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ERASMUS UNIVERSITEIT ROTTERDAM

[MASTER THESIS]

How alternate fuelled vehicles affect the financials of car manufacturers.

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Contents

1. Introduction

1.1 Motivation

Automobiles are a liberating technology for people around the world. The personal automobile allows people to live, work and play in ways that were unimaginable a century ago. Automobiles provide access to markets, to doctors, to jobs. Nearly every car trip ends with either an economic transaction or some other benefit to our quality of life (OICA, 2015). Therefore it may come as no surprise that the automobile industry is the single greatest engine of economic growth in the world.

Nowadays environmental issues play an important role in the development of new vehicles. The Intergovernmental Panel on Climate Change (IPCC) has concluded that reductions of at least 50% in global CO2 emissions from the 2000 levels will be necessary by 2050 in order to prevent dangerous climate change (Halila & Rundquist, 2011). The European Commission and the major automobile manufacturers in Europe are committed to develop more fuel efficient vehicles through improvements in vehicle technology (Caulfield, Farrell & McMahon, 2010). Further, the Obama administration has set a goal of one million plug-in vehicles on the road by 2015 in the USA and has introduced laws and policies supporting this goal. Encouraged by these actions, along with advances in lithium-ion battery technology and recent success stories for hybrid electric vehicles, automakers have begun a major push to develop plug-in battery vehicles. Indeed, all major automakers have R&D programs for electric vehicles and have indicated their intentions to begin mass production within the next few years (Hidure et al., 2011). Innovation plays a key role in meeting all the emission goals. Car manufacturers are forced to develop more economic and environmentally friendly cars. As a result, the production of hybrid and electric vehicles has increased significantly.

But what is the influence of these product innovations on the financials of such firms? And what is the role of R&D in the process? It's very hard to conduct research on the direct effects of product innovation and R&D on the financials of a firm. There are a lot of variables that affect the financials of a firm besides product innovation and R&D. Further, product innovation and R&D do not have a direct effect on the financials in the year after the innovation was developed and should therefore be included with a lag in the model. In this thesis the effect of introducing an alternate fuelled vehicle on the revenues of the manufacturer will be investigated. The role of R&D in this process will be investigated as

well. A distinction is made between the introduction of a hybrid and electric vehicle and its respective effect on revenues. The sample of this research consists of 14 different car manufacturers from countries all over the world in order to avoid country specific results. The financials of the car manufacturers are analyzed between the year 2001 until 2013.

1.2 Problem statement

The automobile industry is one of the most innovative industries in the world. In Europe for example, the automobile industry is the largest private investor in R&D (ACEA, 2015). The most recent examples of these innovations are hybrid and electric vehicles. Car manufacturers have to lower the CO2 emissions of their cars due to government regulations. However, it remains to be seen whether these innovations lead to better financial results. Therefore the following problem statement is formulated:

''Does the introduction of an alternate fuelled vehicle lead to higher revenues, and what is the role of R&D in this relationship?''

To support the problem statement, four sub questions are formulated; (1) What influence does the introduction of a hybrid car have on the revenues of the car manufacturer? (2) What influence does the introduction of an electric car have on the revenues of the car manufacturer? (3) What is the role of R&D expenditures in the relationship between the introduction of a hybrid or electric vehicle and the revenues of the respective manufacturer? (4) What is the relative effect of hybrid and electric cars on the manufacturers' revenues? Further on in this thesis the sub questions will be answered, followed by a conclusion on the problem statement.

1.3 Implications

In the existing literature the effect of innovation and R&D on firm performance has been investigated extensively. Most research in the automotive industry however turned out to be outdated since the respective industry is one of the fastest changing and most innovative industries in the world. The focus of this thesis is therefore on hybrid and electric vehicles. Since these vehicles are developed very recently, there is almost no literature to be found on this subject. This thesis investigates the effect that the introduction of hybrid and electric cars has on the revenues of its manufacturer. Further, the role of R&D in this relationship will be investigated. In a more broad way, this thesis investigates the effect of product innovation on the financials of car manufacturers.

1.4 Outline

This thesis consists of different parts, starting with the introduction above. The introduction is followed by the theoretical framework which presents an overview of the existing literature on the relevant topics for this research. The third chapter describes the automotive industry and the public policy that goes allow with it. Chapter 4 is the methodology chapter in which the research design, sample and data, variables and analysis are discussed. Chapter 5 presents the results. In this chapter the regression analysis is presented, along with its results and the consequences for the hypotheses. After the results the research question will be answered in the conclusion in chapter 6, followed by the managerial implications, limitations and suggestions for further research in chapter 7.

2. Theoretical Framework

A lot of research has been done in the field of product innovation, new product introduction, consumer perceptions, and marketing of new products. This chapter presents an overview of the existing literature in this area.

2.1 Innovation and new product introduction

‘’Innovation is probably one of the most important forces in fueling the growth of new products, sustaining incumbents, creating new markets, transforming industries, and promoting the global competiveness of nations’’ (Sood & Tellis, 2009). Porter and Linder (1995) state that continuous innovation is a vital strategy to overcome pressures from customers, competitors, and regulators. Further Chandy and Tellis (2000) mention that a good product innovation performance can help firms to improve market position, affirm brand name, leapfrog competition, create a breakthrough and attract new customers. These quotes indicate how important innovation is for not only the firms themselves, but for the economy as a whole. Most firms wouldn’t survive without continuous innovation.

Important research in the field of innovation is done by Hauser, Tellis and Griffin (2006). They describe innovation as the process of bringing new products and services to the market, and state that this is one of the most important issues in business research today. They state that innovation is responsible for raising the quality and lowering the price of products and services that have dramatically improved consumers’ lives. By finding new solutions to existing problems, innovation destroys existing markets, transforms old ones, or creates new ones. Marketing plays an important role in the understanding and management of innovation within firms and markets, because a primary goal of innovation is to develop new or modified products for enhanced profitability. An important component of profitability is revenue, which ultimately depends on satisfying customer needs better, or more efficiently, than competitors can satisfy those needs.

‘’I don’t want to invent anything that nobody will use’’ (Thomas Alva Edison)

This quote of Thomas Alva Edison illustrates the importance of the consumer in the innovation process. The success of innovations ultimately depends on the consumer accepting the innovation. Successful innovation rests on first understanding customer needs and then developing products that meet those needs (Hauser, Tellis & Griffin, 2006).

Cooper (1999) developed eight critical success factors for product innovation. These factors are stated below;

- Solid up-front homework; define the product and justify the project.
- Voice of the customer; a slave-like dedication to the market and customer inputs throughout the project.
- Product advantage; differentiated, unique benefits, superior value for the customer.
- Sharp, stable and early product definition; define product before development begins.
- A well-planned, adequately-resourced and proficiently-executed launch.
- Build tough go/kill decision points or gates; kill the project if it is not successful.
- Accountable, dedicated, supported cross functional teams with strong leaders.
- An international orientation; international teams, multi-country market research and global or 'glocal' products.

According to Cooper (1999), these factors determine whether a company is successful in launching a new product or not. In practice however, many firms fail to implement these factors in their process.

Golder, Shacham and Mitra (2009) state that there are three key events in the precommercialization of radical innovations; first concept, first prototype and commercialization. In their research they've come to some striking conclusions. The average time from first concept to macro-commercialization is 20 years, which is much longer than previous research identified. Out of the 29 radical innovations they examined only one firm led product development from the first concept to macrocommercialization. Some other findings are; 38% of the firms who develop the first concept also develop the first prototype, and 59% of the firms with the first prototype are also the first to sell the innovation. Yet only 24% of the firms that are first to microcommercialize an innovation are also the ones to macrocommercialize it. These numbers can be explained by the fact that innovation is a very expensive process and not all firms are able to finance this process throughout the whole product cycle. Another explanation is that firms copy each other's ideas. Golder, Shacham and Mitra also find that many radical innovation borrow from previous innovations in terms of technology, functionality and look-and-feel.

Several studies have identified innovation success as a key contributor to both long-term firm sales and financial and stock market performance (Srinivasan et al., 2009). In particular, investors react favorably to companies that launch pioneering innovations, that

have higher perceived quality, that are backed by substantial advertising support and that are in large and growing categories. They also state that, compared with minor updates, pioneering innovations have an impact on stock prices that is seven times greater, and their advertising support is nine times more effective as well. Further, the perceived quality of new car introductions improves the firm's stock returns. However, it does not improve the customer liking according to Srinivasan et al. One of the reasons they've done their research in the automotive industry is because the industry depends heavily on new products, promotional incentives and advertising. Therefore the main trust of competition is in product development, with each company competing in multiple market segments. In their research Srinivasan et al. find that automobile innovations that are responsive to unmet customer needs in specific segments, have resulted in substantial revenue increases for these companies. Srinivasan et al. distinguish two kinds of innovations in their research;

- New to the company innovations; for example the Porsche Cayenne. A sports car manufacturer that introduces a SUV.
- New to the market innovations; for example the Toyota Prius, which was the first hybrid car to be sold on the car market successfully.

