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Pursuing innovation through alliances and partnerships in the automotive industry

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Introduction

The urge to safeguard the environment is rising on the agenda of the policymakers (Story et al., 2011). The resulting environmental commitment is impacting one of the most important industries in the world, the automotive industry. Regulators are pushing towards new rules that are reshaping the priorities of the major Original Equipment Manufacturers (OEMs) in the industry (Story et al., 2011), whose strategies and actions need to account for the fact that developing functional and reliable cars requires many different competences that must be integrated with the new powertrain technologies that are emerging with the purpose to accomplish the new rules.

In this changing environment, the OEMs are following different strategies to reach the goal of creating environmentally friendly products that can substitute the old thermic engine technology, or at least create an alternative (Cano-Kollmann et al., 2018). Observing how the OEMs react is interesting because the new technologies require competencies completely different from the ones required in the industry before (Hodapp & Dao, 2019). The automotive industry has high barriers to entry, for this reason, it can be difficult for the new entrants to penetrate the market (Zapata & Nieuwenhuis, 2010). At the same time, the actors in the industry are under pressure due to the new policies that threat the advantages linked to the knowledge of the thermic engine. One of the most interesting strategies to reach the goal of gather the new knowledge required to accomplish the environmental policies is innovating through open innovation. Indeed, absorbing the knowledge from outside can be a less costly and faster alternative rather than committing to solo research or pursue an M&A strategy (Cano-Kollmann et al., 2018).

The goal of this thesis is to understand how and to which extent the innovation in the domain of new powertrain technologies in the automotive industry has been pursued through alliances. Moreover, it explores whether the OEMs followed similar or different collaborative paths. The analysis offers a picture of the alliances made to pursue innovation and that be useful to interpret the future behavior and results of the OEMs.

The first chapter of the paper is dedicated to the theory of dominant design, the technology transition in a stable market, the impact of the regulations for which regards the innovation, and a focus on the hybrid intergenerational technologies. In particular, the latter topic is crucial to understand the dynamics that can pursue the OEMs to follow a strategy rather than another. The second chapter explores the theory of open innovation. The topics debated in this section are the absorption of external knowledge, in particular through alliances, the peculiarities of vertical and horizontal partnerships, and the Joint Ventures (JVs) features.

The third chapter focuses on the automotive industry, and specifically on the new trends and technologies that are emerging, the threat of the new entrants, and the role of the alliances in this scenario. This chapter is useful to understand why the new powertrain solutions are becoming crucial for the automotive industry. Then we will talk about how the alliances can help the OEMs to develop those technologies. At the end of the chapter, there is the methodology that has been followed to gather all the data useful to make the analysis.

Finally, there is the fourth and last chapter. In the first part of the chapter, it is possible to enter more in-depth about the strengths and the weaknesses of the new powertrain solutions both from the customer and the OEM side. Then we can find the empirical analysis divided in two paragraphs. In the first one, we have the track of all the joint ventures that aim at the development of the new powertrain solutions. The list is divided into the JVs between OEMs and the JVs between the OEMs and other actors. In the last paragraph there is the analysis of the alliances' data. The analysis is useful to have a picture of all the alliances made for improving the new powertrain solution and outline the different strategies of the OEMs. The results show that the OEMs followed different strategies and focused on alternative technologies. At the same time emerged also the importance of the new actors in the industry for the majority of the OEMs.

