THE ELECTRIC CAR INDUSTRY UNDER PATH DEPENDENCY AND THE LOCK-IN EFFECT

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Abstract

Electric vehicles and their environmental impact have become topics of increased interest in contemporary days, as innovative technologies developed and influenced the automobile industry. There is constant competition between gasoline and electric vehicles, the latter one trying to gain market share and change people's perception about what eco-transportation means and the benefits it can bring. The presented paper recognizes the phenomenon of path dependency and lock-in effect that the automobile industry faces as a result of the dominance of gasoline-based cars and illustrates the pressures executed by these forces. The paper aims at bringing valuable solutions for approaching these issues, by bringing under attention relevant concepts such as skeuomorphs and the network effect. For tackling the topic proposed, the research adopts an illustrative case study technique, that offers a detailed and complex outline of the issues considered in relation to the electric vehicle industry.

Keywords*: electric cars, lock-in effect, network effect, path-dependency, sustainability, technology.*
JEL Classification Codes: Q01, M10

Introduction

The electric car, considered the 'automobile of the future', is a zero-emission vehicle powered by an electric motor that works based on an electrical source. Electric cars; either hybrid, plug-in hybrid or all-electric, have significantly developed in recent times but the future is coming sooner than we expect. These types of cars have experienced technological improvements; the cost of batteries have decreased, and Tesla no longer enjoys the position of market leader but faces real competition. The new technology of the electric motors has resulted in a disruptive innovation for modern times that has slowly affected the automobile industry. Electric vehicles market is increasing in demand, being expected to reach around 29.900.000 units sold by 2030, compared to 3.200.000 units in 2019, with a Compound Annual Growth Rate of 21.1% during the analyzed period. (Marketsandmarkets, 2021)

Background

We can consider the evolution of the electric car being comparable to the case of Thomas Edison's lighting bulb. Even though the technology existed for 75 years, the electric light was not commercially viable when initially invented. Edison was the first person who later identified the needs of the market and brought the electric light and the electric system for commercial use to the public in 1882 (Hardagon and Douglas, 2001). A similar situation can be noticed in the case of the electric car, which, even though invented a long time ago, it has only recently been seriously adopted in modern times. The British inventor Robert Anderson was the first one who invented a crude electric carriage in 1832. However, only in the first half of the 19th century was the idea of using electrical cars seriously taken into consideration by the public, when a series of English and French inventors built usable electric cars. This was facilitated by the fact that starting with 1910, more and more people gained access to electricity which made it easier to charge electric cars, hence making them more popular. However, due to the significant advances in gasoline and developments of the internal combustion engine, electric cars basically disappeared from the market for around 30 years. Only in the 21st century, when the selling price of gasoline increased and high carbon pollution started to represent a constant concern for the economic environment, the electric car reached public's interest again and its market acceptance started to increase at a considerable high rate (Matulka, 2014).

Joseph Schumpeter, an economist from Slovakia, was an important figure in the literature of entrepreneurship. He divided innovation into five main categories: product, process, market, supply and organizational innovation. If we are to consider the idea of electric cars according to one of Schumpeter's categories of innovation, we can define it as a product innovation as it represents a new and different way of transportation that brings additional benefits compared to a gasoline-based car. But how did this concept develop? How did it all start? We know that, according to Rudi Volti, technology can be understood as "a system based on the application of knowledge, manifested in physical objects and organizational forms, for the attainment of specific goals" (Volti, 2001). According to the criteria stated by Volti, we can consider the electric car as being a technology system of certain characteristics. The technology of electric cars did not occur by chance; it was based on knowledge of intellectual human beings, experts in the area of both electricity and automobiles. By organizing the resulting technology as a system, the physical object of the electric motor was produced and was incorporated into a usable object, that of the electric car, to be able to perform certain tasks that would be embraced by the society and that would be socially adopted by us (Carroll, 2017).