Although new product introductions benefit stock returns on average, new to the market products have a greater impact (Chaney, Devinney & Winer, 1991). Holak and Lehmann (1990) state that the new product literature has consistently related innovation success to a product's ability to provide benefits and features not offered by alternative products. Lin, Chen and Huang (2014) verified that eco-innovation practices can help firms minimize waste and promote brands, which in return stimulates market share and new business opportunities. In their research they refer to the Toyota Prius as a status symbol and an example for green-labeling product strategies. Aboulnasr et al. (2008) investigated the competitive response to product innovation. They find that the likelihood of competitive response is substantially higher when the introducing firm is large or market dependent. Further, the response is highest when the innovation in introduced in a small market by a large firm.

In their research Lin, Tan and Geng (2013) find evidence for a positive relation between green product innovation and firm performance. This was not as logical as it seems because some of their empirical findings did indeed find a positive relation between product innovation and firm performance, but a significant amount of other findings suggested

otherwise. Another article, by Lin, Chen and Huang (2014), confirms that green innovation has a positive significant effect on firm performance. There were significant relationships found between green product innovation and market share and reputation.

Pauwels et al. (2004) investigate the effect of new product introductions and promotional incentives on firm performance. They use three financial metrics in their research; top line performance (revenue), bottom line performance (net income) and stock market returns. First, they find that new product introductions increase long-term financial performance and firm value. Promotional incentives on the other hand do not. Second, the investor reaction to new product introduction grows over time, indicating that useful information unfolds in the first two months after product launch. Third, product entry in a new market yields the highest top-line, bottom-line and stock market benefits. Another study about the effect of product innovation on the financial performance of a firm is done by Geroski et al. (1993). They find a significant positive effect for product innovation on profit margins.

According to Holak and Lehmann (1990) the relative advantage of new products is a consistently important determinant of accelerated consumer adoption rate and new product success. Pauwels et al. (2004) state that for most firms, new products are engines of growth. At the same time, the new product failure rate is high (ranging from 33% to greater than 60%) and has not improved in the past few decades. Pauwels et al. further find that revenue from new products may take considerable time to materialize and that revenue levels depend on several factors, including the degree of product innovation. A summary of their most important findings can be found underneath;

Table 1. Summary of findings Pauwels et al.

Summary of Findings

Impact of ...	Short Run	Long Run
New product Introductions on top-line performance	+	++
New product Introductions on bottom-line performance	+	++
New product Introductions on firm value	+	++
Promotions on top-line performance	+	++
Promotions on bottom-line performance	+	–
Promotions on firm value	+	–
New product introductions on the use of promotions	–	–

Notes: + = significant, positive impact; – = significant, negative impact; ++ = intensified positive impact.

(Pauwels et al., 2004)

The research of Pauwels et al. shows that new product introductions have a positive significant effect on the short-term financial performance of firms, and a strong positive

significant effect on the long-term performance. Promotions on the other hand only have a positive effect in the short run, and none in the long run with exception of top-line performance.

Barry, Erickson and Jacobson (2003) find that new product introductions influence profit rate and size. However, they don't find an effect on profit-rate persistence. They also find that the effect of new product introductions of profit rate comes from a reduction in selling and administrative expenditure intensity rather than through an increase in gross operating return. Also, Cooper (1998) states that new products are vital to the success and continued prosperity of the corporation. Finally, Barry, Erickson and Jacobson (2003) mention that previous research studies provide few, and often contradictory, insights concerning how new products influence the underlying drivers of firm performance. They say that consequently, our understanding of the effects of new product introductions on the financial rewards of a firm is very much incomplete.

As the literature shows, revenue is used in multiple articles as a metric for firm performance. In this thesis the effect of the introduction of a hybrid or electric vehicle on the revenues of the car manufacturer, and the role of R&D in this relationship will be investigated. This leads to the following two hypotheses:

H1: The introduction of a hybrid car has a positive effect on the revenues of the car manufacturer.

H2: The introduction of an electric car has a positive effect on the revenues of the car manufacturer.

2.2 Research and development

The automotive industry is one of the most important sectors in terms of total R&D expenditures (ACEA, 2010). Innovation, and thus R&D, is one of the most important requirements to survive in the respective industry. O'brien (2003) states that a high level of R&D intensity does not guarantee the generation of successful innovations. However, firms that invest heavily in R&D are more likely trying to compete on the basis of innovativeness and technology breakthrough. Erickson and Jacobson (1992) argue that R&D-based strategies generate knowledge that can lead to either superior products or more efficient production techniques.

One of the disadvantages of R&D is that it's very costly, and the results are not directly visible for the customer in most cases. Artz et al. (2010) even suggest a 3-year lag for R&D expenditures on firm performance. Another issue regarding the lag that is involved in R&D spending are styling changes. According to Pauwels et al. (2004) the success of styling changes is far from certain, even with extensive marketing research, because product development begins several years before the public launch. Ofek and Sarvary (2003) mention in their research that firms mainly invest in new products in an attempt to attain industry leadership. And thus, securing high profits and benefiting from advantages relevant for the success of future product generations. Further, their analysis reveals that when the current leader possesses higher research and development competence, it tends to invest more in R&D than rivals to retain its lead position.

Although the automotive industry is one of the most important sectors in terms of R&D expenditures, its R&D was less internationalized than any other industry by the mid-1990's, with the exception of the aerospace industry (Pavlinek, 2012). Becker and Dietz (2004) argue that the importance of R&D cooperation has risen steadily as a consequence of the growing complexity, risks and costs of innovation. They also argue that collaboration with other firms and institutions in R&D is a crucial way to make external resources usable. Cooperation between firms offers possibilities of efficient knowledge transfer, resource exchange and organizational learning. In their research Becker and Dietz came to some interesting results. The number of cooperation partners affect the R&D commitment positively. Further, heterogeneous partners in a cooperation releases synergies and enhances research productivity. On the output side, collaboration in R&D stimulates the probability of developing new products. And finally, the number of parties involved in the cooperation is positively related to the likelihood of realizing product innovations. Pavlinek (2012) argues that although R&D cooperation has major advantages, only countries in the global economic core have a chance to attract automotive R&D, unless countries outside the economic core have large market or profitable government regulations. Pavlinek also states that automakers traditionally face the dual challenge of achieving economies of scale in production and R&D and, at the same time, maintaining their ability to design and produce cars that are customized to specific markets.

R&D intensity and marketing expenses are the two major decisions that critically effect a firm's performance (Lin, Lee & Hung, 2006). In their research regarding technology firms, Lin, Lee and Hung found that R&D intensity has no significant effect on firm

performance. This may indicate that technology firms might not be able to enhance competitive advantage solely by increasing their R&D expenditures. According to Erickson and Jacobson (1992) the previous literature indicates very high stock returns to R&D and advertising spending. However, in their research Erickson and Jacobson found significant lower returns than suggested in the existing literature. They also find that isolation mechanisms, which prevent imitation, do not appear sufficient to generate a long-term comparative advantage. Finally, Erickson and Jacobson explain firms' reluctance to invest in R&D and advertising by the fact that these expenses adversely affect current period earnings.

Boulding and Staelin (1995) investigated the demand-side returns to R&D spending. They find that the demand-side returns to R&D spending depend on whether the firm has the ability and motivation to take advantage of the R&D investment. Thus, only firms with high ability and motivation leverage the R&D investment into monopoly rents in the form of subsequent price increases. Finally, Schoeffler et al. (1974) mention an important point in the field of R&D spending and firm performance, namely reverse causality in interpreting the observed results. In other words; does R&D spending lead to firm performance, or does firm performance lead to R&D spending?

The previous literature shows that R&D spending has a positive effect on firm performance in most cases. The results however seem to differ across industries. This thesis investigates the role of R&D in the relationship between the introduction of an alternate fuelled vehicle and the revenues of the respective manufacturer. The hypothesis is as follows:

H3: R&D expenditures have a positive effect on the relationship between the introduction of an alternate fuelled vehicle and the revenues of the respective car manufacturer.

2.3 Marketing and consumer perceptions

In order for new products to be successful, the consumer must be aware of the product. According to Srinivan et al. (2009) awareness is an essential component of new product success. Advertising plays an important role in creating awareness, especially for pioneering innovations. Consumers can consider radical innovations as risky, since they are not yet familiar with the products. Therefore it's important to create a strong brand. Srinivan et al. state that a strong brand can reduce consumers' perceived risk. In their research, Srinivan et al. find that the stock return impact of new product introductions is greater when they are backed by substantial advertising investments. By investing in advertising, the firm is able to

communicate the differentiated added value of their product. This leads to higher firm value effects of innovations. Promotional incentives on the other hand do not increase firm value, because they may signal an anticipated weakness in demand for the new product. Finally, Srinivan et al. find that the stock return impact of new product introductions is higher for products with a higher perceived value. Horsky and Simon (1983) state that one of the most important marketing activities to accompany a product's introduction is advertising. When a firm wants to introduce a new product, it has to carefully design it to reflect the consumers' preferences and support the product introduction with a well-thought-out marketing strategy. Horsky and Simon also mention that new product buyers consist out of two groups; those who adopt the product independently of others (the innovators), and those who are influenced by others (the imitators). Toyota understood the principle Horsky and Simon mention in their research. When they launched the Toyota Prius (the first largely produced hybrid car), several celebrities, famous for their environmentally friendly principles, drove their car. This gave their sales in the US an enormous boost.

