, several researchers proved that positive financial results are linked with proactive corporate environmental strategies which go further than regulatory compliance only and when the organizational capabilities that the firm uses are valuable (Hart, 1995).

Even though the RBT has earned big reputation and attention in economics, there is also criticism about it. For example, the RBT is not a theory of the firm as it lacks explanations of why firms exist and why they possess specific boundaries and organizations (Foss, 1996). However, the lack as a theory of a firm does not affect the explanation of sustainable competitive advantage (Kraaijenbrink, Spender and Groen, 2009).

Although the link between environmental strategies and positive financial returns seem adequate for this research, the RBT doesn't explain sustained competitive advantage as a consequence of entrepreneurial rents (Teece, Pisano and Shuen, 1997). Therefore, another theory is presented in the following.

### **2.3 Dynamic Capabilities**

The Dynamic Capabilities (DC) framework can be seen as an addition to the RBT in the case of fast changing environments (Barney, Wright and Ketchen, 2001), where quick responses to market dynamics and rapid innovation guarantee a company superior performance. It refers to

the ability of firms to react to changes in the external business environment. While the term dynamic refers to the ability of a firm to change their resources in order to ensure congruence with the changing environment, the term capabilities describes the most important aspect of strategic management to sufficiently adapt, integrate and reconfigure resources, organizational skills and functional competences – all of them internal as well as external – in order to fulfill the needs of the new environment. Thus, exploiting opportunities is critical to a firm's competitive advantage (Teece, Pisano and Shuen, 1997).

To encounter tautological issues and to allow different degrees of dynamic capabilities across firms, the following definition has been proposed (Barreto, 2010):

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*“A dynamic capability is the firm’s potential to systematically solve problems, formed by its propensity to sense opportunities and threats, to make timely and market-oriented decisions, and to change its resource base.”*

- (Barreto, 2010)

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While one of these dimensions alone can't represent the whole construct, dynamic capabilities are represented by all of them, without the need that all of them are distributed highly inside a firm (Barreto, 2010).

On the other hand, Dynamic Capabilities was criticized for being vague, confusing and abstract (Williamson, 1999; Kraatz and Zajac, 2001; Winter, 2003; Danneels, 2008). Furthermore, there has been uncertainty about the relevant context in terms of moderately, highly or stable environments and whether testing it empirically ex ante or ex post (Barreto, 2010).

However, Dynamic Capabilities was found to be suitable as underlying theory for this research, as the automotive industry faces fast changing environments. To make timely, market-oriented decisions when sensing an opportunity, such as increased demand towards EVs, can be crucial for achieving competitive advantage. As a consequence of the presented definition (Barreto, 2010), the questions that this thesis is investigating in an academic context are if traditional car manufacturers, which possess a significant market standing since decades, are sensing a possible opportunity regarding increased demand of Electric Vehicles as a result of the Diesel scandal. Furthermore, their strategic reaction in terms of increased development efforts as market-oriented decisions and possible changes in the resource base are investigated.



## 2.4 Selected drivers of the automotive industry

The topic of this research aims to the automotive industry. In this subchapter existing literature about the characteristics and peculiarities of the industry that are relevant for this work is presented.

### 2.4.1 The Diesel gate and the Environment

It is predicted that since 2010, about 80 % of all sold cars and vans in Europe are extremely polluting, exceeding NOx emission limits by over 300 % (Poliscanova, 2017). This indicates that VW is not the only guilty company, many European carmakers are still under suspicion. NOx is harmful for health and contributes to the acidification of ecosystems (Transport & Environment, 2018).

In general, Europe accounts for 70 % of Diesel cars and vans sales compared to the USA with 1 % and China with 2 %. A major reason therefore was the loose air pollution emission limits set by the EU, allowing Diesel vehicles to emit more NOx than those with a combustion engine. Furthermore, fuel and vehicle taxes are significantly lower for Diesel cars in Europe, which incentivized a purchase (Poliscanova, 2017). Thus, an enforcement of the emission controls were claimed (Epstein, 2017), resulting in real driving emission tests (ACEA, 2018a).

There are several identified causes of the DS inside VW. On the one hand, austere leadership styles especially from the former CEO Piëch discouraged open communication across management, cultivated fear and hindered subordinate autonomy. On the other hand, the corporate governance was criticized for being insular, preventing effective organizational learning and enabling repeating errors. Furthermore, negative project information was neglected by the supervisory board because of the governance culture. Thus, product development and sales growth were more important than accountability and sustainability. The feuds between the owner families allowed to prefer emotions over facts. Nepotism raised further criticism about top management members (Jung and Park, 2017).

The consequences include political inquiries and criminal charges, hiring stagnation and economic damage for VW. Furthermore, governments moved toward eco-friendly cars while demand for Diesel cars dropped. VW reacted to the scandal by downplaying the negative effects, attempting to restore the old conditions while calling for perseverance (Jung and Park, 2017; Painter and Martins, 2017).

As the defeat device, which activated certain emission controls during laboratory testing only, is the reason of the scandal (Painter and Martins, 2017), selected research about organizations and the natural environment are considered.

Pollution prevention can guarantee a firm significant savings and therefore cost advantage (Romm, 1994; Hart and Ahuja, 1996). Moreover, the degree of proactiveness towards the adaptation of environmental practices is linked with the size of a firm. Larger companies are more proactive (Aragón-Correa, 1998), while small and medium enterprises (SMEs) lack resources to implement proactive strategies, as such initiatives would reduce their profitability (Russo and Fouts, 1997). Environmental engagement also varies between industries: There is higher evidence for environmental engagement in manufacturing comparing to services or consumer product industries, among others (Banerjee, Iyer and Kashyap, 2003). Thus, the large manufacturing automotive are likely to be environmental proactive and therefore may react to the DS intensely.

Corporate environmentalism consists of two building blocks: Environmental orientation, which reflects the managers ability to recognize the importance of environmental issues their firms are facing and environmental strategy, which represents the degree of implementation of environmental issues in strategic areas of a firm. The environmental orientation is usually observable in mission statements while being separated in internal and external orientation. While internal environmental orientation reflects the values, standards of ethics and commitment to environmental protection inside the company, external environmental orientation refers to the relationships of a company with its external stakeholders (Banerjee, 2002).

To classify orientation into strategies, four levels of strategy are distinguished: Enterprise, corporate, business, and functional strategies (Schendel and Hofer, 1979). The enterprise level mirrors the role in society and fundamental mission of the firm, while the corporate level represents the degree of integration of environmental issues such as starting new businesses, choice of technology, location of plants and R&D investments. Within the business level, product differentiation or targeting niche market are fields of strategy while changing procedures in operations such as purchasing, production, human resources (HR), marketing or sales are decided at the functional level (Carter and Carter, 1998; Banerjee, Iyer and Kashyap, 2003). Green purchasing refers to purchasing activities which focus on reducing waste, promote recycling, among others (Min and Galle, 1981), while regarding production, all activities containing prod-

uct and capacity planning, scheduling, process design, workforce management as well as inventory and quality management should be considered (Gupta, 1995). HR contains the training of employees regarding environmental concerns, which increases the involvement in firm's environmental activities (Govindarajulu and Daily, 2004). Marketing environmental strategies include all activities which aim to satisfy the needs of consumers with the smallest negative impact on the environment (Stanton and Futrell, 1987), while consumers must prefer environmental products that a firm can gain competitive advantage (Polonsky, 1995). For the purpose of this thesis, the impact of the Diesel scandal only on the corporate level of firms is investigated.

### 2.4.2 Automotive Product R&D

Amid research about the drivers of success in the industry, superior performance is linked with flexibility capabilities. Hereby, various dimensions of flexibility which differ in their performance contribution exist. Even though basic flexibility capabilities at the shop floor level are more improved by companies, aggregate flexibility capabilities at the customer-supplier level have a higher correlation with superior performance. The underestimation of the importance of customer-supplier flexibility can therefore harm the competitiveness. In general, companies rely more on flexibility capabilities in environmental uncertain and technologically complex supply chains with mutual understanding but lower interdependence among the involved agents (Martínez and Pérez, 2005).

The RBT suggests that product development is a distinctive intangible resource that has the potential to ensure competitive advantage (Barney, 1991), the research and development of Electric Vehicles is the focus of this work.

In general, a product can be ranked along internal and external complexity. Internal complexity is mainly defined by the production process, quantity of unique components, internal product interfaces and the level of technological component trade-offs. External complexity is mainly defined by the number and types of performance criteria and the scope of which measurable product dimensions are emphasized by the customer. As a result, the automobile is characterized to be both high complex internally and externally (see Figure 3) (Clark and Fujimoto, 1991).

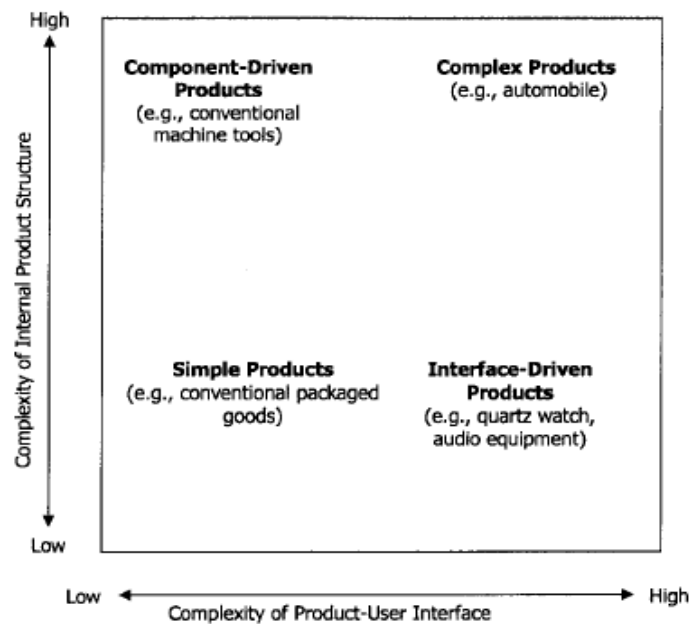


Figure 3: Internal and external product complexity

In a study, Japanese companies were dominant in terms of internal and external integration, developing a design with internal parts consistency and fulfillment of customers' needs in relation to car manufacturers coming from US or EU, while using less long-term project participants. As a result, cross-functional business processes with less reliance on specialists are proposed, which should guarantee high integration and estimation of information asset ability. Furthermore, the degree of integration is a factor of lead-time and productivity. This leads to the conclusion that consistency of the development process using an integrated approach in the automotive industry leads to competitive advantage (Clark and Fujimoto, 1991). This can only be achieved by management focus on an integrated problem-solving process in operations (Wheelwright and Clark, 1992).

