Mergers and innovation – New theoretical insights with an application to the PSA/FCA merger case

Tomás Portela Neves de Almeida

Thesis to obtain the Master of Science Degree in

Industrial Engineering and Management

Supervisor: Profª. Margarida Catalão Lopes

Examination Committee

Chairperson: Prof. Susana Relvas

Supervisor: Prof. Margarida Catalão Lopes

Member of the committee: Prof. Hugo Castro Silva

June 2021

Acknowledgments

I would like to start by thanking Professor Margarida Catalão Lopes, for all the help she gave me in writing this Dissertation. Besides helping me facing the obstacles in carrying out this work, Professor Margarida Catalão Lopes stimulated my interest and critical sense for the topic under analysis.

I would also like to thank my family: my parents, Fernando and Ana, and my sisters, Marta, Catarina, and Madalena, for their unconditional support.

Resumo

Para perceber o efeito das fusões na inovação, é feita uma revisão literária. Não há um resultado absoluto, os efeitos dependem principalmente das características da indústria em análise. É desenvolvido um jogo *à la* Cournot que será aplicado ao caso real da fusão PSA/FCA de modo a prever os efeitos desta nos níveis de inovação da indústria dos veículos elétricos. Este jogo é uma extensão de Ishida et al. (2011), onde os jogadores são considerados assimétricos, o produto é homogéneo e há inovação de processo. Esta inovação torna-se particularmente relevante devido à necessidade urgente de uma transição energética, para a qual a adoção de veículos elétricos pode contribuir significativamente. É concluído que as empresas que se fundem aumentam substancialmente o respetivo nível de inovação. As empresas que concorrem mais diretamente com a empresa fundida reduzem a sua inovação. As empresas que concorrem menos intensamente aumentam o seu nível de inovação (pois os investimentos em inovação são substitutos estratégicos) quando o investimento em inovação é suficientemente eficiente e diminuem-no nos outros casos. A diminuição observada é superior ao aumento, pelo que o efeito desta fusão na inovação da indústria será negativo. Os lucros da indústria aumentam com a fusão. Devido às sinergias criadas pela fusão, este aumento é maior quando o investimento em inovação é menos eficiente. O preço diminui com a fusão quando o investimento em inovação é ineficiente, novamente devido às sinergias criadas, o que proporciona um aumento de bem-estar do lado da procura, medido pelo excedente do consumidor.

Palavras-chave: Fusões, inovação, concorrência, oligopólio, decisões de política, PSA/FCA

Abstract

To understand the effect of mergers on innovation, a literature review is conducted. There is no absolute result, the effects depend mainly on the characteristics of the industry under analysis. Afterwards, it is developed a game *à la* Cournot that will be applied to the real case of the PSA/FCA merger in order to predict its effects on the innovation levels of the electric vehicle industry. This game is an extension of Ishida et al. (2011), where players are considered asymmetric, the product is homogeneous and there is process innovation. This type of innovation becomes particularly relevant due to the urgent need for an energy transition, to which the adoption of electric vehicles can significantly contribute. It is concluded that merging firms substantially increase their level of innovation. Firms that compete more directly with the merging firms reduce their innovation. Firms that compete less intensely increase their level of innovation (because investments in innovation are strategic substitutes) when investment in innovation is sufficiently efficient and decrease it in other cases. The observed decrease is larger than the increase, so the effect of this merger on the industry's innovation will be negative. The industry's profits increase with the merger. Due to the synergies created by the merger, this increase is higher when the investment in innovation is less efficient. The price decreases with the merger when investment in innovation is inefficient, again due to the synergies created, which provides an increase in demand-side welfare as measured by consumer surplus.

Keywords: mergers, innovation, competition, oligopoly, policy, PSA/FCA

Table of contents:

List of Tables

List of Acronymous

EC	European Commission
EV	Electric Vehicles
FCA	Fiat Chrysler Automobiles
FTC	Federal Trade Commission
M&A	Mergers and Acquisitions
PSA	Peugeot Société Anonyme
R&D	Research and Development
SOC	Second Order Conditions
US	United States

1. Introduction

In the last 20 years, more than 790.000 mergers took place worldwide with a known value of over 57 trillion USD. In 2019 alone, there were 49.327 mergers with a total value of 3.370 billion USD. North America and Europe are the regions with the highest number of mergers and the highest total value. In 2019, North America had over 15.500 mergers with a value of almost 2.000 billion USD, while Europe had over 17.000 mergers with a value of almost 900 million USD (Institute for Mergers, Acquisitions and Alliances, 2020). But why do firms engage in mergers?

Several reasons motivate firm merges, such as assess to new intangible assets, the creation of synergies, diversification, and tax benefits. However, the principal merger's key driver is growth. Through the merging of two different businesses, firms increase their size. Also, they get access to new customer segments and business opportunities. In several cases, mergers allow firms to grow faster and with more benefits than if they were to grow organically, which is why mergers occur (Duksaite and Tamosiuniene, 2009).

The growth that mergers proportionate to companies can lead to market power. From the company's perspective, that is a pleasant consequence. However, for the customers, that market power may lead to less consumer welfare. Several entities such as the European Commission (EC) and the Federal Trade Commission (FTC) regulate merger activity. The European Commission, in its *Merger Control Procedures (Council Regulation No 139/2004)*, stated that 'The regulation prohibits mergers and acquisitions which would significantly reduce competition in the single market, for example, if they would create dominant companies that are likely to raise prices for consumers'.

In addition to the EC, several authors such as Federico et al. (2018) defend that after a merger, prices may increase because of the reduction in competition. According to microeconomic foundations, this price increase triggers a consumer surplus decrease; that is, customers will be worse off if there are no countervailing forces associated with the merger, such as cost efficiencies.

Besides competition, mergers also affect innovation. It is not clear whether this influence is positive or negative. This relationship has been studied by several authors. However, there is still not a consensus amongst academics. For example, Régibeau and Rockett (2019), while analysing several perspectives about the impact of mergers on innovation, notice that authors positions differ: some defend the idea that mergers foster innovation, while others believe it decreases innovation. But why is the effect of mergers on innovation such an important subject to study?

In economic terms, innovation is crucial for the world economy since it is the principal determinant of long-term productivity, competitiveness between firms and consumer welfare (Ahmad and Rao, 2001). Therefore, if the effect of mergers on innovation is negative, it may result in consumer harm (Federico et al., 2018). Hence, competition policy is concerned with ensuring that innovation is fostered (Haucap and Stiebale, 2016).

Due to the importance of innovation, competition policy should prioritise forming regulation that contributes to increased innovation. This Dissertation aims to further explore the relationship between mergers and innovation and to comprehensively determine the principal factors that influence it. There are several theories about the polarity of this relationship (positive, that is, mergers foster innovation, or negative, that is, mergers decrease innovation). This Dissertation intends to analyse these different perspectives and contributes to the debate with new results. A theoretical model will be developed to derive new conclusions.

As has been established, the relationship between mergers and innovation is not clear. On the one hand, by joining expertise from two different companies, mergers can increase the ability to create new products and technologies. This leads to an increase in innovation and consumer welfare. However, acquirer firms can target similar companies to soften competition and to avoid the negative impact of rivals' innovation. This second situation leads to a decrease in innovation in the long term and to a decrease in consumer welfare caused by price increases (Ornaghi, 2009).

Merger policy tries to regulate the effects of mergers on innovation. It assumes that mergers decrease competition, hence they may decrease innovation. However, as there are several perspectives about the effects of mergers on innovation, it is difficult to reach a consensus when drawing policy implications (Marshall & Parra, 2019). If mergers foster innovation, merger policy should be more prone to accept them in order to increase innovation and, consequently, benefit consumers. If mergers decrease innovation, merger policy should control them even more, so they do not harm consumers. To better understand this relationship, it is imperative to analyse the primary literature about this topic. Hence, a literature review is presented in this Dissertation.

We will explore several theoretical models about the global effect of mergers on merging firms' innovation and rival firms' innovation. At the end of the literature review chapter, we will address empirical cases to understand how this works practically, starting with the empirical effect on generic industries. Then, we will examine the pharmaceutical industry case in more detail. As it is one of the most widely approached in the primary literature, both in theoretical and empirical models, understanding the polarity of the relationship may allow transposing some conclusions to other industries under certain circumstances.

Mergers can be divided into two types: horizontal and vertical. Horizontal mergers occur when the firms are in the same relevant market, while vertical mergers occur when firms are in upstream or downstream related markets. This Dissertation deals with horizontal mergers. It is also important to highlight that most papers on the subject analysed oligopolists markets, where there is action and reaction among players. In perfect competition and monopolist markets, firms do not react to each other. As this Dissertation intends to understand the firms' reactions to mergers, oligopolist markets are adequate ones to examine. Nevertheless, perfect competition and monopolists' markets will be briefly addressed to understand the effect of competition on innovation.

The literature review identifies a gap on which this Dissertation's theoretical model is based. After analysing several candidates, the framework from Ishida et al. (2011) was considered the most suitable to use as a departing point. The author considers a model in which there are two types of players: low-cost players (low marginal cost) and high-cost players (high marginal cost), that compete in a Cournot framework. Investment in R&D is cost reducing. This paper considers the existence of one low-cost player and N high-cost players and studies the impact of the number of high-cost firms (N) on the innovation level of all players. Then, the authors measure the impact of R&D investment on a change in N. Results show that if N increases, investment in the R&D of low-cost players increases, while investment in the R&D of high-cost firms decreases.

For this Dissertation to contribute to the existing literature on mergers and innovation, some extensions and adaptations will be made to the Ishida et. al (2011) model. In particular, we intend to consider a generic number of low-cost players and a generic number of high-cost players. To the best of my knowledge, this extension has not yet been made. It is relevant since it allows to make the model more realistic.

After developing a new theoretical model, this Dissertation addresses the real-life merger case between PSA and FCA groups. We intend to use the theoretical framework applied to this merger to test the developed model. This can help to predict the effects of the merger on the innovation levels of both the merging companies and the rivals.

The objective of this Dissertation is to develop a new theoretical model to study the effect of this merger on 3 areas. First, we want to evaluate the effects on the investment in innovation of both merging companies and rivals. Then, we want to understand the impact on the profits of the industry. Lastly, we want to evaluate the impact on the price, in order to understand the effect on consumers.

Regarding the practical merger case, PSA, or Peugeot S.A., is a French multinational manufacturer of automobiles sold under Peugeot, Citroen, DS, Opel, and Vauxhall brands. FCA, or Fiat Chrysler Automobile, is an Italian American manufacturer of cars sold under Fiat, Chrysler, Alfa Romeo, Jeep, RAM, Maserati, Lancia, Abarth and Dodge brands. These two companies are merging on a 50-50 deal, worth approximately 50 billion euros (Financial Times, 2020).

The new merged entity, Stellantis, will become the fourth largest car manufacturer in the world. Combined sales are expected to be approximately 8.7 million cars per year, generating revenues of over 190 million dollars (Forbes, 2019).

Since the merged entity will become one of the biggest car manufacturers in the world and due to the high monetary values involved, the EC opened an investigation in June 2020 to evaluate if the merger will have negative impacts according to the Commission's regulation (European Commission, 2020). The EC was concerned that the merger could reduce competition, especially in the light commercial vehicles segment. As outlined in section 3.1, there is a relationship between these two terms. If the degree of competition changes in any given industry, innovation is also expected to change. As innovation is considered very important for consumer welfare (Ahmad and Rao, 2001), the impact of a merger on competition is a crucial point for the EC's evaluation.

The investigation was completed on 21st December, and the merger was allowed by the EC (European Commission, 2020a). The merger was officially sealed by both companies on 16th January 2021 (Reuters, 2021).

One of the principal reasons leading FCA and PSA to merge was the creation of R&D synergies mainly related to electric vehicles (TIME, 2019). Furthermore, considering the current need to promote energy transition and intensify electric vehicles (EV) adoption, it is pertinent to study this merger's impact on innovation in the electric vehicle industry. Applying the theoretical model developed in this Dissertation may shed light on the PSA/FCA merger case and its consequences on innovation, a crucial competition variable in this industry. The results obtained may allow a better assessment of welfare impacts and hence help form the definition of new policies on the subject.

This merger can have serious implications in the EV industry as one of the principal reasons that lead these companies to merge was the development of EV vehicles technology (Auto Express, 2021). Before analysing the effects of this merger on innovation, it is pertinent to clearly understand the legal environmental reasons that influenced this merger and why it is expected that this merger will strongly impact the EV industry.

As more scientists started to understand the long-term impact of human's activity on Earth, sustainability became crucial to avoid climate change. To improve sustainability, businesses started to adapt to the energy transition: change fossil-based energy sources to zero-carbon energy sources. They started to generate power from renewable energies, as electricity, became an important part of the energy transition (S&P Global, 2020). To ensure that car manufacturers respect energy transition, European Union adopted new legislation, Regulation 2019/631. This regulation sets emission reduction as mandatory for all car manufacturers selling vehicles in Europe. It defines a maximum amount of emissions per car, meaning that the average emissions of all cars of a firm must stay below that. If the requirements are not met, firms may suffer heavy fines (European Commission, 2019).

Energy transition may require large investments for companies to stay competitive. Companies that have always produced fossil fuel vehicles started to realise that they had to shift a significant part of their fleet to a renewable energy source to comply with the existing regulation. It is in this context that PSA and FCA decided to merge. These companies, faced by the threat of these new regulations regarding the EV technology, decided to join forces to stay competitive. Both companies expect that the merger will lead to more innovation, so they can develop and improve their electric fleet (Forbes, 2019).

As this merger was strongly motivated by new regulations caused by the need for an energy transition, from fossil to renewable such as electricity, it is very important to analyse the actual effects of this merger on the innovation level of the EV industry. As previously noted, this merger can have a great economic impact on the automobile industry. Because of the economic relevance of this case (as referenced above, the merged entity will become the fourth largest car manufacturer in the world), the theoretical model developed in this Dissertation is applied to this merger in particular. Besides that, few scientific papers evaluate the effects of mergers on innovation in the automotive industry, even less if one considers EV instead of fossil fuel vehicles. Hence, besides addressing an important case, this Dissertation also intends to contribute to the existing literature on this subject.

It is important to note that the characteristics of the chosen industry make it suitable to test the theoretical model that will be developed. If we focus on a particular segment of the EV industry and define it as our relevant market, firms mainly compete in quantities (*à la* Cournot) since the prices and characteristics of EV in each segment are similar. Also, not all carmakers have the same costs, meaning that it is possible to identify high-cost and low-cost players in the industry (firm asymmetry). Besides that, innovation can be used to improve the manufacturing processes, resulting in lower costs. If innovation reduces production costs (such as lower battery costs), prices may drop (Weiss et al., 2012), meaning that EVs will become more accessible to the general population. Because of this, cost-reducing R&D, or process innovation, is considered the most adequate to be included in the Dissertation's model. Nevertheless, in Chapter 3, the characteristics of the EV industry that make it suitable for this model will be analysed in depth.

As mentioned, some extensions are going to be made to Ishida et al. (2011) model. They are very pertinent since they allow the model to be applied to the PSA/FCA case. Assuming that both firms may be considered high-cost players, the theoretical model of this Dissertation is applied to this merger in order to study the effects of the merger between these two high-cost players, determining the impacts on the innovation levels of both merging and rival companies. These effects will also be analysed as a function of N, which captures the general competition level in the market, and x, which captures the general degree of efficiency in the industry. We apply Game Theory, in particular the Nash equilibrium for simultaneous games. As stated previously, mergers can be horizontal or vertical. Since PSA and FCA are in the same relevant market (EV market), the merger under analysis is horizontal, meaning that the theoretical model can be applied to this real-life case.

The equilibrium results namely in terms of price variation and consumer surplus, EVs sales, profits of merging and non-merging companies and innovation levels will be applied in the Dissertation to the PSA/FCA merger case. It will be considered that these firms are high-cost, since both PSA and FCA at this point do not produce high quantities of electric cars. This assumption is analysed in detail in chapter 6. The main objective is to predict the effect of this merger on the merging companies' innovation and on the innovation of the rival brands in the same market segment. Additionally, we estimate the price change following the merger, a measure of consumers' welfare variation.

This Dissertation is organised as follows. In chapter 2, we perform a literature review to understand the positions of different authors regarding this Dissertation's subject. In Chapter 3, we conduct a detailed analysis of the EV industry to correctly identify its main characteristics. In Chapter 4, we explain the research methodology to be employed. In Chapter 5, the theoretical model is developed. In Chapter 6, this theoretical model is applied to the PSA/FCA merger. Finally, Chapter 6 presents the main conclusions.

2. Literature Review

Mergers affect innovation both direct and indirectly, through the change they cause at the competition level. The objective of this literature review is to understand how the authors have been dealing with this subject and to assess whether there is any dominant position on whether mergers spur innovation or not. Papers about both direct and indirect effects will be analysed. The structure of the literature review is the following: first, we analyse the relationship between merger and competition and between competition and innovation (indirect effect). Then, theoretical studies about the direct effect of mergers on innovation are assessed. Lastly, empirical studies based on several different industries are evaluated.

2.1 Competition and Innovation

Mergers tend to decrease competition through price and other strategies coordination by the merging firms (Federico et al., 2018). Since competition influences innovation and mergers influence competition, an indirect effect of mergers on innovation through competition can be recognised. It is crucial to understand this effect before analysing all aspects related to the direct impact of mergers on innovation.

The impact of competition on innovation is not well-defined, as various studies have led to mixed or inconclusive results (Cefis et al., 2007). Schumpeter defended that innovation was stronger in the presence of a monopoly. As there is no competition in this market structure, firms are not concerned with intellectual property being used by competitors. Also, Schumpeter believed that only monopolies had the capacity to invest in R&D considering the uncertainty of potential failures. Since small companies do not have the same resources as a monopoly firm, innovation is not fostered in competitive markets (Schumpeter, 1943).

Schumpeter is not the only author that defends the idea that market power fosters innovative activity. In an empirical study applied to British Manufacturing firms, Blundell at al. (1999) discovered that companies with a higher market share (dominant firms, facing less competition) were more innovative than smaller companies. Considering that dominant firms have more resources than smaller competitors, their incentive to innovate is to preserve their dominant position in the market. Also, dominant firms show more appropriability of innovation: their innovative activity translates into a higher market value when compared to innovative activity of smaller companies.

Arrow has approached this subject differently. The author defended that firms only engage in innovative activity if the post-innovation profits are sufficiently higher than the pre-innovation profits. This means that companies performing in a market with low levels of competition have few incentives to innovate, since the profits may not change in a great proportion. According to this rational, a company in a monopolistic situation does not have the required incentives to innovate since it has no competition, meaning profits after innovating may be very similar to the profits before innovating. Also, if a monopolist innovates, it destroys its previous innovation, an effect called *Replacement Effect*. Arrow stated that it is in perfect competition markets where firms foster more innovation, since they need to innovate in order to escape competition and increase profits (Arrow, 1962). In a recent paper, Boutin (2015) reaches a similar conclusion. The author shows that, in order for innovation to be fostered, there must be competition among firms. It is only in this way that firms have the incentive to increase their technological states and hence increase innovation for consumers.

Aghion et al. (2005) proposed a model that combined both Schumpeter and Arrow perspectives. This model argues that competition and innovation are connected through an inverted U-relationship. Innovation is defined as a "step-by-step" model. One company cannot immediately acquire innovation leadership, it must first go through all innovation steps until it reaches and passes the innovation leader in the industry. Considering this characteristic, it is possible to describe two innovation states in an industry: *neck-a-neck*, when all firms are at the same technological level, and *unlevelled*, when a firm has better technology than others (which are technological followers). Firms decide to innovate due to the increase in the expected profits after innovation. For lower levels of competition, the Arrow perspective is dominant: companies operating neck-a-neck decide to innovate to distance themselves from competition and increase profits – the escape competition effect. For higher levels of competition, the Schumpeterian perspective prevails, that technological followers (unlevelled industries) do not have the incentive to innovate, since the profits after innovation will not be very different from the profits before innovation, due to the presence of an innovation leader.

Tang (2006) confirms empirically Aghion et al. (2005) and Schumpeter (1943) perspective for a high level of competition: technological followers do not have the incentive to innovate, contrary to technological leaders. However, Tang (2006) states that Schumpeter perspective, even though correct, is based on faulty assumptions. The author says that market competition cannot be assessed directly, as Schumpeter suggests. It should be accessed through proxies such as market share and seller concentration. Even though using the new proposed measures to assess market power, Tang (2006) verified empirically that a high level of competition may foster innovation and that larger companies (innovation leaders) are more likely to engage in innovative activities compared to smaller companies (innovation followers).

In sum, there is not one unanimous position on the impact of competition on innovation. The different empirical and theoretical findings are difficult to reconcile (Cefis et al., 2007). This means that is not possible to, a priori, correctly define the exact effect of competition on innovation. It is important to analyse the specific industries' characteristics carefully before clearly understanding how competition and innovation are related (Crepon et al., 1996).

2.2 Theoretical effects of mergers on innovation

The relationship between mergers and innovation is important as it is widely recognised that innovation is one of the principal determinants in long-term growth and customer welfare (Federico et al., 2018). Due to the importance of innovation, competition authorities must control mergers to avoid those that may have a negative effect on innovation, while allowing the ones that may have a positive influence to form (Federico et al., 2017). Since mergers lead to an increase in market power (Denicolò and Polo, 2018; Clougherty and Duso, 2009) and around one quarter of large-scale horizontal mergers lead to collusion synergies (Clougherty and Duso, 2009), it is important for competition authorities to control merger activity.

Evidently, there is not a universally accepted position on how mergers affect innovation. It is necessary to clearly define the market structure and the industry dynamics in order to understand the true effect of mergers on innovation (Hollenbeck, 2020). If authors consider different market structure and industry assumptions, it is expected that different conclusions may arise. Different perspectives about this relationship are going to be analysed in the following sections.

