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The Impact of Tesla's Patent Opening

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Abstract

On June 12th, 2014, Tesla decided to open its patents to everyone. The reason why Tesla decided to do so is uncertain and may never be answered objectively. However, the consequence of such a decision can be measured and it was hitherto uncovered by literature. In the present study, it is proposed to analyze this event through the value of Tesla's shares in the stock market and its potential competitors and suppliers by an event study design. It is important because just as Tesla's patents can be, the company that has been leading the development of electric cars, there may be many other companies whose patents could have a huge environmental impact. Therefore, it is interesting to know what effects this corporate decision has had. Through a law and economics approach, given the potential monopoly power that a patent right provides, by guaranteeing the exclusive use of a certain innovation, which can be translated into a competitive advantage for those who own it, the hypothesis is that during the studied period Tesla's market shares declined while competitors’ and suppliers' rose. From the outcome, it is expected that inferences about the patent system and its use by this kind of industrial organization can be made.

Keywords: Innovation; Patent; Open Innovation; Industrial Organization; Intellectual Property.

JEL Codes: L17; O31; O34.

Word Count: 12.886

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Authorship Declaration

I hereby declare and confirm that this thesis is entirely the result of my own work except where otherwise indicated. I acknowledge the supervision and guidance I have received from Professor Dr. Lela Mélon. This thesis is not used as part of any other examination and has not yet been published.

Débora Cristina De Andrade Vicente,

8th August 2023.

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During the academic year of 2022-23, in several ways, I experienced how every narrative is unique and how fortunate those who have the chance to speak about theirs are, once each one's life has innumerable externalities. I am grateful to every new friend I made during this journey, to all the Professors who shared their knowledge in the best possible way, and to every city and country I lived in.

This work, through the knowledge I acquired during the academic year, is the result of a question that I posed in my letter of motivation when applying to join this Master's program. There are still a huge number of questions to be answered, but I hope the work is sufficiently productive for those who read it and for me only the beginning of many other projects related to Law and Economics.

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Table of abbreviations and definitions

BEV:	Battery electric vehicle
CAR:	Cumulative abnormal return
C.I.:	Confidence interval
EVs:	Electric vehicles
IP:	Intellectual property
OEMs:	Original equipment manufacturers
U.K.:	The United Kingdom
U.S.:	The United States
PHEV:	Plug-in hybrid electric vehicles

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1. Introduction

The day Tesla announced the opening of its patents might have become one of the most memorable days for the market, including Tesla itself. The reasons why Tesla has decided to proceed this way may appear quite controversial. Tesla defends it due to environmental implications as an attempt to potentialize the development and production of electric vehicles (hereafter "EVs"). Meanwhile, its potential competitors, suppliers, and Tesla might have suffered impacts on the stock market since such a decision is related to the use of the patent system by the industrial organization, as well as to how investors perceive such a system in a firm or field.

There are some studies on the decision, however, a study on to which extent such an announcement affected the market is lacking. It shall be important since Tesla is a prominent company in the field of EVs. Moreover, just like Tesla, other companies that are key players in the industry, not only the EVs, might have lots of patent portfolios with environmental implications. Therefore, studying what happened when this announcement was published may lead to conclusions for other companies on the use of the patent system and environmental issues.

It is considered that the best way to conduct a study of the announcement is through an event study research design, as explained in the methodology chapter. Thus, a work seeking to analyze how the market responded to such an announcement will arise making it possible to infer the legal and economic implications and incentives that this decision created regarding competition, innovation, market dynamics, and potential aspects related to the patent system, such as those regarding the regulatory perspective and the industrial organization.

Landes and Posner highlighted that a gradual decline in market share is noted upon a patent expiration (2003, p. 314). However, the authors emphasized that a market analysis on it is complicated because to perpetuate the monopoly a patent holder invests in ways to build customer loyalty to its trademark before the patent expiration *(Ibidem*). Nevertheless, in Tesla's case, the patent opening was unilateral and unprecedented: more than 300 patents have been opened in more than six countries and most of them are directly related to the automotive sector and valid until 2030, which means that Tesla has "given up" approximately more than 15 years of a patent monopoly.

Therefore, it is understood that when Tesla made such a decision it provided exactly the possibility to measure these effects, which can be instrumental in explaining the use of the patent system at least within this kind of industry.

The central research question is: "What are the effects of Tesla's decision to open its patents on Tesla itself and its potential competitors and suppliers?", which emerges from the existing knowledge gap surrounding the consequences of this significant event.

Chapter 2 details the announcement and presents the literature review on it; Chapter 3 explains the main hypothesis; Chapter 4 describes the methodology employed; Chapter 5 outlines the results obtained by employing the event study; Chapter 6 discusses the outcome through a Law & Economics approach; Chapter 7 points out some limitations of this work and suggestions to further exploration; Chapter 8 concludes; Chapter 9 highlights the references; and the appendix contains all the tables referred throughout the study.

2. The announcement

The official announcement made by Elon Musk, Tesla's CEO, on June 12th, 2014 (Tesla, 2014.a), made explicit the argument that patents work as a lobbying tool in the vehicle market and that the patent system does not work for Tesla's goal, because keeping its patents only for the company's ownership is not an advantage for Tesla as EVs programs "at the major manufacturers are small to non-existent" (*Ibidem*) and "the market is enormous" (*Ibidem*). Therefore, according to the announcement, opening Tesla's patents is good news for Tesla, for competitors, for consumers, and for the environment.

The announcement is attached to the Patent Pledge (Tesla, 2014.b), which lists Tesla's patents that should be considered open. Other patents, for example, the ones "owned jointly with a third party or any patent that Tesla later acquires that comes with an encumbrance that prevents it from being subject to this Pledge" (*Ibidem*) should not be considered open. "A list of Tesla Patents subject to the Pledge will be maintained at the following URL: https://www.tesla.com/legal/additional-resources#patent-list" (Tesla, 2014.b).

According to the access made on April 26th, 2023, the Patent Pledge opens 362 patents registered and in effect. 15 of these patents have been published by the patent office of the country of issue after June 12th, 2014. However, from these 15, 6 patent applications relate to a previously published one[1]. Therefore, 9 patents were excluded from the analysis to be conducted in this work for the reason of later publication, since

[1]DE602009013381; US8778519; US8803470; US8970182; US9045030; and US9257825.

the market was not aware of them at the time of the announcement[2]. Moreover, 12 of these patents refer to ornamental designs that are considered to have (almost) no impact in promoting significant breakthroughs for the EVs production and growth. Thus, these 12 patents will also be disregarded for the purposes of this work[3].

Hence, this work considers 341 patents. However, it is necessary to consider that some patents have the same title, abstract, and claims but are filed in different countries through the Patent Cooperation Treaty. This means that a single innovation may be subject to different patent applications in different territories as applications depend on the strategy a company follows in each one. The choice of where to file or to seek an extension of a patent application is a corporative choice that is related to where the company considers it important to seek the protection of its intellectual assets based on the company's business strategy and the potential exploitation of such assets.

Consequently, the countries in which Tesla has protection for its patents may vary depending on the patent[4]. Anyway, Tesla's announcement does not make any geographical differentiation on the opening of patents but instead includes in the Patent Pledge, among other countries, patents registered in China, France, Germany, Japan, the United Kingdom (hereafter "U.K."), and the United States (hereafter "U.S.").

Taking this into account, identifying what are the technologies behind each of these patents is essential. Henceforth, from this announcement, first, it is necessary to observe that of these 341 patents 178 innovations were identified (Table A), given the

[2]US8807637; US8807644; US8817892; US8861337; US8862414; US8887398; US8973965; US9065103; and US9293792.

[3]USD660219; USD660767; USD669008; USD672307; USD673393; USD678154; U D683268; USD694188; USD724031; USD735660; USD74950; and USRE44994.

[4]See, for example, the territorial difference in protection with respect to two patents granted by the European Patent Office: EP 2266201 and EP 2660112.

exclusion of 2 innovations[5], as they are also considered to have (almost) no impact in promoting significant breakthroughs for the EVs production and growth and were then disregarded for the purposes of this work. These 178 innovations are considered essential to Tesla's production, as the majority of them concern the functionality and improvement of batteries in systems applied to electric motors and vehicles.

Second, it is important to note the legal effect of the announcement. Tesla's pledge is taken as "irrevocable and legally binding on Tesla and its successors, is a "standstill", meaning that it is a forbearance of enforcement of Tesla's remedies against any party [which intends to use Tesla's patents] for claims of infringement for so long as such party is acting in good faith" (Tesla, 2014.b). However, it is also considered to bring a lot of responsibility for this party since Tesla has limited it under the following conditions:

> "*[Tesla] will not initiate a lawsuit against any party for infringing a Tesla Patent through* <u>*activity relating to electric vehicles*</u> <u>*or*</u> <u>*related equipment*</u> *for* <u>*so long as such party is acting in good faith*</u>*. […]*
>
> *A party is "acting in good faith" for so long as such party and its related or affiliated companies* <u>*have not*</u>*:*
>
> - *asserted, helped others assert or had a financial stake in any assertion of (i) any patent or other intellectual property right against Tesla or (ii) any patent right against a third party for its use of technologies relating to electric vehicles or related equipment;*
> - *challenged, helped others challenge, or had a financial stake in any challenge to any Tesla patent; or*

[5] US9080352 and US9103143.

- *marketed or sold any knock-off product (e.g., a product created by imitating or copying the design or appearance of a Tesla product or which suggests an association with or endorsement by Tesla) or provided any material assistance to another party doing so.*"

That is, the understanding is that for a party to be able to use Tesla's patents, that party cannot have claimed, directly or indirectly, any intellectual property (hereafter "IP") right against Tesla, cannot have challenged any Tesla patent, and cannot have directly or indirectly marketed or sold any product that imitates or copies the design or appearance of a Tesla product. In relation to third parties, that party shall also not have claimed any patent rights against a third party in cases related to the use of technology in EVs or related equipment.

In practice, this implies that by using Tesla's patents, that party loses enforceability of all its IP assets against Tesla, and also loses enforceability of its patent rights against third parties when the patent relates to EVs or related equipment. This means that Tesla may use any assets of that party and also that when within the expressed scope any third party may use the patents of that party.

From this perspective, one can conclude that the announcement does not aim at handing over patents that are the result of a long R&D process but aims to be a legal bargaining chip. Economically speaking, however, it is clear that Tesla is the leading EVs player in the market, being the first company to scale up production. Therefore, one can assume that, in principle, Tesla has more to offer than to gain.

Finally, it is important to note that what the announcement explains about the Patent Pledge should not be considered as “a waiver of any patent claims […] a license, covenant not to sue, or authorization to engage in patented activities or a limitation on remedies, damages or claims. […] [Neither is] an indication of the value of an arms-length, negotiated license or a reasonable royalty. What this pledge means is that as long as someone uses our [Tesla’s] patents for EVs and doesn’t do bad things, such as knocking off our [Tesla’s] products or using our [Tesla’s] patents and then suing us [Tesla] for IP infringement, they should have no fear of Tesla asserting its patents against them.” (Tesla, 2014.b).

2.1. Potential anticipation

To study the announcement through an event study approach it is extremely important to know if the market somehow anticipated it. The research conducted in virtual newspapers with the help of Google's search tool[6], such as on the blog Engadget, which is dedicated to the publishing of news related to technology, brings the fact that Elon Musk when representing Tesla in the UK launch of the Tesla Model S on 8th June 2014 made a statement saying Tesla might do “something controversial” (Engadget, 2014.a), giving signals that Tesla would open its supercharger system designers to third parties.

It was also found that Musk talked about “sharing patent technology” in earlier June 2014, specifically regarding opening the designs of the Supercharger system to

[6]In particular, by asking Google for a specific search on all results by June 11th, 2014 with the terms "Tesla open patents". See the result in: <https://www.google.com/search?sca_esv=557430156&tbs=cdr:1,cd_max:6/11/2014&q=tesla+open+patents&spell=1&sa=X&ved=2ahUKEwiH5KmxjeGAAxXd_7sIHVbUCs0QBSgAegQICBAB&cshid=1692186432076122&biw=1440&bih=815&dpr=1>.

create a standard technical specification that can be adopted by any other EVs (Engadget, 2014.b).

In covering the announcement, in addition to signaling a similar move by other tech companies in the past, such as Twitter in 2012, Reuters (2012) published a news article on June 12th, 2014, pointing out that any patents belonging to Tesla's supplier Panasonic Corp 6752.T is not included in the opening. Furthermore, it stated that Panasonic plans to be the sole manufacturer of Tesla's gigafactory for battery production. Moreover, Reuters also anticipated a fact that was afterward observed: Tesla continues to apply for patents. One of the justifications is to prevent competitors from obtaining them; another can be to protect themselves against patent troll attacks.

None of the statements found and described above referred specifically to the fact that Tesla was not going to “initiate patent lawsuits against anyone who, in good faith, wants to use (its) technology”, as expressed in the June 12th, 2014’s announcement.

If one considers that the patent system only works because of the enforceability power that the holder of such an intangible asset has, one may arrive at the conclusion that the day to be used for the empirical research would be the 12th of June 2014, since it was the day Tesla, through its CEO's official announcement, stated its impressions about not starting a dispute once all its patents are now open, leaving no doubts about what was open, for who, and in what way. Considering the strength of the patent system, as pointed out in more detail in the Discussion chapter, any act prior to that can be considered mere market speculation, which shall be controlled with the contribution of event study control features.

Regardless, when comparing the results, it is understood that the days 8th and 9th June 2014, which are the dates Tesla's CEO would have hypothetically given signals that Tesla would open its supercharger system designers to third parties, should be taken into consideration under potential anticipation.

2.2. Literature review on the decision

Noteworthy is the research-in-progress by Wolff et al. (2022), which through a qualitative approach aimed to analyze the effects of opening up resources on (1) industrial standardization, (2) technological platforms, and (3) product-service ecosystems. To do so Wolff et al. also took Testa as an example, aiming for results that could serve as the basis for a theoretical model regarding the interrelations between resource openness, competitive advantage, and industrial transformations. It is understood that work developments are in progress. The authors also consider that "understanding the consequences of openness will hence support decision-making processes regarding the sensibleness and timeliness of openness initiatives" (p. 7).

One can also highlight the study conducted by Gitelman et al. (2022) which, through data coming from Tesla's database, demonstrated that the company did not lose in sales or revenue with the opening of its patents. In Tesla's inner analysis, this study can be valuable to competitors and investors. Nevertheless, it is not intended to demonstrate how this decision can be replicated by other companies, nor what was the result of such a decision in the market beyond Tesla.

Wang and Peng (2020) published a work that aimed to answer how Tesla's business model influenced such a decision. The authors state Tesla as being a "representative of patent open-source strategy in the field of non-computer high-tech" (*Ibidem*). Aiming to reference other high-tech fields, China's new energy vehicle industry, and providing a reference for formulating long-term development strategies, the authors analyzed Tesla's patent open-source strategy through its business model strategy.