Agile approaches are the solution to the current and upcoming challenges in automotive R&D. This is not limited to software developing, as agile methods can also be suitable for the development of embedded systems and mechanic projects. The relatively new approach is considered to decrease cost pressure and the time until product market launch in practice. Therefore, the development process can get faster in overall and allows the supposition that the tendency of short-term changes in R&D due to the Diesel scandal rises (Kostron, Brauchle and Hanisch, 2016).

R&D strategy is usually a strategic topic and a long-term process. It relies on considerable investment and stakeholder partnership. The time lasting tests until market maturity require high lead-times to implement the new technology (ACEA, 2018b).

This would result in the statement that short-term events like the Diesel scandal don't influence development strategies which are planned in the long run. However, if there is a change in consumer demand due to the Diesel scandal, there might be a change in R&D of Electric Vehicles as the dynamic capability framework suggests when the OEMs propensity to sense opportunities is high (Barreto, 2010).

### 2.4.3 The four automotive megatrends

The term *Creative destruction* is referred to as the “process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one.” It happens when innovation demolishes long-lasting arrangements and resources are deployed elsewhere (Schumpeter, 1942). Four current automotive trends possess such potential to reshuffle the industry: Connectivity, Autonomous Driving, Shared Services and Electric Vehicles, shortly also referred to as CASE (Daimler, 2018). Specific literature about the four megatrends is presented in this subchapter.

#### 2.4.3.1 Connectivity and Autonomous Driving

Digital technology in cars rises trying to provide easier and safer driving with personalized assistance: Slowing down if the car in front gets too close, monitoring and adjusting the cars road position or alerting when driving out of the lane. Real-time traffic information guarantees the driver to choose the most time-saving route, while detailed information about engine maintenance can save time and money. Further features include smartphone-based device services including social media, e-commerce, smart home integration, music streaming and access to ride hailing or car sharing services. The heart of connected cars are internet access and sensor variety, which allows to communicate with the physical environment and interact with the surroundings and other vehicles via signals. Therefore, Connectivity is the main driver for autonomous driving. To avoid hacking attacks, cyber security is crucial for the adaptation of the technology by the market (Viereckl *et al.*, 2016).

The 6 levels of autonomy, defined by the Society of Automotive Engineers (SAE), are ranging from the total control of the vehicle by the driver to the fully autonomous driving vehicle. Regarding the monitoring of the driving environment, there is a distinction between human and

system. While human monitoring can range from the levels 0 to 2, system monitoring is categorized from 3 to 5. The current market situation is limited to the levels 2 and 4, limiting the system monitoring until the reliability and availability of required services is fully guaranteed. The evolution will therefore be linked with the enabling technologies, engaging chip manufacturers and transport authorities into the automotive ecosystem to define common communication standards. Furthermore, the infrastructure and licenses of telecom companies will be crucial for this transformation. Even though all players are dependent from each other, they will compete for the highest margins (Martínez de Aragón, Alonso-Zarate and Laya, 2018).

Autonomous driving inhibits numerous advantages for the consumer, such as safer driving. Indeed, the vision of industry players is to put the number of deaths caused by car accidents to zero (Continental Corporation, 2018), being one of the highest death causes worldwide (WHO, 2015). It will reduce stress caused by driving (Rudin-Brown and Parker, 2004) and the required space for parking (Alessandrini *et al.*, 2015). Furthermore, it will lead to time savings of each individual of 38 hours per year, saving the economy a vast monetary amount (Shanker *et al.*, 2013), and to new possibilities, businesses, markets and applications (Bartl, 2015).

The acceptability of the technology is crucial to implement it in society (Payre, Cestac and Delhomme, 2014). Hereby, the interaction between the technology and humans plays a non-negligible role in the establishment (Yang and Coughlin, 2014). For example, anthropomorphizing the driving interface with human characteristics such as thinking and feeling increases consumer trust in autonomous vehicles (Waytz, Heafner and Epley, 2014).

### 2.4.3.2 Shared Services

While shared services also include bike sharing or ride sourcing services such as Uber (Scott and Demchur, 2017), only relevant literature about car sharing is considered in this section.

There is a shift in mobility preferences from possessing a car towards car sharing by Generation Y consumers (Corwin *et al.*, 2015). Indeed, most of the carsharing members are between 25 and 45 years, predominantly white and well-educated with higher than average incomes coming from small households (Scott and Demchur, 2017). Furthermore, most of them have been carless before (Martin, Shaheen and Lidicker, 2010). The reasons for consumers to use shared services range from travel for recreation, shopping, social and personal business trips (Millard-Ball *et al.*, 2005) as well as attending to sport events and making personal errands (Ream, 2014).

Round-trip carsharing counts to the most-used business model, but peer-to-peer carsharing is on the rise offering mobility options for low-income households (Dill *et al.*, 2015). Concerning the choice of business location, previously favorable areas are chosen as carsharing companies prefer placing new cars nearby their existing ones. This clustering enables users to choose from a variation of cars within short distance, increasing the brand visibility and geographic coverage. The first choice of the location is made by the criteria where the cars would meet market demand instantly. Such high-performance areas are typically populated densely from well-educated residents with middle income. The infrastructure is mostly mixed-use and well-served by public transit with bad parking situations (Andrew and Douma, 2006).

#### 2.4.3.3 Electric Vehicles

Among Electric Vehicles, different types exist (see Figure 4): On the one hand, pure battery EVs (BEVs) are powered by one or more battery onboard. Plug-in hybrid EVs (PHEVs / HEVs) are powered by batteries and simultaneously with traditional fueled driving which is activated when exceeding a certain driving distance. Powered by hydrogen fuel cells, FCEVs offer the greatest driving range (Underwood, 2015; Wolfram and Lutsey, 2016).

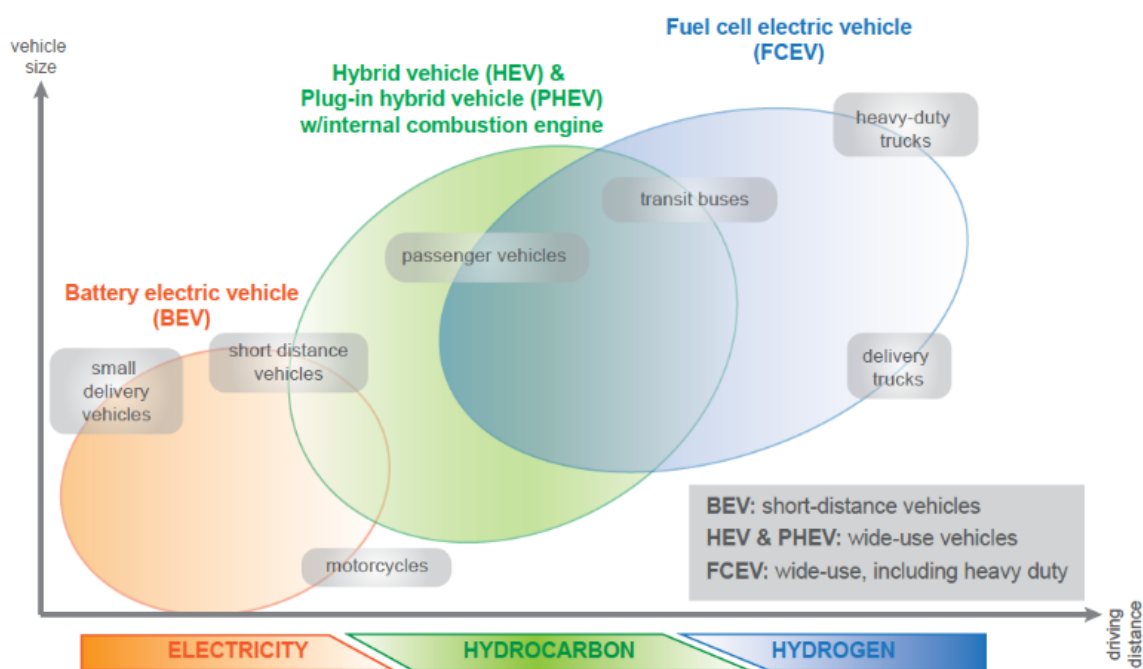


Figure 4: EV types

The interest of consumers towards Electric Vehicles grows while prices decrease and the range of models increase (CFA, 2016). Hereby, financial incentives are important to consumers for buying advanced technology vehicles (Sierzchula *et al.*, 2014). Early adopters of EVs are

mainly those with a high income, education level and interest in technology (Lane and Potter, 2007). High fuel prices (Diamond, 2009) and decreasing household electricity prices are linked with a positive influence on EV demand. An electricity rate structure with lower prices for charging at a point in time when demand is off-peak or there is an excessive generation of electricity, can further incentivize the purchase of EVs (Vergis and Chen, 2014). Exemptions from emissions testing save both testing time and fees, being positively correlated with consumers buying decision towards EVs (Jin, Searle and Lutsey, 2014). On the other hand, consumers are willing to pay more for Electric Vehicles after a three-month trial drive (Bunce, Harris and Burgess, 2014). Positive emotions, joy and pride during the test influence the intentions to adopt to the new technology (Rezvani, Jansson and Bodin, 2015). The lack of knowledge about policies and potential cost savings are main causes of disinterest towards PHEVs (Krause *et al.*, 2013).