Chapter 1- Literature review

1.1 Dominant design

Dominant design theory is crucial to understand the development of technologies. Since no technologies are able to perform in all the dimension there are organizational, technical and political processes that influences the market choice (P. Anderson & Tushman, 1990). We define a dominant design as follows. "*A dominant design is a specific path, along an industry's design hierarchy, which establishes dominance among competing design paths*" (Suarez & Utterback, 1993:3). It may happen in a market that a specific dominant design emerges and all the companies that want to compete in this market have to adapt to this design. If they do not adapt to the dominant design are out of the market, or relegated to some niche (Suarez & Utterback, 1993). Notice that the terms dominant design and standard are usually used as synonymous. The process to become a dominant design has three stages. The first stage is variation. In this stage, new technologies compete and there is not a clear pattern to follow. Then we have the selection stage in which social, economic, and political dynamics influence the market that selects the winning design among the alternatives. The first two stages form the era of ferment because there is not a clear design but several alternatives. Finally, we have the retention. In this phase, the dominant design is emerged and becomes the time for the competition of companies for incremental innovations. In this period the interdependence among the actors in the market and the technical competencies on the dominant design increase (P. Anderson & Tushman, 1990). Technological discontinuities create rivalries between different technological alternatives. Once a technology became a dominant design, we have an era of incremental product innovation, process innovations, and enhancement in the knowledge that increases the performance of the product (P. Anderson & Tushman, 1990). Even though the performance of a standard, or dominant design, is increasing, the best alternative in the market can be broken by an eventual technology breakdown. That technological breakdown can be triggered by many factors, such as random events, the change in taste by consumers, political actions, and the incremental knowledge acquired (P. Anderson & Tushman, 1990). The nature of this phenomenon is cyclic, there are periods of technological change that are followed by a dominant design, and then other disruptive technology that will lead to a new era of technological change. The technology cycle does not depend only on the technical performances, it depends also on the preferences of the consumers and strategic choices. There are plenty of examples that underline how technologically superior products lost a battle for becoming dominant design against inferior technologies. We should not forget that not all the new technologies defeat the older ones, that multiple designs may emerge, and that a new technological discontinuity may not become a dominant design (P. Anderson & Tushman, 1990).

When a dominant design emerges the innovation in the industry is likely to become incremental, competence enhancing, and focused on processes (P. Anderson & Tushman, 1990). Production becomes more standardized, the focus shifts on costs and the economies of scale are crucial to increase the margins. The goals shift to the volume and the efficiency from the product innovation and the effectiveness that emerges in the stage of ferment (P. Anderson & Tushman, 1990). The emergence of a dominant design allows to reduce the uncertainty, in this way the suppliers can invest in one technology reducing the costs. Moreover, a stable system leads to higher levels of compatibility and integration, especially if is the case of a complex product. (David & Bunn, 1988). The nature of the innovation is crucial to understand the uncertainty that the companies must face in the market. One distinction can be made between radical and incremental innovation. Radical innovation causes a fundamental change in the activities of the organization and represents a clear distinction between the old practices and the new ones. On the contrary, an incremental innovation has a minor impact on activities and practices (Dewar & Dutton, 1986) (Ettlie et al., 1984). Another way to consider the nature of the technology is competence enhancing and competence destroying. Since the competence enhancing innovation build on the previous knowledge has less impact on the market compared to the competence destroying innovation (Tushman & Anderson, 1986). The competence enhancing innovations are usually successfully faced by incumbents which have deep knowledge of the current generation technology. Indeed, the exit from the entry-to-exit ratio is small, in other words, the industry does not change so much. Instead, the competence destroying innovation is rarer but has a huge impact on an industry. The number of new entrants that try to penetrate the market with new generation products and without old assets and organizational inertia causes serious difficulties to incumbents. Both competencies enhancing and competence destroying innovations allow new entrants to gain market share, but the competence destroying have a higher impact on the market (Tushman & Anderson, 1986). Even though, competence enhancing is risky for incumbents they can count on their demand-side knowledge, as long as addresses the same customers' needs (Christensen & Bower, 1996).

The cycling nature of the dominant design led the incumbents to pay attention to the new disruptive technologies. At the same time, it is impossible to gain knowledge in every single new technology path. It is needed to have the capabilities to understand and predict when a new technology will reshape the industry. A new dominant design can emerge from different sources, it may emerge from a niche or be completely new. It may come from a similar market or a completely different market (Fernández & Valle, 2019). For this reason, is very difficult to predict where a new threat can come from and at the same time competing on incremental innovation.

The dominant design can be analyzed at different levels of analysis. Indeed, it could be view as a product, as a component of a product, or as a system of products (Murmann & Frenken, 2006). Even the level of abstraction could be different. For example, Abernathy (1978) in "Productivity Dilemma: Roadblock to Innovation in the Automobile Industry" talks about the dominant design in the automotive industry. The first competition analyzed was the Internal Combustion Engine (ICE) engine against the electric engine as the dominant design in 1902. Then in the same opera, the author talks also about the competition among different standards of ICEs. The V-8 ICE engine has been identified as the dominant design in the 1930s. These two comparisons of technologies were made at different level of abstraction. Indeed, the first competition was made according to the energy source, combustion vs steam, and the second competition analyzed concerns to the technical feature of the combustion engine. The two analysis referred to different levels of abstraction. Moreover, not only the level of analysis counts in determining if a technology is a dominant design or not but also the time span is important. If we take into consideration a short amount of time is more less likely to find a change in the market. At the contrary if we take into consideration a longer period is easier to find an alternance of different technologies. In a specific industry is likely to see only one technology that dominates if we take into consideration one year rather than if we take into consideration twenty years (Murmann & Frenken, 2006). For this reason, it is necessary to clarify that a dominant design can be individuated in one analysis but not in another according to the features taken into consideration in the analysis.