''Consumer response determines the success or failure of new products and services''(Hauser & Urban, 1977). Hauser and Urban indicate with their quote how important the consumer, and its perception of new products is. Hauser, Tellis and Griffin (2006) state that consumer innovativeness is the propensity of consumers to adopt new products. Only few concepts in the behavioral sciences have as much influence on consumer behavior as innovativeness. According to Petiot and Yannou (2004) a well designed product should not only satisfy requirements, defined objectively, but should also satisfy consumers' psychological needs, by essence subjective. In order to predict the success of a product, both sides of the need, subjective and objective, should be considered. Petiot and Yannou also say that the perception of the shape of a product is often nothing but a style of design, depending much more on the designer's taste than on real customers' trends. Consumer perception is one of the key elements in new product introduction success. But taking the consumers' perception for product design into account still remains a challenge. Hsu et al. (2000) state that there is still a huge gap between designers' and users' perceptions, due to the fact that subjective criteria are often neither named nor objectively assessed.

Hoeffler (2003) did research on measuring preferences for really new products. He states that a significant barrier to the success of really new products is that existing market research techniques forecast much less accurately for really new products than for more conventional incrementally new products. Existing market techniques start with the premise

that the results are only valid when consumers have some core knowledge relevant to the product. This means the results can't be generalized for really new products. According to Hoeffler, one of the most important principles resulting from the past 15 years of research in decision making is that when preferences are constructed at the time of measurement, rather than retrieved from something the consumer already knows, the trade-offs elicited are unstable and can be easily changed by small changes in measurement procedure.

Feldman and Armstrong (1975) tried to identify buyers of major automotive innovation in their research. They found that the rate of diffusion of an innovation is positively related to consumers' perceptions of the innovation in terms of four characteristics:

- The new product must have a relative advantage over existing products.
- It must be compatible with existing norms, values and behavior.
- It must be easy to communicate the features of the product.
- Good divisibility, the degree to which a product may be tested on a limited basis.

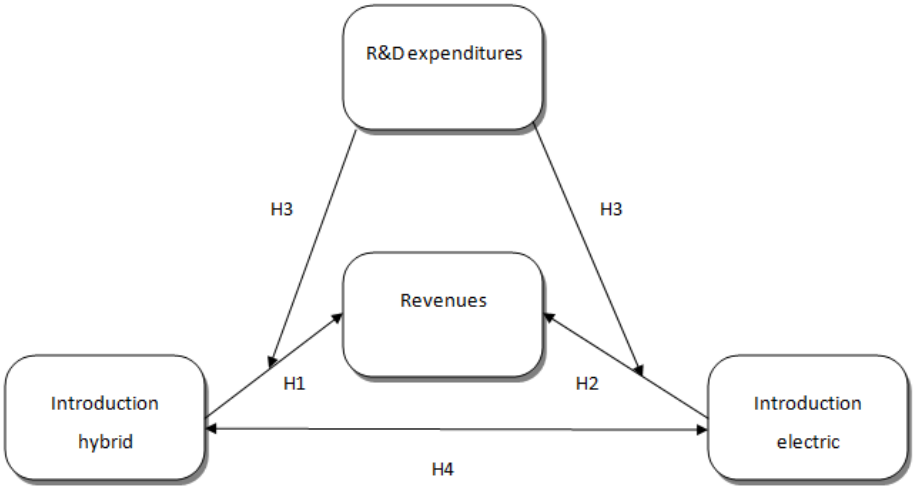
Caulfield, Farrell and McMahon (2010) investigated the preferences individuals have for hybrid and electric vehicles. They conducted a survey in which they tried to obtain factors that influenced individuals' decisions when buying a new car. The results showed that respondents did not rate green house gas emissions or Vehicle Registration Tax (VRT) as crucial attributes when purchasing a new vehicle. The most important attributes that influenced their buying decision were reliability, safety, fuel costs and the cost price. The majority of the respondents however agreed that hybrid and electric vehicles are better for the environment, cheaper to run than conventional vehicles and would be the vehicle of choice in 10 years.

In this research marketing and consumer perceptions play an important role. When the Toyota Prius was introduced in 1999, consumers saw this as a major innovation. But after a few years the Prius received criticism about his batteries and how environmentally friendly those batteries really were. The introduction of the fully electric cars was seen as a major innovation as well. On the other hand there was skepticism about the short driving range of such vehicles at that time. The data of this thesis starts in 2001, because a lot of the required data was not available before 2001. Since the Prius was introduced in 1999, the consumers that influence the financials in our data were already familiar with hybrid cars. Therefore they may not have seen the Prius as a major innovation anymore in 2001. And thus, the effect a major innovation can cause in the financials of a firm is probably not as strong as in the years

after the introduction of the Prius. The introduction of the electric cars on the other hand does fall within our data range. Therefore we expect a stronger effect for the electric car on the manufacturers' revenues than for a hybrid vehicle.

H4: The introduction of an electric vehicle has a stronger effect on the manufacturers' revenues than the introduction of a hybrid vehicle.

This thesis contains four hypotheses which ultimately give an answer to the problem statement. The relationships between the variables are graphically presented in the conceptual model below:

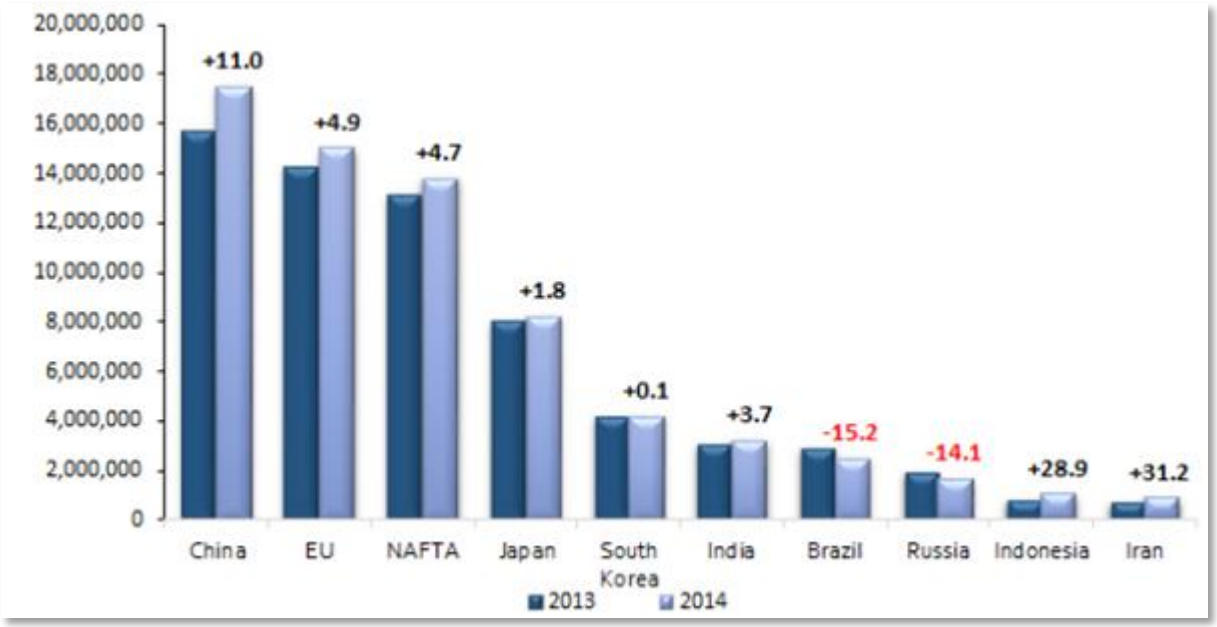


3. The automotive industry

3.1 The industry

According to the ACEA (European Automobile Manufacturer's Association) and Statista there are currently more than 1 billion cars driving the streets worldwide. Therefore it might not be a surprise that the automobile industry is the single greatest engine of economic growth in the world. The industry is a key sector in every major economy in the world. Besides, the automobile industry is one of the largest investors in R&D worldwide. In Europe for example, the automobile industry is the largest private investor in R&D, investing over €45 billion per year in R&D and applying over 6000 patents (ACEA, 2015). Although the electric car market is growing very fast, it still counts for a very small part of the total car market. By the end of 2012 the global electric vehicle stock represented only 0.02% of the total passenger cars according to Statista.