Regarding infrastructure, there is little evidence that the perceived existence of multiple charging stations, other than single ones, slightly increase the interest for PEV (Bailey, Miele and Axsen, 2015). Indeed, the access to charging infrastructure is an important factor (Jin, Searle and Lutsey, 2014). In the US, High-occupancy vehicle (HOV) lanes that are also made available for single-occupied Electric Vehicles affect positively the EV buying decision of a consumer living in the particular state (Gallagher and Muehlegger, 2011). This can depend on the frequency of traffic jams, the number of urban centers or HOV lane miles in the respective state (Vergis and Chen, 2014). The lower the distance a consumer annually drives, the higher the probability of a PHEV purchase (Diamond, 2009).

There is also a debate about how a country's environmental policies and ethics have an influence on EV sales. In-between several measuring indices (Konisky and Woods, 2012), the Yale Environmental Performance Index which ranks environmental regulation and performance by country was not found to be significantly correlated with PHEV market share (Sierzchula *et al.*, 2014). In comparison, when considering the ethics of individuals, consumers with a sustainable lifestyle have a higher willingness to buy HEVs (Kahn, 2007) as it signals pro-environmental attitudes, symbolic meanings, innovativeness and identity (Rezvani, Jansson and Bodin, 2015).



### 3. Conceptual Framework and Hypotheses

Based on the literature review, this chapter inhibits the procedure and hypotheses that will be tested.

The empirical study is divided in two sections: First, a consumer survey will be held to validate if there is a shift in demand in terms of consumers attention and willingness to buy of Electric Vehicles. This is necessary to guarantee more targeted questions in the second research, in which managers of traditional car manufacturers will be confronted with the results of the first research and asked about the impact of the diesel gate on their product development with special focus to Electric Vehicles among the other industry trends (Figure 5).

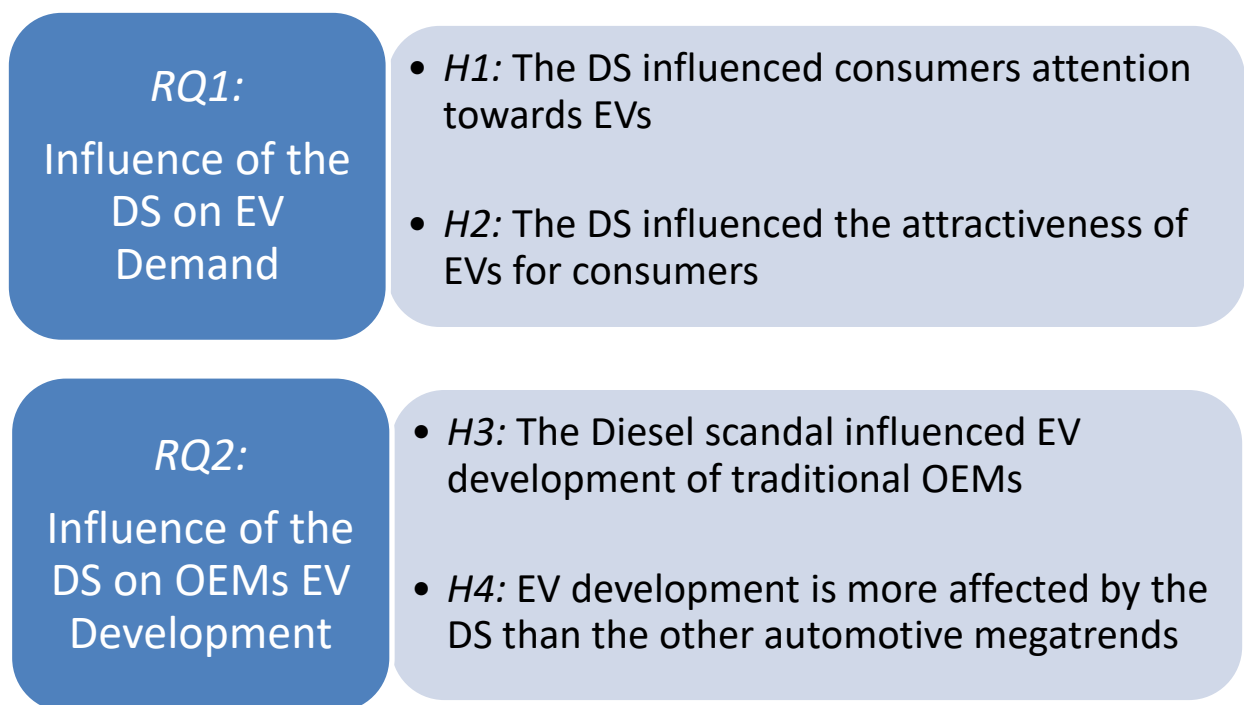


Figure 5: Conceptual framework

With the results of the second research question, the implications of Dynamic Capabilities literature applied to this topic will be validated at the end of chapter 5.3.

## 4. Methodology and Data Collection

The scope of this work is split into consumer and company research. This procedure was crucial to validate and fully understand all aspects of the influence of the Diesel scandal toward Electric Vehicles on consumer side as well on the development side of traditional car manufacturers. To enable the possibility to get in-depth but targeted information from the automotive companies, it was necessary to validate if there has been a change on consumer demand towards Electric Vehicles due to the scandal.

### 4.1 Research Method

It is wrong to make a simple connection between research methodology and research type. Despite the common assumption that realist research requires quantitative research methods such as surveys and databases or interpretive research requires qualitative material such as interviews, quantitative or qualitative material can be conducted by either method, one can interpret numbers with words and vice versa (Fisher, 2007). Generally, the questionnaire of a quantitative method targets large random samples with fixed-choice questions while a qualitative method targets small samples with open-ended questions without necessarily following a clear scheme (Silverman, 1993).

#### 4.1.1 Consumer research method

In general, the consumer research follows a quantitative method to get a representative sample of the real population. In particular, deliberate sampling was selected as the purposive selection of units that represent the universe of the sample allows simplified access and therefore convenience and low costs. Even though the population may not be homogeneous as a result, suitable representatives of the population can be obtained by the researcher. As a consequence, it is used frequently in research where developing hypotheses is desired (Kothari, 2004).

Applied to this research, specific theoretical research questions are not expected to be generalizable to a certain population, as some questions can only be answered adequately from people with a driving license or differ in terms of their continent of origin.

Simple randomly selected sample sizes in quantitative research are determined by maximum sampling error. While an error level of 10 % or lower requires a minimum sample size of 100, the error level of 5 % or lower that this research is targeting requires 400 or more responses (Weisberg and Bowen, 1977).

### 4.1.2 Company research method

As main part of the research, interpretative qualitative research enables honest and comprehensive answers through created trust during the interviews. Immediate reaction to subjectivity, complexity, misunderstood questions or the possibility of gaining deeper information is possible, while non-verbal movements of the interviewee can indicate answers. The interviewee can be motivated to link causal connections as a result of the presence of the interviewer. As disadvantages of qualitative research count the difficult selection of suitable interview partners, the high amount of cost and time expenditures as well as the impossibility of statistical representability. Furthermore, bias can occur when compressing the interview material due to emotional influence through interpersonal contact (Mayring, 2002).

With the use of content analysis, which adds a quantitative element to qualitative research and measures the frequency of mentioned issues or themes during a qualitative research method (Silverman, 1993), the research is split into two parts:

First, it inhibits an online survey with the tool Qualtrics, where beforehand defined and more general questions are asked. The user-friendly design allows easy analyzation and comparability (Diaz-Garrido, Sánchez-López and Martín-Peña, 2016). Self-administered surveys are perceived less intrusive, which is an advantage for questions regarding confidential information (Evans and Mathur, 2005).

Second, the interview partners are asked open questions which are developed and updated continuously to explain a causal relationship between the Diesel scandal and EV development. This follows the rules of grounded theory as an iterative-cyclic, interpretive and multi-level procedure, that enables the researcher to adapt the questioning to the findings during the research process (Schatzman, 1991; Strauss, 1991). This allocation enhanced the probability of getting responses from the online survey compared to time-consuming interviews, as for this thesis only few companies are subject of investigation (Helfferich, 2009).

Qualitative samples are restricted only by the sample size of more than 6 persons to allow hermeneutic interpretation of the most significant insights by the best suitable discussion partners. More importantly, it should follow the principles of saturation, collecting data until new data doesn't bring any more value (Glaser and Strauss, 1967; Eisenhardt, 1989; Gläser and Laudel, 2009).

### 4.2 Sampling

Population is the aggregate of all people sharing a common set of characteristics representing the world for the research problem (Malholtra, 1999). In this research, population is divided into consumers and managers.

#### 4.2.1 Consumer survey sampling

To achieve a significantly high number of responses for the consumer survey, Social media sites served as a valuable and resource saving tool to spread it and reach potential participants. Therefore, a link was created and sent together with a personalized message to enhance attention and willingness to participate.

Furthermore, it was also used the internal database of an automotive Tier 2 supplier where the author did an internship.

To prevent answers from respondents with lack of knowledge about the subject matter, consumers that don't possess a driving license or didn't hear about the Diesel scandal were excluded from the survey.

#### 4.2.2 Company survey and interview sampling

All interviews were non-recurring without preliminary talk. Because it was very hard to get volunteers from the automotive industry, the researcher had to be creative with time and place of the procedure.

A specific group of firms was defined to secure the validity of this study with the following criteria: Managers of traditional car manufacturers are asked about the impact of the diesel gate on their product development strategy with special focus to Electric Vehicles among the industry trends. Traditional car manufacturers are hereby defined as those existing since a minimum of 20 years and a significant market share, being in the one of the top 25 car manufacturer groups worldwide by sales in the JATO Global Car sales 2016 ranking (JATO, 2016). Thus, pure EV producers and recently founded companies like Tesla are excluded.

In the first part, managers of traditional car manufacturers owning a position in which they have important insights to give valuable feedback have been preselected and were sent the link to the online survey in January 2018. For example, respondent positions include R&D, purchasing and upper management.

Second, selected managers of traditional car manufacturer were interviewed. Hereby, personal contacts helped as well as speakers at the largest tech-conference worldwide which took place in Lisbon in November 2017. To enhance the number of participants for the second part, also managers of traditional car manufacturers suppliers were interviewed, as they are close to the business and can provide valuable information as well while potential response bias from OEM managers are alleviated (Barreto, 2010) and to validate the results for practical relevance.