1.1.1 Barriers to entry

As seen above during the emergence of radical innovation the new entrants have the possibility to threaten the incumbents focusing on the new radical technology. Anyway, it is not so easy to penetrate a new market there are barriers that make difficult for the new entrants to compete with incumbents.

One definition of barrier to entry is the following "*as a cost of producing (at some or every rate of output) which must be borne by a firm which seeks to enter an industry but is not borne by firms already in the industry*" (Stigler, 1983:67). In an industry with high barriers to entry, the new entrants would pay higher costs to penetrate the market. For this reason, the new entrants have less likelihood to gain profits. A market that has less perspective of profits than others is less attractive for new entrants and it is less likely that a company would choose to penetrate that market.

There are different classifications of the barriers to entry. It could be useful to make a distinction between exogenous and endogenous barriers because it delimits the boundaries of action for an incumbent. The exogenous barriers to entry are embedded in the industry structure and not under the control of the firms. Instead, the endogenous barriers depend on the behavior of incumbents (Shepherd & Shepherd, 2003). Since the barriers are mutually reinforcing, it is difficult to say with precision how much of a barrier depends on the behavior of the actors of the market (Gable et al., 1995).

One of the most common exogenous barriers is the cost advantage, with a fixed or variable cost advantage the new entrants are forced to invest in scale economies to compete in price (Gable et al., 1995). Another exogenous barrier is the incumbents' product differentiation, it creates a relationship of loyalty between the companies and customer (Pehrsson, 2004). In a market, with loyal customers, the new entrant needs to fight to gain the customer's trust (Johansson & Elg, 2002). Another exogenous barriers are the need for capital (Harrigan, 1981), in a capital-intensive industry, there are high fixed costs that a new entrant has to put in place since the begging. Furthermore, if we are in the first stages of a technology generation is difficult to find a good distribution channel, this could create difficulties to find the right consumers (Han et al., 2001). Other barriers are brand loyalty when the incumbents have well-known brands (Krouse, 1984) and government policy (Delmas et al., 2007). On the contrary endogenous barriers are not intrinsic to the market but depend on the behavior of the incumbents. One example of an endogenous barrier is the expenditure in promotional activity (Demsetz, 1982) or the aggressive price competition (Dixit et al., 2006). Even the expected reaction to new entrants by incumbents is considered a barrier to entry. A new entrant may be opposed by incumbents that see him as a threat to their profitability (Karakaya & Stahl, 1989).

A way to overcome barriers to entry is product innovation. Products that are technologically different from the ones on the market can differentiate and try to compete in a different field without being threatened by the barriers(Han et al., 2001). At the same time facing an established dominant design is never a simple task. The dominant design creates collective patterns and facilitates the development of incremental innovation, in this way previous investments became more and more valuable. For this reason, the challenge between alternative designs involves not only the technologies by themselves but also path dependence features. Some examples of features that could influence the technology path are customers' practices and values, designers’ competencies, ecosystems perimeters, regulations, and so on (James M. Utterback, 2016).

The firms or the group of firms that have developed and promoted a dominant design shape the future generation of products creating a sort of monopoly power of this product. In fact, the dominant design locks out of the competition all those products that have not all the features required (Schilling, 1998). A dominant design, on one hand, promotes process innovation and reducing the technology paths the companies could focus to invest in one single design and increase the efficiency. On the other hand, it increases the creation of monopoly power, increasing the competitors' costs and the market concentration. This phenomenon led to less product choice and development, so, less innovation (Swann, 2001). This effect exacerbates when a product is protected by strong intellectual property rights. Note that when a group of companies with high technological proximity share information and knowledge are able to promote a definite standard (Soh, 2010). This allows the companies to create high barriers for the new entrants.