The authors explain that Tesla might be using patent pools and patent alliances to excel among its competitors by using its own open-source patents to enhance technology standardization, as the more its technology is used "the higher market share Tesla grabs" (*Ibidem*, p. 390). Considering that Tesla "combines software […] with hardware […] [the decision is considered to be] creating a strong Tesla ecosystem" (*Ibidem*). Whereas "those who apply Tesla technology, while enjoying Tesla technology and facilities, can also benefit from Tesla's expanding market […] [so it can be seen as a] win-win cooperation." (*Ibidem*, p. 393). However, according to the authors, Tesla's strategy could only work if it has a technological advantage over its competitors.

It is considered that quantitative research on the effects of such an announcement is lacking.

3. Hypothesis

The rational choice theory under the law and economics approach would be that, under the opening of Tesla's patents announcement, the hypothesis posits that during the examined period, Tesla's market share declined while its potential competitors and suppliers experienced an increase.

To understand the hypothesis, it is needed to access the functioning of the patent system. Once it is established as an open patent, there would be no exclusive rights to the assignee of it, but the patent would be open for everyone's use, which theoretically means that competitors will have easier access to technology production.

Considering the automotive industry, this hypothesis holds because Tesla has prominence in the development and production of EVs. Given the patent opening, the exclusivity of Tesla's patented technologies and processes no longer exists, which may lead its competitors to reduce transaction costs to use these technologies. With an open patent the implication would be that, for example, no competitor would need a license to employ the same technology that Tesla employs.

A patent is an exclusive right capable of generating monopoly power to the benefit of its holder, as it constitutes an intellectual advantage, which can be translated into an economic advantage, between the holder and its competitors. Overall, monopolies are not good because they lead to market failures (Cooter and Ulen, 2016, p. 38). However, the justification for maintaining patents is due to their capacity for providing a trade-off between exclusivity and the availability of innovation to society (*Ibidem*, pp. 116-126).

From an economic perspective, considering the justification for the existence of the patent system, Tesla's decision to open its patents indicates it is good for the general welfare when it remedies market failures caused by the monopoly power of technologies already invented and exploited for a certain period of time exclusively, in addition to enhancing the invention process of new technologies and products in the same field.

Note that the patent system is used by various sectors, including for the protection of sustainable technologies. Data shows that green patent applications by GREEN100 organizations rose between 2015 and 2020: the energy and power sector accounted for 25.48% of these applications, followed by motor vehicles and its parts (24.75%), renewables (10.21%), information and communication (8.32%), airlines (5.24%), industrial machinery (4.53%), building and infrastructure (4.5%), chemicals (2%), healthcare (1.74%) and metal processing (1.4%) (Sagacious IP, 2021).

In the automotive sector, a study published in 2017 shows that between 2012 and 2016, by automaker, the registered patents related to green car technologies represent a significantly higher percentage when compared to the total number of registered patents by these same companies (Wyman, 2017). That is the first step towards patent protection, encompassing all the costs that such transactions involve, such as time, money and specialized teams of engineers and lawyers, have been made by Tesla and its competitors.

Even if Tesla has decided to open its patents - and because of that it is possible to argue that the hypothesis should be reversed, i.e. that Tesla is fully aware of all the consequences of opening patents, which is why it opened them, and therefore expects an increase in its shares and a fall in those of its competitors and suppliers - given the continued use of the patent system by various sectors including the automotive sector and, therefore, its signals of strength, it is understood that the hypothesis presented as it is has legal and economic foundations.

Tesla's unilateral decision to open its patents in 2014 is curious since most of them will expire only in 2030. This fact, however, can be explained by a potential previous observation by the company about a market failure due to this monopoly power that could harm its own economic activity or, as Tesla advocated in its announcement, concerning an exclusivity that is environmentally harmful. This decision may also be explained under the law and economics approach when regarding different lengths of patent protection for different types of innovations (Bayramli, 2013), as well as under the economics of innovation by Arrow and Plant (Landes and Posner, 2003).

Anyway, for the hypothesis to hold, besides the importance of the patent system to the development of innovation, two more conditions must be fulfilled. First, it is being considered that Tesla uses its own patents in the manufacture and development of its own products, without having to bargain the license and use of any third-party technology or products, or at least holding a significant part of the technologies and products employed in its commercial activity. It is important to note, however, that the opposite of the situation described above is feasible and legally possible although no evidence of this sort was found involving Tesla. Moreover, this first condition might be considered true because it may seem strange that a company opens its patents to third parties and at the same time uses technologies from third parties to produce its own products.

Second, it is being considered that Tesla protects the major part of its competitive advantage over competitors through patents, not making significant use of other forms of intellectual asset protection, such as having the competitive advantage protected under trade secrets. However, even if this assumption is made regarding the choice of protection, it is impossible not to consider the importance of Tesla's brand, which has a full influence on its market position. In other words, eventual statistical significance (or not) in relation to the announcement can be explained by factors linked to Tesla's IP other than patents, such as trade secrets and trademarks. Regardless, it is still reasonable to draw conclusions about the use of the patent system within industrial organization.

More considerations on these conditions are given in the Discussion chapter. While understanding Tesla's motivations may be an impossible task as it is subjective, analyzing its effects may not. Thus, this work attempts to answer the following question: "What are the effects of Tesla's decision to open its patents on Tesla itself and its potential competitors and suppliers?". The hypothesis is that, due to the announcement, competitors would produce more and, in turn, so would key suppliers to the production of these technologies and products. Thus, Tesla's shares are expected to fall, since competition will be perceived as expanding, and the shares of its potential competitors and suppliers should increase.

4. Methodology

Following the steps on how empirical legal research should be done is considered important: designing the research, collecting and coding data, analyzing data, and presenting results (Epstein; D. Martin, 2014). Moreover, in the task of collecting data, the importance of identifying the target population, locating or generating data, deciding how much data to collect, and avoiding selection bias is essential (*Ibidem*).

Above, explanations on the design and interval of the event study, the data, abnormal return, and statistical significance, and the selection of the benchmarks are given.

4.1. Event study design

The research design considered the behaviour of the market towards Tesla's announcement of opening the patents through an event study, which is regarded of great value to "examine the behaviour of firm's stock prices around corporate events" (Warner; Khotari, 2006, p. 5).

In an event study approach, one wants to verify whether firms are affected by the event performed in the market. The methodology, therefore, is widely used by the financial sector. As Warner and Khotari (*Ibidem*) taught, it can also be used to measure the economic effects of legal rules. Moreover, it is understood that this study has a law and economics foundation itself as it aims to measure the effects of a corporate decision about the patent system on companies.

Having in mind the law and economics approach, given the potential monopoly power that a patent right provides, by guaranteeing the exclusive use of a certain innovation, which can be translated into a competitive advantage for those who own it, the verification (or not) of the hypothesis will make it possible to conduct inferences on the patent regime, its use by the industrial organization, and open innovation.

When one chooses good indicators, event study tools can provide reliable inferences (*Ibidem*, p. 5). As taught by Khotari and Warner "the conditions under which event studies provide information and permit reliable inferences are well-understood" (*Ibidem*).

However, a common problem is that the variance of a security's abnormal returns can lead statistical tests to be easily misrepresented and, therefore, the null hypothesis to be rejected too often *(Ibidem*). For this reason, Chapter 7 on limitations and further development of the present study should be taken into consideration. Despite these challenges, generally, abnormal return is the difference between the actual stock return and the market return. The degree to which it can be trusted depends on the significance test that accompanies it.

4.2. Interval

Firms can deploy their economic and political power to perpetuate their access to capital (Bae et al., 2021), which is why setting an interval to study is essential. Overall, short-horizon methods are those that take into account a time period of less than a year. They are reliable and represent the cleanest evidence of efficiency when studying an unexpected event (*Ibidem*, p. 8). It is well-specified and powerful when the abnormal performance is concentrated in the event window. Moreover, the test statistic specification is not highly sensitive to the benchmark model of normal returns, assumptions about the cross-sectional or time-series dependence of abnormal returns (*Ibidem*, p. 18).

The short-term event window to be considered varies depending on the companies. For U.S. companies it was possible to consider a gap of 9 days between the market estimation window (100 days) and the event window (total of 5 days). For non-U.S. companies it was considered the straight interval of 30 days before and after the announcement day, i.e. estimation window and event window coincide. Overall, the gap supports the estimation of the market "under normal conditions", as it allows to exclude days of potential anticipation of the announcement; however, as potential anticipation falls within the event window for the second group, it is understood that any abnormal returns on these days can also be captured.

To have a solid research design, one should consider reliability, validity, and robustness check tests (Epstein, L.; D. Martin, 2010, p. 908). Reliability is placed once the study can be replicated; validity occurs as it is a short-horizon event study with features validated by previous researchers; robustness comes through the market share analysis considering geographic reasons and significance in the industry.

4.3. Data, abnormal return, and statistical significance

The daily stock market values of the companies were reunited taking into consideration the country in which each one is listed. The event study was run considering the day of the announcement and the respective interval. An eventual abnormal return for each company or group of companies and its statistical significance was calculated.

4.4. Benchmarks

To define key competitors and suppliers of Tesla and its products and relevant countries, it was considered the following:

Market shares can provide “first indications – no more, no less – of the market structure” (Bergh et. al., p. 502) and the competitive effects. However, attention is drawn to the difficulty in obtaining information about the market share in general. Below, the market scenario of EVs competitors and suppliers was accessed through the clipping of several sources across 2011-23.

4.4.1. Competitors benchmark

4.4.1.1. By company

Exactly because innovation and aggregate assets are not done overnight, it is considered that although today's market share is not the same as in the past it allows access to Tesla's potential competitors at the time of the announcement.

Tesla launched Roadster, its first car, in 2008. By 2022, Tesla's vehicle portfolio included the Model S, Model 3, Model X, and Model Y. This latter was the top-selling EVs model worldwide that year (Visual Capitalist, 2023).

In 2021, however, SAIC-General Motors-Wuling was the most-sold battery electric vehicle (hereafter "BEV") brand in China. The company is a joint venture between SAIC Motor Corporation, General Motors, and Liuzhou Wuling Motors Co. Ltd and produces both combustion and EVs. There were 424,350 units sold in the country, followed by Tesla with 311,830, BYD 296,760, Great Wall Motor 132,960, GAC 122,340, Changan 101,250, Xpeng 96,570, NIO 90,870, Chery 85,620, and SAIC-Passenger Automobile Branch 84.50 (Sina.com.cn, 2022).

Worldwide, the market share of EVs in 2022 by company was: 18.4% to BYD, Tesla 13%, VW Group 8.2%, 7.2% SAIC, 6% Geely-Volvo Car Group, and 47.2% others (Inside EVs, 2023; Gale, 2024). When it comes to EVs production and sales, in 2022 scenario was the following:

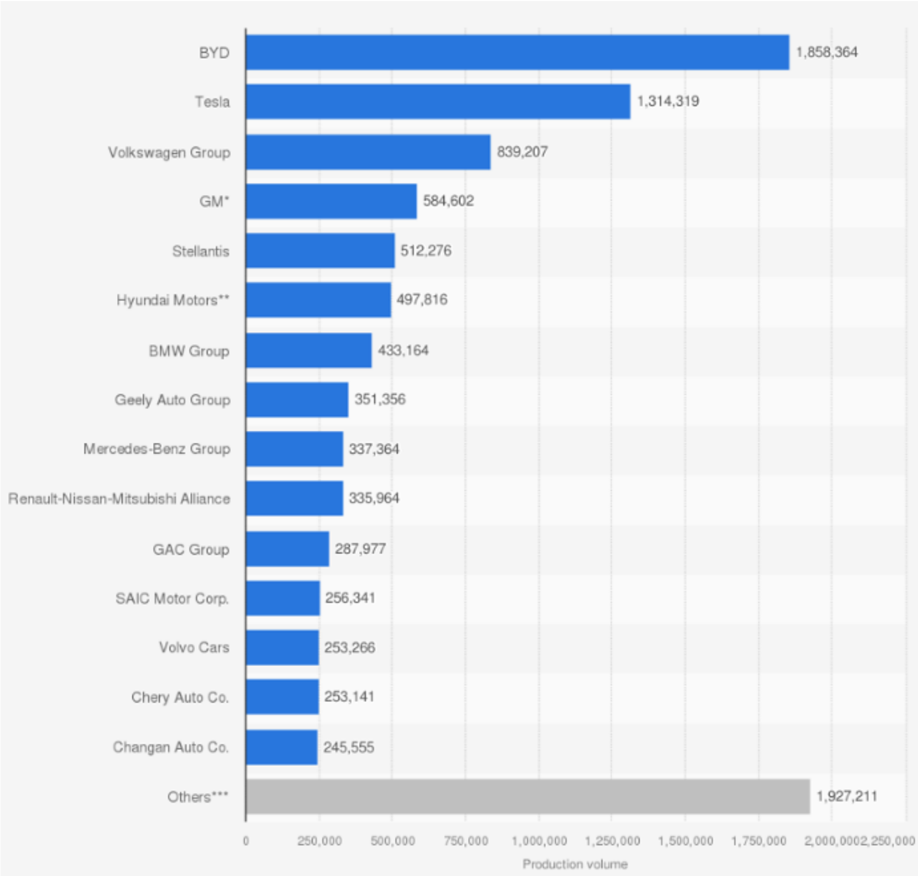

Figure 1: Global EVs production in 2022, by leading automotive manufacturer (Visual Capitalist, 2023).

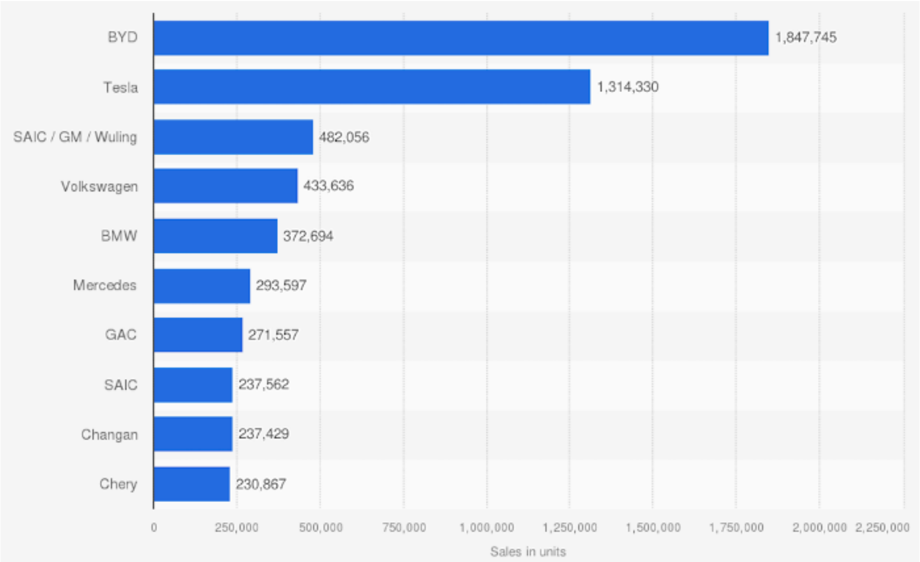

Figure 2: Estimated EVs sales worldwide in 2022, by automaker (CleanTechnica, 2023).

BYD produces both BEV and plug-in hybrid electric vehicles (hereafter "PHEV"), which are cars that still have combustion engines. Therefore, Tesla is the leading company that focuses on BEV exclusively.