To ensure a significant response rate in both the online survey and the interviews, participants are anonymized.

### 4.3 Research Instruments

With the online survey platform Qualtrics, two surveys were conducted to reach maximum audience in a short time period. The main advantage of this procedure is the effective and efficient data collection of surveys filled by a high number of participants with low cost and quick procedure for both the participants and data collection. Moreover, the flexibility and convenience for the audience is a crucial advantage as they can access the survey wherever and whenever it suits their limited possibilities without any restrictions. Furthermore, the online features in creating and customizing the survey as well as the ease of data entry and analysis are a big advantage (Evans and Mathur, 2005). Consumers and managers gain access to the survey via a link which was sent to them. The survey was conducted completely anonymous to avoid non-disclosure restraints of firms.

To prevent possible bias due to unconscious interference of the interviewer, the internet served as an anonymous and non-influencing way to ensure the most truthful data (Tingling, Parent and Wade, 2003).

In the following, the procedure is described in more detail including the dependent and independent variables that are used to test the hypotheses.

### 4.4 Design and Procedure

Both surveys were online between December 2017 and February 2018. The link to the consumer survey was sent via social media while the link to the company survey was sent via E-mail.

To avoid the problems with partial complete surveys and to ensure the participants didn't waste their time because they forgot one important question making the questionnaire useless, all questions were marked as mandatory, making it impossible for respondents to skip questions.

The variable descriptions used in both researches as well as the scale reliability of the consumer survey are listed in the appendix.

Participants were faced at the beginning of the survey with the scope of it, without indices about the study target.

### 4.4.1 Consumer survey design and procedure

At first, if consumers answered the questions about if they possess a driving license or heard about the Diesel scandal with "No", they were automatically sent to the end of the survey and were thanked for participating.

The questionnaire then asked the participants about their general willingness to buy cars instead of leasing as well as the last time they bought a car and the point in time they think they will buy a new one. Considerations regarding buying an Electric Vehicle the last time they bought the car as well as when buying the next car are subject of further investigation. If consumers do consider buying an EV the next time they will buy a car, the reasons behind like expected environmental benefits, price value ratio, understatement or as a result of lost in trust or unattractiveness of traditional engines as a result of the Diesel scandal are asked. To measure if consumers' willingness to buy and attention towards Electric Vehicles changed with the Diesel scandal or not, they were directly asked if they agree with the statement that the diesel scandal increased their interest in Electric Vehicles, followed by a series of items based on a 10-point Likert scale ranging from "Not at all" (1) to "Maximum" (10), where consumers should rate their attention towards and the attractiveness of Electric Vehicles before and after the Diesel scandal.

To bridge the Diesel gate with the other megatrends of the automotive industry, consumers were asked to rank the importance of each Connectivity, Autonomous Driving, Shared Services and Electric Vehicles since 2014 and due to the Diesel scandal.

Last but not least, after consumers were asked to complete a set of demographic questions, they were given the opportunity to place comments about the survey, which allowed receiving interesting information on their thoughts. Finally, they received a message by way of thanks for participating.

### 4.4.2 Company survey and interview design and procedure

The company online survey was designed in a similar setup than the consumer survey. First, they were asked to state if they think there was a shift in demand towards Electric Vehicles due to the scandal. Afterwards, managers were asked to order the priority of each of the megatrends to their company as well as if and how the order changed due to the diesel scandal. Then they were requested to rate the importance of each automotive megatrends to their R&D department before and after the Diesel scandal. After that, they were asked what percentage of their total car sales came from Diesel cars in 2014 and 2017. Furthermore, there was a comment section where respondents could state their opinion giving valuable additional information. At the end, the attendees were asked to classify the country of origin of their company and the department in which they work and were thanked for their time spent.

As grounded theory suggests, the development of the individual interviews followed an iterative-cyclic process (Schatzman, 1991; Strauss, 1991), while literature and the current economic situation like the megatrends in the automotive industry guided to the preparation. The questions have been divided into categories in line with the concept of the cyclic steps (Glaser and Strauss, 1967): Impact of the Diesel scandal in general and on the development of Electric Vehicles and the other industry trends, drivers of EV development, environmental concerns as well as differences among continents.

The new findings of the interviews guided constantly to updates in the next one, which guaranteed the highest possible breadth of insights in the research area. Finally, the results from both the online survey and the interviews were discussed in a final interview with an industry expert.

## 5. Results Analysis

This section provides the results of both the consumer and company research following the research process described earlier. First, all analyses and results of the consumer research are presented, as the company research inherits also consequences from the first part.

The results are organized chronologically, testing the first hypotheses about the increase of consumer attention towards and attractiveness of Electric Vehicles due to the Diesel scandal. Afterwards, the main findings about the hypotheses regarding company strategy are presented.

Finally, the chapter ends with a summary of all findings.

### 5.1 Consumer Research

First of all, descriptive statistical analyses were conducted to check for equal distribution and general characteristics of the sample.

#### 5.1.1 Descriptive Analysis

401 responses have been collected, while 17 of them were sorted out because either of the lack of a driving license or knowledge about the existence of the Diesel scandal of the recipient. However, the sample size conforms with the number of needed observations for a simple randomized sample of 400 observations at an error level of 5 % (Weisberg and Bowen, 1977).

The sample consisted of more male (69.5 %) than female (30.5 %) participants. The majority were European (79.2 %), followed by American (16.7 %) and Asian (4.2 %). This structure was desirable because most Diesel cars are sold in Europe (Poliscanova, 2017). Furthermore, people from Asia didn't mention the Diesel scandal as reasons for them considering buying an Electric Vehicle. This is in line with an interview done to a professional during the WebSummit, where he stated that it didn't influence the Asian market because of the lack of relevance of the Diesel technology. A detailed list of countries represented belonging to these continents is provided below (Table 2).

Regarding age, the majority were between 18 and 25 (41,4 %), followed by the ages 26-40 (29.4 %) and 41-60 (27.1 %). Not surprisingly, participants younger than 18 represented the minority (2.1 %), as people without driving license are excluded and weren't able to fill the survey. However, in Germany or the US it is possible to get the driving license under 18 years already. None of the respondents was aged more than 60.



Furthermore, most respondents either hold a Master's (34,6 %) or Bachelor's degree (32,3 %), followed by participants with a middle school degree (21.4 %). High school degree holders (7 %) and Dr. or Prof. title owners (4.7 %) represent the minority.

Finally, the annual income of most respondents is below 20.000 € (35,2 %), followed by participants owning between 50.000 and 74.999 € (24 %), 20.000 – 49.999 € (19.3 %) and 75.000 – 99.999 € (11.2 %). 8.3 % preferred not to tell their income while 2.1 % earn more than 100.000 € per year. This structure is not surprising because well-educated and rather young people represent a large proposition of the sample which indicates they are just at the beginning of their job career. It seems appropriate since young educated people represent the next generation of consumers with the ability to change future consumption habits (Corwin *et al.*, 2015).

Continent/Country	Responses (No.)	Responses (%)
<b>America</b>	64	16.67 %
USA	64	16.67 %
<b>Asia</b>	16	4.17 %
Japan	2	0.52 %
China Rep.	4	1.04 %
South Korea	10	2.60 %
<b>Europe</b>	304	79.17 %
Austria	15	3.91 %
Czech Republic	2	0.52 %
Finland	3	0.78 %
Germany	242	63.02 %
Italy	2	0.52 %
Netherlands	2	0.52 %
Poland	2	0.52 %
Portugal	31	8.07 %
Slovakia	3	0.78 %
Sweden	2	0.52 %
<b>Total</b>	<b>384</b>	<b>100 %</b>

Table 2: Consumer responds by continent and country

### 5.1.2 Main Results

#### *The Influence of the Diesel scandal on Electric Vehicle demand*

To test the first hypotheses, in which we proposed that the Diesel scandal generated enhanced attention towards and the attractiveness of Electric Vehicles, the results from the consumer survey are subject of investigation.

Regarding the general question if respondents think the Diesel scandal increased their interest in Electric Vehicles, 120 answered “Yes”, 131 were neutral while 133 denied it had an influence.

To examine the Likert-scale items regarding both attention and attractiveness of consumers towards Electric Vehicles due to the Diesel scandal, a Wilcoxon signed-rank test was conducted. It showed that the Diesel scandal influenced consumer attention towards Electric Vehicles ( $Z = -13.561$ ,  $p < 0.01$ ). Indeed, mean score rating was 5.52 before and 6.22 after. The same applies for perceived attractiveness of Electric Vehicles ( $Z = -13.300$ ,  $p < 0.01$ ) with a mean score rating of 7.43 before and 7.73 after the Diesel scandal happened. Even though the mean scores don't seem to differ significantly especially regarding attractiveness, the p-value is smaller than 0.05 in both measurements, indicating a significant difference between before and after the scandal.

These results were also affected by the continent of origin of consumers. It depended significantly  $F(2,381) = 11,567$ ,  $p < .01$  using the Welsh as well as the Brown-Forsythe test. No one from the Asian continent stated that the DS increased their interest and only two were neutral while 14 denied it. European and American did not differ significantly on this question, with a p-value of .08 using a post hoc Tukey Honestly Significant Difference (HSD) test.

To measure the difference-in-differences of EV attention and attractiveness, a one-way ANOVA was conducted. The assumption of homogeneity of variances was tested and found not tenable using Levene's test. Even though there was a significant difference among these variances, the groups were significantly different among each other regardless of that fact. With differences in attention  $F(2,381) = 6,8$ ,  $p = .01$  and attractiveness  $F(2,381) = 5.6$ ,  $p = .01$ , both subjects differed significantly using the Welsh as well as the Brown-Forsythe test. When examining which continents differ, a post hoc Tukey HSD test showed significant differences in consumers attention between Europe and Asia at  $p < .01$  as well as America and Asia at  $p < .01$ . There were no significant differences between Europe and America with a p-value of .93.

The same was true regarding the attractiveness of Electric Vehicles to consumers, with the only difference that the p-value between Europe and America was slightly higher at .96, indicating almost no difference between those two continents.