According to Brem et al. (2016), in the last years the positive correlation between dominant design and process innovation is still strong. At the same time, the negative correlation between radical innovation and dominant design is decreasing. Nowadays, the companies are not abandoning the radical innovation research even though there is a dominant design in the market. Moreover, the industries that presents a dominant design are decreasing over time compared to the past. This process may be an expression of the technology innovation that is becoming more and more dynamic changing quickly than in the past. It is more frequent that a new technology has not the material time to become a dominant design because is overcome by newer technology (Brem et al., 2016).

1.2 New technologies and discontinuities

We can define innovation as "The first successful application of a product or process" (Cumming, 1998). The definition chosen allows us to better understand the meaning of innovation. For first it has to be something new but not in absolute terms of the invention but in terms of application. Then it has to be successful, it does not matter if it has been applied in the past in a small niche. Finally, it can be both a product and a process.

When we are talking about radical innovation the impact of the innovation is game-changing in a specific industry. A definition of radical innovation could be "*A radical innovation is a product, process or service with either unprecedented performance features or familiar features that offer significant improvements in performance or cost that transform existing markets or create new ones*" (Leifer et al., 2001: 102). Radical innovations usually led to "technological discontinuities" that are "those rare, unpredictable innovations which advance a relevant technological frontier by an order-of-magnitude and which involve fundamentally different product or process design" (P. Anderson & Tushman, 1990). Those technological discontinuities are an effect of the incoming of disruptive technologies in a market. It is important to underline the differences between radical innovation and disruptive innovation. The radical nature of innovation is linked with the technological nature of innovation. We have radical innovation when there is a huge technical difference from the previous technology, as previously described (Rogers, 2010). Instead, the term disruptive innovation is linked to the market. In particular, disruptive innovation should change the tastes of the consumers to new criteria for the value of the new product. According to Christensen (2016) The disruptive technologies initially underperform in the mainstream market. Potentially they have all the features to overcome the old ones, but in the first stage, they underperform compared to the established ones. The new technologies are generally supported by new entrants because are not able to satisfy the mass market and incumbents consider them inappropriate to their customers' needs. Initially, their target is a niche of the market, then with the support of R&D investments became enough mature to satisfy the mass market. Likely, incumbents are focused on improving sustaining technology, or incremental technologies performances. At least until new entrants emerge, based on these disruptive technologies. The nature of the technology, if it is disruptive or sustaining, depends on the industry. The same technology may be defined as disruptive in one industry and sustaining in another (Christensen, 2016). Disruptive innovation has a huge impact on the incumbents, a radical innovation may not change the market but only the technology adopted (Rogers, 2010). Since the disruptiveness of innovation is linked to its effect on the market it is really difficult to define if a technology disruptive or not ex-ante (Danneels, 2004).

Moreover, disruptive technologies have a huge impact on the demand side. Often new technologies change the base of competitions and the criteria that a customer search for that product. New technologies may introduce a new way to evaluate a certain product, changing the expectation of the market (Danneels, 2004). One example could be disk drives. Once the capacity exceeded the requirements of the market the competition shift to the size of the drive became the crucial features. For the companies that invested in a disruptive technology and want to bring into the market a product that results from this effort is to identify the application that better satisfy the customer needs. To do that the product must attribute that the technology allows developing, then understand what the right market is to do that (Danneels, 2004). The capabilities required to create radical innovation are very different from the ones to create sustaining technology. Indeed, radical innovation requires a high degree of informality, intense communication and cooperation among actors, low bureaucracy, creativity, and the ability to take risks (Song & Swink, 2002).

1.2.1 Impact of regulation on the innovation

The policymakers can play an important role in the shift toward a new dominant design. The context in which the policymakers operate is crucial for the effectiveness of the environmental objectives and the innovation outcomes. Some of the features that influence a context are infrastructural requirements, capital intensities, technological linkages, performance parameters, and technology paths (Kemp & Pontoglio, 2011). The policymaker can intervene using different instruments. It is possible to make a distinction between economic and regulatory instruments. The economic ones try to address the firms in a certain direction through incentives or fees. The value of the incentives and fees is settled based on the emission, for example. The expectation is that the firms, acting in their own interest, will reduce the amount of emissions (Stavins, 2003). On the contrary, the regulatory instruments affect directly the performance of the firms. Those instruments are for example technological standards (using one technology rather than another), emission standards (an absolute value to reach), and so on. Some of them could be mandatory while other optional but with a penalty. For which regards the economic instruments may be difficult to set a fee or incentives that promote the right effort from firms (Fischer et al., 2012).