According to Freeman (1982), innovation consists in a "process of matching technical possibilities and market opportunities". He defines innovation as being a two sided-activity: recognition of a need or market potential and implication of new or existing technical knowledge. If we consider the case of the electric vehicle, we can state that it fits in Freeman's innovation characteristics; it first recognized the market perception that changed over time in terms of environmental sustainability. The concern of the market when it comes to environmental issues, health problems and noise levels slowly became a critical need. Social movements towards such issues pushed the existing technologies in the automobile industry to innovate and come up with solutions. Using the existing technical knowledge but revolutionizing the technology behind, by replacing the motor with an electric battery, the electric car gradually gained more success.

The electric cars can be therefore considered as being revolutionary, as the concept brings new and radical attributes to the creation and usage of electrical power. However, we should ask ourselves whether electric vehicles are able to escape the **technological lock-in** created by the gasoline cars. The lock-in effect consists in developing technologies that follow specific paths that are usually hard to change. The result can be the continuous usage of an inferior technology, being hard for competitors to reach market shares in the industry. This is mainly due to uncertainty or even ignorance of the consumers about alternative and new products, in terms of their performance, quality and properties (Perkins, 2003). The phenomenon of technological lock-in however, is the result of **path dependency**, which creates an innovation blockage of future improvements to occur. Path-dependency occurs when the dynamics of changes in a product/service within an industry depends on the first step taken at the beginning of its creation. In other words, the development of industries becomes entrenched, following a certain path (Hooker, 2011).

Methods

Research method

The proposed paper was designed to offer an analysis of the state of electric vehicles industry in an innovative context, by engaging factors such as path-dependency and lock-in effect. Therefore the paper proposes a qualitative research design, also known as a naturalistic approach, defined as "understanding the meaning people have constructed, that is, how people make sense of their world and the experiences they have in the world"(Merriam, 2009, p. 13). This type of approach has the advantage of preserving chronological flow, keeping a high degree of contextual validity and having the ability to be more convincing than just some pages of numbers (Hameed, 2020).

To illustrate how does the electric vehicles industry adapt to the forces previously mentioned, we propose an illustrative case study approach. Harvard Graduate School website argues that a case study analysis creates in-depth analysis upon a particular topic at a specific time (Harvard, n.d.). Additionally, Hayes et al. (2015) defines a case study as a type of observational study, which "focuses on the collection of data from a single case or multiple cases of a phenomenon", having as main goal the enhancement of knowledge about a phenomenon.

Therefore, illustrative case study research is a type of case study analysis that is used to describe a situation or phenomenon, and what and why is happening in it. It has the main purpose of informing the audience about a topic, to bridge the gap between researcher and population by engaging common language. Illustrative case study analysis is usually descriptive, being formed of observations of the environment of the topic, of the people involved and what they do (Hayes et al., 2015). Illustrative case studies tend to be in-depth and rich in context by describing aspects of the case in a way that contributes to clear comprehension (Baron and McNeal, 2019). Our research article has therefore considered this type of analysis as being relevant to highlight the electric vehicles industry, to depict circumstances of chosen events and explain current situations. This type of research is aimed at enhancing reader's knowledge in the chosen field by offering details and relevant observations for obtaining a clear picture of the phenomenon.

Theoretical Framework

The proposed research builds its analysis on relevant criteria aimed at obtaining a more consistent picture of the topic. The concepts of *path dependency and lock-in effect* have been considered representative elements for analyzing the current situation of the electric vehicles industry and its potential of becoming the solution of a more eco-friendly environment.

Based on the relevant theory, the research constructs its approach around the driving research question*:* '*How does the electric car industry react under path dependency and the lock-in effect?'*.