Regarding age and salary, there were no significant differences in terms of attention with  $F(2,384) = 1,33$ ,  $p = .27$  for age and  $F(2,384) = .39$ ,  $p = .86$  for salary or attractiveness with  $F(2,384) = .016$ ,  $p = .93$  for age and  $F(2, 384) = .73$ ,  $p = .6$  for salary.

A Welch test had to be conducted as the assumption of homogeneity was not found tenable regarding attention at the education level with  $F(2,379) = 2.484$ ,  $p = .043$ . It resulted in  $F(2,379) = .495$ ,  $p = .739$ . Regarding attractiveness, the assumption of homogeneity with  $F(2,379) = .302$ ,  $p = .877$  for education was found tenable. Therefore, a one-way ANOVA conducted the values  $F(2,379) = .223$ ,  $p = .926$  indicating no differences in attention or attractiveness between education levels.

For sex, the assumption of homogeneity was found tenable with  $F(2,382) = .700$ ,  $p = .403$  for attention and  $F(2,382) = .00$ ,  $p = .995$  for attractiveness. A one-way ANOVA with the values  $F(2,383) = .003$ ,  $p = .956$  for attention and  $F(2,383) = .562$ ,  $p = .454$  indicated that the gender of the respondent didn't influence their opinion.

Concerning the basic car buying characteristics, the influence of the general willingness to buy cars on the results was examined in first place: The assumption of homogeneity of variances was tested and found tenable using Levene's test  $F(2,374) = 1.24$ ,  $p = .269$  for attention and  $F(2,374) = .62$ ,  $p = .78$  for attractiveness. After conducting a one-way ANOVA, the significance for attention was  $F(2,384) = .756$ ,  $p = .657$  and for attractiveness  $F(2,384) = .727$ ,  $p = .684$ , therefore indicating no differences.

In the second place, the variable BoughtLastCar was investigated. After the homogeneity of variances was found tenable with  $F(2,380) = .77$ ,  $p = .511$  for attention and  $F(2,380) = 1,806$ ,  $p = .146$  for attractiveness, a conducted one-way ANOVA with  $F(2,384) = .655$ ,  $p = .58$  for attention and  $F(2,384) = .445$ ,  $p = .721$  for attractiveness denied a significant difference. The last variable in this section, BuyNextCar, indicated the same results. The homogeneity of variances was found tenable with  $F(2,379) = .074$ ,  $p = .511$  for attention and  $F(2,379) = 182$ ,  $p = .146$  for attractiveness. A conducted one-way ANOVA resulted in values  $F(2,384) = .315$ ,  $p = .868$  for attention and  $F(2,384) = .257$ ,  $p = .905$  for attractiveness.

Of a total of 384 total respondents, 56 stated that since 2014 not one of the trends became important to them. As multiple choice was possible, Electric Vehicles (232) and Connectivity (210) were the most mentioned trends, followed by Autonomous Driving (154) and Shared Services (130). When asking which trends became important due to the Diesel scandal, 203 stated None, followed by Electric Vehicles (143), Shared Services (66), Connectivity (49) and Autonomous Driving (35).

As reasons to purchase Electric Vehicles, 183 mentioned the Price/Value ratio and 174 Environmental benefits as the top motives. This is in line with the assertions of interviewed managers, that rate financial motives as more important than environmental issues for consumers buying decisions (see Chapter 5.2.2). While 66 respondents mentioned none of the reasons as they won't buy EVs because they don't buy cars in general or other motives, 48 stated they would buy EVs as an understatement, being trendy and modern, while 32 stated other reasons, including design concerns or branding like Tesla. 31 respondents answered that car with traditional engines became unattractive because of the Diesel scandal, while the same amount lost trust in the future of the Diesel technology because of the scandal.

## 5.2 Company Research

### 5.2.1 Descriptive Analysis

There were 8 online survey participants and 6 interview partners that invested time in this research project, which fulfills the criteria of representability, while the concept of saturation was found to be fulfilled (Gläser and Laudel, 2009).

The first interviews of OEM managers took place at WebSummit, the largest tech conference worldwide. The result guided to the development of the questions for the online survey as well as concerns which were discussed in the further interviews.

### 5.2.2 Main Results

In general, the common line of approach inside firms is to be better, quicker and cheaper than the competition. While following this purpose, managers state they face significantly enhanced scrutiny towards the automotive business and especially towards OEMs because of the Diesel scandal.

*The Influence of the Diesel scandal on Electric Vehicle demand*

The interviewed managers didn't see a clear correlation between the Diesel scandal and EV demand in any continent, while most admit that the general interest has increased. Some claim that in the first step, the consumer demand shifts from Diesel cars to gasoline-driven cars and the second step towards Electric Vehicles.

Interestingly, this shift in demand is not found to be caused by environmental concerns. Besides low consumption, high driving range and the uncertainty about Diesel driving bans, financial incentives play a leading role in consumer demand. This implies that consumers aren't shocked about the negative environmental impact of the scandal and would explain Volkswagen's sales success after it happened.

*The effect of the Diesel scandal on Electric Vehicle development of traditional OEMs among the automotive megatrends*

The general order of the research focus differed a lot between the investigated OEMs. Some managers stated Connectivity is already developed for series in their company and therefore focusing more on Autonomous Driving, while other managers rank Connectivity higher. This makes sense as Connectivity is driving the development of AD (Viereckl *et al.*, 2016), whereby Connectivity needs a certain development level to implement the technology economically, especially about vehicle attributes, driver needs and road conditions. Regarding Shared Services, the research focus is dependent from which strategy OEMs are following: B2B or B2C. Managers were agreed that the development of any of these three trends was not influenced by the Diesel scandal.

Electric Vehicles represent the midfield of R&D importance in the companies of all interviewed managers, being neither the most important nor the least. Reasons for this are presented below, while insights about further drivers of EV development are provided in chapter 6.2.1.

Even though most managers declined a link between the Diesel scandal and the development of Electric Vehicles, one manager stated that it caused an industry-wide switch in resources in terms of development and human resources towards Electrical Vehicles earlier than without the scandal. This is because less sales and the decrease of resale values of Diesel vehicles lead to less development expenditures for the Diesel technology. The lack of sales for those companies with significant Diesel shares causes difficulties to meet the CO<sup>2</sup> targets for their fleet which are set from the government. With normal sales of Diesel cars, they likely would have met

them, while reaching these targets with normal gasoline cars is impossible. To avoid the resulting financial penalties, they enhance the EV development to lower total fleet emissions, although this differs between the OEMs. Some are focusing on Hybrid vehicles or the fuel cell technology in comparison to pure EVs as a result. Laws and regulations are therefore a crucial factor to the development of Electric cars. The success of Electric Vehicles will also depend on emission limitations such as the Zero Emission Vehicle Program of California.

Managers state that consumer demand can be a factor of EV development, even though they currently don't face an increase of EV demand. Rather, current reasons include image concerns, as EVs are an important talking topic of the everyday life.

The backlog of OEMs in terms of their EV offering is another driver of the shift. Gaining competitive advantage while overcoming the current EV disadvantages loading speed, range and costs is their target. Therefore, battery performance is the most important research topic of OEMs regarding EVs to obtain a better standing compared to gasoline car performance. Even if Tesla claim their car can reach 450 km, this distance can only be achieved with a low speed limit. Without coming close to the same values as traditional combustion engines, the public at large won't adopt the new technology.

But even if those issues would already be solved now, the loading infrastructure would be the next challenge. Currently, comprehensive charging is nowhere possible, preventing a plentiful change. In the case that a car runs out of electricity, it must be towed away. Status quo, mass adoption would lead to blackouts in Germany (Stäglich *et al.*, 2018).

According to the interviewed managers, OEMs coming from the EU are affected the most by the Diesel scandal. This is because OEMs from America and Asia aren't much into the Diesel technology. Thus, the amount of Diesel cars in Asia is not significant and therefore the scandal didn't influence their business significantly.

### 5.3 Conclusion of the Results

In general, the DC framework is not fully applicable in the context of EV development. Even though there might be a perceived opportunity caused by the scandal, it depends more on other factors which have been identified earlier and in chapter 6.2.

### **RQ 1: Is the Diesel scandal a driver of increased demand of Electric Vehicles?**

*Hypothesis 1 & 2: The Diesel issue generated enhanced consumer attention towards Electric Vehicles and the attractiveness of Electric Vehicles to consumers*

When examining the consumer survey results, consumer attention towards Electric Vehicles differ significantly before and after the Diesel scandal happened. Even though EV attractiveness has increased due to the scandal, it didn't the same as attention. This makes sense as the development of EV components and especially the infrastructure is not yet ready for mass production. These results depend significantly on the origin of the consumer. Even though the extent of driven Diesel cars is higher in Europe, American consumers state to react almost identical as European consumers. This could be a consequence from where the scandal was detected. Asian consumers are not found to react in any way to the Diesel scandal, which reflects the low amount of Diesel cars driven in their continent.

As these results might be led by subjectivity, managers were asked in the interviews. While they state that they face higher interest for EVs due to the scandal, they deny that the attractiveness has increased. Thus, they neglect that it had an influence on EV demand.

To conclude the first both hypotheses and answer the first research question, consumers' attention towards EVs is found to be increased due to the scandal. Despite the survey results indicate a slight positive change, only the first hypothesis can be confirmed due to the subjectivity potential (see Chapter 6.1) and the manager opinions which deny the attractiveness has increased. Although consumers are more aware about EVs after the DS, it doesn't seem to have an influence on EV demand.

### **RQ2: Did traditional car manufacturers change their R&D regarding Electric Vehicles more than the other industry megatrends Connectivity, Autonomous Driving and Shared Services as a reaction to the Diesel scandal?**

*Hypothesis 3: The Diesel scandal influenced EV development of traditional car manufacturers, but dependent of the origin of the company or extent of their Diesel car production*

According to the interviews, most managers answered that the Diesel scandal didn't influence the EV development directly. However, there are indices that it increased the speed in development, shifting human resources earlier than it would be without the scandal. Furthermore, the lack of Diesel sales force OEMs to react and focus even more on EV development to reach their CO<sup>2</sup> targets, as they rely on diesel vehicles with fuel-efficient performances.