When analysing this relationship, the effect of mergers on the innovation of rival firms is usually not mentioned by competition authorities in the merger's guidelines, they only analyse the impact associated with the merging firms (Haucap and Stiebale, 2016). However, the global effect also depends on the reaction of rival companies (Haucap et al., 2019). Changes and adjustments in the rival firms' innovation strategy are likely to happen after a merger. Hence, these effects should be accounted for in the global effect of mergers on innovation. Theories about the impact of mergers on the innovation of rival firms are also going to be analysed in this chapter.

Innovation usually results from R&D investments. When firms merge, several costs arise, and sometimes firms decide to invest in other areas rather than in R&D. This is unfortunate since the long-term performance of a company is positively related to R&D investments. When studying R&D investment, there are two important aspects to consider: R&D inputs, investment that companies do in R&D, and R&D outputs, which results from the investment (Hitt et al, 1991). In this Literature review, two types of R&D outputs (innovation) are considered: new products (product innovation), or new processes or technologies that allow cost reductions (cost-reducing innovation). Furthermore, cost-reducing innovation is considered to develop this Dissertation theoretical model, as explained in Chapter *2 Problem Definition*.

In the following subsections of this chapter, an extensive literature review about the direct theoretical effects of mergers on innovation will be performed. First, authors whose literature defends the negative effect of mergers on the merging companies' innovation will be analysed. Subsequently, papers that defend the ambiguous and positive effects of mergers on innovation of merging companies will be examined. Finally, to conclude the study of the theoretical effects, literature regarding the effects of mergers on rival companies will be analysed. Although there is limited literature on this topic, understanding the existing perspectives is important to establish an inclusive view on the subject.

2.2.1 Merging companies: negative effects on innovation

This subsection presents several studies that defend the negative impact of mergers on the innovation of merging companies. Prior to the analysis, it is important to mention that sometimes authors defend negative effects due to the circumstances considered or because the models are incomplete. Nevertheless, the papers are presented in this section to attempt to draw some global conclusions.

Federico et al. (2018) examined how horizontal mergers affect product innovation through its influence on market power. The authors consider an oligopoly with a sequential two-stage game: in the first stage, players decide the level of investment, while in the second stage, players decide the price of the products according to their quality. There is product differentiation. The merger brings the ownership of the two products to the same entity, which decides how much to invest and the price. The authors state that the mergers' effects on innovation occurs through two channels: *price coordination* and *innovation externality*. *Price coordination* is the elimination of price competition between the merging firms after a merger. The reduction of price competition increases the post-innovation profits; therefore, the authors consider that this channel has a positive effect on innovation. An *innovation externality* occurs when one of the merging firms sees its profits reduced because the other merging firm innovated. This channel has a negative effect on innovation. The authors observe that the *innovation externality* channel has a larger effect on innovation compared to the *price coordination* channel. Therefore, they conclude that mergers have a negative impact on innovation. The authors also conclude that mergers reduce consumer welfare because price rises and innovation drops. It is important to note that the effect of innovation efficiencies, such as knowledge spillovers and R&D coordination, was not considered in this model. The authors state that if these efficiencies are strong enough, then it is possible to overturn the decline of innovation due to market power.

Gilbert (2019) based their model on Federico et al. (2018) model. The new model was developed to account for an increase in the probability of discovering new innovations that mergers may proportionate and accounted for the existence of information spillovers. Profits at risk, which are the profits lost by one merging firm due to the other merging firm innovation, are not included in the model. The author considers a model with N symmetric firms where they first decide the investment in R&D, and then price the products according to the previous stage results. The paper concludes that competition promotes innovation, therefore if a merger reduces competition, it reduces innovation. For this author, it is important to study a merger in the long-term. Even if merging firms innovate in the short-term, they stop innovating after achieving a superior technological level. Then, innovation investment decreases in the industry because followers do not have an incentive to innovate, there is less competition and followers' profits will not change much. It is also found that, if profits at risk are included in the analysis, mergers tend to reduce even more innovation. This factor is similar to the *Innovation externality* described by Federico et al. (2018). Gilbert (2019) brings a new topic to the discussion. If technological leader spillovers are large enough, mergers can foster innovation. If followers can capture the leader's innovation, the leader will always try to innovate more to escape competition. This perspective is similar to the perspective of Aghion et al. (2005) for neck-a-neck industries.

Kesavayuth et al. (2018) reach a similar conclusion in a duopoly with differentiated goods. In a three-stage game where in the first stage firms decide whether to merge or not, in the second stage they decide which technology to use, and in the third stage they decide the output level, the authors conclude that mergers tend to decrease product innovation unless innovation efficiencies reduce the innovation cost. Through R&D spillovers and R&D coordination, it is possible to invest less in R&D and still be able to come up with innovations.

Motta and Tarantino (2017) focus their studies on cost-reduction innovation. They consider a price competition oligopoly with differentiated goods and more than 2 firms. The game is simultaneous. Firms decide the price of the product and the cost-reducing investment in just one stage. These authors do not address product innovation like Federico et al. (2018) yet reach a similar conclusion: in the absence of efficiency gains, mergers decrease the investment in innovation and reduce consumer welfare. Motta and Tarantino (2017) also defend that mergers reduce competition and, consequently, increase prices and profit margins. The authors found that in the absence of efficient gains, firms may not have sufficient incentives to invest. After a merger, there is pressure for both merging companies to increase prices. If one of the merging firms does not increase prices, demand will fall for the other. Hence, both companies will increase prices, and the total demand will fall. Since the quantity sold is lower, the effects of the investments in the company's profit will be diminished. Hence, due to this effect caused by the reduction in quantity, firms decide to reduce investment after a merger. These authors also defend that only in the presence of considerable merger efficiency gains, mergers will be pro-competitive.

Haucap et al. (2019) show the same negative effect of reduced competition on innovation. The authors develop a theoretical model where each firm in a three-player oligopoly can invest in product innovation and compete in prices and innovation. In their model, two of the firms face low innovation costs while the other faces high costs; the latter merges with one of the other two. The acquirer company could decide i) whether or not to merge with the target, ii) in case of merging, whether to incorporate the target's capabilities or shut it down. The authors find that, in a market with high research intensity before merging activity, the innovation rate declines after the merger. Since competition is softer after the merger, post-innovation profits will not be much different from pre-innovation profits. In technological markets (as the one being analysed), product innovation is used to differentiate products from the competitors and, consequently, increase prices. If competition is low, innovation will not have a differentiating effect compared to when competition is high. Therefore, prices will not increase as much as if we were analysing a very competitive environment. This means that if competition is low, the profits of innovation will be lower compared to when competition is high, meaning that firms will have less incentives to innovate. Therefore, there are less incentives to innovate after a merger, in the considered conditions. However, in markets with low research intensity before the merger, the effect is different: innovation is expected to increase, mainly because rival firms will use innovation as a response to the merger. Also, similarly to Motta and Tarantino (2017), Haucap et al. (2019) defend that if mergers generate sufficient efficient gains (mostly in the form of cost savings), they may increase innovation and, consequently, be beneficial for consumers.

Boutin (2015) state that for an industry to be innovative, it is necessary to have competition among its firms. Boutin defends, similarly to Aghion et al. (2005), that innovation is a "step-by-step" process. Firms innovate to escape competition. The author considers a model with N firms where first firms decide to merge and then decide if the R&D departments also merge (full merger) or are kept separated (conglomerate merger). There is product differentiation due to the different technological level of companies, and firms compete on prices. The author concludes that full mergers are worse for customers than conglomerate mergers because they reduce more innovation. Boutin (2015), alike

Haucap et al. (2019), focuses on the specific case of a merger to duopoly. The author reaches the same conclusion as Haucap et al. (2019): innovation decreases. Boutin states that in the duopoly case, prices rise, and technological leadership persists without being challenged. The author defends that mergers foster innovation only in the cases where there are several competing firms with a similar technological level, since symmetry and rivalry are key drivers for innovation.

2.2.2 Merging companies: ambiguous and positive effects on innovation

Some authors believe that mergers do not necessarily have a negative effect on innovation. The effect can be a priori ambiguous or even positive. In this subsection, papers that support this idea will be analysed.

Jullien and Fefouili (2018) show that the impact of mergers on innovation depends mainly on the balance between four different factors. The impact is not necessarily negative, since there are several factors that may spur innovation. The first factor is related to product innovation. The *Innovation diversion effect*, also described by Federico et al. (2018) as *innovation externality,* is the effect of one firm's innovation in the merging partner profits. Federico et al. (2018) consider that the impact of this factor on innovation is negative. However, Jullien and Fefouili (2018) argue that it may be positive: if one of the merging firms innovates and increases the price of the innovative product, it may not steal customers from the other merging firm because different levels of price may attract different customers. Therefore, this innovative product may increase profits and, possibly, foster more innovation. The second and third factors come from the increased market power originated by a merger. *Demand expansion effect* is the increase in innovation incentives in order to expand demand, due to the profit margin increase, induced by a merger. *Margin expansion effect* is the decrease of the merging firm's output in order to increase profit margins, by setting higher prices. This third factor, also observed in the Motta and Tarantino (2017) scientific paper, occurs in the absence of merger efficiencies, and decreases innovation incentives. The last effect is the *spillover effect*, the benefit of technological spillovers from rivals. This effect increases the incentives to innovate (Gilbert, 2019). Besides these four effects, Jullien and Fefouili (2018) defend that R&D complementarities and efficiencies between merging firms may boost innovation; hence they should also be analysed. Both Federico et al. (2018) and Motta and Tarantino (2017) do not consider these complementarities and efficiencies in their analyses, however they recognise that they could actually foster innovation if their impact is large enough. According to Jullien and Fefouili (2018), only after analysing the effect of the four factors described, is it possible to assess the impact of a merger on innovation. A priori, it is not possible to derive a solid conclusion, even though mergers can have positive effects on innovation.

Bourreau et al. (2019) study the impact of a merger on product innovation considering a duopoly with differentiated products and where firms compete in prices. The authors set a simultaneous game where firms decided prices and innovation levels at the same time. Spillovers and R&D synergies are not considered. These assumptions are similar to the ones in Boutin (2015) and Haucap et al. (2019) analysis for duopolies. However, contrary to these authors, Bourreau et al. (2019) consider that a duopoly merger can spur innovation. A duopoly merger decreases innovation if the innovation diversion ratio (loss of sales of one merging firm due to the other merging firm innovation) is greater than or equal to the price diversion ratio (sales that a company loses by increasing prices), and the per-unit return to investment in innovation does not change much. If these conditions are not verified, the author proves that the merger may foster innovation, with his model.

Hollenbeck (2020) investigates a model of a concentrated industry with differentiated products in which companies compete in prices. Firms first decide whether or not to merge and set the investment level to increase product quality. The author, through two assumptions, challenges an idea defended by Federico et al. (2017, 2018), Motta and Tarantino (2017), Boutin (2015), among other authors previously mentioned. Hollenbeck (2020) states that in a market with low competition, it is possible to foster innovation only if there are low barriers to entry and innovation is occasionally rapid and disruptive. Even though in the short-term after a merger, prices rise and consumer welfare drops, these mergers may create a speculative entry, meaning that outsider firms may enter in the market and start to compete with the existing firm. This is only possible to conclude due to the two assumptions made. In the long-term, the author believes that this increases competition and increases consumer welfare in a large way. Hollenbeck suggests that the competition authority, when controlling mergers, should consider if this effect can take place, because even if in the short-term this merger harms consumers, it may bring several benefits in the long-term.

Both mergers and innovations are key elements in a firm's competitive strategy, since these two elements can bring competitive advantages for a company. It is on this basis that Kleer (2002) studied the relationship between mergers and innovation. His objective was to study how a merger between companies that compete in quantities and invest in cost-reducing innovation would affect the overall investment in innovation. The author considered an oligopoly with 3 firms before a merger took place, with a homogeneous product. The game has two stages: in the first stage, firms decide the level of investment, while in the second phase, firms decided the quantities. The author found that mergers increase the investment in innovation. This effect is mainly driven by the scale effect. If firms invest more in innovation, marginal costs reduce. Hence, equilibrium quantity would increase, resulting in higher profits for the company.

In the Kleer (2012) model, knowledge spillovers between merging firms were not considered, despite the fact that mergers spur innovation. However, the overall effect of mergers on innovation is different if R&D coordination and diffusion of knowledge is considered and if it is not. If merging firms coordinate R&D and share ideas, innovation may increase (Régibeau and Rockett, 2019). In most of the papers analysed in section *2.1 Merging companies: negative effects on innovation,* the effect of R&D complementarities and synergies was not considered. Davidson and Ferrett (2007) proved that R&D synergies could spur innovation. The author proposes an oligopoly model with N firms, product differentiation and cost-reducing innovation. The game has two stages: in the first stage, firms decide the investment in R&D. In the second stage, firms compete on the product market. It was considered two different games: in one, firms competed according to Cournot, while in the other one, firms compete according to Bertrand. The model has the objective to assess the impact of R&D complementarities, synergies, and spillovers on innovation, depending on which quantity or price are the main factor. The authors conclude that, for both cases, these R&D complementarities could actually make mergers procompetitive, because the merging firms would exploit their knowledge and, together, reduce their marginal costs through innovation. The main point where the Cournot and Bertrand model diverge is related to the level of R&D synergies. In a Cournot model, mergers only increase R&D spending when the level of R&D spillovers are considerable, while in the Bertrand model, even with low R&D synergies, merging companies increase their R&D investment.

Denicolò and Polo (2018) also defended that R&D coordination could stimulate innovation after a merger. The authors stated that most papers that support the idea that mergers have a negative impact on innovation, do not consider something crucial: innovation sharing. This term suggests that innovation is not firm-specific, meaning that it can be shared and used by other firms, which implies that merging firms are able to share all R&D information with each other, allowing them to innovate more easily than the competitors. This effect creates a channel in which mergers may increase the value of innovations and hence stimulate R&D.

As we have seen, there are several different perspectives about the effects of mergers on innovation. The following tables summarise the theoretical models presented in sections 3.2.1 *Merging companies: negative effects on innovation* and 3.2.2 *Merging companies: ambiguous and positive effects on innovation.* The first table presents the papers that consider price as the competing variable. The second table presents the papers that consider quantity as the competing variable. In both tables, the papers are ordered by year.

Table 1. Theoretical models – Price competition with product differentiation

Author	Model	Conclusions
Davidson and Ferret (2007)	Oligopoly model with N firms and cost-reducing innovation. In the first stage, firms decide the level of R&D investment. In the second stage, firms decided their prices.	Mergers tend to be procompetitive and increase innovation even if R&D spillovers are not very high.
Boutin (2015)	Oligopoly with product innovation. Firms first decide to merge and then decide if the R&D departments merge or are kept separated.	Mergers reduce innovation because of the decrease in competition.
Motta and Tarantino (2017)	Oligopoly with cost-reducing innovation, simultaneous game where decide the price of the product and the cost-reducing investment in just one phase.	Absent efficiency gains, mergers tend to reduce innovation.
Federico et al. (2018)	Oligopoly with product innovation, sequential two-stage game: in the first stage firms decide R&D investment, in the second stage they decide the price of the product.	Mergers decrease product innovation. If R&D synergies are strong enough, mergers effect on innovation might be positive.
Gilbert (2018)	Oligopoly with product innovation. First, firms invest in R&D, then decide the prices according to the R&D outcomes.	Mergers decrease innovation and consumer welfare in the long-term, even if in the short-term this effect is not so clear.
Bourreau et al. (2019)	Oligopoly with 2 firms and product innovation. Simultaneous game where firms set ate the same time prices and innovation levels.	A duopoly merger, under certain conditions, can spur innovation.
Haucap et al. (2019)	Three-player oligopoly with product innovation. The acquirer company can decide i) whether to merge or not with the target, ii) in case of merging, whether to incorporate the target´s capabilities or shut it down.	In a market with high-research intensity after merger, innovation decreases after the merger.
Hollenbeck (2020)	Oligopoly with N firms and product innovation. Firms decide whether to merge and then the investment in R&D.	In the long-term, mergers foster innovation if there are low barriers to entry and innovation is occasionally rapid and disruptive.

Table 2. Theoretical models – Quantity competition

Author	Product nature	Model	Conclusions
Davidson and Ferret (2007)	Differentiated product	Oligopoly model with N firms and cost-reducing innovation. In the first stage, firms decide the level of R&D investment. In the second stage, firms decided their quantities.	Mergers tend to be procompetitive and increase innovation if R&D spillovers are considerable.
Kleer (2012)	Homogeneous product	Oligopoly model with 3 firms before merger and cost-reducing innovation. In the first stage, firms invest in innovation. In the second stage, firms set quantities.	Mergers spur innovation when innovation results in less marginal costs and firms compete on quantity.
Kesavayuth et al. (2018)	Differentiated product	Duopoly with product innovation, sequential three-stage game: first phase is the mergers decision, second phase corresponds to the technology decision, third phase is the output decision.	Mergers decrease innovation unless the investment cost is sufficiently low.

Although authors do not consider the same assumptions and hence reach dissimilar (and sometimes opposing) conclusions, some global insights can be extracted. In particular: i) Most of the authors that defend a positive effect of mergers on innovation point the same factors as a condition for innovation to spur: R&D synergies, knowledge sharing, R&D spillovers. Considering product innovation, these factors allow companies to improve their products with reduced costs, making it attractive to innovate. In the case of process innovation, these factors allow companies to decrease their production costs with lower investment compared to a no-merger situation. Even though competition decreases after a merger, the aforementioned factors make innovation less costly for the companies and, hence, an attractive option; ii) When analysing models that defend a negative polarity of the relationship under analysis, most of the authors (such as Motta and Tarantino, 2017; Federico et al., 2018; Haucap et al., 2019) do not consider the effect of efficiency gains, R&D synergies and spillovers, R&D coordination (mechanisms that allow merging firms to share information and reduce innovation costs, making it more attractive). Furthermore, these authors state that, in the presence of such factors, mergers may actually foster innovation. Hence, even though there is no consensus in the scientific community, this reasoning leads us to believe that when firms openly share information after a merger and coordinate R&D efforts, mergers can in almost all cases, foster innovation. Similarly, when firms merge but do not share information and do not create synergies, mergers do not foster innovation.

2.2.3 Rival Companies: effects on innovation

There is plenty of literature and different positions on how mergers affect the merging companies' innovation. However, the effect of mergers on rival firms has not been deeply studied (Haleblian et al., 2009). This effect on rival firms is very important, since the global effect of mergers on innovation does not exclusively depend on the merging companies: rival firms also play a key role (Haucap et al., 2019). In this chapter, existing literature about this effect will be analysed.

The effect of mergers on innovation of non-merging companies is a priori unknown. Rivals may behave less aggressively due to the decrease in market competition and, hence, decrease their innovation investment. However, they may also react aggressively and increase innovation in order to become more competitive (Régibeau and Rockett, 2019).

Rivals' reaction to a merger is not always the same, hence, it is difficult to predict. However, it is considered to depend mainly on two factors: market dependence and resource similarity. Nevertheless, it is also considered that the probability of an aggressive response is higher than a non-aggressive one. When the response is aggressive, firms may foster innovation through investment in R&D to create new products and regain market power (Uhlenbruck et al., 2017).

Most often, mergers lead to an increase rival firms' innovation. However, this increase is not enough to offset the decrease in innovation caused by the merging firms. That is why several authors consider a negative effect of mergers on innovation (Federico et al., 2018).

Valentini (2016) has studied the direct impact of mergers and acquisitions on the rival´s innovation strategies. The author performed an empirical study based on data of the pharmaceutical company. The results confirm Federico et al. (2018) position about the increasing in rivals' innovation. Valentini (2016) analysed a set of empirical data regarding the effect of mergers in patenting activity of rivals in a market with high-research intensity. Patents are considered to be the output of R&D; hence, they are proxy for innovation. The author found that rival firms react to a merger by increasing its R&D efforts. After a merger, merging firms need to focus on the organisational integration challenges and the financial short-term challenges. Knowing this, rival firms can engage in riskier R&D projects without risking staying behind the merging companies in case of failure. This means that mergers can be seen as a window of opportunity for rivals to try to innovate with less competitive risks.

Haucap et al. (2019) reach an opposite conclusion regarding high-research intensity markets. These authors also analyse empirical data. They conclude that in markets with high pre-merger research intensity, mergers tend to discourage innovation of rival firms. This innovation decline is due to the competition reduction caused by the merger. The authors also state that, in markets with low pre-merger research intensity, the effect on rivals' innovation is a priori unclear, and according to their theoretical model, it may end up being positive.

2.2.4 Firm asymmetry: effects on innovation

Firms do not all have the same cost structure. Production costs often differ from firm to firm (Ishikawa and Shibata, 2020). When firms have similar costs, they are said to be symmetric or homogeneous. When firms have different costs, they are asymmetric or heterogeneous. The cost difference between firms may influence the level of competition and R&D investment in the industry where they operate. Ishida et al. (2011) analysed this topic. The authors developed a Cournot model with one low-cost firm (low marginal costs) and N high-cost firms (high marginal costs) where R&D investment is cost-reducing. The objective was to evaluate how the intensification of competition, measured by the increase in the number of high-cost firms, would influence the investment in R&D. The author found out that an increase in competition stimulates the R&D investment of low-cost firms, while it always decreases high-cost firms R&D investment. Investment in cost-reducing R&D works as a commitment to expand capacity. If costs decrease and capacity increases, firms have higher margins. When low-cost firms notice that more high-cost firms are entering the market (increasing competition), they can use the R&D expansion strategy to increase their profits. Since low-cost firms can have higher margins than high-cost firms, this strategy works better for the former.