Concerning market value, for decades in the US the most valuable car companies were GM, Ford, and FAC (Richter, 2020). In 2020, with the opening of the new plant in Shanghai, Tesla surpassed them, being "not only far more valuable than Detroit's Big Three. i.e.[,] GM, Ford and Fiat Chrysler […] but also the most valuable U.S. car company of all time. […] [It] surpassed Ford's 1999 market cap peak of $80.8 billion […] after beating GM and Chrysler's highest valuations in the second half of 2019. […] Despite its impressive production ramp-up, the company still produces a fraction of the number of vehicles that GM, Ford, and Chrysler produce. Rather than being based on past achievements or even current results, Tesla's valuation reflects the widespread belief that the future of cars is electric and that the company has enough of a headstart to eventually dominate that future" (*Ibidem*).

In this respect, GM, Ford, and FCA may be seen as Tesla's main US competitors, mainly because of the market's understanding of the future of EVs development. Regarding sales competition within the EVs segment in the US market, Tesla competes not only with GM and FCA but with other automakers:

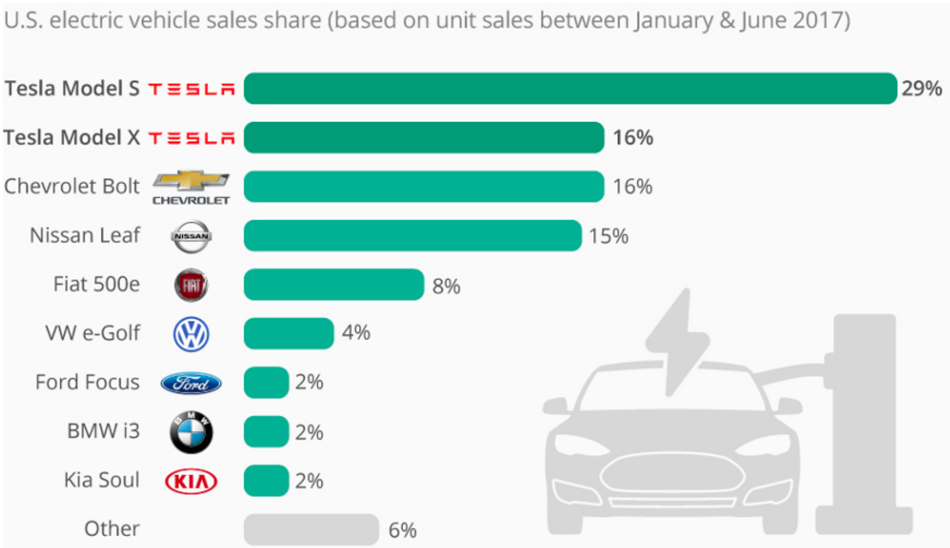

Figure 3: Tesla Dominates the U.S. EVs Market (McCarthy, 2017).

Worldwide, although Tesla Model Y was the 2022 top-seller, seven of the top ten EVs models were from Chinese manufacturers, reflecting the fast-paced EVs market in Asia-Pacific (Visual Capitalist, 2023).

Data from June 2023 regarding the value of the automotive companies, however, shows that Tesla continues to lead:

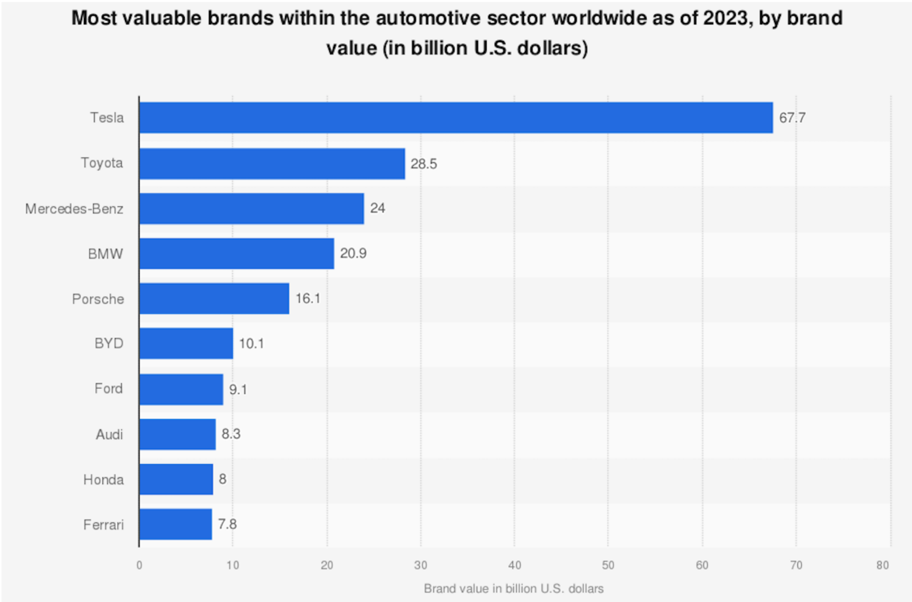

Figure 4: Most valuable brands within the automotive sector worldwide as of 2023, by brand value (L'argus, 2023).

Finally, news from March 2011 shows that GM, Nissan, and Ford were at that time introducing new electric car models to compete with the market share of Toyota, Honda, and Tesla (Cobizmag, 2011).

All the companies mentioned appear to be aware of the market space that EVs have and are concerned on fostering growth in this field.

4.4.1.2. By territory

Geographically, studies projected that China would lead EVs production by 2023, followed by Germany, the U.S., Japan, France, and South Korea (Berger, 2021). In 2021, China consolidated its position as the largest EVs stock market in the world, with approximately 7.8 million units (IEA, 2022).

Data shows that in China the new energy vehicles compared to the total vehicle production increased by 5.52 times from 2014 to 2015. It was estimated from this that by 2022 new energy vehicles in China would hold a market share of around 5.59% of the total vehicle production in the country (PwC, 2017).

When it comes to sales, in 2017 the following scenario was designed:

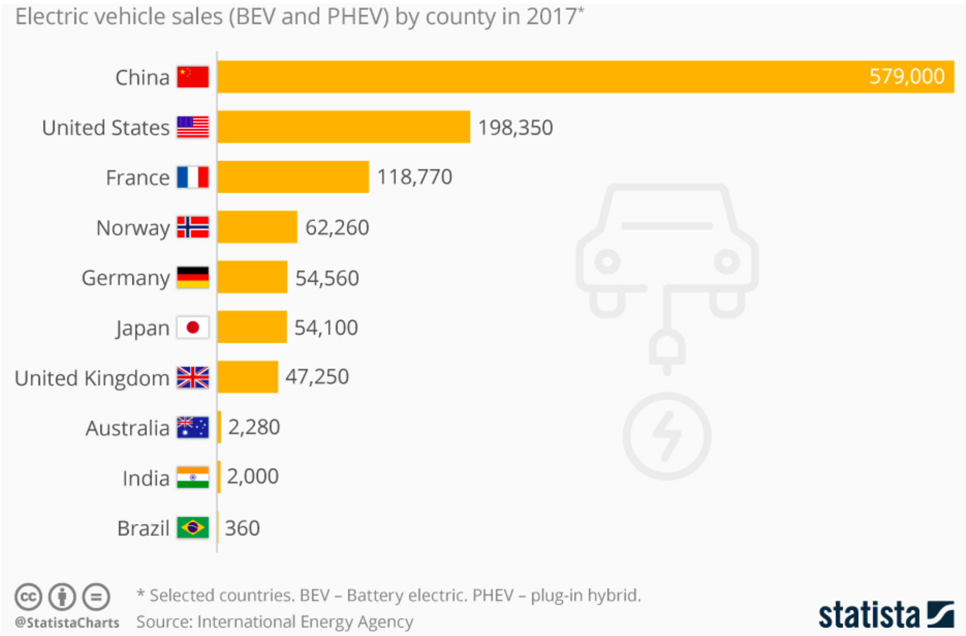

Figure 5: BEV and PHEV by country in 2017 (McCarthy, 2018).

Regarding the use of these cars in each country by 2022, the order changes slightly, projecting China still first, followed by the U.S., Germany, France, the U.K., Norway, the Netherlands, and Japan (IEA, 2023).

In the first quarter of 2015, for example, Norway was the EVs leading market as 33% of its registered vehicles in this period were EVs/PHEV, representing 8,112 vehicles. In the same period, 12,555 EVs/PHEV were registered in China, representing 0.3% of the Chinese market share (McCarthy, 2015). Although Norway is the country with the highest share of EVs per sale the picture changes in terms of absolute numbers. In 2020, the European market, pushed mainly by Germany, experienced a triple of sales in EVs although China continued leading. These are the largest markets in absolute numbers:

Figure 6: Who Leads the Charge Towards Electric Mobility? (Richter, 2021).

4.4.1.3. By patents

Automotive companies with patents related to green vehicles should be considered potential competitors of Tesla. On it, the following market share is placed:

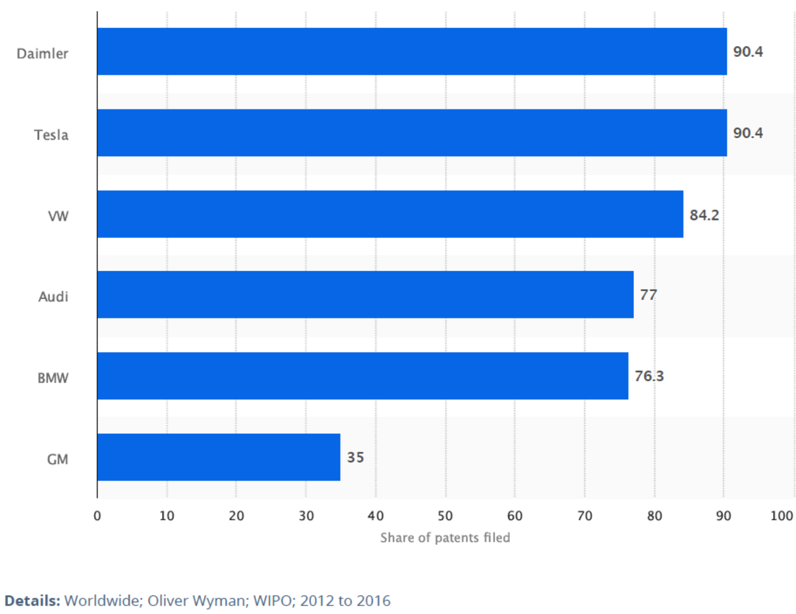

Figure 7: Green vehicle-related patents as a percentage of car brands' worldwide patent filings between 2012 and 2016, by car brand (Wyman, 2017).

Through a substantive analysis of technologies in this sector, Karamitsios (2013) cited Toyota, Honda, and Daimler/Mercedes-Benz as potential competitors of Tesla at the time of the announcement; Wang and Peng (2020) cited the first two and GM.

For all the above, geographically the study focused on China, Germany, Japan, and the U.S. In these locations, the considered competitors were Audi, BMW, BYD, Daimler/Mercedes-Benz, FCA, Ford, GAC, Geely, GM, Honda, Nissan, Porsche, SAIC, Toyota, and Volkswagen (Table B), considering the market share they hold, proximity of products, and relevance in the industry. Chery, Changan, and SAIC Wuling were not considered because they are not listed in the stock market. France was not considered because it has only one company as EVs key-player, although the market share in absolute numbers is great and accounts for the second-largest growth between 2019-20.

4.4.2. Suppliers benchmark

The automotive industry, a complex sector, requires a complex supply chain in terms of quality, volume, efficiency, and cost competition. Among the main auto parts for the manufacture of EVs, it highlighted the batteries, the electric motor, and the motor controller, which enable the motor to start by converting the energy of the battery.

4.4.2.1. Batteries

The battery production for EVs in 2020 (3.5m) increased 7 times when compared to 2015 (0.5m) (Carlier, 2021). In 2016, in this order, the following companies were classified as leading lithium-ion battery cell suppliers regarding the number of contracts won in the field of storage systems or EVs: Panasonic, LG Chem, Samsung SDI, and Guoxuan (Deutsche Bank Research, 2017). In 2017, the global market share by company was:

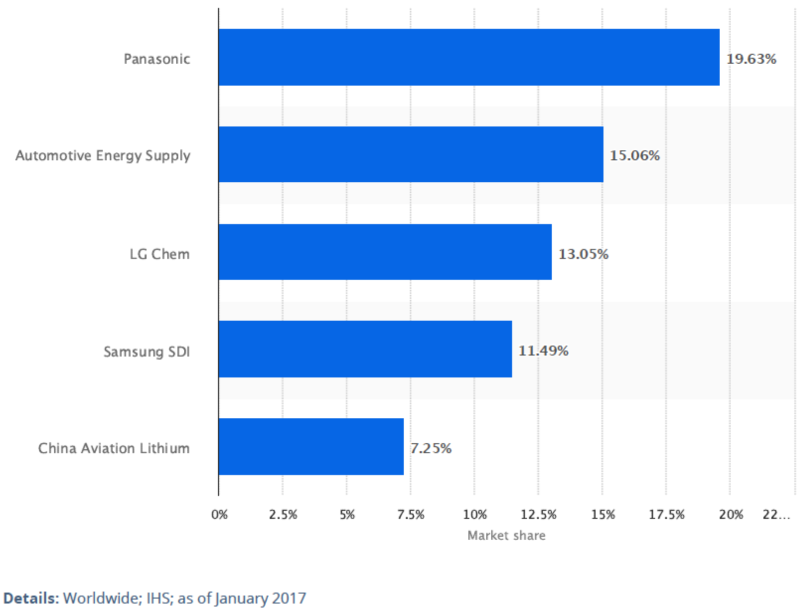

Figure 8: Automotive lithium-ion battery cell suppliers' global market share as of January 2017 (Automotive News, 2017).

4.4.2.2. Electric Motors

In 2016, the market share production of electric motors had the participation of the following companies:

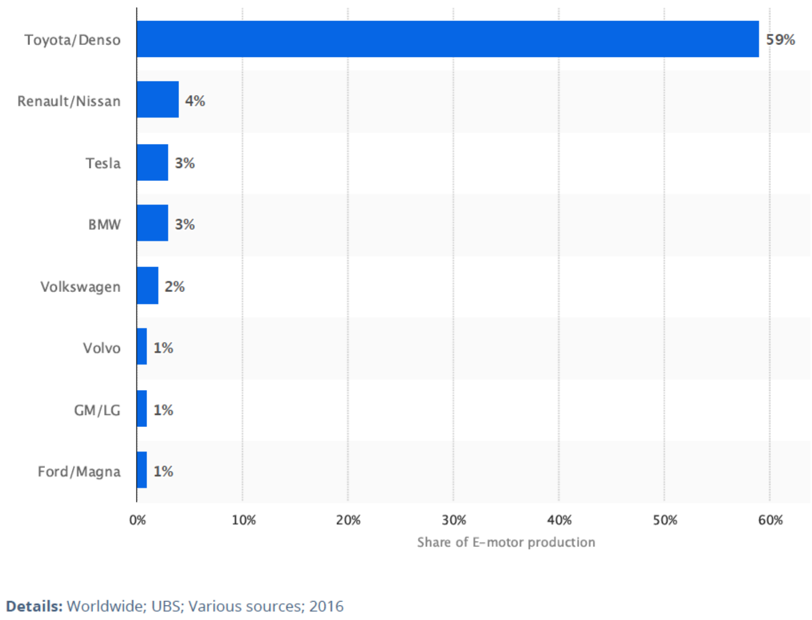

Figure 9: Distribution of global e-motor production in 2016, by supplier (UBS, 2017).