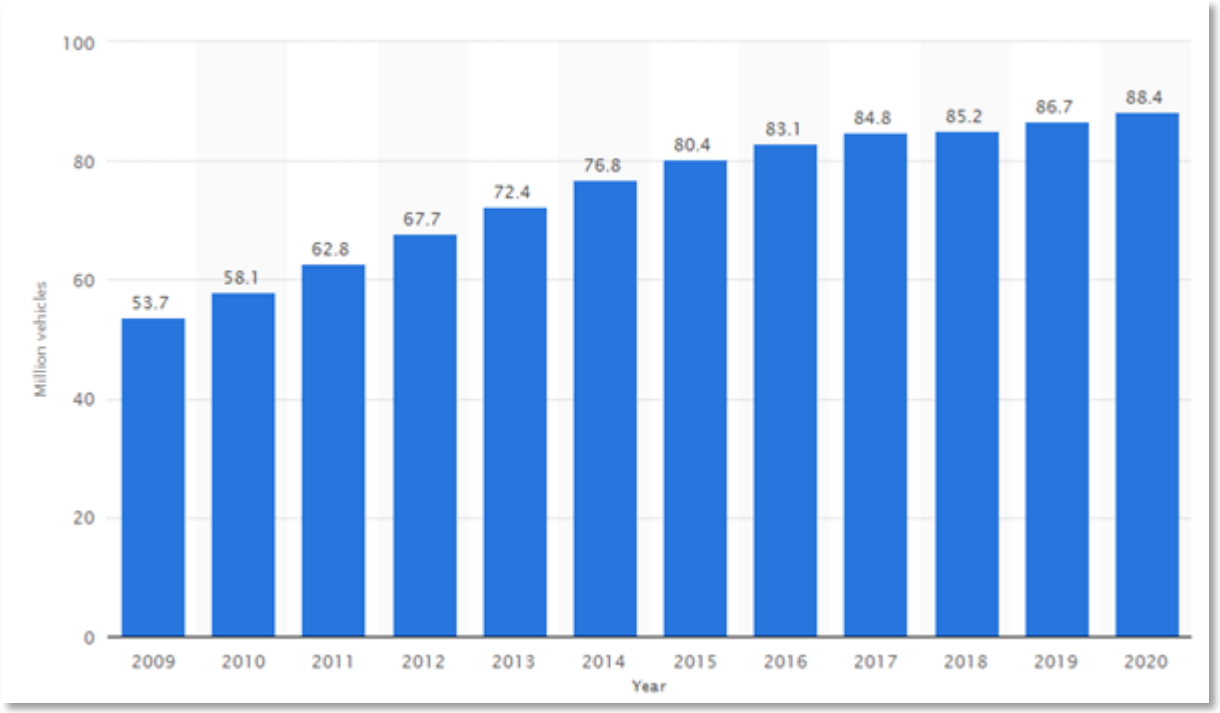
Figure 1. Graphical representation of top 10 world passenger car producers 2013/2014 (PRTM Management Consultants, 2015).



As figure 1 shows, most passenger cars are produced in China, followed by Europe and the NAFTA. The figure also shows the important role of Asian manufacturers in the global automotive industry with 5 Asian countries in the top 10 of largest passenger car

producers. Hybrid and electric vehicles are expected to claim a larger part in the global car market in the future. Figure 2 shows the predicted growth for respective cars.

Figure 2. Forecast for the worldwide number of hybrid and electric cars between 2009 and 2020 (PRTM Management Consultants, 2009).



The production of hybrid and electric cars is expected to grow significantly as shown by figure 2. Since the forecast dates from 2009, the number might have changed a little bit by now. But based on the success of hybrid and electric vehicles in the past few years, the estimated production of respective cars might be even higher than suggested in figure 2.

3.2 Public policy

One of the most important reasons hybrid and electric vehicle production is growing very fast is public policy. Almost every country has public policy regulations for hybrid and electric vehicles. Often, governments offer incentives to consumers in the form of tax reductions or special parking places in order to stimulate people to drive 'green'. These government incentives are driven by the conclusion of the intergovernmental panel on climate change that reductions of at least 50% in global CO2 emissions are necessary by 2050 in order to prevent dangerous climate change (Halila, F. and Rundquist, J. (2011). The Obama administration in the US has set the goal of 1 million plug-in vehicles on the road this year

and has introduced laws and policies to support this goal (Hidure et al, 2011). Although public policy definitely affects the automotive industry, it's hard to draw a general conclusion because the differences between countries are enormous.

Figure 3. State subsidies when buying an electric car in selected countries in 2010 (McKinsey, 2011).

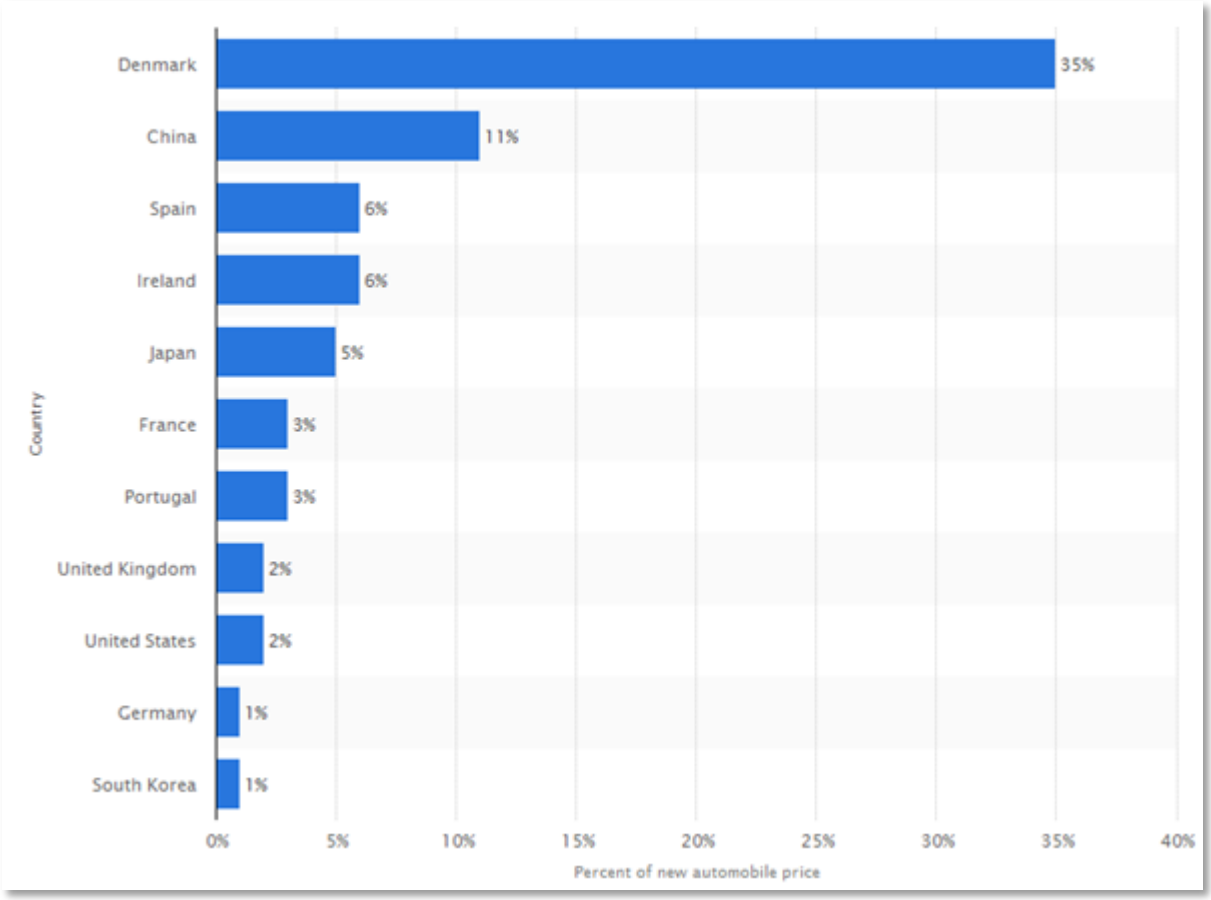


Figure 3 shows the state subsidies per selected country in 2010. This graph illustrates the enormous differences per country in state subsidies. The government in Denmark pays for 35% of the total price of an electric vehicle whereas the government of Portugal for example pays for only 3%. Although this comparison may not be completely valid because Portugal can have other tax incentives for their inhabitants to buy a hybrid or electric car, it is safe to say that public policy plays an important role in the choice of consumers for both hybrid and electric cars.

When hybrid cars were firstly introduced to the market the governmental incentives were very profitable for those cars. However, when more hybrid cars came to the market,

most governments became more critical about their incentives. More economic and environmentally friendly cars got better incentives. When fully electric cars were introduced they got even better incentives since those cars didn't have any emissions at all. In the Netherlands for example the first fully electric lease cars had 0% additional tax. This will change to 4% in 2016. All the changes that are made in public policy in the past years and the enormous differences in public policy between countries make it impossible to incorporate public policy as a variable in this thesis. However, it's impossible to deny that public policy indeed has an effect on the choice of the consumer for hybrid or electric cars. In the past few years for example, the incentives for electric cars in the Netherlands are much more beneficial than for hybrid cars. This definitely plays a role in the decision making process of the consumer.

4. Methodology

In this chapter the methodology of this thesis is discussed. The first paragraph will elaborate on the research design, followed by the sample and data in paragraph two. In the third paragraph the variables which are used in this research will be discussed. And finally, the fourth paragraph presents the analysis for this thesis.