As Ishida et al. (2011), some papers have admitted firm heterogeneity when addressing mergers and R&D. Matsushima et al. (2013) investigated the effect of a merger between two firms on the investment level. Three types of mergers were considered: type 1, between efficient firms (low marginal cost), type 2, between one efficient and one inefficient firm, and type 3, between inefficient firms (high marginal costs). A three-stage model was developed: in the first stage, firms decide whether to merge; in the second stage, firms decide the level of investment in cost-reducing R&D; in the third stage, firms compete according to Cournot competition. When heterogeneous firms merge, the marginal cost of the merged entity becomes the lowest one, and output increases. When homogenous firms merge, the marginal cost remains the same, while output increases. The authors noted that the investment in cost-reducing R&D creates two gains: a direct one and a strategic one. In a Cournot model, when the marginal cost of one player decreases, its output increases - the direct effect caused by the R&D investment. At the same time, when the efficiency of one firm increases, rivals produce less, and the market price might increase - a strategic gain. Both gains depend on the number of players: direct gain decreases with the increase in the number of competitors, while strategic gain increases.

The authors found that mergers of type 1 always increase the investment in R&D. Type 2 and 3 mergers increase the investment in R&D if the cost difference between firms is not large. When a merger occurs, the number of firms in the market is reduced. This means that the direct gain decreases and the strategic gain increases. In the case of type 1 mergers, the number of efficient firms in the market is reduced. This means that the increase in the strategic gain will be higher than the decrease in the direct gain: since there are less efficient rivals, they will produce even less quantity. In the case of mergers of type 2 and 3, the number of efficient firms in the market is not reduced, meaning that firms only increase their investment level if its costs are not large. It was also found that type 1 mergers have a greater impact on the investment level than types 2 and 3. An efficient firm has a greater market share than an inefficient firm. This means that type 1 mergers reduce competition and, therefore, increase more the incentive to innovate than the other type of mergers.

Ishikawa and Shibata (2020) have also analysed the effects of firm's cost asymmetry on R&D investments. The authors developed a model with two asymmetric firms, one low-cost (low marginal costs) and one high-cost (high marginal costs). Firms compete à la Cournot in a simultaneous game with two stages: in the first stage they define the investment in cost-reducing R&D, and in the second stage they set quantities and compete in the market. Results show that, independently from R&D investment being cooperative or non-cooperative between firms, low-cost firms have higher investment levels compared to high-cost firms. This result is in line with Matsushima et al. (2013), where efficient firms (low marginal costs) invest more in cost-reducing R&D because of the increase in the strategic gains.

Although Ishida et al. (2011) and Ishikawa and Shibata (2020) models do not address mergers directly, they allow us to understand the relationship between firm's symmetry or asymmetry and R&D investment. This approach can be transposed to mergers, as it was done by Matsushima et al. (2013). It is very important to understand the relationship between firms' asymmetry and R&D investments since in the theoretical model that will be developed in this Dissertation, players will be asymmetric in terms of costs, as was outlined in Chapter 2 *Problem Definition*.

2.3 Empirical effects of mergers on innovation

Theoretical models predict an effect of mergers on innovation that can either be negative, positive, or ambiguous. There is not a clear conclusion that can be applied to all cases. However, when analysing empirical studies, the conclusion is different. Most empirical studies support a reduction of innovation after a merger (Szücs, 2014). In this section, empirical studies will be analysed. These studies, contrary to the theoretical ones, involved real companies and real data to derive conclusions. First, studies about the effects of mergers on innovation on several different industries will be seen. Then, the pharmaceutical industry is analysed separately, since it is an industry that has been studied by different authors.

As it was previously said, the PSA/FCA merger case is addressed in this Dissertation. Although an analysis on previous studies about the effects of mergers on innovation in the automotive industry would be insightful, this area has not yet been empirically explored in the existing literature. Therefore, it is not addressed in the following chapters.

2.3.1 Generic Industries

Hitt et al. (1991) analyse 191 different mergers and acquisitions from 29 different industries, completed between 1970 and 1986. Through the analysis of empirical data, they found that mergers reduce R&D inputs (investment) and R&D outputs (patents in the studied case) after a merger. In terms of R&D

inputs, mergers reduce the top-management commitment to innovation. If top-management is not committed, middle-management will also not be committed and, therefore, will not foster innovation inside the firm. In terms of R&D output, the authors assert that managers may use mergers as a substitute for innovation. If managers target firms with innovative technologies, they will not need to develop those technologies inside their companies. Hence, R&D outputs are acquired and not produced.

Blonigen and Taylor (2000) analyse the relationship between R&D intensity and merger activity, focusing on acquirer firms. The authors use data from a sample of 217 electronic and electrical US firms between 1985 and 1983, to evaluate the effect of mergers on a high R&D intensity industry. They obtain a negative relationship between mergers and R&D activity. Firms with low R&D activity have a higher probability of acquiring another firm (target). Usually, these targets are firms with a higher level of technology. The conclusion is that instead of investing in R&D, most acquirer firms would engage in mergers. This perspective coincides with the Hitt et al. (1991) theory that mergers may be used as a substitute of innovation.

Szücs (2014) studies the effect of mergers on the innovation of both acquirers and targets. The author uses a sample of 398 firms, from different industries, whose mergers were notified either to the European Commission or to the US Federal Trade Commission, between 1990 and 2009. Two indicators are used: R&D expenditures and R&D intensity (ratio between R&D expenditures and sales). The author finds that most of the targets are firms with an attractive technological portfolio (innovative firms), usually with a high level of R&D investment before the merger, but mostly with low levels of profits. After the merger, both R&D expenditures and R&D intensity decrease substantially in the target companies, which happens mainly because acquirer firms prefer to immediately use the innovative activity developed by the target firms instead of continuing to invest in R&D. Also, acquirer firms prefer to pursue their own agenda instead of keeping most of the target's R&D projects. Therefore, after a merger, targets decrease R&D investment and increase sales, becoming profitable firms. In terms of the acquirer firms, the paper concludes that R&D expenditures also decrease, but in a lower proportion. This decrease can be attributed to the reduction of the top-management commitment to innovation after the merger (Hitt et al, 1991). R&D intensity also decreases for acquirer firms, because sales usually increase in a great proportion after a merger. Szücs (2014) concludes that the effect of mergers on innovation is negative on both acquirers and targets, being more severe in the second case.

Stiebale and Reize (2011) results coincide with the other authors. They use a sample of more than 16.000 observations of German firms from different industries to analyse the impact on the innovation of the target firms. The authors obtain a negative correlation between mergers and innovation in the target firms. After a merger, the acquirer would reallocate the R&D activities and decrease the investment in the target firm's R&D. Hence, innovation would decrease in target firms.

However, not all authors have obtained an empirical negative relationship between mergers and innovation. Bertrand (2009) studied the impact of foreign mergers on innovation. The author considered a sample of 123 mergers and acquisitions of innovative French manufacturing firms from 1995 to 2001. In this sample, foreign companies merged with French targets. It measured the impact of a merger in the domestic R&D investment of the French target firms. It was concluded that when the acquirer is foreign, mergers have a positive impact on innovation of the target firm: the observed R&D budgets of the French target firms increased, meaning that the acquirer firms would invest more in the new R&D projects that the target firms would bring. Also, merging firms coordinate R&D in order to increase efficiencies. Contrary to Hitt et al. (1991), Bertrand (2009) argues that after a merger, managers do not reduce R&D investment. Instead, they seize the opportunity to increase R&D investment, since they believe that it represents a unique opportunity to innovate.

Stiebale (2013) also obtained a positive relationship between foreign mergers and innovation. This study analysed a sample of more than 320 German acquirer firms from different industries that reported M&A activity between 2002 and 2007. Acquirers could be foreign or domestic. The author compared the R&D investment when the acquirer was domestic and when it was foreign. It was observed that when acquirers were foreign, the R&D investment would increase more than when the acquirer firm was not foreign. This result is stronger in high research intensity industries. The author defends that this positive effect is due to policy measures that incentivise foreign companies to invest more.

In the theoretical analysis of mergers and innovation, several authors such as Denicolò and Polo (2018) have suggested that R&D synergies are a key contributing factor to ensuring that mergers stimulate innovation. Bena and Li (2011) analyse the empirical effects of synergies using M&A Thomson´s financial SDC database, with information related to different industries between 1986 and 2004. The authors show that mergers are more likely to occur when either technology synergies or product market synergies are present. When these two types of synergies are present, firms become close competitors competing for the same growth opportunities and market share. Acquirer firms usually look for target firms that fill a certain gap in their activity, hence the importance of synergies. Furthermore, the authors prove that mergers stimulate innovation and that technology overlaps, a form of technology synergy that consists of firms using the same technology in their activities, is the most important factor in ensuring that the post-merger innovation output is greater than the pre-merger innovation output.

2.3.2 Pharmaceutical Industry

The pharmaceutical industry is one of the most interesting industries to study the effect of mergers on innovation. This industry has experienced some of the largest mergers of the last decade. It also presents a high research intensity, meaning that innovation may be the key element of competition. Hence, it is an industry where mergers can raise anticompetitive concerns, making it an interesting study subject (Ornaghi, 2009).

As stated in Chapter 2, the pharmaceutical industry is analysed in detail, in this chapter, as this industry is one of the most studied when it comes to the effects of mergers on innovation.

In the last few years, the pharmaceutical industry has experienced a structural change. Between 1970 and 2010, the productivity of the pharmaceutical innovation did not increase as expected. As such, the cost associated to new innovations have increased, since it is increasingly difficult to make new discoveries. In addition, several patents have expired between 2000 and 2010, forcing companies to spend more money on new patents. To overcome these adversities, some companies looked for mergers, since they allowed R&D synergies (Comanor and Scherer, 2013).

Comanor and Scherer (2013) argue that it could be expected that, considering the previous environment conditions, mergers would foster innovation. R&D synergies would allow R&D costs to decrease, so companies can keep investing. However, the authors observe that mergers have led to fewer innovation. One of the explanations provided is that after a merger, companies would invest in several different projects to achieve the same end (parallel paths). This strategy decreases the focus in each path and, according to the authors, decreases the R&D output, making innovation more uncertain.

Ornaghi (2009) divided the R&D of the pharmaceutical companies into two phases: discovery and development. Discovery is about discovering new compounds and patenting them, while development is about testing those compounds. The author performed a study about how mergers affect the innovation related to the discovery phase. Similarly to Comanor and Scherer, (2013), before analysing empirical data, Ornaghi (2009) posed the hypothesis that the effect could be positive due to the following factors: cost reduction by avoiding duplicative research, knowledge synergies between merging firms and less knowledge spillovers since there is one less competitor. Ornaghi (2009) analysed a sample of 27 mergers between 1988 and 2004. The analysis is restricted to pharmaceutical firms whose stock market value exceed one billion dollars at least once during the analysis period. However, after analysing empirical data, the author discovered that mergers actually reduce innovation. Observed merging firms produced less patents compared to the control group. It was also found that a high level of technology relatedness before mergers, do not lead to better innovation outcomes, and it may incentivise companies to invest less in innovation. This can be explained by the decrease in competition. By joining similar firms, a merger decreases competition and may create technological barriers to entry that decrease innovation.

Haucap et al. (2019) analyse a sample of 65 merger cases among 381 European firms, between 1991 and 2007, provided by the European Commission. As Ornaghi (2009), these authors focus on the discovery phase. To assess the effect of mergers on innovation, the R&D expenditures and the patenting before and after the merger, were compared. The conclusion was clear: mergers reduce R&D expenditures and patenting activity of both the merging entity and competitors. The reduction of the patent activity is 30% for merging firms and 7% for competitors. The authors also found that the target firms usually have lower research intensity compared to the acquirers. Nevertheless, the decrease in the patent activity only happens on average, three to four years after the merger, meaning that firms take time to adjust to the new environment. This innovation decline is due to the competition decrease.

The following table provides a summary of the papers presented in section 3.3 *Empirical effects of mergers on innovation*. The results ordered by industry, first generic and then specific ones, and year, from the oldest to the newest.

Table 3. Empirical Papers

Author	Industry Data	Conclusion
Hitt et al. (1991)	191 different acquisitions from 29 different industries, completed between 1970 and 1986.	Mergers reduce R&D inputs (investment) and R&D outputs (patents).
Bena and Li (2011)	M&A Thomson´s financial SDC database, with information related to different industries between 1986 and 2004.	When there are synergies between merging firms, mergers tend to spur innovation.
Stiebale and Reize (2011)	More than 16.000 observations of German companies from different industries.	Mergers reduce innovation especially in the target firms.
Stiebale (2013)	320 German acquirer firms from different industries that reported cross-border merger activity between 2002 and 2007.	When the acquirer company is foreign, the investment in R&D is higher compared to when the acquirer is a domestic company.
Szücs (2014)	398 firms from different industries, whose mergers were notified either to the European Commission or the US Federal Trade Commission, between 1990 and 2009.	After merging, innovative target firms tend to decrease innovation. Acquirers also decrease innovation.
Blonigen and Taylor (2000)	Electronic and electrical industry in US (high R&D intensity). 217 firms, between 1985 and 1983.	Negative relationship between mergers and innovation. Firms with lower technological levels tend to merge instead of investing in R&D.
Bertrand (2009)	123 cross-border mergers and acquisitions of innovative French manufacturing firms from 1995 to 2001.	In the case of cross-border mergers, target firms usually spur innovation. Mergers tend to increase innovation when the acquirer firm is foreign in relation to the target firm.
Ornaghi (2009)	27 mergers between 1988 and 2004. The analysis is restricted to pharmaceutical firms whose stock market value exceeded	Merging firms decrease its innovation, they produce less patents. Also, Technology relatedness between merging

	one billion dollars at least once during the referred period.	firm's pre-merger is a factor that contributes to the innovation decrease.
Haucap et al. (2019)	65 merger cases among 381 firms in Europe, between 1991 and 2007. Pharmaceutical industry.	Mergers reduce R&D investment and patent activity for both merging firms (30%) and competitors (70%).

Regarding the generic industries, except for Bena and Li (2011) and Stiebale (2013), all the authors agree that mergers will decrease innovation. The main reason noted is that mergers may require a great number of resources. Since resources are finite, if a company spends a great share of them in one area, other areas may naturally suffer from lack of investment. And if competition decreases after the merger, the investment in innovation may not be seen as a priority. Therefore, it may end up being reduced.

All the mentioned authors that studied the effects of mergers on innovation in the pharmaceutical industry reached the same conclusion: innovation decreases. Comanor and Scherer (2013) suspect that this happens because firms, after a merger, invest in a greater number of projects, meaning that the investment is not concentrated, therefore it will produce less results. Ornaghi (2009) and Haucap et al. (2019) point to a different reason, the decrease in competition. If competition is reduced, firms may not need to innovate much to keep their market position.

Unlike in section 2.2, there is little focus on R&D coordination and synergies. Only Bena and Li (2011) refer to this topic. The analysis in this chapter suggests that, empirically, mergers decrease innovation unless there are synergies that truly reduce the investment costs. The model developed in this Dissertation will add to this discussion.

3. Electric vehicles industry Characteristics

In order to apply a theoretical model to a certain industry, it is crucial to understand its characteristics. In this chapter, the EV industry is presented. Four characteristics or assumptions are crucial to choose the model: type of competition (price or quantity), type of product (homogeneous or heterogeneous), cost structure (symmetric or asymmetric players) and type of innovation (product or process).

The EC defines several passenger car classifications (European Alternative Fuels Observatory, 2019). In this Dissertation, these car classifications are treated as market segments because models inside the same segment compete directly with each other. In terms of segments or classes, A class refers to city cars, B class to small cars, C class refers to medium cars, and so on. These market segments are the same for fossil fuel cars and EVs because the defining characteristics of each segment is not the type of fuel, but other specifications such as size and weight.

Inside each class or market segment, despite considering different brands, prices are very similar. To prove this, Table 4 presents A class prices for fossil fuel cars in Portugal, new vehicles, in 2020 or 2021. In this class, it is possible to find several cars such as the Fiat 500, the Opel Adam, the Volkswagen Polo.

Table 4. Class A fossil fuel cars price

Cars	Price in €
Fiat 500	16.000
Opel Adam	15.470
Volkswagen Polo	17.560

Sources: Car Plus (2021); Opel Auto Industrial (2021); Volkswagen (2021)

If we consider standard cars (not special editions), the similarity between prices can be observed in every segment. It is important to consider that prices may slightly differ due to the equipment included or special offers, nevertheless the base price is similar.

Furthermore, it is possible to transpose this conclusion for EVs. Table 5 shows the average prices in European Union for market segment A of EVs.

Table 5. Class A EVs price

Cars	Price in €
Seat Mii Electric	20.650
Skoda Citigo-e iV	20.950
Renault Twingo Z.E.	21.350
Smart ForTwo ED	21.940
Volkswagen e-UP!	21.975

Source: WattEV2Buy (2020)

From this analysis, we make the first assumption of this chapter. Since all of the prices inside a segment are very similar, when a brand wants to launch a new EV for segment A, for instance, it will not be able to decide a different price from the one that is being practiced in that segment. If it chooses a different price, it will compete in an entirely different segment. Inside each segment, a firm can only decide the quantity that it wants to produce (besides other variables, but not price). Therefore, inside each market segment, firms compete à la Cournot.

The second characteristic or assumption that we will make regards product differentiation: are products inside the same segment homogeneous or heterogeneous? To analyse this, we will use the cars described in Table 4. To understand if the cars are similar, the principal characteristics related to the engine (horsepower, fuel consumption, emissions) and the principal extras can be analysed in Table 6. The fossil fuel cars were chosen for this comparison as it is easier to find reliable information about them. Nevertheless, conclusions can be transposed to the EVs, since inside each segment, the main features of the cars are similar too.

Table 6. Class A vehicle characteristics

Characteristics	**Fiat 500**	**Opel Adam**	**Volkswagen Polo**
Horsepower, CV	69	90	80
Fuel Consumption, l/100km	4.2 – 6.2	5.7 – 7.0	5.3 – 5.6
Emissions, g/km	115	129 - 157	121 - 128
Air Conditioner, GPS, ABS	Yes	Yes	Yes

Sources: Car Plus (2021); Opel Auto Industrial (2021); Volkswagen (2021)

As one can see, the main features of the cars are very similar. Although it is possible to find some characteristics in one model that another one does not present, most of the characteristics are common among them, especially the most relevant ones (the ones that impact the user experience). Therefore, we conclude that, from a functional point of view, cars inside each segment are very similar. Hence, we will treat the products as homogeneous inside each market segment.

The third assumption that we make has to do with the cost structure of the EVs producers. Are they cost symmetric or asymmetric? It is difficult to find data directly related to the costs of each producer. However, some indicators can be used to predict if the production cost is the same for all manufacturers. In terms of the PSA/FCA merger, it is known that the PSA group has more advanced technology regarding EVs (Auto Express, 2021). Therefore, it is expected that PSA has lower production costs than FCA. Even though there is not much information publicly available about this topic, it is expected that a company that invests more in R&D (considering cost-reducing investment) will have lower costs. Therefore, it will be considered that players in this industry may have different cost structures.

The fourth and last assumption of this chapter is related to the type of innovation considered. Innovation can be product or process innovation. Both types occur in the EV industry. In terms of product innovation, the range (driving range of a vehicle using only electric powered batteries) may increase, and the charging time may decrease. In terms of process innovation, production costs may decrease (for example, battery costs). Before deciding which type of innovation should be addressed in our model, it is important to understand the main determinants for customers when deciding to acquire an EV.

As explained in Chapter 2, the objective of energy transition is to replace fossil fuel sources of energy by renewable energies. For the automobile industry, this means selling more EVs. In order to help this shift, some Governments started to subsidy the acquisition of EV (Soltani-Sobh et al., 2015). In other words, Governments helped decrease the price of EVs so they would be more attractive for customers. This fact may indicate that price is a determinant factor for customers when deciding to buy an EV. However, it is not the only factor. Becker et al. (2009) defend that the adoption rate of EVs is mainly related to two aspects: price and operating costs related to product characteristics (range, switching batteries). The price can be overcome through cost-reducing innovation, while product characteristics (longest range, lower charging time) can be improved through product innovation. So, which type of innovation should be chosen?

The cost of producing EVs has been falling over the last few years and is expected to continue to do so in the upcoming ones (Hidrue et al., 2009). Between 2010 and 2019, the most used type of battery, Lithium-ion (Carmagazine, 2020), saw its price drop from 1182.9 USD/KWh to 156 USD/KWh (International Energy Agency, 2020). This change in cost, an 87% decrease, is only possible due to cost-reducing innovation and it is expected to decrease the prices of EV (Soulopoulos, 2017), facilitating EV adoption and hence energy transition.

Furthermore, Adepetu and Keshav (2017) analysed the barriers to the adoption of EV. These authors compared the weight of the price and the weight of the driving range in the decision to buy. They found that even though driving range has an influence, the price is the main barrier for a customer to acquire an EV. They also suggest that policies should be implemented to decrease battery costs (in order to decrease the price) since it is the most expensive part of EVs. Once again, it is possible to see that the effects of process innovation (decreasing costs) can overcome the effects of product innovation (increasing range) in the buyer's decision.

As stated in Chapter 1, one of the ways to achieve energy transition is through the adoption of EVs instead of fossil fuel vehicles, since EVs arise as one of the principal solutions for the decarbonisation of the mobility sector. However, the increasing demand of the lithium-ion batteries is creating some environmental concerns, as only around 10% of them are recycled (Gu et al., 2017), with many components ending in landfills or stored. EVs will only be a good alternative to the fossil fuel vehicles when all of its life cycle has a small energetic footprint. Even if they produce less emissions, the rest of its life cycle is still very pollutant, meaning that the balance may not be positive. So, how can the industry solve this problem? With process innovation, through the development of new methods to recycle the existing batteries. The search for efficiency has always been an important driver of the automotive industry. Through the development and adoption of new technology, it is possible to increase up to 80%

the components of electric batteries that are recycled (PV Magazine, 2019), balancing the footprint of EVs and increasing the efficiency of electric batteries.

As process innovation can influence both the decision to buy and the energy transition goal, it is the type of innovation that is going to be considered in this Dissertation theoretical model.