The legal instruments used by the policy maker that affects technology innovations can be divided into general legal instruments and technology-specific instruments. The firsts do not address a specific technology, the focus is on the results, for example setting a standard for emission levels. Instead, the technology-specific instruments goal is to support some technologies rather than others, heavily influencing the technology path. Some author advocate that general instruments are better because does not exclude any technology path that may be the most efficient in the future like (Jaffe et al., 2005). At the same time, others think that general instruments would benefit more the existing technologies rather than new and niche technologies that would remain unused (Sandén & Azar, 2005).

Setting standards is a difficult work that hides many inconveniences. Since a standard for every firm may lead to an exit from the market for those firms that have not the capacity to spend a huge amount of money on R&D innovations. The cost of reaching this standard is not well known at the beginning and differs from firm to firm. If the companies prefer to exit from the market rather than investing in the new technology the overall amount of investment in innovation would reduce (Jaffe et al., 2002).

Another important distinction that could be made is between technology-forcing and technology-following regulations. Technology forcing regulations force the producers to develop innovations to accomplish a specific standard. On the opposite the technology following regulations allows the producers to go step-by-step, the companies have already the capabilities to reach the standard imposed immediately. For example for which regards the emission regulation of the automotive industry some countries are more disposed to promote technology-forcing such as the US with the CAAA (Gerard & Lave, 2005). Instead, the European ones are considered more technology following (Faiz et al., 1996). These different ways of regulating can have different results considering that many companies compete in the same market all over the world. Indeed, foreign regulations have a great impact on domestic innovation, sometimes even higher than domestic regulation (Hascic et al., 2008).

1.2.2 Technological transitions

The technology transition from one existent technology to another is never a simple task, it involves a series of challenges to overcome (McLoughlin et al., 2000). The challenges that a company that wants to shift to new disruptive technology are the following: the creation of new best practices at the production level, the requirement of a new labor force that may be difficult to find and may affect the effectiveness and the efficiency, a new product-mix, the understanding of the new trends linked to the new technology, the change of the supply chain, the individuation of positive externalities to build a proper infrastructure, the threat of possible new entrants that may see the opportunity to enter in a new profitable market, the concentration of firms that the innovation may generate, and the new type of distribution and consumer behaviors that may emerge (McLoughlin et al., 2000).

Established technology infrastructure is needed to use the products on the market and influence their value. It is built on the customer's use of a product. For example, roads and traffic rules for cars. Every actor in the industry that works for the same technology infrastructure has his own activity which is consolidated in a mature industry with his own rules and practices. These groups of rules and practices form a technological regime that gives rise to technological trajectories guiding the activities in the industry. The technological trajectories led to incremental innovation (Geels, 2002) (Nelson, 1982). On the opposite radical innovation are usually generated in niches. In the niches, the selection criteria are very different and the products are isolated by the mass market selection regime where efficiency and price competition would affect the development of the radical innovation (Schot, 1998). What brings a radical innovation from a niche to the mass market is the change in the technological regime that may create the possibility for integration into the market of that innovation. Some examples of changes are political change, demographic change, cultural change, and so on. Once a radical innovation passes through a process of selection it may become a dominant design. A radical technology may not be perceived as a threat at the beginning because it supports the existent technology through a hybridization process and solving the bottlenecks of the previous technology without being an alternative. Also, the enlargement of a niche may make emerge a technology that has been relegated in a small market (Geels, 2002). When we are treating by the switch of technology it is important to consider the performance of the whole system and not only of the product. Indeed, it may be bottlenecking that limits the value of a product for a customer because of complementary products that do not work as expected. For this reason is important to understand which one is under the control of the firm and which not (Adner & Kapoor, 2010).

When a new technological discontinuity emerges, the incumbents face many risks. The first one is failing in the displacing of older technologies. The component innovations are usually not such as big issue for incumbents. On the opposite complement innovations, that change the product structure, are more difficult to face. More than that, incumbents are more focused on the component innovation rather than on the complement because the delivery of a product is dependent on the supplier performance and is viewed as a possible source of bottlenecks. Complement innovation is more difficult to be seen, the company is focused on the customer needs with regards to all that is in the company control, rather than focusing on external factors where the company has less power to intervene. For these reasons, their focus on the current technology may a problem for seeing possible threats (Adner & Kapoor, 2010). Furthermore, even though a company sees a threat, the organizational inertia may block or slow its reaction. Two different kinds of inertia may affect the innovation of a firm. The first one is resource rigidity. The company does not want to invest in new technology. Instead, the routine rigidity blocks the change in logic necessary to deal with completely new and different technology. In other words, people are continuing to have the mindset of the previous era. The second threat is linked to the time to enter the market. Penetrating the market at the wrong time may be a fatal mistake for incumbents that have to disinvest the old technology and reinvest in the new technology (Gilbert, 2005). DA QUA