4.1 Research design

This study investigates the relationships between the dependent variable 'revenues' and the independent variables R&D expenditures, whether a hybrid car was introduced and whether an electric car was introduced. Further, the moderating role of R&D expenditures on the relationship between the introduction of an alternate fuelled car and the revenues of the manufacturer, and the relative effect between hybrid and electric cars will be investigated. The control variables in the model are the gross world product and the crude oil price per barrel. This study makes use of secondary data which was collected from the annual reports of the car manufacturers, news articles and online databases. Based on the nature of the dataset a quantitative research design is used.

4.2 Sample and data

The sample for this study consists of 14 different car manufacturers from all over the world. For each of these companies data was collected from 2001 until 2013 with exception of Tesla which only had data available since 2008. But because Tesla is the only company producing solely electric cars it's interesting to include them in the model as well. The chosen timeline for the data is based on the availability of the financial information of the companies. For some companies there was no data available before 2001. Besides, before 2001 European companies didn't incorporate the euro in their annual reports which makes it even harder to compare the numbers due to volatile exchange rates. As the fiscal years in Asia differ from the European standards, not all annual reports over the fiscal year 2014 were published from Asian companies when writing this thesis. Therefore 2013 was chosen as the most recent year in the dataset.

For this study the car manufacturers with the highest revenues in the fiscal year 2013 are incorporated in the dataset. Figure 1 in the appendix shows the 15 leading car manufacturers based on their revenues in 2013. Unfortunately there wasn't enough data

available for some companies to be incorporated in this study. Therefore Honda, Suzuki and Mazda are excluded from the dataset. Chrysler is not included either since they've become part of the Fiat group. To increase the sample size for this study Audi, Tesla and Volvo are added, based on their proven affection with hybrid or electric vehicles and their long-lasting presence on the market.

In order to make the dataset as random as possible companies from the US, Europe and Asia were selected. The sample contains companies who haven't introduced a hybrid or electric car, companies who have introduced both and companies who have solely introduced electric cars like Tesla. Further the dataset includes manufacturers who produce multiple car brands like the Volkswagen group, but also manufacturers who produce only one brand like Volvo. Some annual reports contain financial information for the manufacturer as a whole. This means Mercedes includes for example information about their truck division in their annual reports as well. For the dataset in this study only the relevant information for the production of cars is used. In the case of Mercedes the annual report contained a separate financial file solely for the production of cars which was used in this dataset.

All the financial data is derived from the annual reports of the companies itself. Since not all companies have the same country of origin the annual reports are stated in different currencies. As 50% of the companies present in the dataset use the Euro in their annual reports, this currency is chosen as the standard. The financial numbers of the non-European companies are converted to the Euro, based on the average exchange rate for each year. These exchange rates can be found in table 1 in the appendix. The revenues for Ford in 2002 are converted based on the average exchange rate in 2002 between the Euro and the Dollar, for example. For the gross world product between 2001 and 2013, data from the World Databank was used. Further the crude oil price per barrel is based on the Macrotrends database. And finally the information about when a hybrid or electric car was firstly introduced comes mostly from news articles and historical information on the car manufacturers websites itself.

4.3 Variables

This paragraph will describe how each variable in the model is measured. First the dependent variable will be explained, followed by the independent and control variables.

Revenues (dependent variable)

The dependent variable in the model are the revenues of each company. The revenues are measured in Euro's per year which means it is a ratio variable. This study investigates how the revenues of car manufacturers are affected by the independent variables as described below. The revenues are always a positive number.

R&D expenditures (independent variable)

This variable is the amount of money a company yearly spends on its research and development. This variable is measured in Euro's per year and is always a positive number. Like the dependent variable, R&D expenditures is a ratio variable. Since it takes several years for a company to benefit from its R&D expenditures this variable is included with a lag. According to (Artz et al., 2010) R&D spending has a 3 year lag on firm performance. Therefore R&D expenditures will be included in the model with a 3 year lag.

Introduction of a hybrid vehicle (independent dummy variable)

The introduction of a hybrid vehicle indicates whether a car manufacturer has introduced a hybrid vehicle in a certain year or not. This is a binary variable which means it can only be '0' or '1'. The variable is coded as '0' if the company has not introduced an hybrid vehicle so far, and is coded '1' if a hybrid vehicle is indeed introduced.

Introduction of an electric vehicle (independent dummy variable)

This variable focuses on the introduction of an electric vehicle. The variable codes '0' if the car manufacturer hasn't introduced an electric vehicle, and '1' if the company already has introduced such a vehicle in the respective year.

Gross world product (control variable)

The gross world product is the gross national product of all countries in the world combined. This could be described as the total global gross domestic product as well. Golder, Shacham and Mitra (2009) included this variable in their research to correct for the general economy. This is a control variable which corrects for the economic environment. The variable is measured in trillions of Euro's and is a ratio variable.

Crude oil price per barrel (control variable)

The crude oil price per barrel is a representative of the gas prices worldwide. Since the oil supplies worldwide are shrinking, and the price per barrel has more than doubled between 2001 and 2013, this may cause a shift in alternate fuelled vehicles. Therefore this variable is added as a control variable to the model. The crude oil price per barrel is a ratio variable which is measured in Euro's.

Lagged revenues (control variable)

This variable was added to the model in order to avoid serial correlation. By adding this variable to the model the Durbin-Watson statistic increased significantly. Revenues is included with a one year lag, is a ratio variable and is always positive.

4.4 Analysis

Since the dependent variable in this study is a ratio variable and the independent variables are both ratio and nominal variables, a multiple linear regression analysis is used. The model for a multiple linear regression looks as follows (Montgomery et al., 2012):

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k + \varepsilon$$

Where y denotes revenues, x_1 denotes the first independent variable (for example R&D expenditures), x_2 denotes the second independent variable and x_k denotes the 'k'th variable. In order to run a proper linear analysis, the data should meet several assumptions which are stated below:

- Linearity; the relationships between the predictors and the outcome variables should be linear.
- Normality; the error terms in the model should be normally distributed.
- Homogeneity of variance (homoscedasticity); the variance in the error terms should be constant.
- Independence; the errors associated with one observation are not correlated with the errors of any other observation.
- Outliers; the model should be controlled for outliers.

Besides the above stated assumptions it's important to check the model for multicollinearity. Multicollinearity can occur when the predictor variables are highly correlated with each other. This can cause problems in estimating the regression coefficients.

5. Results

In the previous chapter the research methodology was introduced. For the purpose of this study a linear regression model is used. This chapter will start with the descriptive statistics of the sample, followed by the assumptions for a good linear regression analysis. The third part of this chapter shows the actual regression analysis, and the chapter will end with checking the hypotheses.

5.1 Descriptive statistics

The sample for this study contains 14 different car manufacturers. For each car manufacturer data was collected between 2001 and 2013, with the exception of Tesla. The data of Tesla starts in 2008. Therefore the total sample size is 175 in the descriptive statistics. For the gross world product the sample size is only 13 since this variable is measured per year, and the timeline for the data is 13 years (2001-2013). The following table presents an overview of the most important descriptive statistics of the sample.

Table 2. Descriptive statistics.

	N	Minimum	Maximum	Mean	Std. Deviation
Revenues (in billion euro's)	175	0.14	197.00	66.98	44.50
R&D Expenditures (in billion euro's)	175	0.019	10.18	3.02	2.05
Introduced Hybrid	175	0.00	1.00	.43	.49
Introduced Electric	175	0.00	1.00	.33	.47
Crude oil price per barrel (in euro's)	175	31.47	69.60	51.53	14.07
Gross World Product (in trillion euro's)	13	32.10	74.73	54.66	14.28

For the revenues the big difference between the minimum and maximum amount may stand out. The relatively low minimum is caused by the year 2008 of Tesla. In that year Tesla only had 312 employees, and was just starting on the electric vehicle market as opposed to major firms like Volkswagen with over 500,000 employees. In the sample of 14 car manufacturers, 12 introduced a hybrid vehicle and 11 introduced an electric vehicle. Further the data shows that Ford had the highest R&D expenditures, opposed to Tesla who had the lowest R&D expenditures.

Table 3. Correlation among the variables.

	1.	2.	3.	4.	5.
1. Introduced hybrid	1.000	-0.015	0.366	0.132	-0.265
2. Introduced electric	-0.015	1.000	0.192	0.192	-0.319
3. R&D expenditures	0.366	0.192	1.000	0.006	0.137
4. Crude oil price per barrel	0.132	0.192	0.006	1.000	-0.837
5. Gross world product	-0.265	-0.319	0.137	-0.837	1.000

The table shows that there is little correlation among most variables. The only noteworthy correlation is between the crude oil price per barrel and the gross world product.

5.2 Assumptions

As described in paragraph 3.4 a linear regression should meet several assumptions, otherwise the results of the regression can be misleading. In the section below all the assumptions for a multiple linear regression model are checked.

5.2.1 Outliers

An outlier in the dataset is a value which is significantly higher or lower than the other values in the sample. Before a proper regression can be conducted, the sample should be controlled for outliers. Outliers can only occur in continuous variables, as binary variables only have two possible outcomes. For this study two different approaches are used in order to determine whether there are outliers in the data. These approaches are the Mahalanobis distance and Cook's distance.