4.4.2.3. Motor controllers

In 2013, the leading suppliers of traction drive inverter installations (i.e., motor controller) in all EVs sold in the U.S. were the following:

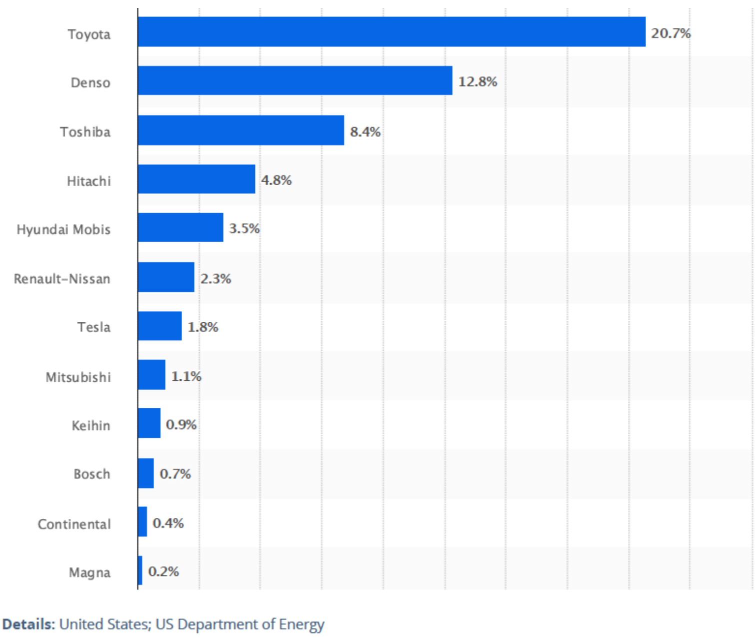

Figure 10: U.S. EVs traction drive inverter installations in 2013, by manufacturer (US Department of Energy, 2014).

For all the above, geographically the study focused on South Korea, Japan, and Germany. In these locations, the considered suppliers were Continental, Denso, Hitachi, Hyundai Mobis, LG Chem, Mitsubishi, Panasonic, Samsung SDI, and Toshiba (Table C), considering the market share they hold, proximity of products, and relevance in the industry.

Bosch, China Aviation Lithium Battery Co., and Keihin were not analysed because they are not listed on the stock market. Automotive Energy Supply Corporation is a joint venture between Nissan and NEC Co. This latter was added to the potential suppliers' list. Nissan was already added as a potential competitor.

Note that identifying suppliers is even more difficult than identifying competitors, as the supplied degree of importance of a product can be kept secret. Moreover, many suppliers may also act as potential competitors.

Lastly, the lack of some competitors or suppliers on the stock market is not considered a barrier because the chosen players are expected to give a picture of the effects of the announcement on the market.

4.5. Conclusion

Following the above steps, it is considered to have addressed (a) the definition of the event window, (b) the selection of the benchmark on competitors and suppliers, (c) the collection of data, (d) the result of abnormal returns, and (e) the statistical significance. All these event study characteristics possibly the (f) interpretation of the results. At first, it was expected that Tesla's abnormal return would be negative (different than zero) and different from the benchmark, which would suggest that the announcement had a harmful impact on its value. On the other hand, the abnormal return of its potential competitors and suppliers should be different than zero and positive, indicating a positive effect due to the announcement.

5. Event study outcome

5.1. U.S. companies

The U.S. Daily Event Study tool available by Wharton Research Data Services (hereafter "WRDS") was used to analyse the U.S. companies through the following market model and abnormal return equations:

$$E\left(R_{i,t}\middle|X_t\right) = \alpha_i + \beta_i Rm_t + \varepsilon_{i,t}$$

Figure 11: Market-adjusted model (WRDS, 2020).

$$AR_{i,t} = R_{i,t} - \alpha_i - \beta_i Rm_t$$

Figure 12: Abnormal return (WRDS, 2020).

100 days was the estimation window, i.e., the length of the period used to estimate the expected return and residual return variance. 70 days out of 100 was the choired minimum number of valid observations within the estimation window. 9 was the gap of days chosen between the estimation window and event window, as it can

cover potential anticipation by the market, as clarified in 2.1. The event window interval is of 2 days before and after the event day.

The Patell's Z test, a parametric test often used in event studies, assumes that each firm's abnormal return is normally distributed and standardizes the event window abnormal returns by the standard deviation of the estimation period of several returns (WRDS, 2020). To show potential statistical significance, it uses the well-known one-tell test (*Ibidem*).

5.1.1.1. Ford and GM

Table D and E show the relevant information to assemble the graph below. Information on FCA could not be obtained through the WRDS.

It was found that under the limits of the announcement the abnormal return shifted downward, maintained somewhat the same between the announcement and one day after it, and shifted upward one day after the announcement, which meant an increase in the companies' value at the end of the study. However, the negative cumulative abnormal return (hereafter "CAR") suggests an unfavourable reaction to the event by investors and the negative buy-hold abnormal return (hereafter "BHAR") shows that the companies' stock underperformed in relation to the market.

It is due to mention that all the p-values are greater than 0.05, which means there is a relatively high probability that the observed effects could have occurred by chance. In this case, there is around 15% chance of the CAR being caused by random market fluctuations. Possible solutions to this point are addressed in Chapter 7.

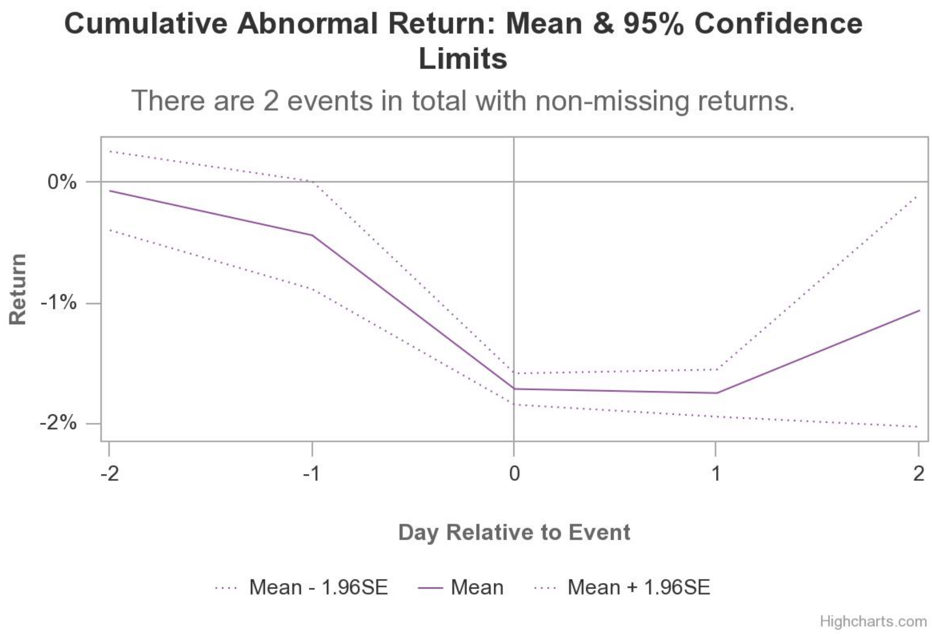

Figure 13: Ford and GM Mean CAR in percentage (WRDS, 2023).

Above, the solid line is the CAR; dotted lines represent the 95% confidence interval (hereafter "C.I."), being the upper the mean of the CAR plus 1.96 times its standard deviation, meanwhile, the lower is the mean minus 1.96 times its standard deviation.

5.1.1.2. Tesla

Tables F and G show the relevant information. The impact of the event increased the value of Tesla. Moreover, its CAR and BHAR being positive show that its stock outperformed what would be expected based on general market movements, indicating a positive reaction to the announcement, and outperformed the market during the event.

However, note that there is no strong evidence to conclude that the outperforming is due to the event, being around 50% the chance of the CAR having occurred at chance.

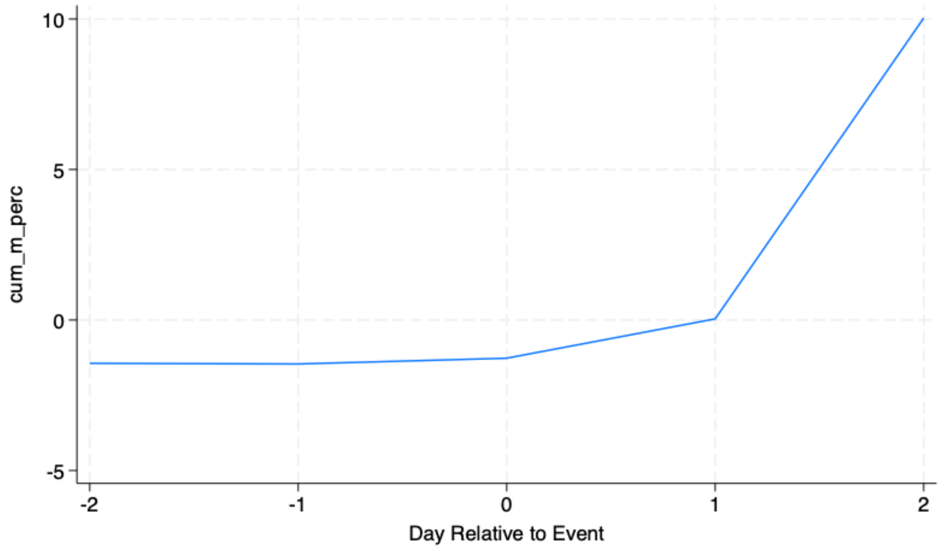

Figure 14: Tesla Mean CAR in percentage (StataCorp, 2023).

5.1.1.3. Ford GM, and Tesla

Although there is a chance the effects occurred randomly, there are indications that the announcement caused effects. For example, when including Tesla, GM, and Ford in the same event study, it is possible to see that the probability of CAR affecting the stocks increases - up to 79% chance of being caused on the day of the announcement. Table H shows the relevant information, and the graph below summarizes the CAR of the companies together.

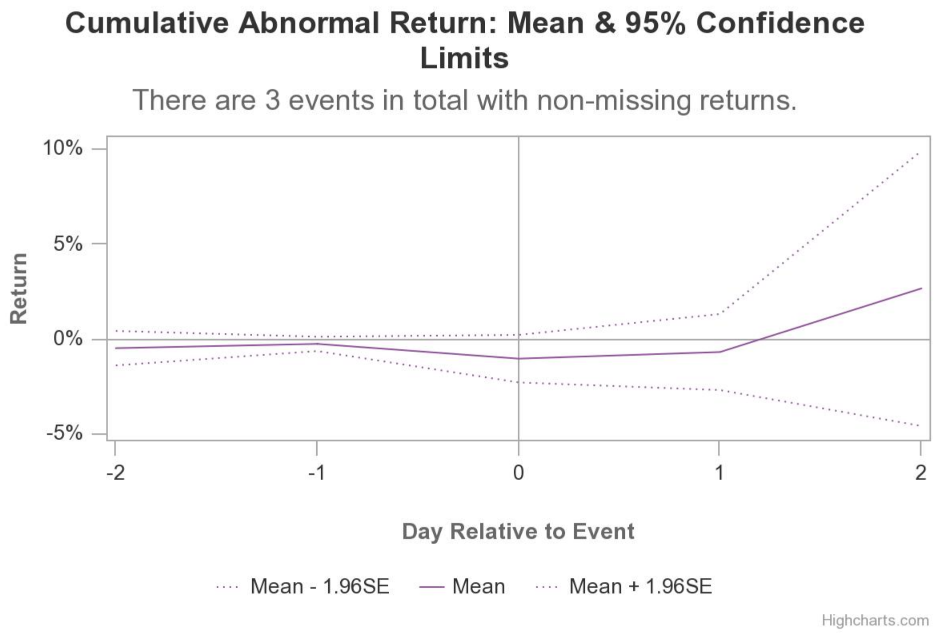

Figure 15: Ford, GM, and Tesla Mean CAR in percentage (WRDS, 2023).

5.2. Non-U.S. companies

The International Event Study tool available by WRDS was used to analyse all the non-U.S. companies. The stock price data are taken from the Compustat Global Daily Security file. The same market-adjusted model and abnormal return equations (Figures 11 and 12) were applied. The market return by the WRDS tool is taken from the daily WRDS indices. The choired missing rate of valid returns was 0.3.

The CAR statistical significance access through Patell's Z test was not possible in WRDS, but it was conducted through the one-sample t-test in Stata (StataCorp, 2023).

5.2.1. Chinese companies

5.2.1.1. Competitors

There was insufficient valid data to run an event study on BYD, GAC, and Geely. For SAIC, the CAR and BHAR were positive. Tables I and J show the relevant information and the graph below SAIC CAR within the event window. P-value indicates 95% C.I. for the mean CAR being different than zero. Moreover, the mean CAR indicates that, on average, there is a positive abnormal return associated with the announcement.

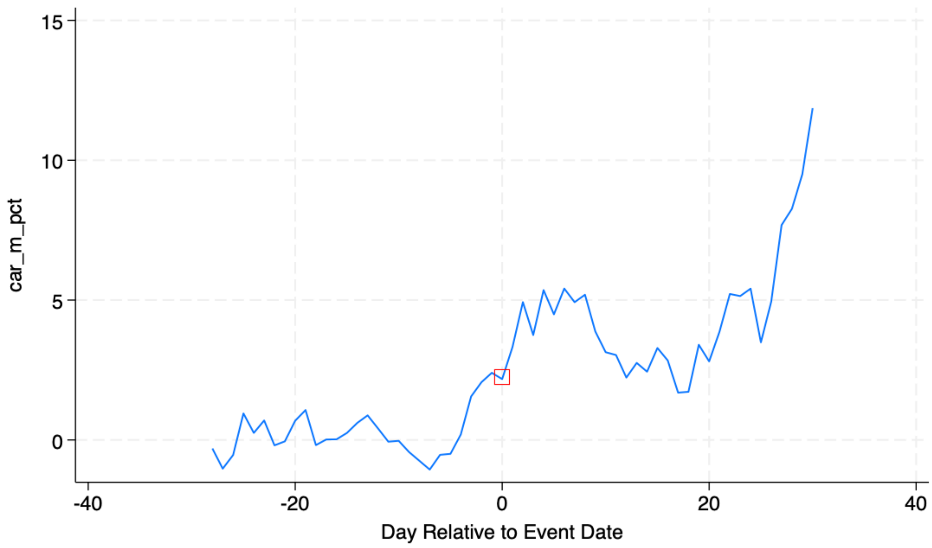

Figure 16: SAIC Mean CAR in percentage (StataCorp, 2023).