Another important aspect of the switching of technology is that we have to consider not only the performances of the new technology and its complementary products but also the old technology performance and the relative complementary products (Adner & Kapoor, 2016). Incumbents may try to make the old technology competitive with a final effort in order to save part of their investment on that technology, exploiting them utile the obsolescence. That final effort could increase the length for a new technology to emerge in the market. Moreover, investing in the new knowledge may create spillbacks that increase the performance of the old technology make it more difficult for the new technology to emerge (Adner & Kapoor, 2016).

1.3 Intergenerational Hybrid Technology

Often incumbents try to respond to the threats of radical and disruptive innovations with recombination of new technology and the technology to create intergenerational hybrids (Furr & Snow, 2014). When a source of technological novelty can lie with the old technology, we have a technological hybrid. Usually, those combinations are not so successful per se, but they led to a potential breakthrough. Those kinds of recombination may be really useful to find a path for radical innovation, even though it does imply an increased number of failures (Fleming, 2001). In fact, firms can differentiate themselves not only on the exploration of the new technologies but also on the exploitation of them. The knowledge of the previous technology can influence the exploitation of hybrid and next-generation products. The exploitation of hybrid technology is important not only to enter into the market but also to gain expertise and knowledge on new technology. Moreover, increasing the research scope has a linear effect on the new product innovation. It happens that some firms spend too much time and investments on a specific scope rather than explore in a different direction. It may be because focalizing a specific area is less costly than make explorative research. The uncertainty plays an important role in deciding in what kind of research to invest in, the choice could be between a known and incremental technology and uncertain new directions (Katila & Ahuja, 2002).

We should not forget the role of the consumers. The demand side is crucial to understand if and when a new technology can overcome the previous one. A technology is dominant when most of the consumers consider it better than the alternatives. New technology may rise a hidden need that was not covered in the previous products. At the same time, new technology can change the criteria and create opportunities for the old ones that can come back in vogue defeating the new generation (Adner & Snow, 2010). On the demand side, the intergenerational hybrids are crucial, there are the possibility to test this technology in the market before that the new generation products (Furr & Snow, 2014). There are many constraints to build up the infrastructure of new technology. The founds and resources may not be sufficient, the market may not be ready, or the complementary products do not support the new technology. In these cases, the hybrid product can be an option. An example is the 3g technology that delayed the entry into the market for all the reasons listed and, in the meantime, the improvements led to the 2.5G technology, a hybrid between the 3g and the 2g technology. The 2.5g technology allowed the companies in the industry to develop supply-side knowledge, demand-side knowledge, and the right timing to entry, fighting the uncertainty and the technology discontinuity (Ansari & Garud, 2009).

When a disruptive innovation emerges, the incumbents have to choose the technology paths that they want to develop. In this choice many criteria influence the paths selected, one of them is their complementary assets. If they have huge assets, including knowledge, they will try to leverage them. Incumbents may try to develop hybrid products exploiting their complementary assets on the old technology in order to gain a competitive advantage or to differentiate their products from the others in the market (Wu et al., 2014). The company chooses to exploit the developed hybrid products only if feels a signal by the market, otherwise, it would advantage the new entrants without any reason. Sometimes understand ex-post if a decision is taken because of strategic inertia finish or if it is a deliberate the strategic choice begin (Wu et al., 2014). The value of complementary assets becomes crucial to make a strategic choice and influence the innovation path (Dosi, 1982). Obviously, it is not the only way to move if you have complementary assets. A successful incumbent may choose to give up his own assets and start focusing directly on the new generation product without and exploiting his assets on the previous generation. In both cases, there is not any linear relationship with the market success (Wu et al., 2014).