Mahalanobis distance

The Mahalanobis distance is a measure of the distance between a point P and a distribution D. It is a multi-dimensional generalization of the idea of measuring how many standard deviations away P is from the mean of D (Mahalanobis, 1936).

To determine whether the data contains outliers according to Mahalanodis distance, a couple of steps have to be taken. First of all the degrees of freedom have to be determined. The degrees of freedom are equal to the number of independent variables in this case. Based on the degrees of freedom the critical value in the Chi-square distribution can be examined. This study uses a model with 5 degrees of freedom. The critical value for the model with 5

degrees of freedom and a 95% confidence interval is 11.07. Observations in the sample that exceed the respective critical value can be considered outliers and are deleted from the model. The maximum value in the residuals statistics indicates whether there are values in the sample that exceed the critical value. In table 3 in the appendix proof of the presence of outliers can be found.

Cook's distance

Cook's distance measures the effect of deleting a given observation. Data points with large residuals (outliers) and/or high leverage may distort the outcome and accuracy of a regression and should therefore be excluded from the model (Cook, 1977).

The rule of thumb for Cook's distance is to delete observations from the model with a value greater than 1. The maximum value for Cook's distance can be found in table 3 in the appendix. All observations with a value higher than 1 are excluded from the sample.

5.2.2 Linearity

In order to run a proper linear regression there needs to be a linear relationship between the dependent variable and all of its independent variables. The linearity assumption is checked visually, based on the partial regression plots provided in SPSS. The plots in the model show proof of a linear relationship between the independent variable 'Revenues' and all independent variables. Although some relations are more visually supported than other, all plots show enough evidence of linearity.

5.2.3 Normality

The second assumption for a linear regression in the normality assumption. This means that the residuals should be approximately normally distributed. If this is not the case, the outcomes of the regression can be seriously biased or misleading. The normality assumption will be tested in two ways: the first test is visually and based on the histogram of the data, while the second test is based on the skewness and kurtosis values.

The histogram can be found as graph 1 in the appendix and shows that the data is approximately normally distributed as compared to the superimposed normal curve in the histogram. In the literature there are several opinions about acceptable skewness and kurtosis values, varying from a -1 to 1 and a -3 to 3 range. For this study the skewness value is 0.962 and the kurtosis value is 0.488. Therefore we can assume that the data is normally distributed.

5.2.4 Homogeneity of variance

Another assumption for a multiple linear regression model is homogeneity of variances. The data needs to show homoscedasticity, which is where variances along the line of best fit remain similar as you move along the line. This study uses two statistical tests to test for homoscedasticity, namely the Breusch-Pagan test and the Koenker test. The Breusch-Pagan test is the more commonly used test, where the Koenker test is more suited for small sample sizes. The test results are presented below:

H0: the data is homoscedastic

Breusch-Pagan test value: 2.456 *p-value: 0.8734*

Koenker test value: 2.124 *p-value: 0.9079*

Since both p-values are larger than 0.05, H0 is accepted which means the data is homoscedastic and the homogeneity of variance assumption is met.

5.2.5 Independence

A multiple linear regression requires that there is no autocorrelation in the data. Autocorrelation occurs when the residuals are not independent from each other i.e. the value of y(x+1) is not independent from y(x). Autocorrelation can be tested by the Durbin-Watson test. The Durbin-Watson statistic is always between 0 and 4, where values around 2 indicate no autocorrelation. The Durbin-Watson statistic is calculated separately for each firm because this thesis uses panel data. According to Bhargava et al. (1982) the critical values for panel data are 1.7999 and 1.9126. Our test statistic is 0.822 which is lower than 1.799. Therefore the null hypothesis of no serial correlation is rejected.

In order to improve the Durbin-Watson statistic we included revenues with a one year lag in the model. This improved the Durbin-Watson statistic significantly. However, Art et al. (2010) used a model without lagged revenues in their research. Besides, the high R^2 of 0.8 in our model already explains most of the variance. Therefore the model without lagged revenues is used. However, the model with lagged revenues in included as table 4 in the appendix.

5.2.6 Multicollinearity

Multicollinearity occurs when two or more independent variables are not only related to the dependent variable, but are also related to each other. Basically, two or more independent variables as a combination predict a substantial part of another independent variable's variance. Multicollinearity can be found by observing the Variance Inflation Factor (VIF) and the tolerance values. The most commonly used rule of thumb for the VIF value is that a value larger than 10 indicates multicollinearity. Further, a tolerance value smaller than 0.100 indicates multicollinearity as well. The table below shows the results for this study.

Table 4. Tolerance and VIF values.

	Tolerance	VIF
Crude oil price per barrel (€)	0.219	4.563
R&D expenditures	0.362	2.764
Introduced hybrid	0.241	4.152
Introduced electric	0.239	4.177
Gross world product (trillions euro's)	0.166	6.017
Hybrid*R&D exp.	0.147	6.793
Electric *R&D exp.	0.201	4.972

The table shows that all tolerance values are above 0.100 and all VIF values are below 10. This means that there's no proof of multicollinearity.

5.3 Regression analysis

In the first subparagraph the model fit of the linear regression is presented, based on the R^2 and the adjusted R^2. The second subparagraph presents the results of the linear regression model.

5.3.1 Model fit

The two most commonly used measures for the goodness of fit of a linear regression model are the R^2 and the adjusted R^2. The R^2 measures the proportion of variation in the dependent variable that is explained by the independent variables. The adjusted R^2 does exactly the same, however the adjusted R^2 takes the number of independent variables into account as well. R^2 can be manipulated by adding more and more independent variables to the model since these variables probably explain a bit of the variation in the dependent variable.

Therefore the adjusted R^2 is a better goodness-of-fit measure. Below the goodness-of-fit statistics for this research are presented:

$R^2 \rightarrow 0.802$

$Adjusted\ R^2 \rightarrow 0.791$

The values of R^2 and adjusted R^2 are always between 0 and 1, where 1 indicates that all variation in the dependent variable is explained by the independent variables. The values in our model are close to 1, which means most of our variation in the dependent variable is explained by the independent variables. This is an indication of a good model fit.

5.3.2 Linear Regression

In the previous subparagraph the model fit is described and can be considered good. This subparagraph shows the results of the linear regression as conducted in SPSS. The following table shows all the variables on the left side, including the 'constant' in the model. The 'B' column stands for the unstandardized Beta, whereas the third column shows the standard error of each variable. The 'Beta' in the fourth column indicates the standardized Beta, which is a measure of the influence each independent variable has on the dependent variable. Finally, the p-value can be used to determine whether an independent variable has a statistical significant influence on the dependent variable. This thesis uses a 95% confidence interval, meaning that variables with a p-value < 0.05 can be considered statistical significant. Table 5 shows the results of the regression analysis.

Table 5. Linear regression results with dependent variable 'Revenues'.

Variables	B	St. Error	Beta	P-value
(Constant)	6291.256	10574.861	-	-
Introduced hybrid	5879.502	6210.329	0.077	0.346
Introduced electric	-16096.012	6588.053	-0.198	0.016
R&D expenditures	14.252	1.373	0.685	0.000
Gross world product	4658.391	322.393	-0.199	0.043
Crude oil price per barrel	905.902	269.901	0.284	0.001
Introduced hybrid * R&D exp.	-0.747	1.853	-0.042	0.687
Introduced electric * R&D exp.	9.475	1.920	0.437	0.000

The next step is to check each of the independent variables for their statistical significance. Since a 95% confidence interval is used in this thesis five variables are statistically significant; namely the introduction of an electric vehicle, R&D expenditures, gross world product, crude oil price per barrel and the interaction variable introduced electric * R&D expenditures. The significance of the introduction of an electric vehicle is very important, because this means that the introduction of an electric vehicle by car manufacturers has a significant positive influence on their revenues. Further, the R&D expenditures have a significant positive influence on a firm's revenues. And finally, R&D expenditures has a positive moderating effect on the relationship between the introduction of an electric vehicle and the revenues of the respective manufacturer as well.

5.4 Hypotheses

In this part of the thesis the hypotheses that were formulated in the theoretical framework will either be supported or rejected, based on the outcomes of the linear regression presented in the previous paragraph.

H1: The introduction of a hybrid car has a positive effect on the revenues of the car manufacturer.

To either accept or reject this hypothesis we will look at the variable 'introduced hybrid' in table 5. The unstandardized beta indicates that the introduction of a hybrid car has a positive influence on revenues. The p-value however is insignificant (0.346), meaning that the introduction of a hybrid car has no effect on the revenues of car manufacturers. Therefore hypothesis 1 is rejected; the introduction of a hybrid car has no effect on the revenues of the car manufacturer.

Conclusion; hypothesis rejected

H2: The introduction of an electric car has a positive effect on the revenues of the car manufacturer.