Results and discussions

Traditional cars based on gasoline consumption, reached dominance over the market since 1905. Only starting with the year 1973, questionings regarding this type of transportation occurred (Cowan and Hultén, 1996). Their highly negative environmental impact in terms of enormous air pollution and the creation of noise in urban areas has made them become a real enemy when it comes to sustainability and healthcare. If we analyse the *advantages* brought by an electric car compared to a gasoline car, we can easily state that the technology they engage is highly superior and that this type of transportation can be the solution for a sustainable future. Firstly, electric cars produce no emissions into the atmosphere, contributing to the worldwide pollution reduction. Some of the manufacturers even use eco-friendly materials, such as the *Ford Focus* Electric car, that is made of recycled materials, while bio-based resources are used for the padding. Health improvements are also implied in this process, as a better quality of air contributes to a considerable decrease in health diseases. Also, high noise levels creating stressful situations can be reduced, as electric cars produce almost no noise when being used. Even though their buying price on the market is still higher compared to a gasoline car, electric car's running costs are considerably lower, their charging electricity being around a third as much per kilometer compared to buying petrol. Being based on a chargeable battery, the electric vehicles have cheaper maintenance costs, considering that no fuel injection systems or radiators are involved. Additionally, many car manufacturers certify a warranty of around eight years for their batteries (Ergon Energy, 2019).

However, **path-dependency** created a strong technological lock-in in the automobile industry that resulted in massive production of gasoline-based cars. This is directly linked to the spread of gasoline in the economy, which became dominant, as its mass production costs lowered and a decrease in selling price of this type of car followed. In time, this resulted in a strong technological lock-in that is difficult to compete with, where we are stuck with potentially worse or less efficient technology, while alternative technologies are locked-out. To overcome such a phenomenon, radical events should occur, with a strong impact over the automobile market and over the whole society.

An already existent factor that is currently influencing people's adoption of the electric car is the *increasing awareness and concern of the environment*. Gasoline cars are the primary cause of global warming; according to statistics issued by the European Parliament, 52% of the cars in Europe run on petrol. In 2016, nearly 30% of total CO2 emissions in European Union were caused by transportation, out of which 72% were due to road transport, followed by water navigation and civil aviation. The reduction rate of CO2 emission has also slowed in recent years due to significant increases in personal

cars. In Europe, passenger cars contribute 60.7% to the total carbon emissions of the area, followed by heavy and light duty trucks (European Parliament, 2019). (See Table 1)

Table No. 1- 2016 Emission breakdown by transport mode in EU

ROAD TRANSPORTATION 72%							
Cars	60.7%	**Heavy duty trucks**	26.2%	**Light duty trucks**	11.9%	**Motorcycles**	1.2%
WATER NAVIGATION 13.6%							
CIVIL AVIATION 13.4 %							
RAILWAYS 0.5%							
OTHER 0.5%							

Source: Adapted by authors based on data provided by European Parliament, 2019

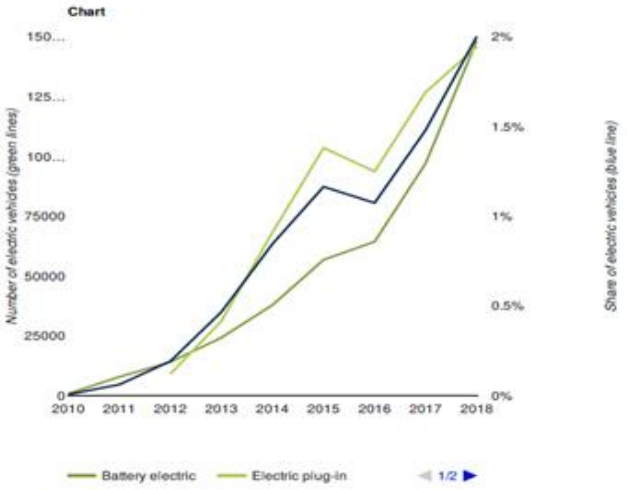
Regulations represent a viable and consistent solution for escaping gasoline cars lock-in. We know that "Institutions are the rules of the game in a society" (Uyarra, 2019). The bodies of European Union represent a formal way of providing relevant information about the negative impact of using gasoline-based vehicles, as well as providing incentives. EU is already making significant efforts to reduce carbon emissions by setting a target of 60% level decrease by 2025 compared to 1990 only from transportation. In order to achieve this goal, EU has enforced the "European Emissions Trade Scheme" for every industry's emissions, that imposes for each plant to hold permits for every CO2 emissions tons emitted (European Parliament, 2019). Also, in May 2017, the legislative measure "Europe on the Move" was published by the commission, where limits of CO2 emission were imposed for cars and vans, as well as favourable incentives for zero emission vehicles (Niestadt and Bjørnåvold, 2019). We can notice that there are actions taken in order to encourage clean vehicles adoption, which, according to their strengths and consistency, could support in time the automobile industry to escape from gasoline vehicles technological lock-in.