The creation of hybrid technology products is more feasible for certain products, while difficult for others. For the products that are modular and with a flexible architecture is more likely and consequential the creation of hybrid products (S. L. Cohen & Tripsas, 2018). Moreover, the company is able to gain a relevant advantage only in certain conditions. One of them is the relevance of the technology incorporated. If a company incorporates an old technology that is far less performant than the new one the risk is to lose the competition (S. L. Cohen & Tripsas, 2018). Other problems may be the underinvestment in the new technology and missing the right time to switch to the new technology without realizing that it is the time for the new generation. On one hand, we can say that the more a company invests in hybrid technologies the weaker is the development of the new one. On the other hand, if the company has a high level of inventive capacity the hybrid may be effective for leveraging the old technology and learn from experience. In other words, the companies with a strong R&D can take advantage of the old technology without investing and developing the new one by the early beginning (S. L. Cohen & Tripsas, 2018). The hybrid products could be also useful not only for the technical knowledge but also for a better understanding of the demand side that can be useful in pushing the next generation product into the market (Teece, 2006). Companies that are able to develop in parallel knowledge on the current technology stimulating incremental innovation and make an explorative search at the same time are more willing to create hybrid products. These experiments led the company to better understand its strength, potential, and weakness in the current and in the new technology. In this way, the firm has the opportunity to develop new and unexplored markets. Even when the experiments are not successful may be useful to learn something about the current technology (Helfat & Raubitschek, 2000). Investing in a technology that has been overcome by the later generation is not always a mistake. For example, in the market of the panel display industry investing in the losing technology has been crucial for winning in the next-generation technology. In this industry, the companies that invested in the plasma technology were able to develop better LCD displays, the winning technology, compared to the ones that choose to invest before in LCD without passing through the plasma technology. Investing in a not successful technology often is better than waiting for solving the issues of the new generation. The companies that developed the plasma screen were able to understand the feature that a product must have to be accepted in the market of flat-screen thanks to the feedbacks of their customers. Instead, the companies that developed the LCD flat-screen were not able to enter the market as early as the plasma producers and were not able to understand the customer needs into that new market. This is also an example of how it is important to leverage the knowledge acquired from previous and non-successful technology (Eggers, 2014).

The development of hybrid products can generate two different kinds of advantages, the spill-back effect and the spill-forward effect (spillovers) (Furr & Snow, 2014). The spill-back effect is the spillover of knowledge from the new generation technology that can results useful even for the incumbent technology. In this case, the hybrid product helps the company to learn something about the current technology generation and improve its product performances involving elements or components of the next technology generation. On the opposite, we have the spill-forward effect. While a company is developing and producing a hybrid product increases the knowledge on the next generation technology through a process of trial and error. The kind of knowledge acquired during the process cannot be acquired by an explorative research without a practical application (Furr & Snow, 2014). We can resume the spill-forward effect as all the advantages that a hybrid technology gives us in the next-generation products. Those advantages are several, one of them is the supply side knowledge and the reduction of uncertainty of the disruptive technologies. It is a way to improve practical knowledge in adopting the new technology facing the difficulties of the practical adoption, including the processes needed for the production and the supply. Solving technical problems include the reduction of uncertainty and increase the willingness to invest in the new technology. Another advantage is the understanding of the demand-side and even the possibility to shape the demand itself, influencing the customer on how they interpret the future requirements of the next products (Furr & Snow, 2014). Putting a product in the market gives to the company a series of feedbacks of the customer requirements that are crucial for the development of future products and their interpretation. Linked to the previous point, we have a deep understanding of the maturity of a market and consequently the right time to entry thanks to the feedback of the market. Finally, there is the influence of the incumbents that develop a hybrid product on institutions. The companies that enter into the market with a hybrid product are usually able to enter into the market before all the players that are working directly on the next generation waiting for the proper timing. For this reason, they have the opportunity to talk with institutions and influence the future adoption of technology and its timing (Furr & Snow, 2014).

Chapter 2 – Theory of Open Innovation

2.1 – Definition of open innovation

Open innovation is defined as a "*distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organization's business model*" (Chesbrough & Bogers, 2014): 17). The positive inflows and outflows of innovation are due to firms' investments in innovation. Companies that invest in innovation do not know the results *ex-ante*. They may produce a great amount of knowledge and innovation not expected that is not close to their core activities and technologies. This technological knowledge may be useful for other companies that are willing to pay or to share their knowledge to gain them (Chesbrough & Bogers, 2014). The purpose of the open innovation model is to exploit the unutilized knowledge-creating channels in order to move this knowledge from inside to outside and from outside to inside. In this way, companies can reallocate in a proper way the knowledge acquired (Chesbrough & Bogers, 2014).