5.2.2. German companies

5.2.2.1. Competitors

Missing returns on Porsche were greater than the choired set, therefore the company was not analysed. Tables K and L show the relevant information and the graph below the mean CAR. The mean CAR, which appears to be statically significant, is different from zero and has 95% of C.I. of being a negative value. This means that the announcement probability resulted in a negative impact for most of these competitors. Note, however, that when BMW is analysed alone it seems to present a positive response within the event window. As these companies are under the same legal rules and territory, it is necessary to check whether other factors may have influenced the observed effects besides the announcement, for example a positive event related to BMW.

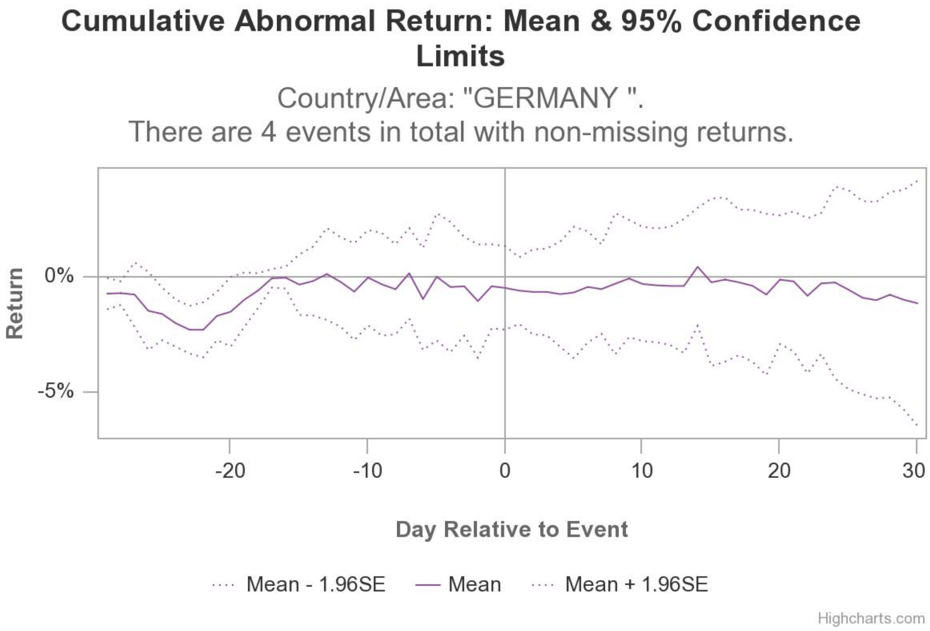

Figure 17: German Competitors Mean CAR in percentage (WRDS, 2023).

5.2.2.2. Supplier

Tables M and N show the relevant information and the graph below the mean CAR, which appears to be statically significant and different from zero, having 95% of C.I. of being a negative value. It conveys that the announcement could have resulted in a negative impact on the supplier's stocks.

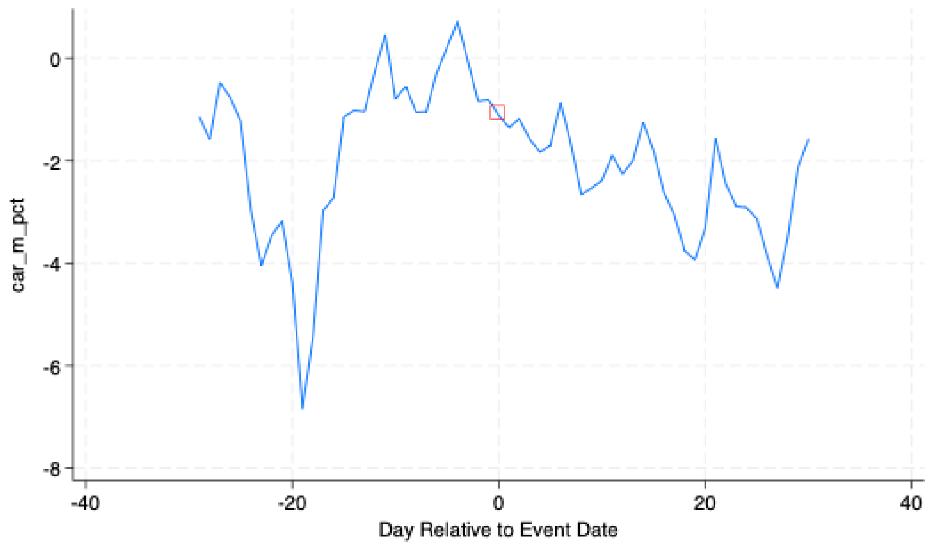

Figure 18: Continental Mean CAR in percentage (StataCorp, 2023).

5.2.3. Japanese companies

5.2.3.1. Competitors

Tables O and P show the relevant information and the graph below the mean CAR. The mean CAR, which appears to be statistically significant, is different from zero and has 95% of C.I. of being a positive value. It is considered that the announcement resulted in a positive impact for most of these competitors. Note that Nissan's stocks, however, experienced a fall within the event.

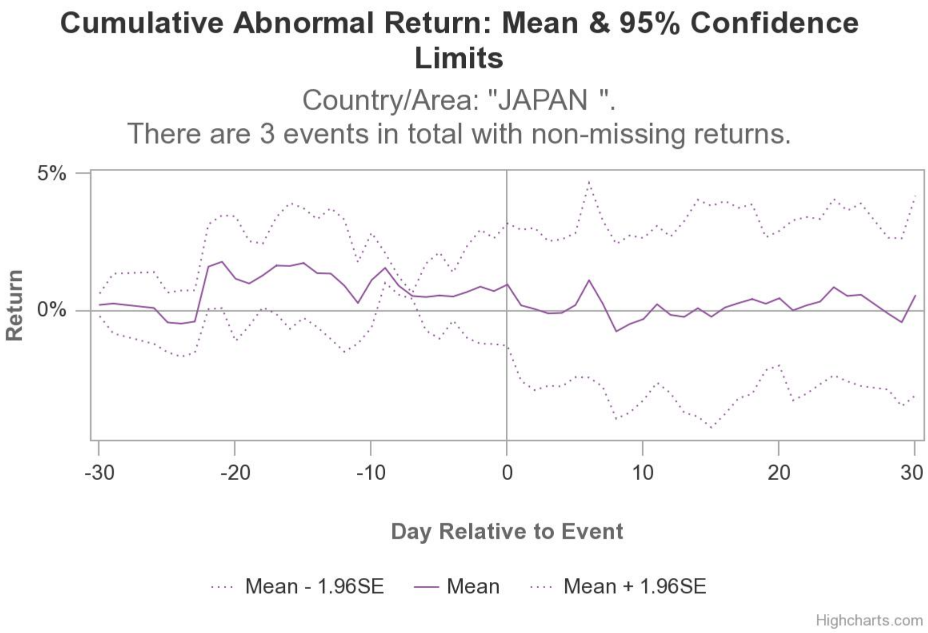

Figure 19: Japanese Competitors Mean CAR in percentage (WRDS, 2023).

5.2.3.2. Suppliers

Tables Q and R show the relevant information and the graph below the mean CAR. The mean CAR, which appears to be statically significant, is different from zero and has 95% of C.I. of being a positive value. The event appeared to be positive for Mitsubishi, NEC Corporation, and Toshiba, but negative for Denso, Hitachi, and Panasonic. Generally, however, there is 95% C.I. that it was positive for the companies' values as there is insufficient evidence to support a negative CAR.

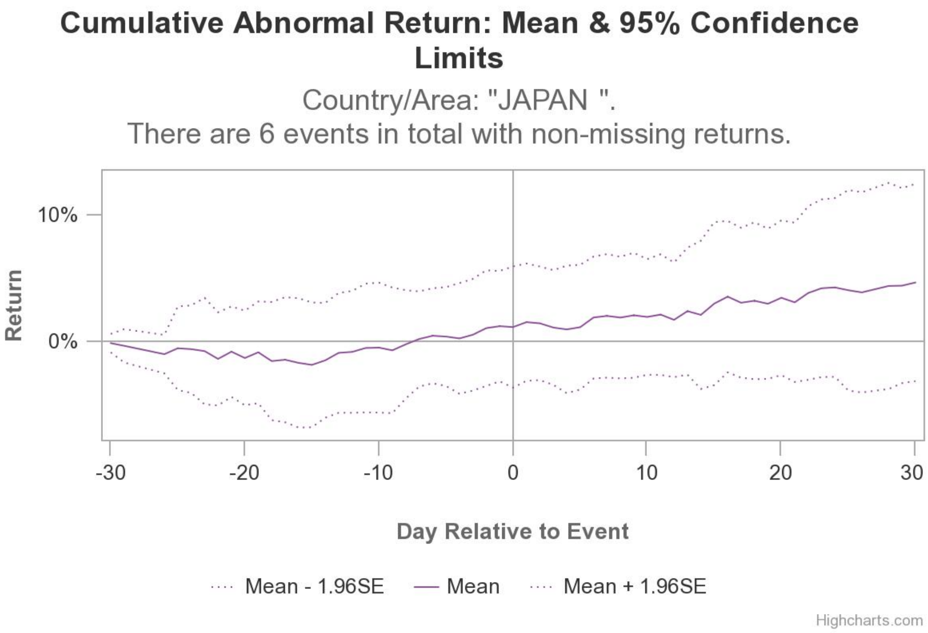

Figure 20: Japanese Suppliers Mean CAR in percentage (WRDS, 2023).

5.2.4. South Korea companies

5.2.4.1. Suppliers

Missing returns on Mando Corporation and LG were greater than the choired set, therefore the companies were not analysed. Tables S and T show the relevant information and the graph below the mean CAR. Although the mean CAR is reported positive during the event window, note that the 95% C.I. lies between negative and positive values. Moreover, the p-value test shows that there is no strong evidence to conclude whether the CAR is negative, positive, or zero; therefore, there is not sufficient data to infer the effects on suppliers.

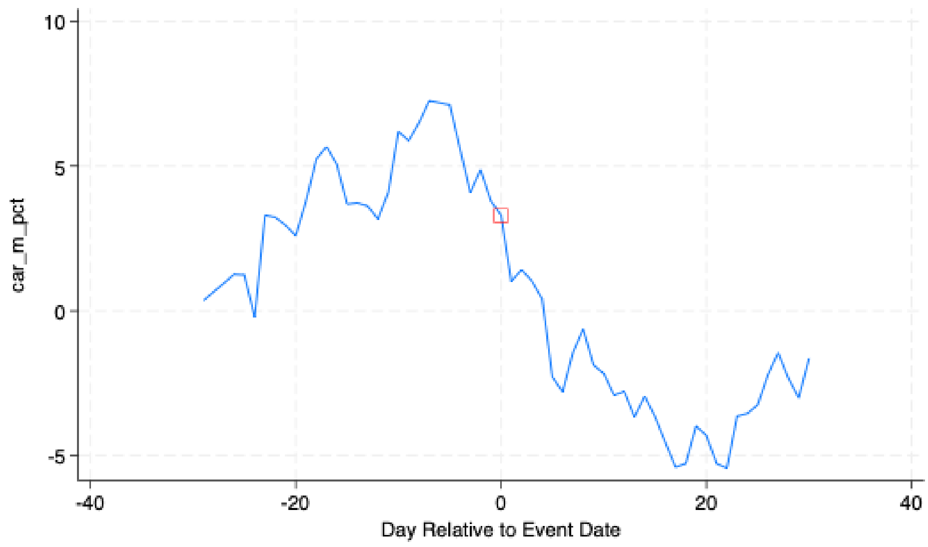

Figure 21: Samsung Mean CAR in percentage (StataCorp, 2023).

5.3. Conclusion

On the U.S. market, on the event day, Tesla's abnormal return is positive, different from zero and the benchmark. It indicates that its stocks outperformed during the event window, suggesting a positive market response to the announcement. On the other hand, the stocks of its potential competitors presented negative abnormal returns, at first suggesting that the stock has underperformed during the event window, showing a negative market response to the event. However, the usual statistical significance was not found. Therefore, it is impossible to dismiss that the abnormal return was not due to other reasons, like common market fluctuation. Nonetheless, there are indications of positive mean CAR when the analysis of these stocks is combined (see 5.1.1.3), which could mean that the announcement caused positive effects on these U.S. shares.

In China, only SAIC's shares could be analysed. It indicated a statistically significant increase in the firm's value associated with the announcement. However, important competitors such as GAC, Geely, and mainly BYD could not be analysed.

In Germany, the shares of Audi, BMW, Mercedes-Benz, and Volkswagen combined show that the announcement might have resulted in a statistically significant negative effect on competitors. BMW's value, however, appears to have increased. Porsche could not be analysed. Finally, Continental's shares represent a negative effect statistically significant related to the announcement on the supplier side.

In Japan, although Nissan, Denso, Hitachi, and Panasonic's values decreased, Honda, Toyota, Mitsubishi, NEC Corporation, and Toshiba's values increased. Overall, the announcement was taken as statistically significant positive for competitors and suppliers.

In South Korea, LG and Mando could not be analysed and there is not enough evidence to conclude whether Samsung's values increased on account of the announcement.

Thus, in general, although it is not possible to confidently confirm or refute our hypothesis since (a) statistical significance was not achieved uniformly within the usual esteemed margin and (b) a few data challenges and constraints occurred, it is possible to state that there are indications that the hypothesis could be refuted, as the announcement appeared to have positive effects on Tesla and some of its potential competitors and suppliers.

6. Discussion

The aim of this chapter is to discuss what happened around the announcement and what can be learned from it. Whether the hypothesis is verified or not, inferences about the patent system can be made, since the main objective of such a system is precisely to weigh the trade-off between the benefits of innovating and the costs of maintaining the exclusivity of an IP. Moreover, since this decision of whether or not to use the patent system occurs in the corporate context, inferences about the industrial organization regarding patentable products and technologies can be made.

Besides the main question, sub-questions are posed: (a) should patents be opened? (b) should patents be protected for 20 years? (c) should the Government open patents that are overall increasing welfare?

6.1. Innovation

Before discussing the legal and economic reasons for protecting an innovation, it is necessary to outline what one is. Innovation can be read as a product, service, or process that involves totally new knowledge and/or brings together old knowledge. It can also be defined as a driving force of economic growth, a market shaper, and a definer of market leaders (Karamitsios, 2013).

Innovation is not a simple process as it involves efforts from different orders and actors. Schumpeter treated it as a dynamic process (2021). Indeed, hardly a firm alone can innovate without the direct or indirect assistance of other actors, from loans and subsidies to infrastructure development and maintenance of good international relations of a country – for example.

Consequently, as Kovac and Spruk taught in explaining Schumpeter's view (2021, p. 5), "the main function of the entrepreneur involves combining new things or innovating and introducing a new product or a new quality in a product, a new method of production, a new market, or a new organization in an industry". Thus, Karamitsios' argument on entrepreneurship "be[ing] crucial for today's corporations in successfully creating, developing and implementing new ventures that renew their technology and product portfolios since markets as well as their existing products mature" (2013) holds, although this is not the only element to ensure innovation.

Innovation depends on lots of resources, therefore, to address market failures that prevent it from occurring, such as hold-up or adverse selection problems, there is an understanding of the need to provide sufficient incentives to the inventor. The reason to protect innovation through industrial property, such as the patent system, rests exactly on this necessity. Once opening patents means placing available technologies with industrial application that originated from extensive R&D investments for (future) competitors, questions on the form in which the inventor's incentive is set in this system arise. Understanding decision effects between these systems requires an appreciation of both.