Additionally, the fact that the electric car was created following the same design and way of using the technology as in the case of the gasoline car accelerated the process of adoption and contributes to escaping the lock-in. This idea is based on the concept of *skeuomorphs*, that, according to Basalla, are certain elements of a new product that are essential for the user's understanding between the innovative products and the object it is aimed to replace. Also, the designer Raymond Loewy noted that the design of an innovation should be the "most advanced yet acceptable" form of a product, keeping close both the familiar side and the innovative side of a new product. (Hardagon and Douglas, 2001). This is also the case of the electric vehicle; the need to bring an innovative way of transportation that works under a totally different technology that is embedded in the existing understanding of the social systems. In this case, using skeuomorphs' principle to introduce the electric vehicle, the gap between the innovation and the institutions was bridged. There is an interdependent relationship between technical and social aspects of an innovation, that requires mediating between innovations and institutions (Hardagon and Douglas, 2001). Just imagine the reaction of the public if the electric vehicle would not have had a steering wheel, but just a controlling lever to indicate the direction of the vehicle. Or if the vehicle would be in the shape of a triangle. The users would become highly skeptical, because no familiarity compared to the old format of the car could be recognised. And here we can observe the concept of robust design, that states that there is an "arrangement of concrete details that embodies a new idea, in mediating between innovations and established institutions" (Hardagon and Douglas, 2001).

According to Volti (2001), technological advance is not primarily based on scientific discoveries. Volti contradicts the "linear model" that states that "scientific discoveries lead to technological improvements which ultimately become commercialized in the form of new products". However, in the case of the electric car, we can question ourselves whether Volti was completely right. This is based on the argument that scientists may be the only ones measuring and proving the immense negative impact of older technology on the environment, as long as coming up with alternative ideas for better technologies that may fit a better world. Technology and science influence each other, doing their best when remaining in close contact (Volti, 2001). However, in this case, evidence provided by science may represent a push for new and better technological innovations. We can therefore consider that, in our case, technology makes heavy use of scientific discoveries in order to develop, to create better products, less harmful for the environment and society. Without science showing the pollution levels and its future effects, the electric vehicle would not be that attractive. The implications of scientific discoveries contribute to the possibility of the modern world to escape from the current gasoline-based lock-in, making technology-dependent and influenced by science.

However, there are still consistent differences when comparing the electric car and the gasoline car that makes the lock-in escape process more difficult. *Disadvantages* of electric cars include battery issues, the life of the battery being too short, necessitating a longer time to be charged, but also the cost of sale of such a car, which is still too high. We can therefore easily state that an escape from the current technological lock-in will not be a fast process, as it will take some time until users and society as a whole will completely trust and adopt this way of transportation. However, recent developments diminished the battery problem. At the moment, a *Tesla Model S* takes 40 minutes to be 80% charged. Three scientists won the Nobel prize in chemistry in 2019 for their contributions to the development of the electric battery. They developed a battery using nick foil, compared to the previous version based on lithium-ion, that is able to reach 80% charge in only 10 minutes, for driving between 200 to 300 miles (Davis, 2019). Also, as technology develops in this sector, more and more people will start using it, in order to benefit from the new features of the car vehicle. This crucial step in the adoption and diffusion of the electric vehicle represents the creation of the **network effect**, which states that the more people start using a product, the bigger the value perceived by that product will become. The phenomenon occurs when "consumption benefits depend positively on the total number of consumers who purchase compatible products" (Church et al. 2002). The network effect describes the situation when positive consumption occurs from the usage of an individual of a good that determines further increases in the number of agents consumption of the same good (Katz and Shapiro, 1985). More precisely, there is a direct relationship between the number of users and the likelihood of adoption of a product. This is validated if we consider the previously stated fact that innovation and institutions are in close contact, innovation being shaped by social interactions (Uyarra, 2019). As more users are willing to benefit from the advantages of electric vehicles, the network effect is created. This results in a snowball that offers the electric car the opportunity to establish a strong market position in the automobile industry. This phenomenon can be already noticed if we analyse the results of research conducted by the European Environment Agency in between 2010 and 2018, among plug-in hybrid electric vehicles (PHEV) and battery-electric vehicles (BEV) in Europe. (See Figure 1)