This is in line with a recent study that was conducted to measure which OEM will likely fail to meet the CO<sub>2</sub> targets set by the EU because of the Diesel scandal. Two scenarios were simulated. In the first case, it is assumed that consumers buy petrol instead of diesel models from the same OEM, while sales from alternative engines were hold stable. Hereby, all investigated OEMs except Peugeot and Toyota would miss the targets. Ford would face the highest risk, while Daimler and BMW would suffer more than Volkswagen, which is confronted with just a marginal diesel and petrol fleet gap (see Figure 6). In the second scenario, it is assumed that consumers buy petrol models as well as vehicles with alternative engines instead of diesel models. This would only reduce, not eliminate the fines for violating the emission targets of all investigated OEMs except Toyota, Mitsubishi and Honda while Ford, Fiat-Chrysler and Renault face the highest risk. Daimler, BMW and VW wouldn't improve their results significantly compared to scenario one.

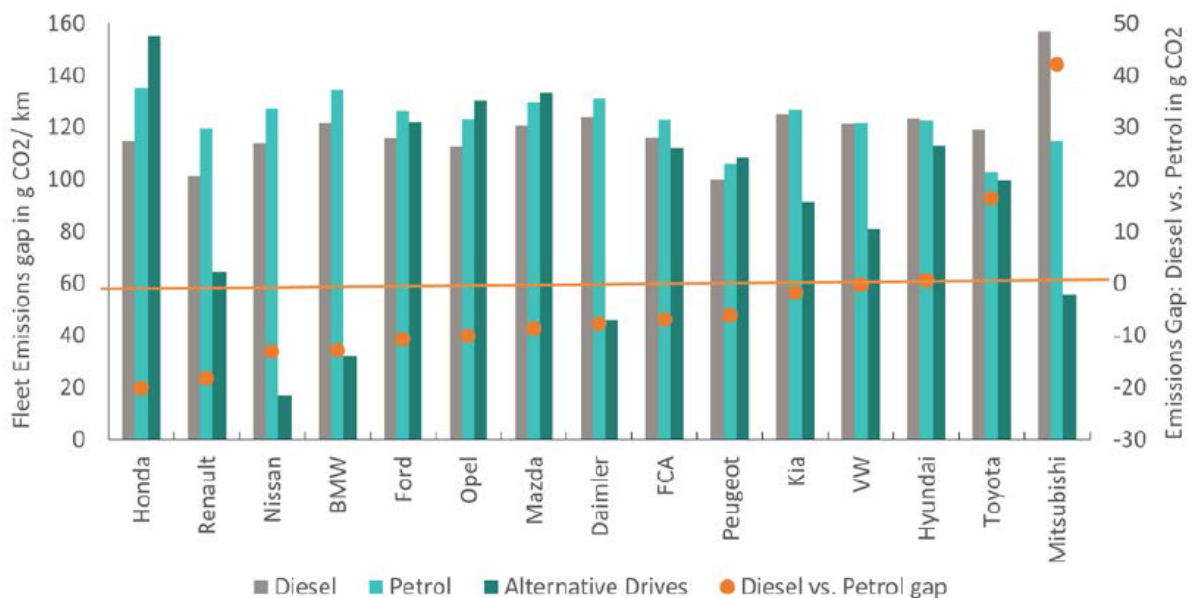


Figure 6: Average fleet emissions by fuel type 2016

Concluding, the results highly depend on the extent of diesel cars in their fleet (Klug, 2017). Also, when facing the company survey respondents, Asian employees stated the minimum possible percentage of how much Diesel cars occupy in their business, while European managers ranked it higher. Thus, the origin and the percentage of diesel cars of the traditional OEMs are slightly similar and both significant when examining the impact of the scandal.

It is concluded, that the Diesel scandal influenced the development indirectly through environmental targets set by governments.



### Hypothesis 4: Electric Vehicles became more important than the other trends because of the Diesel scandal

Managers were agreed that the Diesel scandal didn't influence R&D of the trends Connectivity, Autonomous Driving and Shared Services in their company. As concluded earlier, the results for EVs whereas are divided. So even though the change may not be scalable exactly, it can be concluded that the change in R&D is more noticeable regarding EVs than in the other trend areas. Hence, Hypothesis 4 is accepted.

To conclude the Hypotheses 3 and 4, there is a slight change of R&D regarding EVs, while the other trends aren't affected at all. This change is resulting from CO<sup>2</sup> considerations, especially enforcing OEMs coming from Europe and US to act.

Facing the results of this research including other identified drivers of EV development in chapter 6.2.1, it can be concluded that the development of Electric Vehicles is mainly driven by external settings like infrastructure investments and subsidies. Regarding EV demand, financial incentives by the government can have a major influence. Thus, Dynamic Capabilities as underlying theory lacks importance in this case, as other than expected the success of companies is not mainly driven by sensing opportunities and making timely and market-oriented decisions (Barreto, 2010), but is rather determined by external factors and therefore imply Industrial Organization (I/O) as the best suitable underlying theory.

## 6. Limitations and future research

### 6.1 Limitations

Because of the rareness of suitable literature in the automotive area, it was hard to build a thesis around this topic. However, this obstacle has been overcome by writing around the basic concepts of I/O, RBT and DC which can be related to the impact of the diesel scandal on EV development.

Assumptions which are based on people's intentions rather than their actual behavior are considered as a methodological limitation in consumerism literature (Carrington, Neville and Whitwell, 2010). Indeed, the car buying process inhibits complex decision-making (Kotler *et al.*, 2005) and therefore it is not clear if consumers that stated they will consider Electric Vehicles in their next car buying decision, will actually consider them. The same logic counts for a potential future research on VW's brand reputation: Consumers may state they avoid the brand because of the betrayal software, but in fact VW sales are at an all-time high (Müller, 2017).

Likewise, self-reported behaviors are subject of social desirability bias, which can occur when respondents feel social pressure to answer research questions in a way that they think is socially acceptable (Carrington, Neville and Whitwell, 2010). Applied to this thesis, people may see themselves reacting to the diesel scandal stronger than they actually would. Therefore, they may rate their intention to buy Electric Vehicles higher. This also applies to the consumer survey method, as they may rate the increase of their interest and EV attractiveness higher. However, to measure the data before a scandal happens is nearly impossible, as one would need insider information. To limit the possible bias, managers were asked if they face increased EV demand during the interviews.

The small sample size of the online company survey was a result of the limited number of automotive manufacturers existing and the fact that not all managers of them have been relevant for this study, respectively answered the survey. However, as it served preliminary for the interviews, the results were valuable for the research.

Because data was obtained from a single respondent in each firm, common method bias may have occurred. Therefore, confidentiality was assured more than once to limit this risk.

Managers confirm that they perceived increased interest of consumers, even though they neglect it influenced the demand. Thus, there might be more drivers of EV demand than attractiveness and attention. However, increased attention of consumers will pave the way for quick mass adoption as soon as the infrastructure and development level are well-engineered.

The real impact of the Diesel scandal on EV development is also a matter of how OEMs deal with the imminent fines for not meeting the CO<sup>2</sup> targets in 2021. If they don't care about violating the targets, they most likely won't change their R&D focus because of the DS.

Including managers from the automotive industry, a study investigated the attention model of top managers' opportunity beliefs for strategic action with different types of environmental change such as the complexity of managerial knowledge structure and the extent of top-down processing influences (Shepherd, McMullen and Ocasio, 2016). Even though different knowledge structures of managers might have an influence on the results concerning if a manager considers the Diesel scandal as an opportunity for EV development or not, this was not further considered in the research, since external conditions were found to be more important.

## 6.2 Future Research Implications

### 6.2.1 Academic Research Implications

As one of the results and insights of this work, the Diesel scandal could have impacted other megatrends of the industry. One could therefore apply the type of this research and investigate the impact of the Diesel scandal to the consumer attention and usage of Shared Services such as Car sharing, as well as to the attractiveness of fuel cell based cars as an alternative to EVs for the future roads.

Because of the interview insight regarding the minor role of environmental aspects in the buying decision of consumers in relation to EVs and the Diesel scandal, one could examine the reasons of why VW broke their sales record and reached their long-time target despite the DS and how guilt and pride (Antonetti and Maklan, 2010) are involved in the purchase decision.

As already described in chapter 6.1, a before-and-after analysis of differences in consumer attention and the attractiveness of EVs caused by the Diesel scandal would require insider information, which in this case would most likely be dubious from a legal perspective. However, it could be of interest to validate the two variables in relation with the other industry megatrends.

To fully understand the impact of the Diesel scandal on EV development of traditional OEMs, managers were asked about the drivers of EV development. An academic could use the identified drivers to check for significance of each of them. It would be interesting to find out how much all of them together explain the development and which drivers are missing. Besides the results provided in chapter 5.2.2, the further findings could help academic researchers to understand the construct of EV development:

In general, the major OEMs are boosting the trends, as they have the power to require political actions by the government, while smaller OEMs must balance their limited R&D budget carefully thought out. In fact, suppliers occupy an important role in the development of technologies, as they invest and create norms, while OEMs customize the technology. For EV batteries, there currently still doesn't exist any norm, while for fuel cells it does.

To protect the automobile industry from stagnation because of trade restrictions from specific countries, research about alternative materials is on the run. Even though OEMs are dependent from the access to raw materials, it is not a big issue for them. While some OEMs are developing the engines by their own, they are not producing the parts to save cost when buying elsewhere. Magnesium-based chassis is a current topic to reduce the weight of a car, allowing higher driving distances.

Major interest holdings like the recent from the Geely CEO Li Shufu in Daimler are suspected to have an influence in EV development. In this specific case, the Asian investment in the European company is expected to boost EVs significance in Daimler (Reimann *et al.*, 2018), even though the investor might see his stake chiefly as an investment.