6.2. Patent System

Posner defended that the trade-off between incentives and access has been shown to be “intractable at the level of abstract analysis” (2005). Thus, the present study is an attempt to objectively analyze it in this case.

Different strategies are formed to pursue innovation. Miller and Olleros (2007, p. 37) suggest that (i) patent-driven discovery, (ii) cost-based competition, (iii) systems integration, (iv) systems engineering and consulting, (v) platform orchestration, (vi) customized mass-production, and (vii) innovation support and services are the main elements for innovation strategies.

Several authors address the need to have a defined purpose to design the most appropriate strategy to achieve goals. Theoretical examples on the purpose requirement are brought both in the private sector (e.g., *Ibidem*) and public sector (e.g., Mazzucato, 2014).

Especially in the private sector, the patent system is well known, and often questioned, precisely because patentability “provides an additional incentive to produce inventions but requires that the information in patents is published and that patents expire after a certain time limit the ability of the patentee to restrict access to the invention" (Posner, 2005, p. 57).

Depoorter highlights that through a utilitarian perspective, “the scope of IP rights must be that the access-incentive trade-off is optimal: the marginal incentive benefits of additional protection equal the marginal costs of any further reduction of access to the public and follow-up creators and innovators” (2019).

Landes and Posner note that the patent system employs a few "devices to minimize social costs" (2003, p. 302) of giving exclusivity. One of them is the patent's limited term. Although it may be "largely illusory" because it does not completely discount the present value and its interaction with depreciation (*Ibidem*). Another is the publicity of information, which can be seen as a way to maintain a patent and its possible violations easily tractable and the scope well-defined, minimizing social costs.

Even considering these equal devices, if one considers that the announcement opened in the same way patents that were filed years or months before it, one can arrive at the conclusion that innovation values are indeed different over time as through the announcement different lengths of monopolies were used by Tesla.

Moreover, patents have a high cost, both for society and the right holder, as the first is, at least in the beginning, excluded to develop an innovation that falls under a patent scope, and the latter needs to invest considerable resources in research, procedures, fees, trackability, and enforcement of its rights. To a right holder, the patent benefits are based on the series of legal and economic tools that are granted; for example, the right to assign, license, and prevent others from exploiting the same right. To society, the benefits rest on a potentially positive value that the (future) innovation developments can bring.

By the way, the costs involved in patent proceedings are much similar to the license's costs, which justifies the choice to open the assets instead of creating a pro-license environment. As taught by Buccafusco et al. (2017), IP rights led to the substantive influence of transaction costs when dealing with sequential innovation. The authors explain that Calabresi and Melamed's classic formulation highlights that "IP rights are generally structured as property rules, whereby downstream creators must individually locate upstream creators and negotiate licenses to use their works and inventions. These transaction costs can be steep and will often prevent otherwise efficient licensing from taking place" (*Ibidem*).

Another point to be considered under the patent system is the fact that it should ex-ante discourage IP violations and ex-post compensate a right holder for lost profits caused by an infringement (Depoorter, 2019), otherwise, it might not be efficient.

6.3. Open Innovation

It is a popular topic in innovation management. Under this system companies can be exposed to new potential business models rather than just focusing on their existing business activities (Wolcott and Lippitz, 2007).

Karamitsios defends that R&D alliances can improve the firm's innovative performance, being more effective than M&A (2013, p. 12). A negative point may be that although open innovation by coupled processes assists in achieving better results in innovation, it can reduce the company's ability to benefit from these activities; however, when partnerships between players are established, this negativity can diminish or disappear (*Ibidem*).

The author highlights the example given by the theorist Holmberg in 2011, suggesting that companies can benefit from positioning themselves at the center of large inter-organizational partnerships and pursuing more strategically designed alliance portfolios that can be dynamically changed over time (*Ibidem*). Specifically, about green technology, Holmberg highlights that “establishing large inter-organizational alliances can benefit (…) firms” (*Ibidem*).

On the administrative costs, Kovac and Spruk argue that its persistence “such as agency costs, and lack of coordination among many others are mainly responsible for the innovations that are not generated” (2021). Therefore, whether open innovation can increase the levels of coordination, should benefit innovation development.

Adén and Barray (2008) highlight Google and Apple's action as a successful case of open innovation in the late 2000s. It may be proof that “openness itself could be a tool supporting both competitive advantage[s] as well as industrial transformation” (*Ibidem*). However, it needs to be noted this kind of industry is different from the automotive one, therefore the same success may not be replicable.

Nonetheless, when establishing the trade-off of R&D inter-organizational collaborations, several authors (Karamitsios, 2013; Faems et al., 2010; Belderbos; Faems, 2010) highlight that potential disadvantages might surpass possible advantages. Specifically, Karamitsios (2013) notes that the party ready to be part of an alliance network should succeed in visualizing potential (i) hidden costs, (ii) opportunistic behaviour, (iii) and the likelihood of financial issues that can affect the cooperation. It can be translated to the trade-off analysis between property rights and open access where the patent system may represent a more secure way for companies to care for their intellectual assets.

Anyhow, if one considers that patents work mainly to leverage small and medium-sized companies and that open innovation may work better for large companies, one should consider open innovation a great response to the market failure that patents can cause by blocking interactions and products that can have greater social benefit when shared and not placed exclusively. In addition, the patent system would provide incentives to the most vulnerable inventor in the innovation chain, who is usually the first and/or smallest entrepreneur.

Adén and Barray (2008) argue that it is still difficult to apply a cost-benefit analysis on the use of open innovation because the answer to how exactly it supports the industrial transformation and the competitive advantage remains to be addressed by the literature.

However, along with the first mover advantage, the industrial standardisation attempt seems to be sufficiently beneficial in the analysis; meanwhile, the costs under the open innovation system seem to be lower than those generated by patents or licenses. Thus, the announcement can be seen as good news for Tesla.

Moreover, even the authors highlighted that open innovation despite "dilemmas and negative side-effects" seems to contribute to the dynamic of companies' capabilities and adaptability by "creating ecosystem-related novel business models and on[sic] enabling long-term organizational learning" (*Ibidem*).

Perhaps one of the most important lessons coming from an open innovation choice is that when a company decides to follow up in this way, it is changing the rules and competition within an industry and, therefore, it is affecting how organisations create value and stay competitive (*Ibidem*).

Further understanding of how open innovation can change the incentive rules to innovate may consider that, through standardisation, a company aims to generate another kind of monopoly, that does not come from patents, but from "the introduction of minimum environmental standards" (Faber; Frenken, 2008).

Although open innovation appears to have positive aspects, it was considered not to change the hypothesis of this work because it is understood that the use of the patent system, meaning the certain exclusivity right of one company in relation to another that is capable of generating scarcity and competitive advantage, has equal or even stronger weight. This system is taken as used by several valuable companies and, therefore, considered a factor of interest to investors, in a positive correlation.

6.4. Automotive Industrial Organization

The aim of this subchapter is to discuss potential economic implications and incentives created by the automotive industrial organization concerning the patent system and open innovation.

First, it is necessary to observe that the room for growth of EVs is enormous. In 2014, they represented 0.54% of all cars in the world; in 2016 1.10% (Richter, 2017). A fleet of 50 million EVs would represent 5% of the world fleet (*Ibidem*). The expectation of the International Energy Agency was that in 2022 the EVs fleet would reach up to 20 million and in 2025 between 40-70 million (*Ibidem*). In 2022, EVs numbered 26 million (IEA, 2023).

The EVs market growth is related to the way this automotive sector organizes itself. Is production efficient enough to achieve the mark of 70 million by 2025? To answer this question, according to the law and economic perspective, it is necessary to observe if the right amount of incentives for development is posed.

The incentives for electric vehicle production and diversity are not just based on an increase in sales but may be related to complying with legal obligations. It is due to note that the purchase and use of EVs, and therefore the growth of this industry, is very much linked to public policies to be implemented by the governments. As expressed in subchapter 4.4.1.2, the Government of Norway is an example of that. Therefore, it stands that both the industrial organisation and public capacities should accomplish goals toward pushing the growth of the EVs market.

Even if the environmental agenda seems to have no space in the industry, it is increasingly gaining ground to tackle environmental problems, once passenger cars account for more than 40% of carbon dioxide emissions from the transport sector worldwide, a share that rises to more than 60% when medium and heavy-duty trucks are included (IEA, 2023).

See, for example, (a) the legislation created by the Californian state to make it compulsory for car manufacturers to sell a minimum of 2% of zero-emission vehicles by 1997 and 15% by 2003 (Beaume; Midler, 2009), (b) the role of the governments of Israel and Denmark in creating a space with reduced risks and credible markets for EVs projects to the automotive manufacturers and its suppliers (*Ibidem*), (c) the latest developments regarding the European Green Deal, the actions by the Environmental Protection Agency in the U.S., and (c) the role played by the Federal Ministry of

Economic Affairs and Employment (BMWA) in Germany, this latter responsible for creating a program that has generated investments and partnerships in research of hydrogen and fuel cell technologies (Furrer et al., 2018).

In a nutshell, public policies may play a role regarding environmental regulations and product standards to achieve these rules (Köhler et al., 2019). In this context, public authorities would also be essential to analyse companies' market shares and power that might be prejudicial for the economy.

The focus of this work is not to discuss whether electric cars are the best solution to address the world's environmental issues. Carbon emissions, nonetheless, certainly have an impact on this trade-off and EVs find significant growing space in the market.

In addition to focusing on ways to develop R&D to accelerate growth, the automotive industry needs to address solutions to the problems and concerns that potential consumers of these products have. In China, for example, a 2016 study shows that consumers' main motivations for not buying EVs are, in this order: fear of scarce charging locations, high prices, technical failures, and slow charging (McKinsey & Company, 2016).

Having in mind what Buccafusco et al. (2017) taught on costs and incentives on patents and licenses, with the announcement competitors might not have the impact of choosing between innovating "on" or "around" the patent in terms of transaction costs, because once the patents are open their costs assumed as zero or insignificant. However, the corporate decision remains in terms of the companies having to choose between applying what the authors called "redundant ideas" or "furtherance of new developments". For competitors, this choice is quite important because, as the authors suggested, generally, a mistake in the decision of innovating on or around a previous technology influences the costs of the production and, therefore, may influence the production existing at all (pp. 7-13).

Further research to investigate the correlation between the announcement and the growth of EVs models launched is due, however, it is due of note that the EVs sector experienced unprecedented growth:

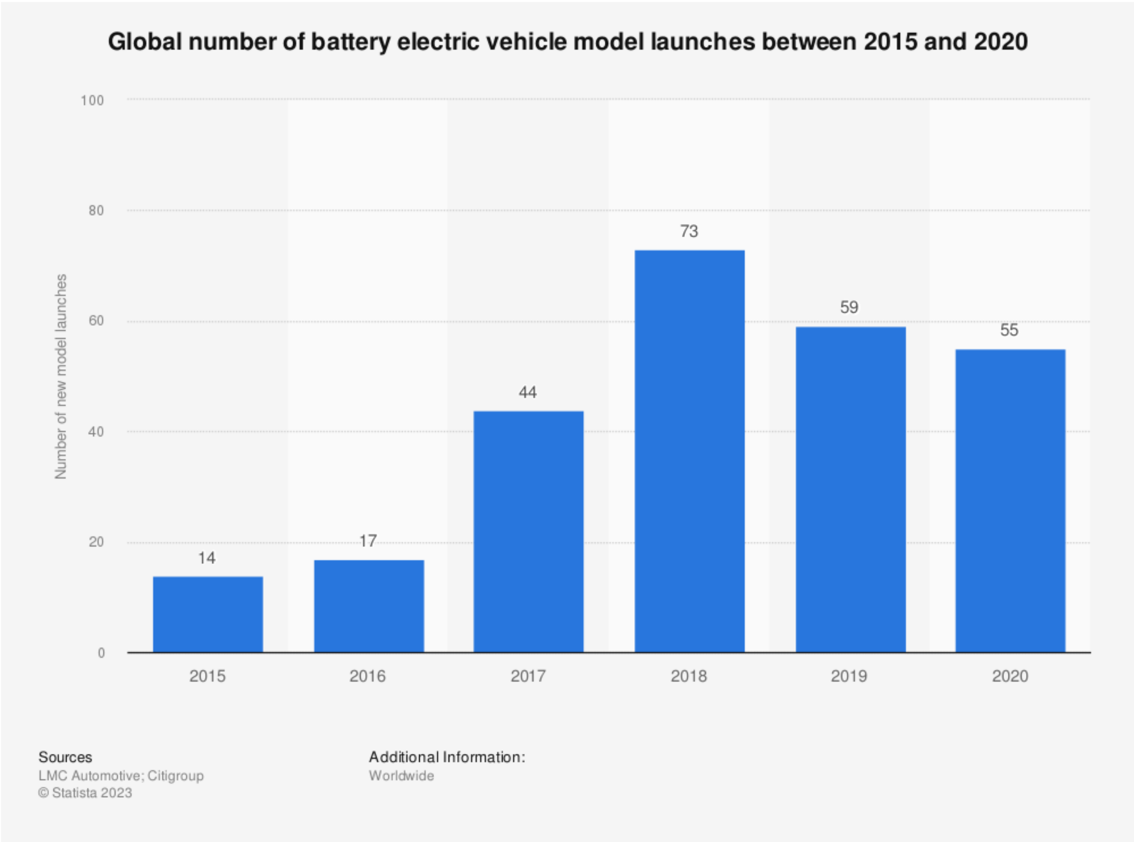

Figure 22: Global number of battery electric vehicle models launched between 2015 and 2020 (Statista, 2023).

Beaume and Midler (2009) suggest that investing on new forms to reinvent the individual eco mobility could “reconfigure the whole value chain in the automotive industry by: modifying the competitive position of traditional equipment manufacturers [hereafter “OEMs”], transforming the suppliers network, and favouring new entrants like battery suppliers, while components like engine, air conditioning and others are deeply transformed by the adoption of electricity as energy source”.

The authors argue that the most challenging side of EVs growth is the development and production of batteries. It was acknowledged in the article “The Achilles heel of the EV has always been the battery” in TheEconomist, however, since the 90s consumer electronic devices demanding high energy density batteries along with a hybrid vehicles prospective market “pulled the development of new automotive batteries” *(Ibidem).*

Especially when it comes to transnational companies, the management of innovation within a globalisation/integration approach on R&D and manufacturing can lead “to greater advantage of time, quality, flexibility, and cost” (Gerybadze; Reger, 1999).

6.5. Tesla’s Case

Accessing the economic implications and incentives created by Tesla's decision becomes a more objective task when applying what has been covered above.

Tesla appears to have introduced a new game to the market and the automotive industry. In this context, Tesla's goodwill is very relevant. It is considered that the prominence of the company in the electric vehicle industry is due to having "the world's second-largest market capitalization in the automotive industry with great technical, financial and management advantage of the industry" (Wang and Peng, 2020). Moreover, it is considered that by the decision Tesla aims to further increase its technological advantage through a "monopoly of the technology standard" (*Ibidem*).