4. Research Methodology

The literature review has shown that the results among the scientific community on whether mergers increase or decrease innovation, are numerous and varied. Many different theoretical models and empirical cases were analysed, and the results varied case by case, according to the assumptions considered. The purpose of this Dissertation is to contribute to the discussion of this important topic through the creation of a new theoretical model and its application to a pertinent real-life case. So, in the first part, a theoretical model with oligopoly competition will be proposed and the corresponding Nash equilibrium obtained. Before that, in this chapter, three different candidates (models) are going to be analysed to choose the starting point of the theoretical model. Then, in the second part, this model is used to analyse the PSA/FCA merger, in order to predict its effects on the EVs industry and to help derive policy implications that stimulate innovation and increase social welfare. As demonstrated, the EV industry is considered to be a highly relevant topic of study, due to the changes that are occurring (energy transition) and the economic impact of the PSA/FCA merger.

We intend to address the impact of mergers on innovation of both merging companies and rivals from a point of view of cost-reducing innovations, considering cost asymmetry between players, an issue which, although clearly relevant, has been almost neglected in the literature. Also, most of the reviewed models analyse games where players compete in prices. Also, we have the objective of exploring the impact of mergers on innovation when firms compete in quantities to complement the existing literature. These characteristics can be applied to market segments of the EV industry.

When performing the literature review, three papers emerged as candidates to be the starting point of the theoretical model that we intend to develop: Ishida et al. (2011), Kleer (2012) and Haucap et al. (2019).

Ishida et al. (2011) investigate the strategic R&D investment in cost-reducing innovations, considering an oligopoly with N firms competing in quantities in the market for a homogeneous product. The game is two-stage: in the first stage, firms decide the level of investment in R&D; in the second stage, players engage in Cournot competition, considering the effect of the previous R&D investment on marginal cost. There are two types of players: one low-cost player (low marginal cost) and N-1 high-cost players (high marginal cost). Knowledge spillovers occur. The authors found that an increase in competition may stimulate the R&D investment of low-cost firms, while it always decreases high-cost firms' R&D investment. In order to create an extension to this model and make it more realistic, the number of low-cost players could be generalised to X instead of just one.

Kleer (2012) develops an oligopoly model with three firms before merger and cost-reducing innovation. Products are homogeneous and firms compete in quantities. In the first stage, firms invest in innovation. In the second stage, firms set quantities. Before deciding whether to invest in innovation or not, firms choose if they want to merge. If so, the game is played by two companies instead of three. Knowledge spillovers are not considered. The authors have the objective to evaluate the effect of horizontal mergers on process innovation of both merging firms and outsider firms. Since knowledge spillovers are not considered, innovation stays within the company, it cannot be used by its rivals. It was discovered that mergers foster innovation when innovation reduces marginal costs and firms compete on quantity. To the best of my knowledge, an extension of this model has not yet been executed, considering the fact that knowledge spillovers happen. Therefore, it is a possibility for the theoretical model of this Dissertation.

As previously described, Haucap et al. (2019) investigate the effect of horizontal mergers on product innovation. The authors consider a three-company oligopoly in which firms compete on prices and products are heterogeneous. In this model, one of the firms is less efficient innovating (higher costs to innovate) while the others are more efficient (lower costs to innovate). One of the most efficient firms merges with the less efficient. The authors found that mergers reduce innovation of both merging companies and rivals. One possible extension for this model would be to consider quantity competition instead of price competition since it has not yet been done.

As highlighted in Chapter 3, there are several characteristics that must be respected to consider the EV industry. Not all the extensions proposed respect those characteristics. Even though the Kleer (2012) model describes quantity competition and cost-reducing innovation, it assumes that, in the beginning, all the firms have the same marginal costs. As we will see in chapter 6, firms produce very different quantities, and production costs may differ. Therefore, the extension to Kleer (2012) is discarded. The extension to Haucap et al. (2019), would assume product innovation and price competition. We intend to address process innovation and quantity competition, so, we will evaluate the impact of marginal cost reductions in quantity. Therefore, this extension is also discarded and can returned to in future work which considers product innovation.

In turn, Ishida et al. (2011) seems suitable to model the EV industry. It considers quantity competition, process innovation, players with different marginal costs, homogeneous product. Therefore, it will be chosen to proceed with this Dissertation's theoretical model.

In the intended extension, the model will be adjusted by generalising the number of low-cost players (X). We intend to assess the effect of mergers on innovation as a function of X and N, in a three-stage game in which players initially decide whether to merge or not, then decide the level of innovation in cost-reducing R&D and finally compete à la Cournot. Cost-reducing R&D is considered since it allows to reduce EVs prices, making them more attractive to customers. This is very important since lower EVs prices can contribute for the FCA/PSA to achieve the EC regulation policies, that have the objective to achieve the energy transition. The subgame perfect Nash equilibrium will be derived, and conclusions drawn. Finally, policy implications will be derived.

The next chapters have the following structure. First, based on Ishida et al. (2011) model, we define the theoretical model that we intend to apply to the PSA/FCA merger case. Then, we analyse data regarding the European EV industry in order to determine the number of companies that operate in the market. Afterwards, we apply the theoretical model to the merger under analysis. We first calculate the equations relative to the investment levels in innovation and quantity supplied in the pre-merger scenario. Then, we simulate the merger and obtain the new equations. Following on from this, we analyse merger profitability as well as its impact on price, quantity and consumer surplus. Using the data presented in

Chapter 3, we simulate different results for this merger. We intend to draw conclusions especially in terms of innovation, profits, quantity and price, and consumer surplus. This Dissertation will culminate with a conclusion of the main findings of the study.

5. Theoretical Model

5.1 Setup

The theoretical model for this Dissertation is based on Ishida et al. (2011). Therefore, we will consider a standardised version of Cournot competition with cost-reducing R&D investments. We consider an industry with a total number N of firms denoted by i є {1, 2, …, N}, which can be high-cost firms (there are n_H of these) or low-cost firms (there are n_L of these, with $n_H+n_L=N$). As we intend to allow for the possibility of mergers inside each group, both n_H and n_L must be larger than or equal to 2. The model has two stages. In the first stage, firms decide the level of cost-reducing R&D investments, which will determine the marginal cost of production. In the second stage, considering the marginal cost previously defined, firms engage in Cournot competition, defining the quantities that they will make available in the market.

Consider x_L and x_H the investment level chosen by low-cost and high-cost firms, respectively. A unit increase in the level of investment will reduce the firm´s marginal cost in the same proportion. Let z_L and z_H be the ex-ante marginal cost (before innovation) of the low-cost and high-cost firms, respectively. It is important to note that $z_H > z_L$. If a firm decides to invest in innovation, its marginal cost becomes $c_L \equiv z_L - x_L$ for a low-cost firm and $c_H \equiv z_H - x_H$ for a high-cost firm. c_L and c_H are the ex-post marginal costs (after innovation). Subsequently, the total production cost is given by $(z_L - x_L)q_L$ for low-cost firms and $(z_H - x_H)q_H$ for high-cost firms, where q_H and q_L denote the production level of firms.

When firms invest in cost-reducing innovation they incur a cost, represented by γx_L^2 for low-cost firms and by $\gamma\, x_H^2$ for high-cost. Parameter γ represents the efficiency of the investment in cost-reducing R&D. If this investment is efficient, meaning that it is possible to innovate with fewer resources, γ is low. If the investment is not efficient, meaning that a great number of resources are needed to reduce the marginal cost, γ is high.

The inverse demand function can be written as P = 1 – Q, where $Q = \sum_{j=1}^{nH} qj + \sum_{k=nH+1}^{N} qk$ (sum of the high-cost and low-cost firms quantities, respectively). The total quantity can also be written as $Q = n_H.q_H + n_L.q_L$.

5.2 Subgame perfect Nash equilibrium

In this subsection, the subgame perfect Nash equilibrium is obtained. The optimisation problems faced by the companies will be examined in order to reach an equilibrium that describes the game.

As usual, we solve the game backwards. That is, we start in the second stage where firms decide the quantities conditional on the investment levels chosen in the first period, and then go back to obtain the investment levels, Finally, we replace these in the quantities to reach the final equilibrium expressions. The objective of each firm is to choose its quantity in order to maximise own profit. This optimisation problem can be written as:

(1)

$$\text{Max}_{q_L} \pi_L^E = [1 - n_H q_H^E - n_L q_L^E - (z_L - x_L)]\ q_L^E - \gamma x_L^2$$

$$\text{Max}_{q_H} \pi_H^E = [1 - n_H q_H^E - n_L q_L^E - (z_H - x_H)]\ q_H^E - \gamma x_H^2$$

The superscript E henceforth denotes the equilibrium value of the variable. Assuming that interior solutions exist, the equilibrium values of the quantity variables can be written as (usual Cournot competition result, under this model specificities):

(2)

$$q_L^E = \frac{1+(n_L-1)(z_L-x_L)+n_H(z_H-x_H)-(n_H+n_L)(z_L-x_L)}{1+n_H+n_L}$$

$$q_H^E = \frac{1+n_L(z_L-x_L)+(n_H-1)(z_H-x_H)-(n_H+n_L)(z_H-x_H)}{1+n_H+n_L}$$

The expressions in (2) are a function of the investment levels, x_H and x_L. As expected, each group's quantity is increasing in own innovative activity, and decreasing in the other group's level of x, that is $\frac{\partial q_i}{\partial x_i} > 0$ and $\frac{\partial q_i}{\partial x_j} < 0$ (i, j = L, H). Replacing the optimal quantity in the profit function, we obtain the equilibrium profit as a function of the number of firms in each group, marginal costs, investment levels and the investment efficiency.

(3)

$$\text{Max}_{x_L} \pi_L^E = \frac{[1-(z_L-x_L)+n_H((z_H-x_H)-(z_L-x_L))]^2}{(1+n_H+n_L)^2} - \gamma {x_L}^2$$

$$\text{Max}_{x_H} \pi_H^E = \frac{[1-(z_H+x_H)+n_L((z_L-x_L)-(z_H-x_H))]^2}{(1+n_H+n_L)^2} - \gamma {x_H}^2$$

The equilibrium profit of each type depends negatively on own production costs and positively on the other type's costs. The investment cost is quadratic, so the marginal investment cost is linear, growing with innovation (if the investment cost was linear, the marginal cost of innovation would be constant).

In the first stage, firms simultaneously choose the investment level to reduce marginal cost. The first-stage optimisation problem faced by each firm can be described as choosing x_L/x_H to maximise π, taking other firms' choices as given.

(4)

$$\frac{\partial \pi_L^E}{\partial x_L^E} = 0 \;\Leftrightarrow\; x_L^E = \frac{(n_H+1)(1-(n_H+1)z_L-n_H(x_H-z_H))}{\gamma(1+n_H+n_L)^2-(1+n_H)^2}$$

$$\frac{\partial \pi_H^E}{\partial x_H^E} = 0 \;\Leftrightarrow\; x_H^E = \frac{(n_L+1)(1-(n_L+1)z_H-n_L(x_L-z_L))}{\gamma(1+n_H+n_L)^2-(1+n_L)^2}$$

These are the reaction functions of the investment level: ceteris paribus, how each firm's innovative activity responds to a change in the innovative activity of the other group. As is evident from the expressions, x_L and x_H are strategic substitutes: the cross derivatives are positive in the equilibrium. This means that an increase/decrease in the innovative activity by one group triggers an increase/decrease in the innovative activity by the other group. The response depends on the competition level in each group, as measured by the respective numbers of firms n_L and n_H, and on the investment efficiency parameter γ.

Solving the system of equations given in (4), we obtain the equilibrium investment levels, as a function of the number of firms, the initial marginal costs, and the efficiency level of the innovative investment.

(5)

$$x_L^E = \frac{(n_H+1)[\gamma\,(n_H+n_L+1)\big(1-z_L+n_H(z_H-z_L)\big)-(1-z_L)(n_L+1)]}{\gamma\,(n_H+n_L+1)[\gamma\,(n_H+n_L+1)^2-(n_H+1)^2-(n_L+1)^2]+(n_L+1)(n_H+1)}$$

$$x_H^E = \frac{(n_L+1)[\gamma\,(n_H+n_L+1)\big(1-z_H-n_L(z_H-z_L)\big)-(1-z_H)(n_H+1)]}{\gamma\,(n_H+n_L+1)[\gamma\,(n_H+n_L+1)^2-(n_H+1)^2-(n_L+1)^2]+(n_L+1)(n_H+1)}$$

In section 6.2, we analyse in detail how the marginal costs and γ affect the investment in innovation.

In order to ensure positive investment levels, we must impose a condition on γ. Since this parameter also affects other expressions, in the next chapter, we see all of the conditions associated with it and choose the most binding one, so it can be applied to all cases. This step is imperative to ensure that our model gives reliable conclusions.

Replacing the equilibrium levels of x_L and x_H into the quantities' expressions, we obtain the equilibrium quantities as functions of the number of firms in each group, the corresponding marginal costs and the efficiency of the innovation investment.

(6)

$$q_L^E = \frac{(n_H+n_L+1)\gamma\,[\gamma\,(n_H+n_L+1)\big(1-z_L+n_H(z_H-z_L)\big)-(1-z_L)(n_L+1)]}{\gamma\,(n_H+n_L+1)[\gamma\,(n_H+n_L+1)^2-(n_H+1)^2-(n_L+1)^2]+(n_L+1)(n_H+1)}$$

$$q_H^E = \frac{(n_H+n_L+1)\gamma\,[\gamma\,(n_H+n_L+1)\big(1-z_H-n_L(z_H-z_L)\big)-(1-z_H)(n_H+1)]}{\gamma\,(n_H+n_L+1)[\gamma\,(n_H+n_L+1)^2-(n_H+1)^2-(n_L+1)^2]+(n_L+1)(n_H+1)}$$

As expected, the equilibrium quantity for each type of firm depends negatively on its own marginal costs, and positively on the other type's marginal cost. This means that the firms with a lower marginal cost will produce more compared to its competitors, what is expected since we are considering Cournot competition. Also, the equilibrium quantity depends positively on γ. This is also expected, because if the investment in cost-reducing R&D is more efficient, it will produce lower marginal costs and the quantity produced increases subsequently.

5.3 Conditions for high-cost and low-cost firms existence

Before we proceed with the development of this model, we must set conditions for solutions to be interior, that is, to determine whether the interior solutions actually exist. Our first reasoning led us to believe that to determine the existence of these solutions, we only need to look at the high-cost firms. If the high-costs operate, then the low-costs surely also do, as they have lower marginal costs, so higher profits ceteris paribus. If low-cost companies have very small costs, high-cost companies may not operate in this market. Therefore, we need to ensure that the second order conditions (SOC)<0, x_H^E> 0, and q_H^E> 0. However, with cost-reducing innovation, the marginal cost of the initial high-cost firms may become smaller compared to the low-cost firms, and the effect may be the opposite, initial high-cost companies driving low-cost ones out of the market. Therefore, we will analyse the profit, investment, and quantity expressions also for low-cost companies. In the end, we choose the most binding conditions to ensure the reliability of this model.

All the conditions are solved according to γ . As previously stated, this parameter reflects the efficiency of companies in innovative activity. Since this parameter may be difficult to determine a priori in a real-life application, having restrictions on it may contribute to the reliability of this Dissertation model. Also, as this Dissertation aims to analyse the impact of mergers on innovation, we consider that this innovation parameter is interesting to analyse in detail.

Before starting to analyse more deeply our model, it is important to recall the conditions imposed on the other variables: n_H, n_L >2; z_H, z_L < 1; z_H > z_L. Also, before advancing to the conditions, note that the denominator of x_H, x_L, q_H, and q_L is equal. To simplify the presentation of the equations, the expression of the denominator is going to be presented as "Denominator > 0" or "Denominator > 0". These terms refer to the following solutions:

Denominator > 0:

(7)

$$\gamma < \frac{2n_H+2n_L+n_H^2+n_L^2+2-\sqrt{4n_H^2+4n_H^3+n_H^4+4n_L^2+4n_L^3+n_L^4+2n_H^2n_L^2-n_Hn_L}}{2(1+n_L+n_H)^2} \lor$$

$$\gamma > \frac{2n_H+2n_L+n_H^2+n_L^2+2+\sqrt{4n_H^2+4n_H^3+n_H^4+4n_L^2+4n_L^3+n_L^4+2n_H^2n_L^2-n_Hn_L}}{2(1+n_L+n_H)^2}$$

Denominator < 0:

(8)

$$\gamma > \frac{2n_H+2n_L+n_H^2+n_L^2+2-\sqrt{4n_H^2+4n_H^3+n_H^4+4n_L^2+4n_L^3+n_L^4+2n_H^2n_L^2-n_Hn_L}}{2(1+n_L+n_H)^2} \lor$$

$$\gamma < \frac{2n_H+2n_L+n_H^2+n_L^2+2+\sqrt{4n_H^2+4n_H^3+n_H^4+4n_L^2+4n_L^3+n_L^4+2n_H^2n_L^2-n_Hn_L}}{2(1+n_L+n_H)^2}$$

Condition 1: $\frac{\partial^2 \pi_H}{\partial x_H^2} < 0$

(9)

$$\gamma > \frac{(1+n_L)^2}{(1+n_L+n_H)^2}$$

Condition 1 is related to the satisfaction of the SOC. If the second-degree derivative of the high-cost firms´ profit in order to their investment is negative, it means that we are at a maximum point. If we are at a maximum, the equilibrium investment level is the one that gives the firms the highest profit.

Condition 2: $x_H^E > 0$ and $q_H^E > 0$

(10)

$$\gamma > \frac{(1-z_H)(1+n_H)}{(n_H+n_L+1)(1-z_H-n_L(z_H-z_L))} \ \wedge \text{ Denominator} > 0$$

(11)

$$\gamma < \frac{(1-z_H)(1+n_H)}{(n_H+n_L+1)(1-z_H-n_L(z_H-z_L))} \ \wedge \text{ Denominator} < 0$$

When solving $x_H^E > 0$ and $q_H^E > 0$ in order to γ the results are the same since the expressions are similar. Therefore, to simplify, these two conditions are grouped into one.

Condition 2 states that the investment in cost-reducing R&D and the quantity produced by high-cost firms must be positive. This basic condition is logical since firms only operate in a certain market if they produce for there. From equation (5) and (6) for high-cost companies, one can interpret that there are two possibilities to ensure that $x_H^E > 0$ and $q_H^E > 0$: both the numerator and denominator are positive (10), or both are negative (11). Therefore, multiple conditions are retrieved from here.

Condition 3: $\frac{\partial^2 \pi_L}{\partial x_L^2} < 0$

(12)

$$\gamma > \frac{(1+n_H)^2}{(1+n_L+n_H)^2}$$

Like condition 1, condition 3 is related to the satisfaction of the SOC but focusing on the low-cost firms.

Condition 4: $x_L^E > 0$ and $q_L^E > 0$

(13)

$$\gamma > \frac{(1-z_L)(1+n_L)}{(n_H+n_L+1)(1-z_L+n_H(z_H-z_L))} \ \wedge \text{ Denominator} > 0$$

(14)

$$\gamma < \frac{(1-z_L)(1+n_L)}{(n_H+n_L+1)(1-z_L+n_H(z_H-z_L))} \ \wedge \text{ Denominator} < 0$$

When solving $x_L^E > 0$ and $q_L^E > 0$ the results are the same, as the expressions are similar. Therefore, once again, these two conditions are grouped into one.

Condition 4 states that the investment in cost-reducing R&D and the quantity produced by low-cost companies must be positive. This basic condition is logical since firms only operate in a certain market if they produce there. From equation (5) and (6) for low-cost companies, one can see that there are two possibilities to ensure that $x_L^E > 0$ and $q_L^E > 0$: both the numerator and denominator are positive (13), or both are negative (14). Therefore, two more conditions are retrieved from here.

Once all the conditions of existence are analysed, it is necessary to identify the most binding ones, so the results of this Dissertation model are more reliable. As it is possible to see, these conditions depend on several different variables: n_H, n_L, z_H, and z_L. Without knowing any relationship between these parameters, it is not possible to identify the most binding conditions. Even though some conditions may be very similar, since numerical relationship a priori between n_H/n_L and z_H/z_L is not established, conclusions cannot be derived. In order to identify the necessary conditions, some assumptions will have to be done. These assumptions are chosen according to the case that the model intends to explain.

6. PSA/FCA model

In this chapter, we intend to define a relationship between n_H and n_L so it becomes possible to identify the most restrictive conditions of existence of the companies. Since this Dissertation intends to analyse the EV industry, we find it pertinent to analyse the number of high-cost and low-cost players in this industry, to apply the general model to it.

The EV industry is a worldwide industry. However, not all players operate in all markets. This Dissertation will focus on the European market. Not surprisingly, there is no public information available regarding the production costs of EV car brands. Therefore, we will use the total production as a proxy for the costs. Although the model being developed only applies to players in the same market segment (it cannot be used to compare players that operate in different market segments, as stated in Chapter 4), we assume that if a brand produces a higher total quantity, it can achieve lower production costs across all of its car segments.

The EV component with the highest cost is the battery, since it represents almost half of the total production cost (König et al., 2021). With the exception of the battery, all of the other car parts are the same in EV and fossil-fuel vehicles (exterior, interior, chassis, assembly, etc.). Therefore, it is in the battery where car manufacturers have the possibility to decrease production costs. If a car brand produces more quantity than a competitor, it is assumed that it will take more advantage of scale economies and, therefore, incur in lower average costs. As such, we will assume that car brands with higher production levels are low-cost, and car brands with lower production levels are high-cost.