The unstandardized beta shows proof of a positive relationship between the introduction of an electric car and the revenues of the manufacturer. Further the p-value of 0.016 is smaller than 0.05, meaning that the variable has a significant influence on the dependent variable. Therefore we can conclude that the introduction of an electric vehicle has a significant positive influence on the revenues of the car manufacturer.

Conclusion; hypothesis supported

H3: R&D expenditures have a positive effect on the relationship between the introduction of an alternate fuelled vehicle and the revenues of the respective car manufacturer.

Since an alternate fuelled vehicle can be hybrid and electric, the purpose of this hypothesis is twofold. First the relationship between the introduction of a hybrid car and the revenues of the manufacturer should be investigated. Secondly, the role R&D expenditures play in the relationship between an electric car and the revenues of its manufacturer should be researched. The table shows that the first relationship is not significant (p-value = 0.687). R&D expenditures do not play a role in the relationship between the introduction of a hybrid vehicle and the revenues of its manufacturer. The second relationship on the other hand is significant (p-value = 0.000). The R&D expenditures have a positive moderating effect on the relationship between the introduction of an electric vehicle and the revenues of the respective manufacturer.

Conclusion; hypothesis partly supported

H4: The introduction of an electric vehicle has a stronger effect on the manufacturers' revenues than the introduction of a hybrid vehicle.

This hypothesis investigates the relative effect of hybrid versus electric cars on the revenues of the manufacturer. Hypothesis 1 shows that the introduction of a hybrid vehicle has no significant effect on the revenues of the firm. On the contrary, hypothesis 2 shows that the introduction of an electric car does have a significant effect on a firms' revenues. Therefore we can conclude that the introduction of an electric car indeed has a stronger effect on the manufacturers' revenues than the introduction of a hybrid vehicle.

Conclusion; hypothesis supported

6. Conclusion

This chapter will provide an answer to the research question. This is done based on the results of the linear regression and its respective hypotheses. The research question for this thesis as formulated in the introduction is as follows:

''Does the introduction of an alternate fuelled vehicle lead to higher revenues, and what is the role of R&D in this relationship?''

The research question is supported by four hypotheses. The first hypothesis states that the introduction of a hybrid vehicle has a positive influence on the revenues of the car manufacturer. Further, the second hypothesis states that the introduction of an electric car has a positive influence on the revenues of the manufacturer. The third hypothesis states that the R&D expenditures have a positive moderating effect on the relationship between the introduction of an alternate fuelled vehicle and the revenues of its manufacturer. And finally the fourth hypothesis states that the introduction of an electric vehicle has a stronger effect on the manufacturers' revenues than the introduction of a hybrid vehicle.

In the theoretical framework a lot of evidence was found for a positive relationship between product innovation and firm performance. More specifically, Lin, Tan and Geng (2013) found evidence for a positive relationship between green product innovation and firm performance. This was confirmed by research of Lin, Chen and Huang (2014) who showed that there was indeed a positive significant relationship between green product innovation and firm performance. Pauwels et al. (2004) found that new product introduction has a positive relationship with both short-term and long-term firm performance. On the contrary, Barry, Erickson and Jacobson (2003) state that previous research provide few and often contradictory insights in the drivers of firm performance. They mention that our understanding of the effects of new product introductions on firm performance is very much incomplete.

The first hypothesis of this thesis is: *'' The introduction of a hybrid car has a positive effect on the revenues of the car manufacturer.''* The results of the regression analysis, which can be found in table 5, show that this relationship is insignificant which means the hypothesis is rejected. The introduction of a hybrid car has no positive influence on the revenues of the car manufacturer. The reason for this insignificant relationship might be that consumers need time to adopt alternate fuelled vehicles. Caulfield, Farrell and McMahon

(2010) mention that most respondents in their research thought that hybrid vehicles would be their vehicle of choice in 10 years. At this moment however, they preferred other vehicles.

The second hypothesis is: *'' The introduction of an electric car has a positive effect on the revenues of the car manufacturer.''* Table 1 shows a p-value of 0.016 which means this hypothesis is supported. The introduction of an electric vehicle does indeed have a positive influence on the revenues of the car manufacturer. Whereas consumers need time to adopt to hybrid vehicles, electric vehicles doesn't seem to have that problem. Since hybrid vehicles were introduced before electric vehicles, the consumer already had time to adopt alternate fuelled vehicles. Furthermore, electric vehicles are even more economic than hybrid vehicles and in most countries the government incentives are more beneficial for electric cars.

The third hypothesis suggests a positive moderating effect of R&D expenditures on the relationship between the introduction of an alternate fuelled vehicle and the revenues of the respective firm. The hypothesis therefore is: *R&D expenditures have a positive effect on the relationship between the introduction of an alternate fuelled vehicle and the revenues of the respective car manufacturer*. The answer on this hypothesis is twofold since this hypothesis is tested for both hybrid and electric vehicles. Table 5 shows that the moderating variable is only significant for the relationship between the introduction of an electric vehicle and the revenues of the manufacturer. So increased R&D expenditures have a positive indirect effect on the revenues of a car manufacturer when an electric vehicle is introduced.

The fourth hypothesis investigates the relative effect that the introduction of a hybrid or electric car has. The hypothesis is: *The introduction of an electric vehicle has a stronger effect on the manufacturers' revenues than the introduction of a hybrid vehicle.* The results of hypotheses one and two prove that the introduction of an electric car indeed has a stronger effect than the introduction of a hybrid vehicle. This result was expected as mentioned in paragraph 2.3. Since our data started in 2001 and the first hybrid car (Toyota Prius) was introduced in 1999, the effect of a major innovation was already gone when our data starts. The first introduced electric car on the other hand does fall within our data range. Therefore the stronger effect of the electric car may come as no surprise.

The answer to the research question is twofold; (1) The introduction of an alternate fuelled vehicle can indeed lead to higher revenues. It's important though to make a clear distinction between hybrid and electric vehicles. As mentioned, the introduction of a hybrid vehicle does not lead to higher revenues whereas the introduction of an electric vehicle does.

(2) The role of R&D is somewhat harder to define. On the one hand our research shows that R&D expenditures does not have a moderating effect on the relationship between the introduction of a hybrid car and the revenues of its manufacturer. On the other hand, R&D expenditures does have a positive significant effect on the relationship between the introduction of an electric vehicle and the revenues of the respective manufacturer. Finally, Schoeffler et al. (1974) mention an important issue in measuring the relationship between R&D spending and firm performance, namely reversed causality. R&D spending can lead to better firm performance, but better firm performance can also lead to higher R&D spending. This thesis proves that R&D spending can have a moderating effect as well. R&D spending therefore has an indirect effect on firm performance.

7. Managerial implications and limitations

7.1 Managerial implications

This thesis has several managerial implications. First of all, managers of car manufacturers should keep in mind that the production of hybrid vehicles does not stimulate the revenues of the firm. The production of electric vehicles on the other hand does. If managers want to increase the revenues of the firm, the introduction of an electric vehicle can stimulate such an increase. Further, the R&D expenditures play a role as well in these relationships. Higher R&D expenditures can indirectly stimulate the revenues. Important to note is that this is only the case when an electric vehicle is introduced. R&D expenditures do not have a moderating effect on the relationship between the introduction of a hybrid car and the revenues of the respective firm.

Manufacturers that produce both hybrid and electric vehicle should focus on selling electric vehicles when they want to increase their revenues. It's important to keep in mind that the measure for firm performance is revenues. An increase in revenues does not per se say anything about the profits of a firm. Firms who have only introduced a hybrid vehicle should consider introducing an electric vehicle as well. Such firms probably already have a lot of knowledge about the required technology for respective vehicles. Further, firms who have neither introduced a hybrid or electric car should keep the results of this thesis in mind. When such firms consider producing an alternate fuelled car, an electric car should have the preference since this car has a significant positive effect on the manufacturers' revenues.

Finally, regulators can respond to these results as well. Most governments try to stimulate the purchase of alternate fuelled vehicles, and in particular the purchase of fully electric vehicles due to their low CO2 emissions. With the results of this thesis in mind, regulators can stimulate car manufacturers even more to develop electric cars by for example providing subsidies for electric vehicles or R&D.

7.2 Limitations and suggestions for further research

Every research has its limitations, and so does this thesis. The first limitation is the sample size. Our sample consists out of 14 different car manufacturers, while there are obviously more manufacturers worldwide. Unfortunately, the required data was not available for some firms. Further, the data was collected between the year 2001 until 2013. It was not

possible to obtain data from before 2001 for many firms. Toyota introduced their Prius in 1999, which means the effect of their introduction could not be incorporated in this research. Because the sample size is limited, so is the number of explanatory variables. In this thesis, three explanatory variables were used accompanied by two control variables. Since hybrid and electric cars are relatively young, only the short-term effects of their introduction can be investigated. Future research can also focus on the long-term effects of these introductions.

The second limitation is the fact that firm performance is measured by revenues. Firm performance can be measured in multiple ways. Revenues does not per se say anything about the profitability of a firm. In the beginning of this thesis, net profit was included in the model as well. However, the model with net profit as a dependent variable did not meet the assumptions for a good linear regression. Therefore net profit was left out the model. In future research, firm performance can be measured in different ways, such as net profit or stock returns.