The work of Karamitsios (2013), published before Tesla's announcement, demonstrates how the creation of a "new innovation market [can be created] through open innovation based on the theory of coupled process " (p. 6). It highlighted that automotive companies generally suffer in implementing entrepreneurship and that the competitive paradigm of this sector appears to have changed from a firm-to-firm to a network-to-network competition, precisely through strategic and networks of partnerships (*Ibidem*).

Specifically, Karamitsios analyzed the Tesla company applied to the open innovation scenario possibility. Tesla's approach has been to maintain close to its competitors and suppliers (*Ibidem*). First, it is important to bear in mind that Tesla has followed alliance strategies of suppliers, R&D, and OEMs with other automobile manufacturers. For example, Tesla performed a supply partnership with Panasonic for grade lithium-ion battery cells in 2011, which was considered to lead Tesla to meet its margin and cost targets for the Model S, to introduce the collaboration on the next-generation grade battery cells, and to expand partnerships by the initiation of Tesla's partnership with Freightliner, a Daimler affiliate (*Ibidem*). Tesla also had successful partnerships with Toyota, the latter both as developer and manufacturer, as well as with Sotira, this one as a supplier (*Ibidem*).

In summary, it is relevant to highlight the following partnerships:

Strategic Alliance Partner and Location	Type of Alliance	Equity, Non-equity or Joint Venture Alliance	Products/Services Provided
Sotira (France)	Supplier	Non-equity	Manufacturers carbon fiber body and sends it to Lotus in U.K.
Lotus (U.K.)	Supplier	Non-equity	Build unique chassis and sends it to Tesla in Menlo Park, CA.
Panasonic, multiple suppliers (Japan)	Supplier	Equity alliance	Battery cells for Tesla's battery pack
Borg Warner (U.S.)	Supplier	Non-equity	Single-speed gearbox
Panasonic (Japan)	R&D	Equity alliance	Battery cell R&D; working on developing nickel-based lithium-ion battery cells
Dana Holding Corp. (Canada & U.S.)	R&D	Non-equity	Heat kills batteries. Designed heat-exchange technology to keep batteries operating at peak efficiency using Tesla's climate control system
Daimler (Germany)	OEM for other auto mfg.	Equity alliance *	Daimler integrates Tesla's battery packs and charging electronics into Smart Fortwo development
Freightliner (owned by Daimler); Toyota; and Others	OEM for other auto mfg.	Equity alliance	Develop electric vehicles, powertrain components, battery packs, chargers, parts and production systems and engineering support
Toyota	OEM for other auto mfg.	Equity alliance	Develop electric version of Toyota's Rav4 SUV in Tesla's new Los Angeles, CA. manufacturing plant (former GM-Toyota manufacturing plant); production and sales begins in 2012
US Government—DOE		Loans	Loans to accelerate production of affordable, fuel-efficient vehicles.

Figure 23: Tesla's Partnerships (Holmberg, 2011; Karamitsios, 2013).

As several authors stress the cooperation between players as good outcomes for these players and society, especially in the green technology sector (Holmberg, 2011) and in the clean-tech vehicle market sector (Beaume; Midler, 2009), there might be a large room for Tesla collecting the goods of its decision.

It is understood that open innovation would not address the problems of lack of employee incentives and difficulty in tracing authorship. However, it gives more tools for the company's management team to coordinate team activities, setting objectives originating from inside and outside the company, and allowing greater dynamism in visualizing new trends in the market. In other words, the outcome generated by open innovation appears to result in greater management power for the company and more knowledge resources for employees. In what concerns incentives, it might be that Tesla's goodwill other than patents may be enough to maintain its growth.

Nevertheless, it cannot be disregarded that Tesla approved a three-for-one split of its common stock in the form of a stock dividend in August 2022. It was argued by the company that it was done to make stock ownership more accessible to employees and investors. However, considering all the possible motivations that lead to this decision and its potential effects, one should consider a possible problem with the company's cash flow. Since the company has never experienced it before and it occurred approximately eight years after the announcement, it can indicate a liquidation problem that is not excludable related to the decision.

On the other hand, however, it is due to the recent announcements made by Honda and Toyota deciding to use Tesla's superchargers in their vehicles. This fact may represent that along with open innovation in the automotive industry, powerful partnerships between key players may be a valuable asset to increasing market share.

Moreover, it may also represent that Tesla (and its competitors) is knowing how to choose their partnerships, as those are companies that hold a relevant market share.

Lastly, due to note that Tesla continues maintaining its previous patent assets by paying the required patent offices fees for maintenance and applying for new patents, which means that the company is not signaling giving up these rights, although their enforceability might be posed at a lower level after the announcement. Considering that the maintenance of patents requires higher costs, Tesla may have good reasons to proceed this way, such as avoiding patent troll attacks or even maintaining its stock market value.

From the above, it is considered that the *ex-post* patent system benefits regarding loss of profits due to infringement were not enough incentive for Tesla to maintain its patents in exclusive property, but its costs might be higher than benefits and the implementation of an open innovation economy, which may appear as a game changer for Tesla, that so far continues to play a pioneering role regarding EVs, and for other companies related within this automotive industry.

Answering the main question of this work, despite all of its constraints, it seems that the effects of the decision were generally positive for Tesla and a part of its potential competitors and suppliers. Regarding the sub-questions posed at the beginning of this chapter, it appears right to affirm that:

(A) The cost-benefit analysis between the patent system and open access shows that both economies have advantages and disadvantages. When the patent system is not efficiently working, regarding enforcement, for example, or is not sufficient compared to the benefits an open access system can bring, this latter may be preferred. This analysis, however, is complex and requires company strength to deal with lots of externalities to survive and aggregate even more value through its R&D and innovation processes when compared to a patent system economy. Thus, the decision in opening patents shall depend on such cost-benefit analysis applied case by case.

(B) An efficient length of patents may be pretty much related to the type of innovation, industry, and bargaining power coming from the innovation and its right holder. This latter could be related to other IP rights, such as trademarks. Therefore, it seems that the same interval of exclusivity for all innovations is not efficient. This argument finds its place with many scholars; however, it is also argued that it could bring more lobbying for the IP system, which may lead to prejudice in the market. Nonetheless, it is considered that a cost-benefit feature that guarantees the analysis of innovation-by-innovation should be regarded. Depending on the costs involved, the implementation of a different system should be efficient in the end.

(C) Governments and jurisdictions play a key role in the successful development of EVs. Therefore, it reveals true that public authorities should keep open the opportunity to employ a cost-benefit analysis to guarantee open access to different innovations, checking whether they would increase welfare, what are the cost-benefits for companies, and what can be addressed by the Government as incentives in case of lacking and if it is, in the end, worth it. When such decisions come in the form of legislation, not depending on the ruling of courts, for example, it can provide a high-level legal certainty that tends to boost economic activities.

7. Limitations and scope for future works

Many are the limitations/subjects for further development of this work. For clarity and conciseness, it was chosen to outline them below through bullet points.

- As stated in the hypothesis chapter, one cannot disregard the possibility of Tesla's competitive advantage lying in other proprietary aspects apart from patents, such as trademarks and potential trade secrets. In this case, the present event study would be unable to cover potential effects, given the difference in scope or confidentiality matters. Regarding trademarks, for example, the ideal approach would be through trademark strength market-assessment. It may bring inferences about how the patent and trademark systems, together or not, maintain or stimulate a company's value.

- The legal effect of the Patent Pledge may differ based on the jurisdiction, potentially resulting in different interpretations of usage and commitment to investments depending on the territory.

- The assumptions for the hypothesis to hold (namely: the strength of the patent system; no need for Tesla to license third-party property rights for its production; and the competitive advantage of Tesla's patents for its product production, development, and sales) may have limitations.

- The assumption that competitors would lower their transaction costs when using Tesla’s patents now open may not hold as it depends on the nature of resources these competitors need initially to employ to use the patents. Factors such as access to suppliers, knowledge about innovations and processes, and time and resources to incorporate Tesla’s technology into their products could pose constraints on utilization.

- It is taken for granted that potential competitors, suppliers, and investors of Tesla are fully aware of the announcement and its implications according to the patent system. However, this may not be an absolute truth. A study aimed at interviewing competitors, suppliers, as well as key investors of Tesla can be designed to capture the effects of this decision within each corporate environment and behind the financial market.

- The event study, by taking into account the market share, compares companies that produce vehicles other than electric ones, meanwhile, Tesla only produces electric vehicles.

- The companies and intervals considered might not be enough to catch all the effects of the announcement. A higher or lower event window and data on other companies should be considered.

- Different significance tests and the data absence from some companies can yield results different from the findings. An event study considering a larger data pool with a model controlling potential externalities could answer the hypothesis with higher confidence.

Specifically subjects for further development:

- Artificial intelligence can be used to evaluate and define Tesla's competitors and suppliers. By linking, for example through node statistics, the personal evaluation with artificial intelligence, one can experience an improvement to analyze the best-fit players. It was not implemented due to time and word constraints, and possible robustness lack of AI tools.

- A correlation analysis between the different stocks presented can be performed to identify any significant correlations between these variables and understand how they (can) influence each other.

- A correlation analysis between companies' stock values and the number of intellectual assets protected by patents, in the automotive and other business sectors, can assist in further visualizing the tradeoff involving patents.

- A problem of correlation to be addressed might be to better understand to what extent and manner the advancement of the EVs sector worldwide depends on the opening of Tesla's patents, as there may be many other factors that boosted (and can boost even more) the sector, such as the falling costs of ion-lithium batteries.

- Potential impact of the announcement on Tesla's subsidiaries.

- As the innovation process tends to be complex and time-consuming, capturing a correlation between the announcement and the companies' value a decade later could generate more knowledge about the patent system trade-offs.

- In March 2022, Russia issued a decree allowing the unauthorized use of inventions, utility models, and industrial designs owned by IP holders from non-friendly countries. This scenario can be studied to highlight the significance of the patent system for companies and how it is perceived by investors.

- Analyze potential growth in the market share of any Tesla competitor or supplier and the potential correlation between an increase in patent applications by these actors after the announcement.

8. Conclusion

An event study is relevant not only for providing evidence on market efficiency but for laying out a measure of the unanticipated impact of the event on the wealth of the firms' shares, evidence for understanding corporate decisions, examining effects, and assessing risks.

The potential monopoly power that a patent provides by guaranteeing exclusive exploitation, which can be translated into a competitive advantage for those who own it, is a system placed as an asset to the development of this work. The study hypothesis and its assumptions are held by these patent system features.

A stock market analysis of Tesla and its potential competitors and suppliers was conducted within an interval. The hypothesis posits that during the examined period, Tesla's market share declined while its competitors and suppliers experienced an increase. Through an event study methodology, it was found that contrary to the hypothesis, Tesla's shares and part of its competitors and suppliers appear to have risen. However, for the hypothesis to be refuted (or not) with the needed confidence challenges and limitations remain to be addressed.

From the discussion under law and economics, the justification of this effect seems to have space in the doctrine of open innovation, which asserts the sharing of knowledge between companies as a decision that tends to generate positive effects. This approach has increasingly gained ground within the industrial organization. However, this does not seem to be realistic for all companies, since the use of the patent system appears to be more efficient for the growth of some companies, especially small and medium-sized.

The present study does not aim to highlight possible negative features of the patent system but is an attempt to prove empirically the value that such a system has in the automotive industry. It should be noted that there are several externalities involved in the value of companies, from the profile of investors to the significance of other properties, such as trademarks. However, it is understood that the attempt to measure the patent system is necessary for better visualization of the trade-off that this system involves between incentive and open access, especially given that many inventions that may benefit society, such as those related to sustainable matters, are protected by patents.

Yet, theorizing about the benefit of the opening of patents for total welfare is impossible, because the present event study brings the constraints of every quantitative empirical legal research, as Epstein, L. and D. Martin taught, which is that observable implications are only conceptual claims about the relationship between or among variables (2010, p. 907).

Hence, regarding patents, open innovation, and industrial organization, continuing to observe what occurs with Tesla and its potential competitors and suppliers is essential for conclusions to be reached in the sector.

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Appendix

Table A: Tesla's innovations identified by the author

1	Battery charging based on cost and life
2	Method and apparatus for mounting, cooling, connecting and protecting batteries
3	Battery pack and method for protecting batteries
4	System and method for an efficient rotor for an electric motor
5	Selective cure of adhesive in modular assemblies
6	Thermal management system with dual mode coolant loops
7	Trickle charger for high-energy storage systems
8	Mitigation of propagation of thermal runaway in a multi-cell battery pack
9	Method and apparatus for identifying and disconnecting short-circuited battery cells within a battery pack
10	Varying flux versus torque for maximum efficiency
11	Improved heat dissipation for large battery packs
12	Induction motor with improved torque density
13	Flux controlled motor management
14	Battery pack temperature optimization control system
15	User configurable vehicle user interface
16	Adaptive soft buttons for a vehicle user interface
17	Active thermal runaway mitigation system for use within a battery pack
18	Battery Pack Enclosure with Controlled Thermal Runaway Release
19	Electric motor
20	Manufacturing method utilizing a dual layer winding pattern
21	Adaptive audible feedback cues for a vehicle user interface
22	Battery pack with cell-level fusing and method of using same
23	AC current control of mobile battery chargers
24	Charging efficiency using selectable isolation
25	Battery pack gas exhaust system
26	Park lock for narrow transmission
27	Host initiated state control of remote client in communications system

28	Battery pack enclosure with controlled thermal runaway release system
29	Intelligent temperature control system for extending battery pack life
30	Multi-mode charging system for electric vehicle
31	Active thermal runaway mitigation system for use within battery pack
32	Adaptive vehicle user interface
33	Method and device for maintaining completeness of cell wall using high yield strength external sleeve
34	Method for determining dc impedance of battery
35	System for improving cycle lifetime for lithium-ion battery pack and battery cell pack charging system
36	Battery pack having resistance to propagation of thermal runaway of cell
37	Preventing of thermal runaway of cell using double expansible material layers
38	Battery cell charging system using adjustable voltage control
39	Battery Pack Dehumidification System and the Method of Controlling the Humidity of a Battery Pack
40	Charge disruption monitoring and notification system
41	Electro mechanical connector for use in electrical applications
42	Liquid cooled rotor assembly
43	Method of balancing batteries
44	Multi-mode charging system for an electric vehicle
45	Method for interconnection of battery packs and battery assembly containing interconnected battery packs
46	Systems, methods, and apparatus for battery charging
47	Electric vehicle communication interface
48	Method and apparatus for maintaining cell wall integrity during thermal runaway using an outer layer of intumescent material
49	System and method for battery preheating
50	Control system for an all-wheel drive electric vehicle
51	Traction control system for an electric vehicle
52	Method and apparatus for maintaining cell wall integrity during thermal runaway using multiple cell wall layers
53	Battery charging time optimization system based on battery temperature, cooling system power demand, and availability of surplus external power