According to the Schmidt Automotive Report of December 2020 (Financial Times, 2020a), sales of EV by brand in Europe were the following:

Table 7. Car sales by manufacturer, December 2020

Car Manufacturer	December 2020 sales (units)	% of total sales
VW Group	44.790	27,8%
Tesla	26.881	16,7%
Renault / Nissan / Mitsubishi / Dacia	26.020	16,2%
Hyundai / Kia	16.251	10,1%
Mercedes / Smart	10.408	6,5%
PSA	9.451	5,9%
Volvo	6.385	3,9%
BMW / Mini	5.242	3,3%
Fiat	5.058	3,1%
Jaguar	4.597	2,9%
Mazda	3.064	1,9%
Saic / MG	1.436	0,9%
Honda	1.375	0,8%

Sources: Financial Times (2020a)

Since there is no sales data available for the market segments, we use the sales data for the entire market in our model. We assume that companies sell the same quantity across all segments.

Some car brands appear together since they share platforms in EV production. As is clear in Table 7., there is a great variation in the sales of EVs across all brands. If a certain brand sells fewer cars, it will also produce fewer cars. Following the rationale outline thus far, brands with higher sales and, subsequently, higher production will take advantage of economies of scale.

In this Dissertation, we consider that the 4 manufacturers with the highest sales are low-cost, while the other 9 are high-cost. We are thus taking 10% of market share as the bottom line for firms to start having low marginal costs in their production. This assumption implies that $n_H >> n_L$ and will help to define the conditions of existence for both types of firms. Of course, this assumption is specific to the industry being analysed and must be adjusted if the general model is applied to other industries.

Regarding the PSA and FCA groups, it is possible to see that PSA is represented on the table while FCA is not. As stated in Chapter 1, the FCA group is composed of several car manufacturers. From these manufacturers, only Fiat sells EVs in Europe. Therefore, only Fiat is represented in Table 7., representing the FCA group.

6.1 Investment level of the firms in the EV industry

After defining n_L and n_H, we are left with 3 variables: z_H, z_L, and γ. These variables will guide the analysis of this Dissertation theoretical model. Considering $n_L = 4$ and $n_H = 9$, the investment levels of both types of firms can be computed:

(15)

$$x_L^E = 5\,\frac{126\gamma\, z_H - 140\gamma\, z_L + 14\gamma - 5(1 - z_L)}{1372\gamma^2 - 875\gamma + 25}$$

$$x_H^E = 5\,\frac{-35\gamma\, z_H + 28\gamma\, z_L + 7\gamma - 5(1 - z_H)}{1372\gamma^2 - 875\gamma + 25}$$

As outlined in Section 5.3, we must ensure that the investment level of both types of companies is positive (otherwise there is no game being played). We will keep using γ in order to obtain the existing conditions. z_L will also be used. If low-cost companies have very small costs, they may drive high-cost companies out of the market. Therefore, z_L must comply with a minimum condition relative to z_H in order to ensure that high-cost firms exist in the market.

<u>Second-Order Conditions:</u>

Before analysing the investment level functions, it is important to recall the SOCs, equations (9) and (12). If we replace n_L and n_H, it is possible to obtain the first γ condition:

(16)

$$\gamma \geq \max\{(\frac{n_H+1}{n_L+n_H+1})^2, (\frac{n_L+1}{n_L+n_H+1})^2\} = \max\{(\frac{9+1}{4+9+1})^2, (\frac{4+1}{4+9+1})^2\} = 0.510$$

From the SOCs, it is possible to derive that $\gamma > 0.510$ to ensure that the equilibrium values obtained for the investment levels are indeed maximums (and not minimums).

x_L conditions:

After analysing the SOCs, we proceed to the investment level functions. Since the denominators of both x_L and x_H are equal, we start by analysing them:

(17)

$$1372\gamma^2 - 875\gamma + 25 = 0 \Leftrightarrow \gamma = 0.030 \vee \gamma = 0.608$$

The equation above is a convex quadratic function. After calculating the zeros, we observe that the denominator is positive when $\gamma < 0.030$ or $\gamma > 0.608$, and it is negative when $0.030 < \gamma < 0.608$. Recall that we have already established that $\gamma > 0.510$.

Looking at the x_L function, its numerator can be either positive or negative. Therefore, we need to look closely to understand its sign.

(18)

$$\frac{\partial(126\gamma z_H - 140\gamma z_L + 14\gamma + 5z_L - 5)}{\partial\gamma} = 14(9(z_H - z_L) + 1 - z_L) > 0, \text{since } (z_H - z_L) > 0 \text{ and } (1 - z_L) > 0$$

(19)

$$126 * 0.510z_H - 140 * 0.510z_L + 14 * 0.510 + 5z_L - 5 =$$

$$= 64.26(z_H - z_L) + 7.14(1 - z_L) - 5(1 - z_L) > 0$$

By deriving the x_L numerator in order to γ, expression (18), it is possible to see that it is positive, meaning that the numerator increases its value if γ increases too. If we substitute the minimum $\gamma = 0.510$ in the numerator of x_L, (19), its value is positive. Since the numerator of x_L is positive in its minimum, it is possible to conclude that the numerator of x_L is always positive for $\gamma > 0.510$.

However, for $0.510 < \gamma < 0.608$, x_L is negative because the denominator is negative. Then, to ensure that $x_L > 0$, we must impose $\gamma > 0.608$.

x_H conditions:

As it was said previously in this chapter, z_L must have a minimum so high-cost firms can compete in the market. In order to find this minimum, we derivate the numerator of x_H in order to γ:

(20)

$$\frac{\partial(-35\gamma\, z_H + 28\gamma\, z_L + 7\gamma + 5z_H - 5)}{\partial\gamma} =$$

$$= -35z_H + 28z_L + 7 = -7(5z_H - 4z_L - 1) = 7[-4(z_H - z_L) + 1 - z_H] > 0 \Leftrightarrow z_L > \frac{5z_H - 1}{4}$$

As has been concluded, γ >0.608, hence the denominator is positive. Therefore, to ensure that x_H>0, a positive condition was imposed in (20). This minimum z_L value must be respected.

After determining a minimum value for z_L, we look at the γ condition for x_H. We already know that the derivative of x_H to γ is always positive, meaning that x_H increases with γ. Therefore, we substitute γ =0.608 in the x_H numerator to know if x_H is positive in its minimum:

(21)

$$-35(0.608)z_H + 28(0.608)z_L + 7(0.608) + 5z_H - 5 = -16.28(z_H - z_L) - 0.744(1 - z_L)$$

Since the x_H numerator is negative and the denominator is positive, x_H is negative. This means that γ =0.608 does not assure that high-cost firms exist. Therefore, in order to find a new value for γ, we need to ensure that the numerator is larger than 0:

(22)

$$-35\gamma\, z_H + 28\gamma\, z_L + 7\gamma + 5z_H - 5 > 0 \Leftrightarrow \gamma > \frac{5(1-z_H)}{7(1-z_H)-28(z_H-z_L)} \;\; if \;\; 7(1-z_H) - 28(z_H - z_L) > 0 \;\; or \;\; \gamma < \frac{5(1-z_H)}{7(1-z_H)-28(z_H-z_L)} \;\; if \;\; 7(1-z_H) - 28(z_H - z_L) < 0$$

It can be seen that $7(1 - z_H) - 28(z_H - z_L) < 0$ is not possible since $z_L > \frac{5z_H-1}{4}$.

$\gamma > \frac{5(1-z_H)}{7(1-z_H)-28(z_H-z_L)}$ guarantees that x_H and x_L>0. Therefore, from now on, γ has to respect this limit as well as the previous one, γ>0.608.

Before advancing, let us analyse the denominator of the previous γ condition:

(23)

$$7(1 - z_H) - 28(z_H - z_L) > 0 \Leftrightarrow z_L > \frac{5z_H - 1}{4}$$

This condition was already seen in equation (22). It also needs to be considered to ensure that x_H and x_L>0.

Before advancing to the quantity analysis, let us compare the level of investment of L and H firms before the merger:

(24)

$$x_H^E - x_L^E = \frac{(z_H - z_L)(25 - 805\gamma) + \gamma(35z_L - 60)}{1372\gamma^2 - 875\gamma + 25} < 0$$

It is clear that low-cost firms invest more in innovation than high-cost ones. One possible explanation suggests that since firms L have lower costs, they can invest more resources in innovation. Even though the investment in innovation decreases costs, H firms may not be able to spend as many resources as L firms on it.

6.2 Quantity produced in the EV industry

Besides assuring that the investment levels are positive, the quantities produced by both types of companies must also be positive. Considering $n_L = 4$ and $n_H = 9$, the quantities of both types of firms can be computed:

(25)

$$q_L = 7\gamma \frac{126\gamma z_H - 140\gamma z_L + 14\gamma + 5z_L - 5}{1372\gamma^2 - 875\gamma + 25}$$

$$q_H = -14\gamma \frac{35\gamma z_H - 28\gamma z_L - 7\gamma - 5z_H + 5}{1372\gamma^2 - 875\gamma + 25}$$

Before analysing the sign of the quantities above, it is interesting to understand which type of company produces the highest quantity. We expect it to be the low-cost type, let us confirm:

(26)

$$q_H - q_L = \frac{-5(1 - z_H) + 5(z_H - z_L) - 196\gamma(z_H - z_L)}{1372\gamma^2 - 875\gamma + 25} < 0 \; if \; \gamma > 0.608$$

For $\gamma > 0.608$, $q_L > q_H$. This result shows that low-cost firms produce more quantity, which is expected as they have lower marginal costs. This result also shows that with the increase of γ, the difference between q_L and q_H also increases. The dominance of low-cost firms increases, and the industry becomes more asymmetric in terms of market shares.

If $q_H > 0$, $q_L > 0$ because $q_L > q_H$. The denominator of both quantities is equal to the denominator of the investment levels, which means that we already know its sign. Therefore, we start by looking at the numerator of q_H:

(27)

$$-14\gamma(35\gamma z_H - 28\gamma z_L - 7\gamma - 5z_H + 5) > 0 = \gamma(7 - (35z_H - 28z_L) - 5(1 - z_H)) > 0 =$$

$$= \gamma > \frac{5(1 - z_H)}{7(1 - z_H) - 28(z_H - z_L)} \text{ if } 7(1 - z_H) - 28(z_H - z_L) > 0$$

This condition is the same as the one obtained in the previous section. Hence, the conditions of positivity ensure that x_L, x_H, q_L, and q_H are all positive, as required.

Note that $\frac{q_H}{x_H} = \frac{14}{5}\gamma$, whereas $\frac{q_L}{x_L} = \frac{7}{5}\gamma$. In other words, $\frac{\frac{q_H}{x_H}}{\frac{q_L}{x_L}} = 2$.

This result shows that the quantity/innovation ratio is more favourable for H firms (or, equivalently, the innovation/quantity ratio is more favourable for L firms). In other words, H firms produce more per euro invested in innovation, which can mean that they are more efficient at transforming innovation into output. This can be explained by the fact that, since H firms have higher marginal costs, they have more to gain by investing in innovation than L firms. Hence, if the objective was to decrease the price for consumers, we should prefer an increase in x_H to an increase in x_L. Or, stated differently, if the Government was to subsidise process innovation with the objective of increasing the availability of the product to consumers through lower prices, these subsidies should preferably be directed to H firms.

6.3 The effects of marginal costs and γ on innovation

As outlined in the literature review, policymakers are concerned about the impact of mergers on the competitive environment of the markets. If a merger gives rise to a dominant company that has anti-competitive behaviour, it can be prohibited. However, more factors influence competition besides mergers. For instance, the investment in cost-reducing innovation may influence competition. If a company invests in innovation much more than its rivals, it may become more competitive and increase its dominance over all firms in the market. Therefore, it is interesting to analyse how z_L, z_H, and γ influence the investment in innovation and, consequently, the increase in dominance.

<u>Low-cost companies' investment (x_L) and marginal costs (z_L and z_H)</u>:

First, we want to evaluate the effect of z_L on x_L:

(28)

$$\frac{\partial x_L}{\partial z_L} = -25\frac{28\gamma - 1}{1372\gamma^2 - 875\gamma + 25} < 0, \text{since } 28\gamma - 1 < 0 \text{ only if } \gamma < 0.035 \text{ (out of range)}$$

It can be concluded that, for the admissible range of γ, the innovation of low-cost companies decreases with an increase in its marginal costs. This means that the investment in innovation is higher if a company is more efficient (lower marginal costs). This result is somehow logical if we consider that companies with higher costs have fewer resources to invest in innovation.

Also, it is interesting to understand how the investment in innovation of low-cost companies behaves according to the marginal cost of high-cost companies:

(29)

$$\frac{\partial x_L}{\partial z_H} = \frac{630\gamma}{1372\gamma^2 - 875\gamma + 25} > 0$$

It can be inferred that the innovation of low-cost companies increases with the marginal cost of high-cost companies. This result is expected since it can be viewed as an opportunity for low-cost companies to reinforce their position.

High-cost companies investment (x_H) and marginal costs (z_H and z_L):

Following the same logic as before, we start analysing the relationship between x_H and z_H:

(30)

$$\frac{\partial x_H}{\partial z_H} = -25\frac{7\gamma - 1}{1372\gamma^2 - 875\gamma + 25} < 0, \text{since } 7\gamma - 1 < 0 \text{ only if } \gamma < 0.143 \text{ (out of range)}$$

Once again, it can be concluded that, for the admissible range of γ, the innovation of high-cost companies decreases with an increase in its marginal costs. This means that the investment in innovation is higher if a company is more efficient (lower marginal costs).

We then proceed to analyse how the investment in innovation of high-cost companies is influenced by the marginal costs of low-cost companies:

(31)

$$\frac{\partial x_H}{\partial z_L} = \frac{140\gamma}{1372\gamma^2 - 875\gamma + 25} > 0$$

Once again, the result shows that the investment in innovation increases with the marginal costs of the competitors.

From (28)-(31) it can be concluded that there are several scenarios of increasing dominance, that can be summed up in two general cases: the more efficient a company is (lower marginal costs), the higher the investment in innovation; the less efficient the rivals are, the higher the investment in innovation of the company. The higher the investment in innovation, the most dominant a company is, because a higher level of investment allows a company to reduce its costs, and consequently, to be more competitive than its rivals. Thus, competition authorities should be concerned about stimulating innovation but never forgetting that there exists a possibility that it may result in anti-competitive behaviour.

Low-cost companies' investment (x_L) and γ:

If investment in innovation is more efficient (lower γ), it is expected that companies invest more in innovation. In the next calculations, we intend to confirm this assumption.

(32)

$$\frac{\partial x_L}{\partial \gamma} = -35\frac{\gamma^2(24696(z_H - z_L) + 2744(1 - z_L)) - \gamma(1960(1 - z_L)) + 450(1 - z_H) + 125(1 - z_L)}{1372\gamma^2 - 875\gamma + 25}$$

We already know that the denominator is positive. Then, we need to analyse the numerator:

(33)

$$\gamma^2(24696(z_H - z_L) + 2744(1 - z_L)) - \gamma(1960(1 - z_L)) + 450(1 - z_H) + 125(1 - z_L) = 0$$

$$\gamma = \frac{5}{196}\frac{14(1 - z_L) \pm 3\sqrt{14}\sqrt{-1 - 21z_H + 18z_H^2 + 23z_L - 4z_L^2 - 15z_H z_L}}{9(z_H - z_L) + (1 - z_L)}$$

It can be seen that the numerator is a convex quadratic function. If the term inside the square root is negative, there are no roots, and the quadratic function is always positive. If the quadratic function is always positive, $\frac{\partial x_L}{\partial \gamma} < 0$ because of the negative sign at the beginning of the expression.

(34)

$$-1 - 21z_H + 18z_H^2 + 23z_L - 4z_L^2 - 15z_H z_L = 0 \Leftrightarrow z_L = 5.706 - 4.706z_H \vee z_L = 0.44 + 0.956z_H$$

The first root is bigger than 1, which is impossible since z_L cannot exceed 1 (the maximum willingness to pay by consumers). Thus, we look at the second root:

(35)

Root 2 – Root 1 = $(0.44 + 0.956z_H) - (5.706 - 4.706z_H) = 0.294(1 - z_H)$>0

Root 2 > Root 1, meaning that Root 2 is also larger than 1. Since the quadratic function inside the square root is concave in z_L and the roots are both larger than 1, for the considered range of $z_L < z_H < 1$, the term inside the square root is always negative. Therefore, the numerator is negative and $\frac{\partial x_L}{\partial \gamma} < 0$.

The calculations confirm that if γ decreases (which means an increase in the efficiency of the innovation activity), the investment of low-cost companies in innovation increases.

<u>High-cost companies investment (x_L) and γ</u>:

For high-cost companies, the expected result is the same. Let us proceed to the calculations to confirm it:

(36)

$$\frac{\partial x_H}{\partial \gamma} = -140\frac{\gamma^2((1 - z_L) - 5(z_H - z_L)) - \gamma(490(1 - z_H)) + 150 - 25(z_H - z_L)}{1372\gamma^2 - 875\gamma + 25}$$

We already know that the denominator is positive. Then, we need to analyse the numerator:

(37)

$$\gamma^2((1 - z_L) - 5(z_H - z_L)) - \gamma(490(1 - z_H)) + 150 - 25(z_H - z_L) = 0$$

$$\gamma = \frac{5}{49}\frac{7(1 - z_H) \pm \sqrt{7}\sqrt{1 + 21z_H - 18z_H^2 - 23z_L + 4z_L^2 + 15z_H z_L}}{(1 - z_L) - 5(z_H - z_L)}$$

The denominator of the roots is positive since $z_L > \frac{5z_H - 1}{4}$. The numerator is a convex quadratic function. If the term inside the square root is negative, there are no roots and the quadratic function is always positive. If the quadratic function is always positive, $\frac{\partial x_H}{\partial \gamma}$<0 because of the negative sign at the beginning of the expression.

(38)

$$1 + 21z_H - 18z_H^2 - 23z_L + 4z_L^2 + 15z_H z_L = 0 \Leftrightarrow z_L = 5.706 - 4.706z_H \vee z_L = 0.44 + 0.956z_H$$

The roots are the same verified in the low-cost firms' case. Therefore, we can conclude that the numerator is negative and $\frac{\partial x_H}{\partial \gamma} < 0$.

Once again, it can be concluded that if γ decreases (increase in efficiency), the investment of high-cost companies in innovation increases.

6.4 The effects of mergers on innovation in the EV industry

In this chapter, we intend to assess the effects of mergers on innovation. The PSA/FCA merger case is the basis for this Dissertation analysis. It was seen in Table 7 that both companies involved in this merger present high costs, since they have small levels of production compared to the firms classified as low-cost. However, after the merger, the merged entity will be responsible for almost 10% of the total EVs production. This 10% value is important since it is considered to be the bottom line that distinguishes low-cost from high-cost companies. Besides that, as it was seen in the literature review, several authors such as Davidson and Ferret (2007) asserts that mergers may lead to synergies and R&D spillovers that contribute to the reduction of marginal costs. Therefore, it is reasonable to assume that the merger will give rise to a low-cost producer, that is, the PSA/FCA merged entity is low-cost. In addition, as highlighted in Chapter 1, the new merged entity becomes the fourth largest car manufacturer in the world (Forbes, 2019).

Therefore, after this merger, the European EV market will be composed of 7 high-cost firms and 5 low-cost firms, since 2 high-cost firms merge to become 1 low-cost firm.

This chapter intends to deeply analyse the effects of this merger on innovation activity in the European EV industry. Firstly, we obtain the investment in innovation for both types of companies individually after the merger. Secondly, we assess the effects of the merger on the total innovation of the industry. Lastly, we analyse this variation of innovation separately, for each type of company.

6.4.1 Low-cost companies after the merger

The number of each type of companies changes after the merger, which means that there is a new cost-reducing innovation formula, now with n_L=5 and n_H=7:

(39)

$$x'_L = 8\frac{13\gamma + 6z_L + 91z_H\gamma - 104z_L\gamma - 6}{2197\gamma^2 - 1300\gamma + 48}$$

To understand the sign of this formula, we start by analysing the denominator. It is a convex quadratic function. The respective roots can be calculated:

(40)

$$2197\gamma^2 - 1300\gamma + 48 = 0 \Leftrightarrow \gamma = 0.040 \vee \gamma = 0.552$$

The denominator is positive if γ <0.040 and γ >0.552, and it is negative if γ is between these two roots. Given that γ >0.608, this denominator is always positive. This means that the numerator will decide the sign of the formula.

(41)

$$13\gamma + 6z_L + 91z_H\gamma - 104z_L\gamma - 6 > 0 \Leftrightarrow 91\gamma(z_H - z_L) + (1 - z_L)(13\gamma - 6) > 0$$

If (13 γ-6)>0, the numerator will always be positive. Since γ >0.608, this is always true, so the numerator is always positive. From this analysis, we can conclude that, for the considered range of γ, innovation in low-cost companies after the merger is always positive.

6.4.2 High-cost companies after the merger

The new cost-reducing innovation formula for high-cost companies is the following one:

(42)

$$x'_H = 6\frac{13\gamma + 8z_H - 78z_H\gamma + 65z_L\gamma - 8}{2917\gamma^2 - 1300\gamma + 48}$$

The denominator is equal to the low-cost firms', meaning that it is always positive. Then, we need to evaluate the numerator.

(43)

$$13\gamma + 8z_H - 78z_H\gamma + 65z_L\gamma - 8 > 0 \Leftrightarrow \gamma > \frac{8(1 - z_H)}{13[(1 - z_H) - 5(z_H - z_L)]} \text{ if} 13[(1 - z_H) - 5(z_H - z_L)] > 0 \text{ or}$$

$$\gamma < \frac{8(1-z_H)}{13[(1-z_H)-5(z_H-z_L)]} \text{ if } 13[(1 - z_H) - 5(z_H - z_L)] < 0$$

However, $13[(1 - z_H) - 5(z_H - z_L)] < 0$ is not possible because $z_L > \frac{6z_H-1}{5}$, hence we are left with the condition $\gamma > \frac{8(1-z_H)}{13[(1-z_H)-5(z_H-z_L)]}$. It can be seen that this threshold for γ decreases with z_L, which means that it is maximum for the minimum z_L, and minimum for the maximum z_L. This new condition on γ must also be considered to ensure that $x'_H > 0$. The condition for the denominator of this threshold to be positive yields.