Thirdly, there are only two control variables in the regression, the gross world product and the crude oil price per barrel. Obviously there are more factors that influence a firm's revenues, such as public policy. Future research should focus on more variables that influence a firm's revenues and incorporate those variables in their model. Finally it could be interesting to look at firm specific results. Why does the introduction of a hybrid or electric car does have a positive influence for one firm, but not for another? Do cultural differences have any effect on the purchase decision of the consumer? There are many ways to extend the research on this topic.

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Appendix

Figure 1. Revenues of the leading car manufacturers worldwide in the fiscal year of 2013.

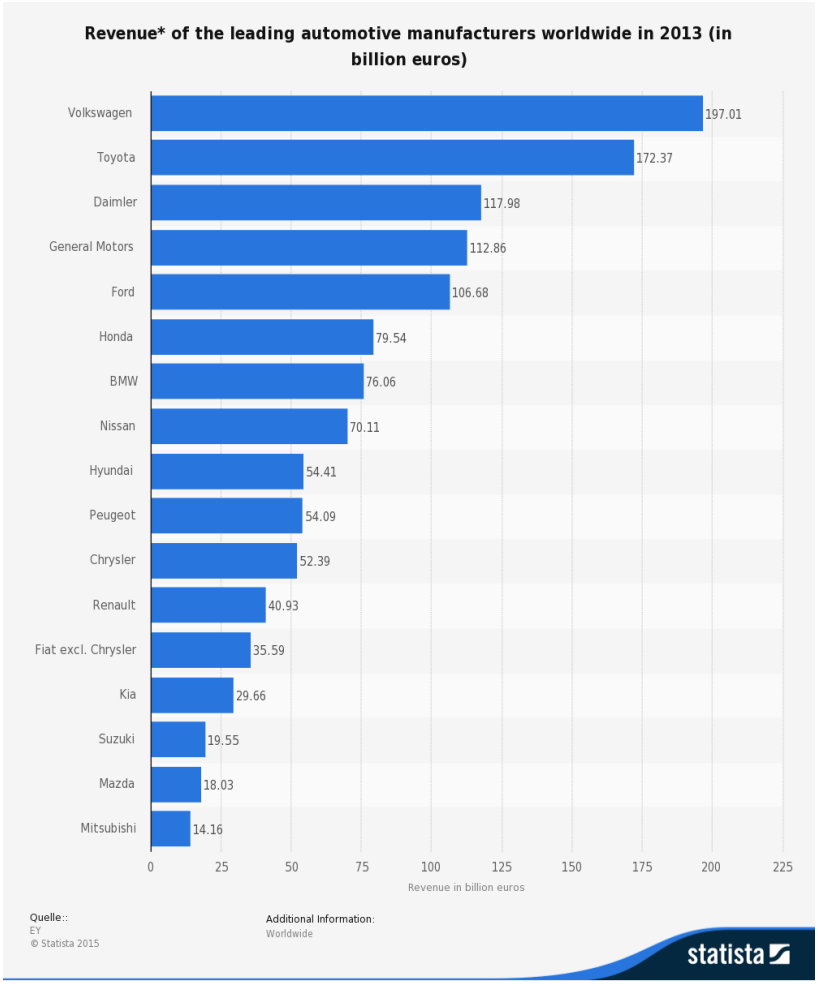

Table 1. Average conversion rates per year per currency.

Yen/Euro		Dollar/Euro		Korean Won/Euro		Swe. Krona/Euro	
2001	0.0092	2001	1.1163	2001	0.0009	2001	0.1082
2002	0.0085	2002	1.0606	2002	0.0008	2002	0.1091
2003	0.0076	2003	0.8851	2003	0.0007	2003	0.1096
2004	0.0074	2004	0.8048	2004	0.0007	2004	0.1096
2005	0.0073	2005	0.8043	2005	0.0008	2005	0.1077
2006	0.0069	2006	0.7968	2006	0.0008	2006	0.108
2007	0.0062	2007	0.7306	2007	0.0008	2007	0.1081
2008	0.0066	2008	0.6832	2008	0.0006	2008	0.1041
2009	0.0077	2009	0.719	2009	0.0006	2009	0.0942
2010	0.0086	2010	0.7546	2010	0.0007	2010	0.1048
2011	0.009	2011	0.7188	2011	0.0006	2011	0.1107
2012	0.0098	2012	0.7781	2012	0.0007	2012	0.1149
2013	0.0077	2013	0.7532	2013	0.0007	2013	0.1156

Table 2. Chi-Square Distribution.

Percentage Points of the Chi-Square Distribution

Degrees of Freedom	Probability of a larger value of x^2								
	0.99	0.95	0.90	0.75	0.50	0.25	0.10	0.05	0.01
1	0.000	0.004	0.016	0.102	0.455	1.32	2.71	3.84	6.63
2	0.020	0.103	0.211	0.575	1.386	2.77	4.61	5.99	9.21
3	0.115	0.352	0.584	1.212	2.366	4.11	6.25	7.81	11.34
4	0.297	0.711	1.064	1.923	3.357	5.39	7.78	9.49	13.28
5	0.554	1.145	1.610	2.675	4.351	6.63	9.24	11.07	15.09
6	0.872	1.635	2.204	3.455	5.348	7.84	10.64	12.59	16.81
7	1.239	2.167	2.833	4.255	6.346	9.04	12.02	14.07	18.48
8	1.647	2.733	3.490	5.071	7.344	10.22	13.36	15.51	20.09
9	2.088	3.325	4.168	5.899	8.343	11.39	14.68	16.92	21.67
10	2.558	3.940	4.865	6.737	9.342	12.55	15.99	18.31	23.21
11	3.053	4.575	5.578	7.584	10.341	13.70	17.28	19.68	24.72
12	3.571	5.226	6.304	8.438	11.340	14.85	18.55	21.03	26.22
13	4.107	5.892	7.042	9.299	12.340	15.98	19.81	22.36	27.69
14	4.660	6.571	7.790	10.165	13.339	17.12	21.06	23.68	29.14
15	5.229	7.261	8.547	11.037	14.339	18.25	22.31	25.00	30.58
16	5.812	7.962	9.312	11.912	15.338	19.37	23.54	26.30	32.00
17	6.408	8.672	10.085	12.792	16.338	20.49	24.77	27.59	33.41
18	7.015	9.390	10.865	13.675	17.338	21.60	25.99	28.87	34.80
19	7.633	10.117	11.651	14.562	18.338	22.72	27.20	30.14	36.19
20	8.260	10.851	12.443	15.452	19.337	23.83	28.41	31.41	37.57
22	9.542	12.338	14.041	17.240	21.337	26.04	30.81	33.92	40.29
24	10.856	13.848	15.659	19.037	23.337	28.24	33.20	36.42	42.98
26	12.198	15.379	17.292	20.843	25.336	30.43	35.56	38.89	45.64
28	13.565	16.928	18.939	22.657	27.336	32.62	37.92	41.34	48.28
30	14.953	18.493	20.599	24.478	29.336	34.80	40.26	43.77	50.89
40	22.164	26.509	29.051	33.660	39.335	45.62	51.80	55.76	63.69
50	27.707	34.764	37.689	42.942	49.335	56.33	63.17	67.50	76.15
60	37.485	43.188	46.459	52.294	59.335	66.98	74.40	79.08	88.38

Table 3. Mahalanobis distance and Cook distance values.

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-548321728.0	170897145856.0	64130638404.5	34486428381.7	134
Std. Predicted Value	-1.875	3.096	.000	1.000	134
Standard Error of Predicted Value	2578980096.000	8311761920.000	4158500631.048	1120567324.250	134
Adjusted Predicted Value	-2047666304.0	168829730816.0	64150819394.3	34570128862.4	134
Residual	-42625630208.0	47074758656.0	-.00004	17152010049.3	134
Std. Residual	-2.419	2.671	.000	.973	134
Stud. Residual	-2.550	2.754	-.001	1.008	134
Deleted Residual	-47372181504.0	50017591296.0	-20180989.8	18388168787.2	134
Stud. Deleted Residual	-2.608	2.829	.000	1.017	134
Mahal. Distance	1.856	28.596	6.948	4.545	134
Cook's Distance	.000	.091	.009	.016	134
Centered Leverage Value	.014	.215	.052	.034	134

Table 4. Linear regression results, model with 'lagged revenues' and a Durbin-Watson statistic of 1.723.

Variables	B	St. Error	Beta	P-value
(Constant)	-8021.401	4595.685	-	-
Introduced hybrid	2393.656	2697.152	0.031	0.377
Introduced electric	-6387.428	2886.918	-0.079	0.029
R&D expenditures	0.682	0.832	0.033	0.414
Gross world product	-79.031	141.984	-0.024	0.579
Crude oil price per barrel	154.235	121.386	0.048	0.206
Lagged revenues	0.937	0.040	0.907	0.000
Introduced hybrid * R&D exp.	-1.262	0.804	-0.070	0.119
Introduced electric * R&D exp.	3.704	0.868	0.171	0.000

Graph 1. Histogram for dependent variable 'Revenues'.