Figure No. 1 Sector CO2 evolution in the EU



Source: European Environment Agency, 2019.

Numbers show that even though the market share of electric vehicles is not dominant, sales of these two types of eco-transportation means are in a constant increase, reaching 2% market share in 2018 as a proportion of the total vehicles fleet, compared with 1.5% in 2017. Also, sales in BEV doubled compared to 2017, while PHEV sales increased by 15% (European Environment Agency, 2019).

Gradually, higher demand in the electric cars sector will lead to larger production volume, resulting in economies of scale, that in end will decrease the unit selling price of an electric car, making it an accessible asset for the large population.

Research limits

The study therefore proposes in-depth research on the subject of electric vehicles, based on the theoretical framework that has been previously identified. There is however no extensive research added to the current knowledge in the field that would examine the situation at a broader level, by also engaging primary data such as large-scale surveys and interviews. Primary data would have had the ability to bring increased reliability and authenticity to the study (formpl.us, 2020). We therefore consider these aspects as being the main limitations of the paper.

Conclusions

It is difficult to decide whether electric car will dominate the future the car markets, but it is clear these will represent the main solution for a sustainable way of living. Starting from Robert Anderson until the present time, the electric way of transportation had various fluctuations. It's been a difficult subject to tackle with, as it has many advantages, but also disadvantages compared to the gasoline car. This article represents a step forward for the assessment of the evolution of electric vehicles under the influence of certain forces. An analysis of the lock-in effects and path dependency have been realized to emphasize the current position of the electric cars and to draw suggestions. It can be clearly observed that the automotive industry follows a strong path dependency resulting in a gasoline technology lock-in effect, created as a result of the

low cost of production and sales price of such cars compared to the electric ones. However, the large population's increased awareness of the importance of adopting eco-friendly transportation alternatives made us reconsider the potential of electric vehicles. With implications coming from the network effect, skeuomorphs and regulations, the industry of electric automobiles can significantly develop and make become a trend whose value increases as more users join it.

As an endpoint, by addressing the driving research question *'How does the electric car industry react under the path dependency and lock-in effect?'*, the current situation of the electric car industry was established and we can easily state that its adoption in the future can be the key to success for a cleaner environment. However, due to the influences coming from gasoline path dependency and technological lock-in effect that executes forces upon the industry, the transition to electric mobility is still ambiguous and complex. The dynamics of research show that an escape from the gasoline lock-in and path dependency is difficult to occur, as these phenomena are well entrenched in worldwide economies. Socially speaking, individuals seemed to have understood the essence of such a transition, so perception changes may luckily occur and increases in the value of electric cars are possible.

Recommendations

A series of recommendations are proposed for future initiatives that would encourage the development of the subject under analysis. **First of all,** we consider that studies regarding the electric vehicle should be broadened by intense experimental research that can provide both sellers and buyers with informative findings and can bring more details in order to better understand the phenomenon in terms of the current state of the environment and the benefits that an electric vehicle can bring. **Secondly**, relevant information regarding the previously stated issues should be more intensively communicated to the users, through various channels such as informative campaigns, either physical or digital, on the TV, social media or on other internet-based websites. Once better informed, the demand for using such vehicles may increase as mindsets of the users can change. Moreover, as technology evolves, **we recommend** producers to pay increased attention to the selling price of this type of car, as, from buyer's perspective, this is one of the main impediments when it comes to making a decision in between a gasoline and an electric car (Khalid, 2019)

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