(44)

$$(1 - z_H) - 5(z_H - z_L) > 0 \Leftrightarrow z_L > \frac{6z_H - 1}{5}$$

This new z_L condition is different from the previous one computed in equation (23). Then, which one should be considered?

(45)

$$\frac{6z_H - 1}{5} - \frac{5z_H - 1}{4} = \frac{1}{20}(1 - z_H) > 0$$

The new condition is more stringent than the first one, as it ensures that the investment in innovation is positive before and after the merger, while the first condition only ensures before the merger. Therefore, for the purpose of analysing the merger impacts we need to use the new condition.

Before advancing, let us recall the conditions that ensure that this merger occurs:

$\gamma > \max\{0.608, \frac{8(1-z_H)}{13[(1-z_H)-5(z_H-z_L)]}, \frac{5(1-z_H)}{7(1-z_H)-28(z_H-z_L)}\}$ and $z_L > \frac{6z_H-1}{5}$, with $z_H < 1$.

6.4.3 Comparison of innovation investment levels after the merger

As it was done for the pre-merger situation in Section 6.1, let us compare the investment in innovation of L and H firms after the merger:

(46)

$$x'_H - x'_L = -2\frac{13\gamma(1 - z_L) + 598\gamma(z_H - z_L) - 24(z_H - z_L)}{2917\gamma^2 - 1300\gamma + 48} < 0$$

Once again, the level of investment of low-cost firms is higher than the level of investment of high-cost firms. This means that even after the merger, low-cost firms can take the most advantage of innovation. This result shows that the marginal cost difference has a great influence on the investment in innovation, since low-cost firms always invest more.

6.4.4 Merger effect on total innovation

In the last section it was established that, after the merger, both types of companies still invest in innovation. But is this investment higher or lower when compared to the pre-merger scenario? This section intends to find an answer to this question.

First, we need to calculate the total pre-merger innovation. In this situation, there are 4 low-cost companies and 9 high-cost companies. Therefore, total innovation can be calculated as:

(47)

$$X = 4x_L + 9x_H$$

$$X = \frac{-325 + 225z_H + 100z_L + 595\gamma + 945z_H\gamma - 1540z_L\gamma}{1372\gamma^2 - 875\gamma + 25}$$

After the merger, 2 high-cost companies become 1 low-cost, which means that there will be 5 low-cost companies and 7 high-cost companies. Then, the total innovation after the merger can be computed as:

(48)

$$X' = 5x'_L + 7x'_H$$

$$X' = \frac{-576 + 336z_H + 240z_L + 1066\gamma + 364z_H\gamma - 1430z_L\gamma}{2197\gamma^2 - 1300\gamma + 48}$$

To understand if the merger increases or decreases innovation, we calculate the difference between X' and X. If it is greater than 0, this merger fosters innovation. If it is lower than 0, this merger decreases innovation.

(49)

$$\Delta X = X' - X$$

$$\Delta X = \frac{1200[(1-z_H)-2(z_H-z_L)] + [79590-37760z_H-41830z_L]\gamma}{(1372\gamma^2-875\gamma+25)*(2197\gamma^2-1300\gamma+48)} + \frac{[-1497(1-z_L)+713170(z_H-z_L)]\gamma^2 + [-273063(1-z_L)-2257157(z_H-z_L)]\gamma^3}{(1372\gamma^2-875\gamma+25)*(2197\gamma^2-1300\gamma+48)}$$

We start by looking at the denominator. From calculations (17) and (40) we already know that, for $\gamma>0.608$, both quadratic functions in the denominator are positive. Hence, the denominator is positive. Therefore, it suffices to understand the numerator's sign to know the impact of mergers on innovation.

Given that the numerator is cubic in γ, we start by taking the derivative of ΔX in order to γ. If this derivative is greater than 0 and it is positive for the minimum γ, we can conclude that the numerator is positive, and that this merger fosters innovation.

(50)

$$\frac{\partial \Delta X_{numerator}}{\partial \gamma} = [79590 - 37760z_H - 41830z_L] + 2[-1497(1 - z_L) + 713170(z_H - z_L)]\gamma + 3[-273063(1 - z_L) - 2257157(z_H - z_L)]\gamma^2$$

From this equation alone, it is not possible to understand the numerator's sign. This equation is a convex quadratic function. Hence, to study its sign, we calculate its roots:

(51)

$$\gamma = \frac{-1497(1-z_H)+713170(z_H-z_L)}{21[39009(1-z_L)+322451(z_H-z_L)]} \pm \frac{\sqrt{65201493519+505869087252z_H+255058175929z_H^2-636272074290z_L-1015985439110z_Hz_L+826128756700z_L^2}}{21[39009(1-z_L)+322451(z_H-z_L)]}$$

The denominator of the roots is positive. However, the numerator has no clear sign. It depends on z_L and z_H.

However, we can try to establish a z_H condition that, together with the z_L and γ previous conditions, ensures that mergers foster innovation. Looking at the ΔX numerator, we need to find a z_H condition that assures that it is positive. To do this, we will analyse all terms and establish conditions.

(52)

$$1200[(1-z_H)-(z_H-z_L)] > 0, \text{because } z_L > \frac{6z_H-1}{5}$$

$$79590 - 37760z_H - 41830z_L > 0, \text{because } z_L, z_H < 1$$

$$-1497(1-z_L) + 713170(z_H-z_L) > 0 \Leftrightarrow z_H > \frac{1497+711637z_L}{713170} = 0.002 + 0.998z_L$$

$$-273063(1-z_L) - 2257167(z_H-z_L) < 0 \ \forall\, z_L, z_H \text{ because } z_H > z_L$$

Since the last condition is always negative, it is not possible to retrieve any conclusions. It is not possible to conclude anything about the sign of the numerator of ΔX, which is a third-degree polynomial.

Hence, it is not possible to conclude a priori if the FCA/PSA merger will foster or decrease innovation. Further in this Dissertation, we perform a merger simulation, where conclusions will be determined.

6.4.5 Innovation change for low-cost companies

After analysing total innovation, we find it interesting to understand how the merger impacts each type of company individually. Hence, we start by analysing the change in innovation by low-cost companies.

We first need to compute this variation, which can be characterised as:

(53)

$$\Delta X_L = x_L' - x_L$$

$$\Delta X_L = \gamma \frac{8740(1-z_L) - 12040(z_H-z_L) + [7069(1-z_L) + 182000(z_H-z_L)]\gamma + [-61502(1-z_L) - 838894(z_H-z_L)]\gamma^2}{(1372\gamma^2 - 875\gamma + 25)(2197\gamma^2 - 1300\gamma + 48)}$$

We already know that the denominator is always positive for the admissible range of γ. Hence, we need to analyse the numerator. To do this, we re-write it as:

(54)

$$(1-z_L)[8740+7069\gamma-61502\gamma^2]+(z_H-z_L)[-12040+182000\gamma-838894\gamma^2]$$

This is the sum of two concave quadratic functions. To understand its sign, we calculate the roots:

(55)

$$8740+7069\gamma-61502\gamma^2=0 \Leftrightarrow \gamma=-0.324 \vee \gamma=0.439$$

$$-12040+182000\gamma-838894\gamma^2<0 \;\forall\, \gamma$$

The first quadratic function is negative for γ >0.439 and the second is always negative. This means that, after the merger, the innovation of low-cost companies individually decreases, $x_L'-x_L<0 \;\forall\, \gamma$.

6.4.6 Innovation change for high-cost companies

Applying the same reasoning for high-cost companies, we compute the innovation variation:

(56)

$$\Delta X_H = x_H' - x_H$$

$$\Delta X_H = \gamma\frac{9770(1-z_H)-3030(z_H-z_L)+[-15681(1-z_H)+174931(z_H-z_L)]\gamma+[4921(1-z_H)-126700(z_H-z_L)]\gamma^2}{(1372\gamma^2-875\gamma+25)(2197\gamma^2-1300\gamma+48)}$$

We already know that the denominator is always positive for the admissible range of γ. Hence, we need to analyse the numerator. To do this, we re-write it as

(57)

$$(1-z_H)[9770-15681\gamma+4921\gamma^2]+(z_H-z_L)[-3030+15920\gamma-126700\gamma^2]$$

This is the sum of 1 convex and 1 concave quadratic functions. To understand the sign of this sum, we calculate the roots:

(58)

$$9770-15681\gamma+49212\gamma^2=0 \Leftrightarrow \gamma=0.850 \vee \gamma=2.337$$

$$-3030+159250\gamma-126700\gamma^2=0 \Leftrightarrow \gamma=0.019 \vee \gamma=1.238$$

Upon analysing the roots, it is possible to conclude that, for 0.019< γ <0.850, innovation investment increases in high-cost companies. For 1.238< γ <2.337 innovation investment decreases. For the other ranges of γ it is not possible to conclude without attributing numerical values to z_L and z_H. The unclear behaviour of X_H is the reason for the unclear sign of ΔX explained before.

6.5 Merger effect on consumers

In this section, we intend to evaluate the impact of the merger on the consumers. Does the price increase or decrease? This analysis is very important for competition authorities. If price increases after the merger, consumers will be worse off. Therefore, competition authorities should estimate the effect of a proposed merger on prices before allowing it.

To evaluate the effect of the PSA/FCA merger, we start by calculating the price before merger, P:

(59)

$$\mathrm{P} = 1 - \mathrm{Q} = 1 - \mathrm{n_L q_L} - \mathrm{n_H q_H}$$

$$\mathrm{P} = \frac{25 - 105\gamma - 630z_H\gamma - 140z_L\gamma + 98\gamma^2 + 882z_H\gamma^2 + 392z_L\gamma^2}{1372\gamma^2 - 875\gamma + 25}$$

After that, we calculate the price after the merger, P':

(60)

$$P' = 1 - \mathrm{Q}' = 1 - \mathrm{n_L}'\mathrm{q_L}' - \mathrm{n_H}'\mathrm{q_H}'$$

$$\mathrm{P}' = \frac{48 - 182\gamma - 728z_H\gamma - 390z_L\gamma + 169\gamma^2 + 1183z_H\gamma^2 + 845z_L\gamma^2}{2197\gamma^2 - 1300\gamma + 48}$$

Then, we calculate the difference between the prices, P'-P. If it is greater than 0, it means that the price increases after the merger. If it is lower than 0, it means that mergers create a reduction in price.

(61)

$$\mathrm{P'\text{-}P} = \gamma\frac{12040z_H - 194761z_H\gamma - 3030z_L + 161559z_L\gamma - 9010 + 496769z_H\gamma^2 - 457275z_L\gamma^2}{(1372\gamma^2 - 875\gamma + 25)(2197\gamma^2 - 1300\gamma + 48)} + \frac{33202\gamma - 39494\gamma^2 + 16562\gamma^3 - 314678z_H\gamma^3 + 298116z_L * \gamma^3}{(1372\gamma^2 - 875\gamma + 25)(2197\gamma^2 - 1300\gamma + 48)}$$

The denominator is always positive for the admissible range of γ. Therefore, we need to evaluate the numerator. This can be written as:

(62)

$$\text{Numerator} = [-9010(1 - z_H) + 3030(z_H - z_L)] + [33202(1 - z_H) - 161559(z_H - z_L)]\gamma + [-39494(1 - z_H) + 457275(z_H - z_L)]\gamma^2 + [16562(1 - z_H) - 298116(z_H - z_L)]\gamma^3$$

$$\text{Numerator} = (1 - z_H)[-9010 + 33202\gamma - 39494\gamma^2 + 16562\gamma^3] + (z_H - z_L)[3030 - 161559\gamma + 457275\gamma^2 - 298116\gamma^3]$$

At this stage, it is not possible to conclude if the numerator is positive or negative, given that it is cubic in γ. Hence, we will calculate its derivative in order to γ.

(63)

$$\frac{\partial \text{numerator}}{\partial \gamma} = (1 - z_H)[33202 - 789\gamma + 49686\gamma^2] + (z_H - z_L)[-161559 + 914550\gamma - 894348\gamma^2]$$

Then, we analyse the sign of this function, that is composed by 2 quadratic functions, one convex and another concave.

(64)

$$33202 - 7898\gamma + 49686\gamma^2 > 0 \; \forall \, \gamma$$

$$-161559 + 914550\gamma - 894348\gamma^2 = 0 \Leftrightarrow \gamma = 0.227 \vee \gamma = 0.796$$

Through the analysis of the roots, we can conclude that the numerator surely grows when 0.227< γ <0.796. Since there is a condition that stated γ >0.608, the numerator actually grows when 0.608< γ <0.796. If the numerator is positive for γ =0.608, it will surely be positive until γ =0.796 since the numerator function grows inside this interval. If we perform the calculations:

(65)

$$\gamma = 0.608\text{: numerator} = 299.710(1 - z_H) + 6836.960(z_H - z_L)$$

The numerator is positive for this γ range, which means that price increases after the merger if 0.608< γ <0.796. For γ >0.796, price may decrease after the merger from a certain point. As stated in Section 6.1, the parameter γ represents the efficiency of the investment in cost-reducing R&D. If this investment is efficient, γ is low. If the investment is not efficient, γ is high. This result shows us that when the investment in innovation is not efficient, prices decrease after the merger. How can this be explained?

When the investment in innovation is efficient (low γ), firms invest more. As a result, firms become more asymmetric, which can lead to an increase in market power. If market power increases, price increases too, because firms will use their power to increase the price and, consequently, increase their profits. On the other side, when the investment in innovation is not efficient (γ high), firms will invest less in innovation, which means that the market becomes more symmetric. If the market is symmetric, firms do not have market power, meaning that they cannot easily influence the price. Since firms are similar and cannot influence the price, competition increases, which leads to a price decrease.

From a consumers' point of view, the impact of the merger is measured by the size of γ (the higher the γ, the lower the prices) and by the asymmetry of firms, $z_H - z_L$ (the higher the asymmetry, the higher the prices).

6.6 Merger profitability

When studying the effects of mergers on companies, we need to evaluate their profitability. If the merger decreases the joint profit, companies do not merge. However, several factors influence the profitability of the merger. Since this Dissertation is largely focused on innovation, in this section, we analyse the relationship between the profit of the merger and γ. First, we analyse the profits of both types of companies, pre-merger. Then, we evaluate them after the merger. In the end, we compare both to see if it is possible to find any condition that assures this merger's profitability.

6.6.1 Pre-merger profits

We start by analysing the profit of both types of companies before the merger. Starting with low-cost firms, using the equations in steps (15) and (25) profit can be computed as:

(66)

$$\pi_L = \gamma(49\gamma - 25)\frac{(-5 + 5z_L - 140z_L\gamma + 126z_H\gamma + 14\gamma)^2}{(1372\gamma^2 - 875\gamma + 25)^2}$$

$$(49\gamma - 25) > 0 \Leftrightarrow \gamma > 0.51$$

Both the numerator and the denominator are raised to 2, meaning that they will always be positive. Hence, the sign of this expression is determined by γ. Evidently, the $(49\gamma - 25)$ defines if the profit of low-cost companies before the merger is positive or negative. Since $\gamma > 0.608$, this profit is always positive.

Following the same logic, the profit of high-cost companies can be computed using the equations in step (15) and (25):

(67)

$$\pi_H = \gamma(196\gamma - 25)\frac{(5 - 5z_H - 28z_L\gamma + 35z_H\gamma - 7\gamma)^2}{(1372\gamma^2 - 875\gamma + 25)^2}$$

$$(196\gamma - 25) > 0 \Leftrightarrow \gamma > 0.13$$

Similarly, the profit of high-cost companies before the merger companies will always be positive for the admissible range of γ.This implies that there is no upper bound on γ.

Indeed, one of the requirements to develop this Dissertation model is that high-cost firms must have a positive profit, meaning that they exist in the market. It is important to remember that this condition was focused on high-cost companies and not low-cost ones because if low-cost companies were too efficient, they could drive high-cost companies out of the market. We have already determined a lower bound for γ that assured this requirement, but is there any upper bound for γ? Looking at the profit expression, both the numerator and the denominator are a fourth-degree polynomial. However, the denominator is greater than the numerator, since the term with γ^4 is considerably bigger than the denominator. This means that the expression tends to 0, whatever the value of γ. Hence, γ has a lower bound but not an upper bound in our model.

6.6.2 Post-merger profits

After the merger, the market structure changes: 2 high-cost companies become 1 low-cost, meaning that we now have 5 low-cost companies and 7 high-cost. As is expected, the profits will change compared to the previous situation. Starting with the low-cost companies, its profit after the merger can be computed:

(68)

$$\pi_L' = \gamma(169\gamma - 36)\frac{(8 - 8z_H - 65z_L\gamma + 78z_H\gamma - 13\gamma)^2}{(2197\gamma^2 - 1300\gamma + 48)^2}$$

$$(169\gamma - 36) > 0 \Leftrightarrow \gamma > 0.213$$

Once again, the sign of the expression is determined by γ. Since γ is always larger than 0.213, the profit of low-cost companies is always positive.

Similarly, we can compute the profit after merger of high-cost companies:

(69)

$$\pi_H' = \gamma(169\gamma - 64)\frac{(-6 + 6z_L - 104z_L\gamma + 91z_H\gamma + 13\gamma)^2}{(2197\gamma^2 - 1300\gamma + 48)^2}$$

$$(169\gamma - 64) > 0 \Leftrightarrow \gamma > 0.379$$

Once again, the profit of high-cost firms is always positive after merger for the admissible range of γ.

To study merger profitability, it is not enough to analyse if the profit of companies is positive after the merger. We need to evaluate the sign of $\pi_L' - 2\pi_H$, which is the difference between the profit after the merger of the merging company, and the profits before the merger of both merging companies.

(70)

$$\pi_L' - 2\pi_H = \frac{\gamma(169\gamma - 36)(8 - 8z_H - 65z_L\gamma + 78z_H\gamma - 13\gamma)^2(1372\gamma^2 - 875\gamma + 25)^2}{(2197\gamma^2 - 1300\gamma + 48)^2(1372\gamma^2 - 875\gamma + 25)^2} -$$

$$\frac{2\gamma(196\gamma - 25)(5 - 5z_H - 28z_L\gamma + 35z_H\gamma - 7\gamma)^2(2197\gamma^2 - 1300\gamma + 48)^2}{(2197\gamma^2 - 1300\gamma + 48)^2(1372\gamma^2 - 875\gamma + 25)^2}$$

If this equation is positive, it means that the merger increases the profits of the involved companies. If it is negative, companies will not propose the merger. The denominator of the expression is always positive. Therefore, the sign of the expression depends on the numerator. If we expand the equation, it can be seen that it is an eight-degree polynomial, for which the sign cannot be determined. At this stage, we will assume that the merger is profitable, otherwise companies would not be proposing it. Even if $\pi_L' - 2\pi_H < 0$, we can assume that merging firms benefit from fixed cost savings that are not captured in this analysis (note that these are only the variable components of profits, depending on the quantity and on the innovation level, which are co-determined). This is in the spirit of Salant et al. (1983), who first showed the famous merger paradox: in a linear demand, linear cost context, mergers involving less than 80% of the firms in the industry would not be profitable for the merging parties unless fixed cost savings were sufficiently high but would be profitable for the outsiders (giving them an incentive to free-ride). The next chapter shows the results of simulating the merger for several specific values of the parameters.

7. PSA/FCA merger simulation

In this chapter, we simulate the merger between PSA and FCA to evaluate its impact on innovation, price, and profit of the firms in the EV industry. To do this, we need to assign values to z_L, z_H and γ.

7.1 Binding Conditions

As established in Chapter 6, firms were considered low or high-cost according to their level of production. Firms with higher production levels were considered low-cost, while firms with lower production levels were considered high-cost. To assign values to z_L and z_H, we use the market share values of table 7. If we divide the average market share of firms L by the average market share of firms H, we get 5.46. Following this reasoning, we assume that firms L produce on average 5.46 times more than firms H. We use this information to proceed backwards to establish a relationship between z_L and z_H:

(71)

$$q_L = 5.46q_H \Leftrightarrow z_L = \frac{1240 - 1561\gamma + z_H(12705\gamma - 1365)}{11144\gamma - 125}$$

It is necessary to assure that z_L is positive. We start by analysing the denominator:

(72)

$$11144\gamma - 125 > 0 \Leftrightarrow \gamma > 0.011$$

We have seen before that $\gamma > 0.608$. Therefore, the denominator is always positive. We then need to evaluate the numerator:

(73)

$$1240 - 1561\gamma + z_H(12705\gamma - 1365) > 0 \Leftrightarrow z_H > \frac{1561\gamma - 1240}{12705\gamma - 1365}$$

Since $12705\gamma - 1365 > 0$ for $\gamma > 0.608$. As for the numerator of this expression:

(74)

$$1561\gamma - 1240 > 0 \Leftrightarrow \gamma > 0.794$$

We thus obtain a new condition on γ, more stringent than the previous one. From now on, $\gamma > 0.794$. We have assured that both z_L and z_H are positive. We need to check if z_H<1. A necessary condition is that:

(75)

$$\frac{1561\gamma - 1240}{12705\gamma - 1365} < 1 \Leftrightarrow \gamma > 0.011$$

As we can see, z_H is smaller than 1 since γ is larger than 0.011. We also need to confirm that z_L is lower than z_H: (76)

$$\frac{1240-1561\gamma+z_H(12705\gamma-1365)}{11144\gamma-125}<z_H \Leftrightarrow (z_H-1)(1561\gamma-1240)<0 \Leftrightarrow \gamma>0.794$$

This γ condition is the same established in (74). Therefore, z_H is always larger than z_L. Let us express condition (73) as a function of γ:

(77)

$$z_H>\frac{1561\gamma-1240}{12705\gamma-1365} \Leftrightarrow \gamma>\frac{1365z_H-1240}{12705z_H-1561}$$

Note that: (78)

$$1365z_H-1240>0 \Leftrightarrow z_H > 0.908$$

$$12705z_H-1561>0 \Leftrightarrow z_H > 0.123$$

Hence, for $z_H > 0.908$, the γ condition in (77) is active, meaning that γ needs to be greater than a positive value. When $0.123<z_H< 0.908$, the condition mentioned earlier is not a binding restriction because it establishes that γ needs to be greater than a negative value, hence it will not influence our model since we consider that γ is a positive number. When $z_H < 0.123$, both numerator and denominator are negative. As then $12705z_H-1561<0$, the sign of the inequality changes:

(79)

$$\gamma<\frac{1365z_H-1240}{12705z_H-1561} \text{ if } z_H < 0.123$$

As we can see, in this particular case, the γ condition is an upper bound instead of a lower bound. From this analysis, we retrieve 2 types of conditions:

(80)

$$\text{If } z_H>0.123\text{: } \max\left\{\frac{8(1-z_H)}{13[(1-z_H)-5(z_H-z_L)]},\frac{5(1-z_H)}{7(1-z_H)-28(z_H-z_L)},\frac{1365z_H-1240}{12705z_H-1561},0.794\right\}<\gamma$$

$$\text{If } z_H<0.123\text{: } \max\left\{\frac{8(1-z_H)}{13[(1-z_H)-5(z_H-z_L)]},\frac{5(1-z_H)}{7(1-z_H)-28(z_H-z_L)},\quad 0.794\right\}< \gamma <\frac{1365z_H-1240}{12705z_H-1561}$$

7.2 Simulation results and Discussion

After determining our model conditions, we are now able to proceed to the merger simulation.