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*“China will lead the world in EV development”*

*- William C. Ford Jr., executive chairman of Ford Motor Co.*

(Bradsher, 2017)

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According to a European manager, the push for Electrical Vehicles in Asia is driven by air pollution problems. While Japan and Korea currently are focusing on combustion engines and gradually adapt to E-Mobility, China sees its chance to become a major player in this industry since they lag in the development of combustion engines. The monetary incentives by the government (Nieuwenhuis and Wells, 2015) lead to a startup environment and competitive advantage of Chinese OEMs, letting the others face a big challenge.

The following graphic concludes the identified drivers of EV development:

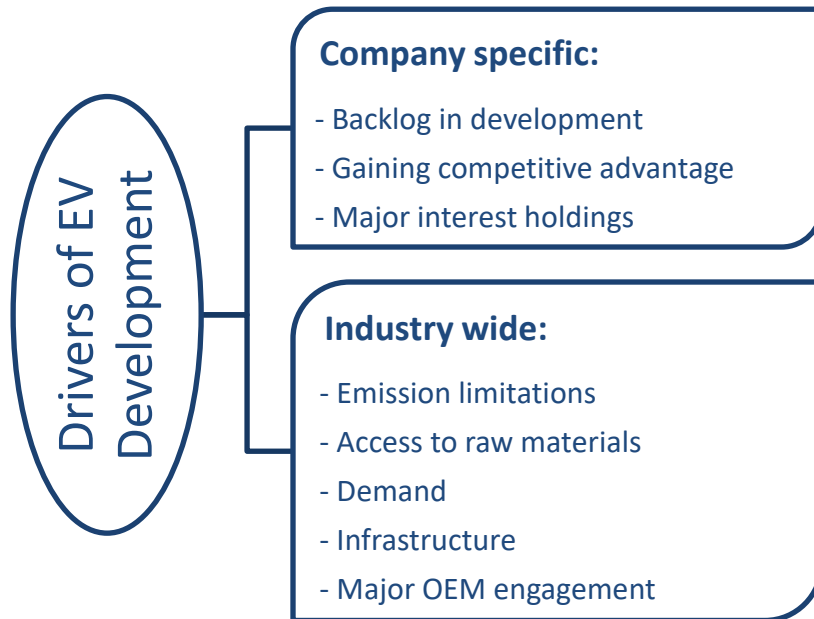


Figure 7: Drivers of EV development

### 6.2.2 Practical Research Implications

Another interesting aspect that came out from an interview is the environmental value of Electric Vehicles. All the interviewed managers doubt that they are the best solution regarding those aspects considering the overall energy-environmental balance. Even though the air pollution in the respective cities where the cars are driven will be lower. But this is just a relocation of the problem itself. According to a manager, the solution would inhibit green electricity from coal-fired power stations, but the current situation in Germany is that most of the energy comes from nuclear power plants from the neighbor countries. Furthermore, the production as well as the dumping or replacement of the batteries is environment harming and expensive, generating no overall benefit compared to combustion engines.

Indeed, according to a recent study, EV's advantages compared to Internal combustion engine vehicles (ICEVs) include a 10 to 24 percent decrease in global warming potential (GWP) when powered with the current electricity mix in Europe and a lifetime of 150.000 km. Despite EV's potential to reduce greenhouse gas emissions compared to ICEVs inhibits a certain degree of problem shifting. Thus, when considering the whole life cycle, it is not enough to only compare transportation usage options, but also the production process and the end of life. Hereby, the

environmental damage in terms of human toxicity, fresh-water eco-toxicity, freshwater eutrophication and metal depletion was higher for EVs when examining the production phase for all categories excluding the terrestrial acidification potential. Hence, promoting EVs where the electricity is generated from oil, coal and lignite is inadvisable while a sharpened life cycle policy is necessary (Hawkins *et al.*, 2013).

According to another study, lifecycle CO<sup>2</sup> emissions for Diesel are higher compared to petrol, therefore suggesting to drop the Diesel technology, stop wasting further money and effort (Poliscanova, 2017). However, they compared different mileages with the reasoning that consumers drive more with diesel cars due to lower fuel price. For the future of the technology, it is vital to know the exact benefits of the technology, as demand is expected to shrink due to driving bans and consumers lost in trust.

Besides the further improvement of the battery range, vital for the success of EVs will be how fuel cell cars will proceed, as there is still uncertainty among car manufacturers. However, for European OEMs it will be important to overcome quickly the development advantage of Asian OEMs in both Electric Vehicles and fuel cell cars.

Even though this thesis underlines that environmental concerns don't influence the buying decision of consumers decisively, improvements in the production stage are needed immediately to increase the environmental value of EVs in contrast to traditional engines.

# Appendix

Appendix 1: Survey Questionnaire for Consumers..... X  
Appendix 2: Variable Descriptions ..... XIV  
Appendix 3: Validation of the consumer survey results ..... XIX  
Appendix 4: Survey Questionnaire for Managers..... XX

## Appendix 1: Survey Questionnaire for Consumers

Dear participants,

Welcome and thank you for taking the time to complete this survey.

The survey is part of a master thesis in its final stage. Your participation is very important and contributes to its completion. This survey takes approximately 5 minutes to complete.

All data obtained will be used **anonymous and confidential** and it is not possible to link any answer to your company. Therefore, I ask you to answer honestly and spontaneously. There are no right or wrong answers. If you have questions or feedback regarding the survey, please contact: 152116091@alunos.lisboa.ucp.pt

Thank you in advance –

Wolfgang Lohmeier

The survey consists of **two** pages. On the first page, you will see questions regarding the impact of the diesel gate on your interests. Please take a moment to have a careful look. The second page consists of questions regarding some basic demographic data.

### Entry Questions:

1. Do you have a driving license?
  - a. Yes
  - b. No
2. Have you heard about the Diesel scandal of VW?
  - a. Yes
  - b. No

*(If one or both of them are stated with “no”, then the survey ends immediately)*

---- Next Page ----

3. Please rate your general willingness to buy a car instead of renting/leasing  
1 (I avoid buying) ... 5 (medium) ... 10 (I will always prefer buying)
4. When did you buy your last car?
  - a. 1-3 years ago
  - b. 4-6 years ago
  - c. more than 6 years ago
5. When do you think you will buy a new car?



- a. in less than 12 months
  - b. in between 12 – 24 months
  - c. in about 2-4 years
  - d. not earlier than in 4 years
6. When you bought your last car, did you consider an Electric Vehicle?
- a. Yes
  - b. No
7. When buying your next car, will you consider an Electric Vehicle?
- a. Yes
  - b. Maybe
  - c. No
8. **IF YES/Maybe at Q7:** What are the reasons for you considering buying one? (MC)
- a. Environmental benefits
  - b. Good Price / Value ratio
  - c. Trendy / Modern / Understatement
  - d. Diesel scandal: Car with traditional engines became unattractive
  - e. Diesel scandal: Lost trust in the future of Diesel technology
  - f. Other, please state: \_\_\_\_\_
9. Please rate the following statement: “The Diesel scandal increased my interest in Electric Vehicles”
- a. Yes
  - b. Neutral
  - c. No
10. Please rate your attention towards Electric Vehicles before the Diesel scandal
- 1 (Not at all) ... 5 (medium) ... 10 (Maximum)
11. Please rate your attention towards Electric Vehicles after the Diesel scandal
- 1 (Not at all) ... 5 (medium) ... 10 (Maximum)
12. Please rate the attractiveness of Electric Vehicles before the Diesel scandal
- 1 (Not at all) ... 5 (medium) ... 10 (Maximum)
13. Please rate the attractiveness of Electric Vehicles after the Diesel scandal
- 1 (Not at all) ... 5 (medium) ... 10 (Maximum)
14. Which of the following trends have become more important to you since 2014? (MC)
- a. Connectivity
  - b. Autonomous Driving

- c. Shared Services
- d. Electric Vehicles
- e. None

15. Which of the following trends have become more important to you due to the Diesel

Scandal (MC)

- a. Connectivity
- b. Autonomous Driving
- c. Shared Services
- d. Electric Vehicles
- e. None

---- Next Page ----

16. Please state your country of origin

- a. - List of all countries to choose -

17. How old are you?

- a. 16-18
- b. 18-25
- c. 26-40
- d. 41-60
- e. 61 and above

18. What is your gender?

- a. Male
- b. Female

19. What is your school level?

- a. Main school degree or equivalent (German Hauptschulabschluss)
- b. Middle school degree (German Realschulabschluss)
- c. High school degree or equivalent (e.g. GED, A-levels, German Abitur)
- d. Bachelor degree or equivalent
- e. Master degree or equivalent
- f. Dr. / Prof.

20. What is your salary level?

- a. Less than 20.000 €
- b. 20.000 – 49.999 €
- c. 50.000 – 74.999 €
- d. 75.000 – 99.999 €

e. 100.000 € and above'

f. Prefer not to say

21. If you have any comment related to this survey, please place it here:

---- SUBMIT ----

Thank you for participating in this survey! Your response has been counted.

## Appendix 2: Variable Descriptions

The dependent and independent variables for each of the surveys are listed in tables in the following.

### Consumer Survey Dependent Variables

<i>GenWilBuyCars:</i>	10-point Likert scale to measure if the consumer rather prefers buying a car or taking public transport or renting or leasing a car. [1 (Avoid buying a car) - 10 (Will always prefer buying a car)]
<i>BoughtLastcar:</i>	Represents the years ago when the consumer last bought a car.  Scale: Never, 0 – 3, 4 – 6, more than 6
<i>Buynextcar:</i>	Represents the time (years) when the consumer think he or she will buy a new car.  Scale: Never, less than 1 year, 1-2, 2-4, more than 4
<i>BoughtConsiderEV:</i>	Question about if the consumer considered buying an Electric Vehicle the last time he or she bought a car. Skipped if the consumer never bought a car so far.  Scale: Yes, No
<i>BuyConsiderEV:</i>	Question about if the consumer will consider buying an Electric Vehicle the next time he will purchase a car.  Scale: Yes, Maybe, No
<i>ReasonsBuyEV:</i>	Multiple Choice question about the reasons why the consumer includes Electric Vehicles in his or her next car buying decision. Skipped if the consumer won't consider it.  Scale: Environmental benefits, Good Price / Value ratio, Trendy / Modern / Understatement, Diesel scandal: Car with traditional engines became unattractive, Diesel scandal: Lost trust in the future of Diesel technology
<i>ReasonsBuyEVOther:</i>	When crossed “other” as a reason to consider buying a Electric Vehicle, the consumer has the opportunity to state the reasons.