54	Cell thermal runaway propagation resistance using dual intumescent material layers
55	Cell thermal runaway propagation resistance using an internal layer of intumescent material
56	Electric vehicle thermal management system
57	Cell thermal runaway propagation resistant battery pack
58	Voltage estimation feedback of overmodulated signal for an electrical vehicle
59	Centralized multi-zone cooling for increased battery efficiency
60	Tunable frangible battery pack system
61	Early detection of battery cell thermal event
62	Thermal energy transfer system for a power source utilizing both metal-air and non-metal-air battery packs
63	Battery capacity estimating method and apparatus
64	AC motor winding pattern
65	Systems and methods for diagnosing battery voltage mis-reporting
66	Voltage dividing vehicle heater system and method
67	System for optimizing battery pack cut-off voltage
68	Cell cap assembly with recessed terminal and enlarged insulating gasket
69	Battery thermal event detection system using a thermally interruptible electrical conductor
70	Charge state indicator for an electric vehicle
71	Common mode voltage enumeration in a battery pack
72	Battery thermal event detection system using an optical fiber
73	Interface for vehicle function control via a touch screen
74	Corrosion resistant cell mounting well
75	Method of controlled cell-level fusing within a battery pack
76	Condensation-induced corrosion resistant cell mounting well
77	Battery thermal event detection system using an electrical conductor with a thermally interruptible insulator
78	Battery thermal event detection system utilizing battery pack isolation monitoring
79	Method and apparatus for battery potting
80	Efficient dual source battery pack system for an electric vehicle

81	Method for the external application of battery pack encapsulant
82	Integrated battery pressure relief and terminal isolation system
83	Leakage current reduction in combined motor drive and energy storage recharge system
84	Battery pack dehumidifier with active reactivation system
85	Liquid cooling manifold with multi-function thermal interface
86	Cell with an outer layer of intumescent material
87	Vehicle battery pack ballistic shield
88	Apparatus for the external application of battery pack encapsulant
89	Collection, storage and use of metal-air battery pack effluent
90	Method and apparatus for maintaining cell wall integrity using a high yield strength outer sleeve
91	Battery pack pressure monitoring system for thermal event detection
92	Operation of a range extended electric vehicle
93	Compact energy absorbing vehicle crash structure
94	Method and apparatus for maintaining cell wall integrity using a high yield strength outer casing
95	Cell separator for minimizing thermal runaway propagation within a battery pack
96	Method and apparatus for the external application of a battery pack adhesive
97	Method and apparatus for electrically cycling a battery cell to simulate an internal short
98	Charge rate modulation of metal-air cells as a function of ambient oxygen concentration
99	Front rail configuration for the front structure of a vehicle
100	Dual mode range extended electric vehicle
101	Fast switching for power inverter
102	Hazard mitigation through gas flow communication between battery packs
103	Method of controlling a dual hinged vehicle door
104	Method of operating a recharging system utilizing a voltage dividing heater
105	Electric vehicle extended range hybrid battery pack system
106	Dual motor drive and control system for an electric vehicle

107	Rigid cell separator for minimizing thermal runaway propagation within a battery pack
108	Bidirectional polyphase multimode converter including boost and buck-boost modes
109	Integrated energy absorbing vehicle crash structure
110	Dynamic anti-whiplash apparatus and method
111	Vehicle port door with wirelessly actuated unlatching assembly
112	Thermal barrier structure for containing thermal runaway propagation within a battery pack
113	Overmolded thermal interface for use with a battery cooling system
114	Low temperature charging of li-ion cells
115	Method for optimizing battery pack temperature
116	Battery pack venting system
117	Battery pack directed venting system
118	Dual load path design for a vehicle
119	Bumper mounting plate for double channel front rails
120	Swept front torque box
121	Method for making an efficient rotor for an electric motor
122	Front rail reinforcement system
123	Hazard mitigation within a battery pack using metal-air cells
124	Funnel shaped charge inlet
125	Rear vehicle torque box
126	Cleaning feature for electric charging connector
127	Vehicle front shock tower
128	Fuel coupler with wireless port door unlatching actuator
129	State of charge range
130	Method of operating a multiport vehicle charging system
131	Fast charging with negative ramped current profile
132	Battery coolant jacket
133	Electromechanical pawl for controlling vehicle charge inlet access
134	Battery pack overcharge protection system
135	Battery pack exhaust nozzle utilizing an sma seal retainer
136	In-line outer sliding panorama sunroof tracks

137	Power electronics interconnection for electric motor drives
138	System for absorbing and distributing side impact energy utilizing a side sill assembly with a collapsible sill insert
139	System for absorbing and distributing side impact energy utilizing an integrated battery pack and side sill assembly
140	Sunroof utilizing two independent motors
141	Charge port door with electromagnetic latching assembly
142	Reinforced b-pillar assembly with reinforced rocker joint
143	Extruded and ribbed thermal interface for use with a battery cooling system
144	Rotor temperature estimation and motor control torque limiting for vector-controlled AC induction motors
145	Method and apparatus for extending lifetime for rechargeable stationary energy storage devices
146	Mechanism components integrated into structural sunroof framework
147	Sunroof mechanism linkage with continuous one part guide track
148	Illumination apparatus for vehicles
149	Multiport vehicle dc charging system with variable power distribution according to power distribution rules
150	Host communications architecture
151	Integration system for a vehicle battery pack
152	Methodology for charging batteries safely
153	Dynamic current protection in energy distribution systems
154	Vehicle battery pack thermal barrier
155	Vehicle user interface with proximity activation
156	Low temperature fast charge
157	Battery module with integrated thermal management system
158	Electric vehicle battery lifetime optimization operational mode
159	Battery pack configuration to reduce hazards associated with internal short circuits
160	Integrated inductive and conductive electrical charging system
161	Robotic processing system and method
162	Power release hood latch method and system
163	Single piece vehicle rocker panel

164	Charge rate optimization
165	Method of withdrawing heat from a battery pack
166	Traction motor controller with dissipation mode
167	Wire break detection in redundant communications
168	Thermal management system for use with an integrated motor assembly
169	Electrical interface interlock system
170	Steady state detection of an exceptional charge event in a series connected battery element
171	Pyrotechnic high voltage battery disconnect
172	Charging efficiency using variable isolation
173	Active louver system for controlled airflow in a multi-function automotive radiator and condenser system
174	Battery cap assembly with high efficiency vent
175	Response to over-current in a battery
176	Secondary service port for high voltage battery packs
177	Controlling a compressor for air suspension of electric vehicle
178	Air outlet directional flow controller with integrated shut-off door

Table B: List of potential competitors

Competitor	**Company**	**Origin country**
Competitor 1:	Audi	Germany
Competitor 2:	BMW	Germany
Competitor 3:	BYD	China
Competitor 4:	Daimler/Mercedes-Benz	Germany
Competitor 5:	FCA	U.S.
Competitor 6:	Ford	U.S.
Competitor 7:	GAC	China
Competitor 8:	Geely	China
Competitor 9:	GM	U.S.
Competitor 10:	Honda	Japan
Competitor 11:	Nissan	Japan
Competitor 12:	Porsche	Germany
Competitor 13:	SAIC	China

Competitor 14:	Toyota	Japan
Competitor 15:	Volkswagen	Germany

Table C: List of potential suppliers

Supplier	**Company**	**Origin country**
Supplier 1:	Continental AG	Germany
Supplier 2:	Denso Co.	Japan
Supplier 3:	Hitachi, Ltd.	Japan
Supplier 4:	Hyundai Mobis/Mando Corporation	South Korea
Supplier 5:	LG Chem/ LG Energy Solutions	South Korea
Supplier 6:	Mitsubishi Group	Japan
Supplier 10:	NEC Co.	Japan
Supplier 7:	Panasonic Co.	Japan
Supplier 8:	Samsung SDI	South Korea
Supplier 9:	Toshiba	Japan

Table D: Summary of the Event Study – FCA, Ford and GM (WRDS, 2023)

Day Relative to the Event	**Mean Abnormal Return**	**Patell Z Test for Abnormal Return**	**Cross-sectional t-statistic for Abnormal Return**	**Patell Z for CAR (at the end of the event window)**	**Probability Patell Z for CAR (at the end of event window)**
-2	-0.000776	-0.063946	-0.466186	- 0.663166	0.4885929
-1	-0.00368	-0.460381	-6.004771	-0.663166	0.4073038
0	-0.012748	-1.70418	-4.340625	-0.663166	0.1594749
1	-0.000341	-0.051171	-1.009283	-0.663166	0.1539822
2	0.0068478	0.7967925	1.746554	-0.663166	0.253612

Table E: CAR and BHAR – FCA, Ford, and GM (WRDS, 2023)

Company	CAR	BHAR
FCA	-*	-*
GM	-0.005778	-0.005939
Ford	-0.015615	-0.015649

*Missing information.

Table F: Summary of the Event Study – Tesla (WRDS, 2023)

Day Relative to the Event	Mean Abnormal Return	Patell Z Test for Abnormal Return	Cross-sectional t-statistic for Abnormal Return	Patell Z for CAR (at the end of the event window)	Probability Patell Z for CAR (at the end of the event window)
-2	-0.014361	-0.420978	-*	1.3095463	0.4253337
-1	0.0141266	0.4141154	-*	1.3095463	0.4987757
0	0.0021539	0.0631393	-*	1.3095463	0.5100394
1	0.0111492	0.3268329	-*	1.3095463	0.5680186
2	0.0868213	2.5451248	-*	1.3095463	0.9048253

* It returned without value. It might be because the statistical test did not find significant variability in the abnormal returns across the sample of securities during the event window.

Table G: CAR and BHAR – Tesla (WRDS, 2023)

CAR (at the end of the event window)	BHAR
0.0998903	0.1001201

Table H: Summary of the Event Study – Ford, GM, and Tesla (WRDS, 2023)

Day Relative to the Event	Mean Abnormal Return	Patell Z Test for Abnormal Return	Cross-sectional t-statistic for	Patell Z for CAR (at the end of the event window)	Probability Patell Z for CAR (at the end of the

			Abnormal Return		**event window)**
-2	-0.005304	-0.295263	-1.145802	0.2145939	0.4474741
-1	0.0022558	-0.13681	0.3793866	0.2145939	0.4233898
0	-0.007781	-1.355004	-1.482408	0.2145939	0.2120858
1	0.0034891	0.1469165	0.9098028	0.2145939	0.2316262
2	0.0335056	2.1200068	1.252369	0.2145939	0.584958

Table I: Summary of the Event Study – SAIC (WRDS, 2023)

CAR (at the end of the event window)	**BHAR**
0.1186313	0.1292243

Table J: T-test Mean CAR – SAIC (StataCorp, 2023)

```
One-sample t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. err.   Std. dev.   [95% conf. interval]
---------+--------------------------------------------------------------------
   CAR_M |      58    .0250554    .0036037    .0274451    .0178391    .0322717
------------------------------------------------------------------------------
    mean = mean(CAR_M)                                            t =   6.9527
H0: mean = 0                                     Degrees of freedom =       57

    Ha: mean < 0                 Ha: mean != 0                 Ha: mean > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000
```

Table K: Summary on the Event Study – Audi, BMW, Mercedes-Benz, and VW (WRDS, 2023)

Company	**CAR**	**BHAR**	**Mean CAR (at the end of the event window)**
BMW	0.0663839	0.0680769	-0.011824
Audi	-0.027448	-0.027961	-0.011824
Mercedes-Benz	-0.027452	-0.029331	-0.011824
VW	-0.058778	-0.060479	-0.011824

Table L: T-test Mean CAR – Audi, BMW, Mercedes-Benz, and VW (StataCorp, 2023)

```
One-sample t test

------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. err.   Std. dev.   [95% conf. interval]
---------+--------------------------------------------------------------------
   CAR_M |      60   -.0065451    .0007288    .0056453   -.0080034   -.0050868
------------------------------------------------------------------------------
    mean = mean(CAR_M)                                            t =  -8.9807
H0: mean = 0                                     Degrees of freedom =       59

    Ha: mean < 0                 Ha: mean != 0                 Ha: mean > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000
```

Table M: Summary of the Event Study – Continental (WRDS, 2023)

CAR (at the end of the event window)	BHAR
-0.015798	-0.018742

Table N: T-test Mean CAR – Continental (StataCorp, 2023)

```
One-sample t test

------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. err.   Std. dev.   [95% conf. interval]
---------+--------------------------------------------------------------------
   CAR_M |      60   -.0203331    .0018839    .0145928   -.0241029   -.0165634
------------------------------------------------------------------------------
    mean = mean(CAR_M)                                            t = -10.7929
H0: mean = 0                                     Degrees of freedom =       59

    Ha: mean < 0                 Ha: mean != 0                 Ha: mean > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000
```

Table O: Summary of the Event Study – Honda, Nissan, and Toyota (WRDS, 2023)

Company	CAR	BHAR	Mean CAR (at the end of the event window)
Honda	-0.028181	-0.031682	0.0050519
Nissan	0.0362312	0.0375498	0.0050519
Toyota	0.0071054	0.006856	0.0050519

Table P: T-test Mean CAR – Honda, Nissan, and Toyota (StataCorp, 2023)

```
One-sample t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. err.   Std. dev.   [95% conf. interval]
---------+--------------------------------------------------------------------
   CAR_M |      58    .0043728    .0008436    .0064244    .0026836     .006062
------------------------------------------------------------------------------
    mean = mean(CAR_M)                                            t =   5.1837
H0: mean = 0                                     Degrees of freedom =       57

    Ha: mean < 0                 Ha: mean != 0                 Ha: mean > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000
```

Table Q: Summary of the Event Study – Denso, Hitachi, Mitsubishi, NEC Corporation, Panasonic, and Toshiba (WRDS, 2023)

Company	CAR	BHAR	Mean CAR (at the end of the event window)
Denso	-0.059462	-0.067461	0.0460487
Hitachi	-0.014453	-0.020677	0.0460487
Mitsubishi	0.077484	0.0855785	0.0460487
NEC Corporation	0.2177699	0.2583373	0.0460487
Panasonic	-0.003765	-0.007341	0.0460487
Toshiba	0.0587187	0.0631709	0.0460487

Table R: T-test Mean CAR – Denso, Hitachi, Mitsubishi, NEC Corporation, Panasonic, and Toshiba (StataCorp, 2023)

```
One-sample t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. err.   Std. dev.   [95% conf. interval]
---------+--------------------------------------------------------------------
   CAR_M |      58    .0106693    .0025374    .0193241    .0055883    .0157503
------------------------------------------------------------------------------
    mean = mean(CAR_M)                                            t =   4.2048
H0: mean = 0                                     Degrees of freedom =       57

    Ha: mean < 0                 Ha: mean != 0                 Ha: mean > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0001          Pr(T > t) = 0.0000
```

Table S: Summary of the Event Study – Samsung (WRDS, 2023)

CAR (at the end of the event window)	BHAR
-0.016434	-0.021348

Table T: T-test Mean CAR – Samsung (StataCorp, 2023)

```
One-sample t test

Variable |   Obs      Mean    Std. err.   Std. dev.   [95% conf. interval]
---------+------------------------------------------------------------------
   CAR_M |    56   .0041083    .0050706    .0379449   -.0060534     .01427
----------------------------------------------------------------------------
    mean = mean(CAR_M)                                          t =   0.8102
H0: mean = 0                                   Degrees of freedom =       55

    Ha: mean < 0                 Ha: mean != 0                 Ha: mean > 0
 Pr(T < t) = 0.7893         Pr(|T| > |t|) = 0.4213          Pr(T > t) = 0.2107
```