Table 8. Merger Simulation

γ	z_H	z_L	$\frac{z_L}{z_H}$	$\frac{x'_L - x_L}{x_L}$	$\frac{x'_H - x_H}{x_H}$	$\frac{x'_L - 2x_H}{2x_H}$	$\frac{X' - X}{X}$	$\pi'_L - \pi_L$	$\pi'_H - \pi_H$	$\pi'_L - 2\pi_H$	$\frac{\pi'_T - \pi_T}{\pi_T}$	$\frac{q'_L - q_L}{q_L}$	$\frac{q'_H - q_H}{q_H}$	$\frac{Q' - Q}{Q}$	$\frac{P' - P}{P}$	$\frac{CS' - CS}{CS}$
0.8	0.9	0.899	0.9999	-44.3%	13.2%	204%	-10.5%	-0.00008	0.00006	-0.00011	15.3%	-35.3%	85.1%	-0.74%	0.08%	-1.5%
1.0	0.9	0.897	0.9968	-32.7%	-1.3%	268%	-7.1%	-0.00013	0.00011	-0.00021	30.3%	-21.8%	34.5%	-0.26%	0.03%	-0.5%
2.0	0.9	0.892	0.9906	-22.6%	-18.8%	323%	-4.0%	-0.00021	0.00019	-0.00038	44.2%	-10.2%	-8.1%	0.37%	-0.04%	0.7%
4.0	0.9	0.889	0.9875	-20.0%	-24.3%	337%	-3.1%	-0.00025	0.00022	-0.00046	47.3%	-7.1%	-18.9%	0.63%	-0.07%	1.3%
10.0	0.9	0.887	0.9857	-18.8%	-27.0%	344%	-2.7%	-0.00027	0.00024	-0.00050	48.6%	-5.7%	-23.8%	0.77%	-0.08%	1.5%
0.8	0.7	0.699	0.9996	-44.3%	13.2%	204%	-10.5%	-0.00076	0.00052	-0.00097	15.3%	-35.3%	85.1%	-0.74%	0.31%	-1.5%
1.0	0.7	0.691	0.9875	-32.7%	-1.3%	268%	-7.1%	-0.00120	0.00095	-0.00193	30.3%	-21.8%	34.5%	-0.26%	0.11%	-0.5%
2.0	0.7	0.675	0.9636	-22.6%	-18.8%	323%	-4.0%	-0.00193	0.00167	-0.00343	44.2%	-10.2%	-8.1%	0.37%	-0.15%	0.7%
4.0	0.7	0.666	0.9518	-20.0%	-24.3%	337%	-3.1%	-0.00227	0.00199	-0.00410	47.3%	-7.1%	-18.9%	0.63%	-0.26%	1.3%
10.0	0.7	0.661	0.9447	-18.8%	-27.0%	344%	-2.7%	-0.00247	0.00218	-0.00449	48.6%	-5.7%	-23.8%	0.77%	-0.32%	1.5%
0.8	0.5	0.499	0.9990	-44.3%	13.2%	204%	-10.5%	-0.00210	0.00145	-0.00269	15.3%	-35.3%	85.1%	-0.74%	0.72%	-1.5%
1.0	0.5	0.485	0.9709	-32.7%	-1.3%	268%	-7.1%	-0.00332	0.00263	-0.00535	30.3%	-21.8%	34.5%	-0.26%	0.25%	-0.5%
1.2	0.5	0.476	0.9522	-28.2%	-8.4%	292%	-5.8%	-0.00403	0.00334	-0.00685	36.7%	-16.6%	15.3%	-0.02%	0.02%	0.0%
2.0	0.5	0.458	0.9151	-22.6%	-18.8%	323%	-4.0%	-0.00535	0.00463	-0.00954	44.2%	-10.2%	-8.1%	0.37%	-0.35%	0.7%
4.0	0.5	0.444	0.8874	-20.0%	-24.3%	337%	-3.1%	-0.00630	0.00553	-0.01140	47.3%	-7.1%	-18.9%	0.63%	-0.59%	1.3%
10.0	0.5	0.435	0.8709	-18.8%	-27.0%	344%	-2.7%	-0.00685	0.00606	-0.01247	48.6%	-5.7%	-23.8%	0.77%	-0.73%	1.5%
0.8	0.3	0.299	0.9977	-44.3%	13.2%	204%	-10.5%	-0.00412	0.00285	-0.00528	15.3%	-35.3%	85.1%	-0.74%	1.64%	-1.5%
1.0	0.3	0.280	0.9320	-32.7%	-1.3%	268%	-7.1%	-0.00651	0.00516	-0.01049	30.3%	-21.8%	34.5%	-0.26%	0.58%	-0.5%
2.0	0.3	0.241	0.8019	-22.6%	-18.8%	323%	-4.0%	-0.01049	0.00907	-0.01869	44.2%	-10.2%	-8.1%	0.37%	-0.80%	0.7%
4.0	0.3	0.221	0.7373	-20.0%	-24.3%	337%	-3.1%	-0.01234	0.01085	-0.02234	47.3%	-7.1%	-18.9%	0.63%	-1.33%	1.3%
10.0	0.3	0.210	0.6988	-18.8%	-27.0%	344%	-2.7%	-0.01343	0.01188	-0.02444	48.6%	-5.7%	-23.8%	0.77%	-1.63%	1.5%
1.0	0.1	0.074	0.7378	-32.7%	-1.3%	268%	-7.1%	-0.01077	0.00854	-0.01733	30.3%	-21.8%	34.5%	-0.26%	1.97%	-0.5%
2.0	0.1	0.024	0.2358	-22.6%	-18.8%	323%	-4.0%	-0.01733	0.01500	-0.03090	44.2%	-10.2%	-8.1%	0.37%	-2.64%	0.7%
3.0	0.1	0.007	0.0697	-20.8%	-22.6%	333%	-3.4%	-0.01939	0.01697	-0.03495	46.5%	-8.0%	-15.7%	0.54%	-3.81%	1.1%
3.7	0.1	0.001	0.0070	-20.2%	-23.9%	336%	-3.2%	-0.02015	0.01770	-0.03644	47.1%	-7.3%	-18.2%	0.61%	-4.23%	1.2%

7.2.1 Parameters setting

The first 3 columns of Table 8 refer to the variables that we control, and which will originate the experimental results. We first establish a value for z_H. Our objective is to approach several different cost scenarios, so we decrease z_H from 0.9 until 0.1. Then, we establish values for z_L and γ that respect the conditions previously derived. As we have seen before, z_L depends directly on z_H and γ. Hence it varies according to the different scenarios.

Let us start by analysing column $\frac{z_L}{z_H}$, which intends to show the difference between the marginal costs of both types of companies. As this ratio increases (decreases), companies are more symmetric (asymmetric). From the table we observe that as γ increases, $\frac{z_L}{z_H}$ decreases, which means that inefficient investment in innovation leads to more asymmetry between firms. We expected this result. If innovation is expensive (high values of γ), not all companies have the necessary resources to invest. In our case, low-cost companies may have more resources to invest than high-cost companies. Therefore, low-cost companies invest more than high-cost companies, resulting in more asymmetry between them. On the other side, as γ decreases, $\frac{z_L}{z_H}$ increases. If innovation is very efficient (low values of γ), high-cost companies may take advantage of this opportunity and invest more, reducing costs and approaching low-cost companies. Furthermore, as z_H decreases, $\frac{z_L}{z_H}$ decreases too, which means that the competitive advantage of low-cost firms is stronger when production is efficient than when it is not so efficient. Note that in this model, we have two efficiency measures: one that refers to efficiency in production, captured by the levels of z_L and z_H, and one that refers to efficiency in innovation investment, captured by γ.

7.2.2 Innovation results

In section 6.4.5 we analysed algebraically the variation of the investment of low-cost companies caused by the merger. We have seen that $x_L' - x_L$ is always negative. The analysis of Table 8 is consistent with this result. This can be explained by the fact that, after the merger, the competition among low-cost companies increases since there is one more company operating in the market. Hence, facing more competition, companies may have less resources to invest in innovation. Moreover, for given z_H, as γ decreases, $\frac{x_L' - x_L}{x_L}$ decreases too, becoming more negative and the percentual variation is indeed stronger in absolute value. This means that when the investment in innovation is very efficient (low γ), L firms invest even less after the merger compared to before the merger. This result is not intuitive since it is expected that efficient innovation leads to higher investment. However, competition in the L group increases. If innovation is efficient, it is available to everyone, meaning that competition can increase even more since all companies have an easy way to become more competitive. Hence, they may choose different investments that allow them to truly differentiate themselves. On the other hand, when innovation investment is not efficient (which means that γ is high or, in other words, this investment is very costly), it is likely that only a few companies have enough resources to invest on it. Hence, these companies may increase their investment considerably in order to escape competition. It is interesting to observe that the percentual adjustment in the equilibrium innovation levels only depends on γ, the innovation investment efficiency, being insensitive to production efficiency (measured by z_L and z_H). The absolute adjustment depends on z_L and z_H, as it does make sense, but not the relative one.

Similarly, in section 6.4.6 we analysed algebraically the variation of the investment of high-cost companies caused by the merger. We have seen that $x_H' - x_H$ is always positive if γ<0.850, it is always negative if 1.238< γ<2.337, and it might be positive or negative for the other possible values of γ. The results in Table 8 are consistent with this finding. Furthermore, for a certain z_H, as γ decreases, $\frac{x_H' - x_H}{x_H}$ increases both in absolute terms and as a percentage of the pre-merger value. This means that very efficient innovation investment tends to favour H firms, which would be expected since these firms use innovation to decrease their high production costs and, therefore, become more competitive.

Hence, we observe that as γ decreases, the percentual reduction of x_L becomes stronger, while the percentual variation of x_H improves (becomes less negative or more positive). This means that inefficient innovation investment favours more low-cost firms, while efficient innovation investment favours more high-cost firms. If innovation investment is inefficient, it is more expensive. Therefore, since L firms have lower marginal costs, they are in a better position to innovate than H firms. On the other hand, when innovation investment is efficient, H firms may have the resources to invest and become more competitive. Even though innovation investment is efficient for both types of firms, H firms may take more advantage of it than L firms, mostly because they need more to decrease their marginal costs.

Even when the merger increases high-cost firms investment in innovation, total innovation in the industry is reduced ($\frac{X' - X}{X}$, measured as a percentage of the pre-merger innovation). This reduction may be of more than one quarter of the pre-merger innovation and is larger when innovation investment is more efficient (low γ). But why does the merger always decrease total innovation?

Column $\frac{x_L' - 2x_H}{2x_H}$ allows us to understand the contribution of the merger to the innovation level of the industry. Let us recall that this Dissertation merger case is between 2 high-cost companies that turn into 1 low-cost company. Hence, this column can be interpreted as the difference between the investment in innovation of the merged entity (L firm) and the merging firms before the merger (2 H firms). As it can be seen, $\frac{x_L' - 2x_H}{2x_H}$>0 for every γ, which means that this merger alone contributes to innovation. Then, why is the variation of total innovation always negative? The answer can be found in the outsider firms (firms that do not participate in the merger) response. Recall that investments in innovation are strategic substitutes. This means that when one firm increases its investment in innovation, its rivals decrease. The merging firms always increase their investment in innovation, so outsiders decrease theirs. The balance of these moves is a negative effect on the total innovation of the industry.

In parallel with this strategic substitution effect, there is also a change in the level of competition, which helps to explain this negative variation of total innovation in terms of groups of firms. With the merger, 2 high-cost companies become 1 low-cost. This means that competition among low-cost firms increases (we have 1 more company), while competition among high-cost firms decreases (we have 2 fewer high-cost companies). Since competition among L firms increases after the merger, they may have fewer resources to spend on innovation, meaning that $\frac{x_L' - x_L}{x_L}$ may be negative. If the newly merged entity is an L firm that increases its investment in innovation, the L outsiders will decrease their investment in innovation because of the strategic substitution effect and, on top of that, because there is more competition. Regarding the H firms, the effect of the merger is not as simple. On the one hand, the decrease in competition increases the firms' availability to innovate. On the other hand, we have the negative strategic substitution effect that decreases the outsiders' investment in innovation. That is why we can have positive or negative values for $\frac{x_H' - x_H}{x_H}$. Therefore, we can conclude that the variation of the total innovation is explained by the strategic substitution effect and the change in competition among the 2 groups of firms.

7.2.3 Profits

Now, let us analyse the profits of the companies. Starting with the $\pi_L' - \pi_L$ column, we can see that L firms always decrease their profits individually after the merger. The merger increases competition among low-cost firms; therefore, their profit is expected to decrease. The percentual decrease only depends on γ and is less pronounced the lower is γ, which is not surprising

Contrarily to the low-cost firms' case, the merger always increases the profits of high-cost firms individually, as $\pi_H' - \pi_H$ is always positive, which is justified by the fact that the merger has softened competition among this group of firms. The percentual increase in profit is less pronounced the lower is γ, because if innovation investment is efficient all firms may innovate more and, consequently, competition may increase inside this firms' group.

Column $\pi_L' - 2\pi_H$ shows the profit variation of the merging companies, that is, the profitability of the merger. According to our simulations, the profits of the merging companies always decrease after the merger. This result, which may seem surprising, is common in the merger literature and is known as the "merger paradox". It was first presented by Salant et al. (1983), who analyse a Cournot model in which a merger reduces the profits of the insiders, while it increases the profits of the outsiders. The authors start by arguing that, if players can decide whether to merge or not, it is not rational to merge knowing that profits will decrease. Then, why would firms merge? Mergers can create efficiency gains through economies of scale and other cost synergies. While variable costs are considered in the derivatives, fixed costs are not since they do not depend on quantity and would be irrelevant for the interior equilibrium. This means that the merger analysis is considering the reduction in fixed costs. Hence, even though the profit of the insiders may decrease, the decrease in fixed costs may compensate and, therefore, firms may have true incentives to merge.

Our merger simulation illustrates the merger paradox. By merging, PSA and FCA may manage to create cost synergies in terms of fixed costs that offset the decrease in profit observed in Table 8. These firms only merge because they take advantage of it, otherwise they would play a different move. We can also observe that percentual merger unprofitability (disregarding fixed cost savings) only depends on γ and is lower for small γ, which means that when innovation investment is not sufficiently efficient, fixed cost savings may not be enough to cover theses losses and the merger would risk not taking place. Therefore, the fact that the merger is observed tells us that γ is not so high.

It is also interesting to link the results of columns $\pi'_L - \pi_L$ and $\pi'_H - \pi_H$ with the merger paradox. For outsiders H, the merger is beneficial since it increases profits. As we have seen, this is because of the reduction in competition. Moreover, for outsiders L the merger is harmful since it decreases profits. From here we can conclude that this merger tends to favour high-cost firms and hurt low-cost firms. Moreover, the incentive to free-ride, common in the merger literature, only occurs in our model for H firms. Since we have two groups of firms, we have two groups of outsiders too, and hence we obtain a new result, that the incentive to free ride does not hold for all outsiders.

Let us now look at column $\frac{\pi'_T - \pi_T}{\pi_T}$, which represents the profitability of the merger for the whole industry. As is apparent, total profit always increases after the merger, which was expected since the industry becomes more concentrated. The percentual profit increase is higher for higher γ, as a result of the stronger increase in H firms' profits. Actually, when the investment in innovation is inefficient, it is more costly to innovate. Under these circumstances, only firms with enough resources may innovate. In our case, only L firms may invest significantly in innovation. This means that L firms increase their competitive advantage over H firms, increasing their profits, which explains the higher values of $\frac{\pi'_T - \pi_T}{\pi_T}$. On the other hand, when the investment in innovation is efficient, both L and H firms innovate, meaning that competition between these two groups of firms may increase. This may lead to lower profits, which explains the lower values of $\frac{\pi'_T - \pi_T}{\pi_T}$. To confirm this reasoning, let us look at columns $\frac{x'_L - x_L}{x_L}$ and $\frac{x'_H - x_H}{x_H}$. For high values of γ, L firms innovate more after the merger than H firms, increasing their cost advantage. For low values of γ, H firms innovate more after the merger, which means that they become more competitive and, therefore, the competition in the industry increases, resulting in lower total profits.

7.2.4 Quantities

Let us now look at the quantity variation of low-cost firms, $\frac{q'_L - q_L}{q_L}$. The quantity produced by low-cost firms always decreases after the merger, as expected because we have one more L firm, and decreases especially when innovation is efficient (γ is low), because competition inside this group is fiercer. Moreover, competition among high-cost firms decreases, leading them to eventually produce more. If high-cost firms produce more, low-cost firms produce less because quantities are strategic substitutes. This decrease is maximum when innovation investment is efficient because high-cost companies can innovate more than when innovation investment is inefficient. The decrease in $\frac{q_L' - q_L}{q_L}$ is minimum when γ is high. When innovation is inefficient, high-cost firms innovate less, and their production decreases after the merger. Recalling the strategic substitute effect, if high-cost firms decrease their innovation, low-cost firms increase theirs. However, since there is more competition among low-cost firms, the strategic substitution effect is not enough to offset the competition effect, meaning that $\frac{q_L' - q_L}{q_L}$ is negative.

For high-cost firms, $\frac{q_H' - q_H}{q_H}$ only increases if γ is low enough. Even though competition decreases after the merger because there is one less company, there are still 7 high-cost companies, meaning that competition is still high. If innovation is not very efficient, the competition effect prevails over the decrease in costs (due to innovation) and the quantity produced decreases.

Let us now look at the variation of the total quantity, $\frac{Q' - Q}{Q}$**.** For low levels of γ, quantity always decreases after the merger, even though we have a great increase in the production of high-cost companies. But as high-cost companies produce significantly less than low-cost ones and the latter decrease production substantially when γ is low, the total effect on quantity is negative. For high γ both low-cost reduce less their production and high-cost increase, so the global effect may be positive. Actually, in the beginning of the chapter, we established that L firms produce 5.46 times more than H firms (a figure derived from the observed real quantities sold). Even though H firms increase their production by over than 85%, L firms decrease their production by more than 35%, meaning that the net effect in the total quantity produced is negative. When γ is high, even though H firms decrease their quantity by almost 24%, L firms only decrease by 6%. Since there is one more L firm after the merger, the total quantity increases.

7.2.5 Price and Consumer Surplus

Let us now analyse the variation of price. If γ is low (high) enough, price increases (decreases) after the merger. The variation of price is directly related with the variation of quantity: if quantity increases, price decreases, and the opposite also. When innovation is efficient, we have already seen that total investment in innovation decreases with the merger, because low-cost firms perform less cost-reducing innovation. Since low-cost firms represent most of the market production, if they innovate less after the merger, price may increase. The opposite reasoning is also correct: when innovation is inefficient, low-cost firms innovate more to escape competition. Therefore, since innovation is cost-reducing, price decreases after the merger.

If quantity decreases, price increases and, consequently, the consumer surplus (CS) also decreases. These 3 variables are directly related: if firms produce less, prices increase, meaning that customers are worse off (decrease in consumer surplus). From Table 8 it is possible to see that this merger is only beneficial for consumers if γ is high enough. Before the simulation, one could think that low levels of γ would benefit the consumers, because firms would innovate more. However, we have seen that this does not happen. When γ is low, even though H firms innovate more, L firms do not. Since L firms produce much more than H firms, the effect on consumer surplus is mostly controlled by these firms. The same is verified regarding total innovation: the variation is always negative because low-cost firms always decrease their investment in innovation after the merger. The quantification of the consumer surplus variation shows that the possible loss of welfare (which occurs for γ <1.2) does not surpass 1.5% of the departing figure, and that the possible welfare increase also does not exceed 1.5% of the initial consumer surplus. These figures are associated with an expected small price change, lower than 0.1% upwards or downwards. Hence, the loss of consumer surplus, being so small, is likely to be compensated, in social terms, by fixed costs savings that are not explicitly modelled here, so the merger could be quietly authorized by antitrust authorities.

8. Conclusion

The effect of mergers on innovation is a topic that does not generate consensus among the scientific community. As highlighted in the literature review, this effect can be either positive, negative, or ambiguous, depending on several factors. Competition Authorities have the power to disapprove mergers that may harm consumers.