<i>StateIncrInterest:</i>	The consumer is asked to answer the statement “The Diesel scandal increased my interest in Electric Vehicles” with Yes, Neutral or No.
<i>EVatten_bef:</i>	10-point Likert scale to self-assess the attention paid to Electric Vehicles before the Diesel Scandal [1 (low) - 10 (high)]
<i>EVatten_aft:</i>	10-point Likert scale to self-assess the attention paid to Electric Vehicles after the Diesel Scandal [1 (low) - 10 (high)]
<i>EVattrac_bef:</i>	10-point Likert scale to self-assess the attractiveness of paid to Electric Vehicles before the Diesel Scandal [1 (low) - 10 (high)]
<i>EVattrac_aft:</i>	10-point Likert scale to self-assess the attention paid to Electric Vehicles after the Diesel Scandal [1 (low) - 10 (high)]
<i>ImpTrendsSince2014:</i>	Multiple Choice question about which trends have become important to the consumer since the year 2014.  Possible Answers: Connectivity, Autonomous Driving, Shared Services, Electric Vehicles, None
<i>ImpTrendsDiesel:</i>	Multiple Choice question about which trends have become important to the consumer because of the Diesel scandal.  Possible Answers: Connectivity, Autonomous Driving, Shared Services, Electric Vehicles, None

Table 3: Consumer Survey Dependent Variables

### **Consumer Survey Independent Variables**

<i>Continent:</i>	Describes the continent of origin to allow comparisons between Asian, European and American consumers.
<i>Country:</i>	Describes the country of the consumer. Even though, comparisons are made at the continent level.
<i>Gender:</i>	Allows comparisons between male and female respondents.
<i>Age:</i>	Represents the age of the consumer in one of the groups.

	Scale: Under 18, 18-25, 26-40, 41-60, 61 and above
Salary:	The annual income of the consumer.  Scale: Less than 20.000 €, 20.000 – 49.999 €, 50.000 – 74.999 €, 75.000 – 99.999 €, 100.000 € and above, Prefer not to say.
Education:	The highest educational level which the consumer gained so far.  Scale: Main school degree, Middle school degree, High school degree, Bachelor degree, Master degree, Dr. / Prof.

Table 4: Consumer Survey Independent Variables

**Company online survey Dependent variables**

EVDemandDiesel	The manager is asked to answer the statement “The Diesel scandal is a driver of increased demand towards Electric Vehicles” with Yes, Neutral or No.
ResearchFocus	The managers are asked to order the trends Connectivity, Autonomous Driving, Shared Services and Electric Vehicles by the research priority of their company
FocusChange	Question about if the Diesel scandal influenced their current priority order of the trends.
ResearchFocusNew	If the order of the trends has changed due to the Diesel scandal, managers are asked to state the order prior to the happening.
ConBefore	10-point Likert scale about the Importance of the Trend Car Connectivity to the company’s R&D before the Diesel Scandal  Scale: 1 (Not at all) ... 5 (medium) ... 10 (Maximum)
ConAfter	10-point Likert scale about the Importance of the Trend Car Connectivity to the company’s R&D after the Diesel Scandal  Scale: 1 (Not at all) ... 5 (medium) ... 10 (Maximum)

AutonomBefore	10-point Likert scale about the Importance of the Trend Autonomous Driving to the company's R&D before the Diesel Scandal  Scale: 1 (Not at all) ... 5 (medium) ... 10 (Maximum)
AutonomAfter	10-point Likert scale about the Importance of the Trend Autonomous Driving to the company's R&D after the Diesel Scandal  Scale: 1 (Not at all) ... 5 (medium) ... 10 (Maximum)
SharedBefore	10-point Likert scale about the Importance of the Trend Shared Services to the company's R&D before the Diesel Scandal  Scale: 1 (Not at all) ... 5 (medium) ... 10 (Maximum)
SharedAfter	10-point Likert scale about the Importance of the Trend Shared Services to the company's R&D after the Diesel Scandal  Scale: 1 (Not at all) ... 5 (medium) ... 10 (Maximum)
EVBefore	10-point Likert scale about the Importance of the Trend Electric Vehicles to the company's R&D before the Diesel Scandal  Scale: 1 (Not at all) ... 5 (medium) ... 10 (Maximum)
EVAfter	10-point Likert scale about the Importance of the Trend Electric Vehicles to the company's R&D after the Diesel Scandal  Scale: 1 (Not at all) ... 5 (medium) ... 10 (Maximum)
PercentDiesel2014	Percentage of the company's total car sales that came from Diesel cars in 2014.  Scale: 0 %, 1 - 20 %, 21 - 40 %, 41 - 60 %, 61 - 80 %, more than 80 %
PercentDiesel2017	Percentage of the company's total car sales that came from Diesel cars in 2017.  Scale: 0 %, 1 - 20 %, 21 - 40 %, 41 - 60 %, 61 - 80 %, more than 80 %

Table 5: Company online survey Dependent

**Company online survey Independent variables**

Continent:	Describes the continent of origin to allow comparisons between Asian, European and American companies.
Department	Indicates the department the respondent manager works in.  Scale: Board member, Top management, Finance, Human Resources, R&D, Sales & Marketing, Purchasing, Other.

Table 6: Company online survey Independent Variables



### Appendix 3: Validation of the consumer survey results

To measure if the scales measuring consumers attention of and attractiveness towards Electric Vehicles are reliable, Cronbach's alpha is a suitable procedure (Bland and Altman, 1997) that measures the internal consistency of data on a scale from 0.1 to 1, whereas higher values indicate high degrees of internal consistency and therefore data reliability. It provides information if items measure the same latent variable and should rather be averaged into one scale (Bonett and Wright, 2015). Even though there is no clear consensus on which number indicates which degree of consistency, values ranging from 0.6 – 0.9 are applicable for research purposes while higher values than 0.9 indicate item redundancy (Streiner, 2003), while the alpha coefficient was found to be likely underestimating the consistency when the number of test items is too small (Tavakol and Dennick, 2011).

	No. of items	Cronbach's alpha	Cronbach's Alpha Based on Standardized Items
Attention	2	.804	.811
Awareness	2	.869	.873

Table 7: Cronbach's alpha of consumer attention and awareness scales

By analyzing Table 7, it can be conducted that Cronbach's alpha for both variable groups are higher than 0,7 which indicates internal consistency of the data.

Due to the impossibility of missing answers, non-response bias is unlikely to exist and therefore wasn't tested.

## Appendix 4: Survey Questionnaire for Managers

### *Introduction to the survey*

Dear participants,

Welcome and thank you for taking the time to complete this survey.

The survey is part of a master thesis in its final stage. Your participation is very important and contributes to its completion. This survey takes approximately 5 minutes to complete.

All data obtained will be used **anonymous and confidential** and it is not possible to link any answer to your company. Therefore, I ask you to answer honestly and spontaneously. There are no right or wrong answers. If you have questions or feedback regarding the survey, please contact: 152116091@alunos.lisboa.ucp.pt

Thank you in advance –

Wolfgang Lohmeier

The survey consists of **two** parts. At the first part, you will see questions regarding the impact of the diesel gate on your firm's development focus. Please take a moment to have a careful look. The second page consists of questions regarding some data of your company, which can't be traced back to it.

1. Please rate the following statement: "The Diesel scandal is a driver of increased demand towards Electric Vehicles"
  - a. Yes
  - b. Neutral
  - c. No
2. Please order the research fields of your company by priority?
  1. Connectivity
  2. Autonomous Driving
  3. Shared Services
  4. Electric Engine
3. Did the order change with the Diesel scandal?
  - a. Yes
  - b. No
4. If Yes: Please state the prior order:
  1. Connectivity

2. Autonomous Driving
3. Shared Services
4. Electric Engine
5. Please rate the importance of Car Connectivity to your R&D focus before the Diesel scandal  
1 (Not at all) ... 5 (medium) ... 10 (Maximum)
6. Please rate the importance of Car Connectivity to your R&D focus after the Diesel scandal  
1 (Not at all) ... 5 (medium) ... 10 (Maximum)
7. Please rate the importance of Autonomous Driving to your R&D focus before the Diesel scandal  
1 (Not at all) ... 5 (medium) ... 10 (Maximum)
8. Please rate the importance of Autonomous Driving to your R&D focus after the Diesel scandal  
1 (Not at all) ... 5 (medium) ... 10 (Maximum)
9. Please rate the importance of Shared Services to your R&D focus before the Diesel scandal  
1 (Not at all) ... 5 (medium) ... 10 (Maximum)
10. Please rate the importance of Shared Services to your R&D focus after the Diesel scandal  
1 (Not at all) ... 5 (medium) ... 10 (Maximum)
11. Please rate the importance of Electric Vehicles to your R&D focus before the Diesel scandal  
1 (Not at all) ... 5 (medium) ... 10 (Maximum)
12. Please rate the importance of Electric Vehicles to your R&D focus after the Diesel scandal  
1 (Not at all) ... 5 (medium) ... 10 (Maximum)

---- Next Page ----

13. Please state your companies' continent of origin
  - a. EU
  - b. America

c. Asia

14. What percentage from your total car sales came from cars with Diesel engines in 2014?

- a. 0 %
- b. 1 - 20 %
- c. 21 – 40 %
- d. 41 – 60 %
- e. 61 – 80 %
- f. more than 80 %

15. What percentage from your total car sales comes from cars with Diesel in 2017?

- a. 0 %
- b. 1 - 20 %
- c. 21 – 40 %
- d. 41 – 60 %
- e. 61 – 80 %
- f. more than 80 %

16. Please state in which department you are working in your company

- a. Board member
- b. Top management
- c. Finance
- d. Human Resources
- e. R&D
- f. Sales & Marketing
- g. Purchasing
- h. Other, please state: \_\_\_\_\_

---- SUBMIT ----

Thank you for participating in this survey! Your response has been counted.

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