In this Dissertation, we proposed to evaluate the impact of the PSA/FCA merger on innovation in the EV industry. This merger was considered very relevant to analyse because of the impact it may have on the environment, especially regarding innovation concerning EVs production and EVs price (or accessibility for customers), towards energy transition (changing from non-renewable sources of energy to renewable ones, such as electricity). If the newly created merged entity, Stellantis, contributes to the shift of conventional automobiles to electric vehicles, it may help to achieve the energy transition. The PSA and FCA merger intended to create a new company that would be more competitive in the EV industry, through cost synergies, so the production of accessible EVs is expected to increase. The merger was carefully evaluated by the EC and ended up being approved. It finally took place officially in January 2021.

The EV industry characteristics were carefully analysed in this Dissertation to develop a reliable model. Based on real data, it was concluded that, inside the same market segment of cars, the characteristics are very similar, as are the prices. Therefore, we considered that quantity competition with homogeneous products was the most suitable characterization of this industry considering that our model is applied to each market segment separately. Furthermore, we analysed the production levels of the different EV car manufacturers. There is a significant discrepancy in the levels of production. Hence, we considered that firms are cost-asymmetric: firms with higher production levels incurred fewer costs than firms with lower production levels. Regarding the type of innovation, product, or process, the decision was not easy. In the last few years, the production cost of EVs has been falling, and it is expected to continue to do so in the upcoming ones (Hidrue et al., 2009), which is possible due to process innovation. Adepetu and Keshav (2017) found out that the price is the main barrier for a customer to acquire an EV. Knowing this, to increase the EV adoption, these authors suggested that policies should be implemented to decrease battery costs (to decrease the price) since it is the most expensive part of EVs. Furthermore, as we argued in Chapter 3, process innovation influences not only the decision to buy an EV because it can improve its performance, but it also contributes to energy transition since it reduces the environmental impact of electric batteries. Therefore, even though it is not an easy decision, we believe that process innovation is the most suitable for this Dissertation theoretical model.

The Ishida et al. (2011) model was selected as the most promising environment to address the EVs industry merger cases, in particular the important PSA/FCA merger. The model was adjusted according to the characteristics expressed before, to better fit the industry in question, and in this way also filling a gap in the literature that has to do with the more realistic approach of considering a generic number of low-cost firms and high-cost firms in the Ishida et al. (2011) setup, instead of a generic number of high-cost and just one low-cost.

Then, we analysed the levels of production of EV producers in Europe. Based on the quantities, we observed that in the pre-merger situation there are 4 low-cost companies and 9 high-cost ones, being both PSA and FCA high-cost players. However, by joining resources and expertise, we assumed that the merged entity would become a low-cost firm, meaning that the market would then have 5 low-cost companies and 7 high-cost ones. Our model was developed based on this important assumption.

After developing the model, we performed several simulations to understand the impact of this merger on innovation, profits, quantities, price, and consumer surplus. Regarding innovation, we have seen that this merger decreases total innovation investment in the industry. Low-cost firms always decrease their investment because, after the merger, competition increases among these groups (2 high-cost firms become one low-cost). Also, the newly merged entity is a low-cost firm that increases its investment. Therefore, because of the strategic substitution effect, the other L firms decrease their investment in innovation. Relatively to high-cost firms, innovation investment may increase or decrease, depending on its efficiency. On the one hand, competition inside this group decreases. On the other hand, we have the strategic substitution effect (caused by the investment increase of the newly merged entity). Nevertheless, since merging companies increase their investment in innovation, the decrease in total innovation is due to the response of outsiders. The decrease in total innovation investment is lower (higher) when the investment in innovation is less (more) efficient.

After the merger, the profits of H firms always increase because there is less competition in the industry. In contrast, the profits of L firms decrease because competition increases inside this group. Nevertheless, the total profits of the industry increase after the merger. It is interesting to note that the variation of profits of the merging companies is negative (merger paradox). However, they still decide to merge because efficiency gains are not considered in our model, such as the reduction of fixed costs. It is also interesting to see that this merger benefits high-cost companies, while it harms low-cost ones.

We also wanted to understand the effect of the merger on quantity, price, and consumer surplus. The quantity produced by L firms always decreases after the merger. Since competition increases (one more L firm after the merger), firms produce less. Also, when H firms increase their production, the strategic substitution effect contributes to the decrease of the L firms' quantity. Regarding H firms, the quantity output only increases if the investment in innovation is sufficiently efficient. Even though competition decreases (one firm less), there are still 7 companies, meaning that competition is still high. In terms of total quantity produced, it only increases if the investment in innovation is not very efficient. Even though H firms increase their production if γ is low enough, L firms decrease because of the strategic substitution effect. Since L firms produce 5.46 times more on average, total quantity only increases when the decrease in the production of L firms is minimum, which occurs for inefficient investment in innovation (high γ). By decreasing the price, this merger may contribute to two important events: first, an increase in the welfare of consumers; second, if the price drops quantity increases, meaning that the adoption of EV increases, and we approach green energy transition. Actually, if γ is high (low) enough, price decreases (increases). So, in terms of consumer welfare, this merger is only desirable if the investment in innovation is inefficient (high γ), which may be a surprising result, but derives from the fact that high γ mitigates the quantity adjustment by low-cost producers after the merger, especially due to stronger synergy effects that drive a more pronounced increase in the quantity of the newly created low-cost firm as compared with the sum of the pre-merger productions of the two former high-cost firms. Also, if prices decrease, the rate of adoption of EVs increase, which is a desirable effect towards green energy transition. This is very important since the energy transition is highly beneficial for society.

The practical application of our model has some limitations related to the data used. First, market segments may be difficult to identify in the EV market. Second, as stated in chapter 6., we use sales data regarding all the industry, even though our model is applied to market segments individually. Due to the lack of data we had to consider this option. Furthermore, despite some brands producing more units for the European market, we did not consider the total production of each brand. One brand may produce only a few units for Europe but have a very high production for countries outside Europe that generates scale economies, which means that our classification of low-cost and high-cost brands may not be fully correct.

Our model considers a linear demand where both the maximum price and the slope are equal to 1. This approach was selected for simplification purposes, given the complexity of the model, with many different parameters. As an extension, we propose not to normalize the demand intercept to one, using another parameter instead. This could capture the effect of product innovation, through different values for this parameter, associated with higher or lower valuations of the product, according to its perceived quality. However, we predict that conclusions would become even more difficult to extract without simulation. It would also be interesting to observe the impact on the results of changes in demand elasticity, partially captured by the slope.

References:

Adepetu, A., & Keshav, S. (2017). The relative importance of price and driving range on electric vehicle adoption: Los Angeles case study. *Transportation*, 44(2), pp. 353–373. https://doi.org/10.1007/s11116-015-9641-y

Aghion, P., Bloom, N., Blundell, R., Griffith, R., & Howitt, P. (2005). Competition and innovation: An inverted-u relationship. *Quarterly Journal of Economics*, 120(2), pp. 701-728. https://doi.org/10.1162/0033553053970214

Ahmad, A. Rao, S. (2001). The Importance of Innovation for Productivity. *International Productivity Monito,* 2, pp. 11-18. https://www.researchgate.net/publication/24051620_The_Importance_of_Innovation_for_Productivity

Arrow, K. 1962. Economic welfare and the allocation of resources for invention. *The Rate and Direction of Inventive Activity: Economic and Social Factors*. Princeton University Press, pp. 609–626.

Auto Express. (2021). *Stellantis: FCA and Group PSA merger confirmed*. https://www.autoexpress.co.uk/fiat/108280/stellantis-fca-and-groupe-psa-merger-confirmed [Accessed 22/02/2021]

Becker, T. A., Sidhu, I., Tenderich, B. (2009). Electric Vehicles in the United States A new model with Forecasts to 2030. *Center for Entrepreneurship & Technology, University of California, Berkeley*. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1048.8973&rep=rep1&type=pdf

Belleflamme, P., & Vergari, C. (2011). Incentives to innovate in oligopolies. *Manchester School*, 79(1), pp. 6-28. https://doi.org/10.1111/j.1467-9957.2009.02131.x

Bena, J., & Li, K. (2011). Corporate Innovations and Mergers and Acquisitions. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.1917215

Bertrand, O. (2009). Effects of foreign acquisitions on R&D activity: Evidence from firm-level data for France. *Research Policy*, 38(6), pp. 1021-1031. https://doi.org/10.1016/j.respol.2009.03.001

Blonigen, B. A., & Taylor, C. T. (2000). R&D intensity and acquisitions in high-technology industries: Evidence from the US electronic and electrical equipment industries. *Journal of Industrial Economics*, 48(1), pp. 47-70. https://doi.org/10.1111/1467-6451.00112

Blundell, R., Griffith, R., & Van Reenen, J. (1999). Market share, market value and innovation in a panel of British manufacturing firms. *Review of Economic Studies*, 66(3), pp.529-554. https://doi.org/10.1111/1467-937X.00097

Bourreau, M., Jullien, B., & Lefouili, Y. (2019). Mergers and Demand-Enhancing Innovation. Working Papers, no 18-907, Toulouse School of Economics (TSE). https://EconPapers.repec.org/RePEc:tse:wpaper:32578

Boutin, X. (2015). Mergers and the Dynamics of Innovation. Working Papers ECARES 2015-15, Universite Libre de Bruxelles (ULB). https://ideas.repec.org/p/eca/wpaper/2013-199235.html

Car Plus. (2021). *Fiat 500 Usado ou Novo: Preço, Interior e Extras*. https://www.carplus.pt/noticias/fiat-500/ [Accessed 24/02/20201]

Carmagazine. (2020). *Electric car batteries: everything you need to know.* https://www.carmagazine.co.uk/electric/ev-car-battery-capacity-tech/ [Accessed 10/03/20201]

Cefis, E., Sabidussi, A., & Schenk, H. (2007). Do mergers of potentially dominant firms foster innovation? Working Papers, Utrecht School of Economics. https://www.researchgate.net/publication/40099402_Do_Mergers_of_Potentially_Dominant_firms_foster_Innovation

Clougherty, J. A., & Duso, T. (2009). The impact of horizontal mergers on rivals: Gains to being left outside a merger. *Journal of Management Studies*, 46(8), pp. 1365-1395. https://doi.org/10.1111/j.1467-6486.2009.00852.x

Comanor, W. S., & Scherer, F. M. (2013). Mergers and innovation in the pharmaceutical industry. *Journal of Health Economics*, 32(1), pp.106-113. https://doi.org/10.1016/j.jhealeco.2012.09.006

Crepon, B., Duguet E., Kabla I. (1996). *Schumpeterian Conjectures: A moderate Support from Various Innovation Measures*. London, Palgrave Macmillan. https://doi.org/10.1007/978-1-349-13917-0_3

Davidson, C., & Ferrett, B. (2007). Mergers in multidimensional competition. *Economica*, 74(296), pp. 695-712. https://doi.org/10.1111/j.1468-0335.2007.00595.x

Denicolò, V., & Polo, M. (2018). The Innovation Theory of Harm: An Appraisal. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3146731

Duksaite, E. & Tamosiuniene, R. (2009). Why Companies Decide to Participate in Mergers and Acquisitions Transactions. *Mokslas – Lietuvos ateitis*, 1 (3), pp. 21-25. https://www.researchgate.net/publication/277231701_Why_Companies_Decide_to_Participate_in_Mergers_and_Acquisition_Transactions

European Alternative Fuels Observatory. (2021). *European Vehicles Categories*. https://www.eafo.eu/knowledge-center/european-vehicle-categories [Accessed 24/02/2021]

European Commission. (2019). *Reducing CO2 emissions from passengers' cars*. https://ec.europa.eu/clima/policies/transport/vehicles/cars_en [Accessed 21/12/2020]

European Commission. (2020). *Mergers: Commission opens in-depth investigation into the proposed merger of PSA and FCA*. https://ec.europa.eu/commission/presscorner/detail/en/IP_20_1117 [Accessed 21/12/2020]

European Commission. (2020a). *Mergers: Commission approves the merger of FCA and PSA, subject to conditions.* https://ec.europa.eu/commission/presscorner/detail/en/IP_20_2506 [Accessed 21/12/2020]

Federico, G., Langus, G., & Valletti, T. (2017). A simple model of mergers and innovation. *Economics Letters*, 157*,* pp. 136-140. https://doi.org/10.1016/j.econlet.2017.06.014

Federico, G., Langus, G., & Valletti, T. (2018). Horizontal mergers and product innovation. *International Journal of Industrial Organization*, 59, pp. 1-23. https://doi.org/10.1016/j.ijindorg.2018.03.001

Financial Times. (2020). *PSA and Fiat Chrysler overhaul terms of €50bn merger*. https://www.ft.com/content/8c1192db-125b-46a7-b15b-abaad29583f9 [Accessed 21/12/2020]

Financial Times. (2020a). *The European electric vehicle landscape.* https://www.ft.com/content/4cbf843e-2503-462c-a9cf-1fdc502ffddc [Accessed 03/04/2021]

Forbes. (2019). *New Technology Threat Motivates FCA_PSA Merger*. https://www.forbes.com/sites/neilwinton/2019/12/22/new-technology-threat-motivated-fca-psa-merger-expect-more-global-upheaval/?sh=5bc48c6c34a4 [Accessed 21/12/2020]

Gilbert, R. J. (2019). Competition, Mergers, and R&D Diversity. *Review of Industrial Organization*, 54(3), pp. 465-484. https://doi.org/10.1007/s11151-019-09679-5

Gu, F., Guo, J., Yao, X., Summers, P.A., Widijatmoko, S.D., & Hall, P. (2017). An investigation of the current status of recycling spent lithium-ion batteries from consumer electronics in China. *Journal of Cleaner Production*, 161, pp. 765-780. https://doi.org/10.1016/j.jclepro.2017.05.181

Haleblian, J., Devers, C. E., McNamara, G., Carpenter, M. A., & Davison, R. B. (2009). Taking stock of what we know about mergers and acquisitions: A review and research agenda. *Journal of Management*. 35(3), pp. 469-502. https://doi.org/10.1177/0149206308330554

Haucap, J., Rasch, A., & Stiebale, J. (2019). How mergers affect innovation: Theory and evidence. *International Journal of Industrial Organization*, 63, pp. 469-502. https://doi.org/10.1016/j.ijindorg.2018.10.003

Haucap, J., & Stiebale, J. (2016). How mergers affect innovation: Theory and evidence from the pharmaceutical industry*. International journal of industrial organization*, 63, pp. 283–325. http://hdl.handle.net/10419/130193

Hidrue, M. K., Parsons, G. R., Kempton, W., & Gardner, M. P. (2011). Willingness to pay for electric vehicles and their attributes. *Resource and Energy Economics*, *33*(3), pp. 686–705. https://doi.org/10.1016/j.reseneeco.2011.02.002

Hitt, M., Hoskisson, R., Ireland, R., & Harrison, J. (1991). Effects of Acquisition on R&D Inputs and Outputs. *The Academy of Management Journal*, 34(3), pp. 693-706. https://doi.org/10.2307/256412

Hollenbeck, B. (2020). Horizontal mergers and innovation in concentrated industries. *Quantitative Marketing and Economics*, 18(1), pp. 1-37. https://doi.org/10.1007/s11129-019-09218-2

International Energy Agency. (2020). *Evolution of Li-ion battery price, 1995-2019.* https://www.iea.org/data-and-statistics/charts/evolution-of-li-ion-battery-price-1995-2019 [Accessed 10/03/2020]

Institute for Mergers Acquisitions and Alliances. (2020). *M&A Statistics*. https://imaa-institute.org/mergers-and-acquisitions-statistics/ [Accessed 21/12/2020]

Ishida, J., Matsumura, T., & Matsushima, N. (2011). Market competition, R&D and firm profits in asymmetric oligopoly. *Journal of Industrial Economics*, 59(3), pp. 484–505. https://doi.org/10.1111/j.1467-6451.2011.00461.x

Ishikawa, N. Shibata, T. (2020). Market competition, R&D spillovers, and firms' cost asymmetry. *Economics of Innovation and New Technology*, 29(8), 847-865. https://doi.org/10.1080/10438599.2019.1673564

Jullien, B., & Lefouili, Y. (2018). Horizontal Mergers and Innovation. *Journal of Competition Law & Economics*, 14(3), pp. 364-392. https://doi.org/10.1093/joclec/nhy010

Kesavayuth, D., Lee, S. H., & Zikos, V. (2018). Merger and Innovation Incentives in a Differentiated Industry. *International Journal of the Economics of Business*, 25(2), pp. 207-221. https://doi.org/10.1080/13571516.2017.1389818

Kleer, R. (2012). The effect of mergers on the incentive to invest in cost-reducing innovations. *Economics of Innovation and New Technology*, 21(3), pp. 287–322. https://doi.org/10.1080/10438599.2011.580109

König, A., Nicoletti, L., Schröder, D., Wolff, S., Waclaw, A., & Lienkamp, M. (2021). An overview of parameter and cost for battery electric vehicles. *World Electric Vehicle Journal*, 12(1). https://doi.org/10.3390/wevj12010021

Marshall, G., & Parra, Á. (2019). Innovation and competition: The role of the product market. *International Journal of Industrial Organization*, 65, pp. 221-247. https://doi.org/10.1016/j.ijindorg.2019.04.001

Matsushima, N., Sato, Y., Yamamoto, K., (2013). Horizontal mergers, firm heterogeneity, and R&D investments. *The B.E. Journal Economic Analysis & Policy*. 13(2), pp. 959–990. https://doi.org/10.1515/bejeap-2012-0058

Motta, M. Tarantino E. (2017), The effect of horizontal mergers, when firms compete in prices and investments. Economics Working Papers, Department of Economics and Business, Universitat Pompeu Fabra. https://EconPapers.repec.org/RePEc:upf:upfgen:1579

Opel Auto Industrial. (2021). *Opel Adam*. https://opel.autoindustrial.pt/veiculos/veiculos-de-passageiros/adam/index/ [Accessed 24/02/2021]

Ornaghi, C. (2009). Mergers and innovation in big pharma. *International Journal of Industrial Organization*, 27(1), pp. 70-79. https://doi.org/10.1016/j.ijindorg.2008.04.003

PV Magazine. (2019). *Innovation boots lithium-ion battery recycling rate to over 80%.* https://www.pv-magazine.com/2019/03/25/innovation-boosts-lithium-ion-battery-recycling-rate-to-over-80/ [Accessed 01/05/2021]

Régibeau, P., & Rockett, K. E. (2019). Mergers and Innovation. *The Antitrust Bulletin*, 64(1), pp. 31-53. https://doi.org/10.1177/0003603X18822576

Reuters. (2021). *After long journey, Fiat Chrysler and PSA seal merger to become Stellantis.* https://www.reuters.com/article/us-stellantis-deal-idUSKBN29L001 [Accessed 04/04/2021]

Salant, S. W., Switzer, S., & Reynolds, R. J. (1983). Losses from horizontal merger: The effects of an exogenous change in industry structure on cournot-Nash equilibrium. *The Quarterly Journal of Economics*, 98(2), pp. 185-199. https://doi.org/10.2307/1885620

Schumpeter, J. (1943). *Capitalism, Socialism and Democracy*. London, Unwin University Books.

S&P Global. (2020). *What is Energy Transition?* https://www.spglobal.com/en/research-insights/articles/what-is-energy-transition [Accessed 21/12/2020]

Soltani-Sobh A., Heaslip K., Bosworth R., Barnes R., Yook D. (2015). Investigating factors affecting electric vehicles adoption: an aggregated panel data analysis over U.S. states. *World Electric Vehicle Journal*, 7(4), pp. 681-691. https://doi.org/10.3390/wevj7040681

Soulopoulos, N. (2017). *When will Electric Vehicles be Cheaper than Conventional Vehicles*? Bloomberg New Energy Finance. https://www.blogmotori.com/wp-content/uploads/2017/07/EV-Price-Parity-Report_BlogMotori_COM_MobilitaSostenibile_IT.pdf

Stiebale, J. (2013). The impact of cross-border mergers and acquisitions on the acquirers' R&D - Firm-level evidence. *International Journal of Industrial Organization*, 31(4). https://doi.org/10.1016/j.ijindorg.2013.04.005

Stiebale, J., & Reize, F. (2011). The impact of FDI through mergers and acquisitions on innovation in target firms. *International Journal of Industrial Organization*, 29(2), pp. 155-167. https://doi.org/10.1016/j.ijindorg.2010.06.003

Szücs, F. (2014). M&A and R&D: Asymmetric Effects on acquirers and targets? *Research Policy*, 43(7), pp. 1264-1273. https://doi.org/10.1016/j.respol.2014.03.007

Tang, J. (2006). Competition and innovation behavior. *Research Policy*, 35(1), pp. 68-82. https://doi.org/10.1016/j.respol.2005.08.004

TIME. (2020). *3 Reasons a Fiat Chrysler – Peugeot Merger Makes Sense, According to the Experts*. https://time.com/5715804/fiat-chrysler-psa-peugeot/ [Accessed 21/02/2021]

Uhlenbruck, K., Hughes-Morgan, M., Hitt, M. A., Ferrier, W. J., & Brymer, R. (2017). Rivals' reactions to mergers and acquisitions. *Strategic Organization*, 15(1), pp. 40-66. https://doi.org/10.1177/1476127016630526

Valentini, G. (2016). The Impact of M&A on Rivals' Innovation Strategy. *Long Range Planning*, 49(2), pp. 241-249. https://doi.org/10.1016/j.lrp.2015.02.007

Volkswagen. (2021). *O Polo*. https://www.volkswagen.pt/pt/modelos/vw-carro-urbano-polo.html [Accessed 24/02/2021]

WattEV2Buy. (2020). *European EV Price List*. https://wattev2buy.com/european-ev-market-price-list-electric-cars-eu/ [Accessed 24/02/2021]

Weiss, M., Patel, M., Junginger, M., Perujo, A., Bonnel, P., Van Grootveld, G. (2012) On the electrification of the road transport – Learning rates and prices forecasts for hybrid-electric and battery-electric vehicles. *Energy Policy*, 48, pp. 374 – 393. http://dx.doi.org/10.1016/j.enpol.2012.05.038