According to the Gassmann & Enkel (2004) model, there are three flows of knowledge in the open innovation model. The first one is the outside-in, in this way the company can enrich its knowledge base by absorbing knowledge from outside the boundaries of the firm, for example creating alliances with supplier, customer, and other actors, or through licensing and patent purchase. The second one is called the inside-out flow. In this way, the company is able to exploit its knowledge, even the one that is not useful from the core activities. Through alliances, it is possible to exchange the knowledge or on contrary, it is possible to sell it through out-licensing or selling patents gained reaching a profit. There is also another flow of knowledge in the open innovation model which is called coupled process. In the coupled process there is an outside-in and inside-out process among different actors at the same time. The latter, and more complex flow, is possible to obtain through alliances with complementary partners (Gassmann & Enkel, 2004).

The ability to exploit external knowledge is crucial to increase innovation capabilities. The capacity to recognize the value of information, assimilating and exploiting for commercial purposes can be called "absorptive capability" (W. M.

Cohen & Levinthal, 1990). The absorptive capability of an organization depends on the absorptive capability of the individuals that form it, but it is not a simple sum of them. There are also organizational aspects that influence the absorptive capability of a firm. The companies have to be able to leverage on the organizational aspect improving the ability to transfer the knowledge acquired throughout the organization (W. M. Cohen & Levinthal, 1990). It is possible to make a distinction between two different organizational behavior which are alternatives, the outward and inward looking. Thanks to an inward-looking organization the actors inside the company would share a common language and would be able to communicate effectively among them but not outside. On the contrary, the outward-looking perspective allows the company to communicate effectively outside the boundaries but not inside. Each company should find the right balance between inward and outward-looking in order to exploit their knowledge and be able to absorb new ones (W. M. Cohen & Levinthal, 1990). The absorptive capacity influences also the technology path. Indeed, prior knowledge influences the new knowledge acquisition. That happens because, in order to easily acquire the new knowledge, the latter should be closely related to the company's one. This implies that accumulating knowledge in the first period will aid the company to accumulate more knowledge in the second and influences the kind of knowledge absorbed in the second period. In other words, the absorptive capacity led to an accumulation of knowledge that is path-dependent and history-dependent (W. M. Cohen & Levinthal, 1994). Stopping investing in explorative research and on the absorptive capacity may lead to an insufficient ability to see a new opportunity or threat. In order to increase the absorptive capacity, the firms tend to invest in generic research even though many of their efforts are not directly useful for the direct application. These investments allow the company to understand and exploit the potential new knowledge that may emerge. In this way, the company would be able to respond quickly (W. M. Cohen & Levinthal, 1994). Acquiring knowledge from outside means increasing the knowledge in two different ways, increasing the specialization on a particular field, or integrating different knowledge. Both of them are important but they do not represent a strategic alternative. They have to be implemented in the right balance according to the specific goal of the research (Mudambi et al., 2012).

The R&D function is not the only one that influences the absorptive capacity, functions like manufacturing and marketing are important sources of knowledge inputs, too. Both of them are becoming even more important for a production company. The marketing function is a particularly important function for stimulating the absorptive capability because is able to gather customer knowledge (Bogers & Lhuillery, 2011). Moreover, it is useful to increase the awareness of rival's innovations and knowledge. Even the importance of the external sources varies according to the type of knowledge. For example, customers are crucial for product innovation since they use the product can develop an expertise and know the technical features that should be improved. On the opposite alliances with rivals and business groups are more common for process innovation because they are the only actors to have experience on the production process (Bogers & Lhuillery, 2011).

According to the Hagedoorn & Duysters, (2002) model there are three main strategies to gather external knowledges. The first one is through M&As, the second is through strategic alliances and the third one is a mixed strategy. The strategy changes according to the appropriability regime of an industry which depends on the technological background. In industries with a low level of technological background, the companies are more willing to follow M&A strategies, at the high level they prefer strategic alliances, in the mid-level (such as automotive) they prefer mixed strategies. The reason is linked to the technological change. In high-tech industries we have a faster technological change so more flexible strategies to gather knowledge are preferred because the new knowledge expires quickly. At the opposite in low-tech industries the technological change is slower and the appropriation of external knowledge can be assured though more formal mechanisms (Hagedoorn & Duysters, 2002). In choosing the right strategy there is also another key factor that influences the choice between alliance and M&A, which is the proximity of the innovation to its core business. If the target innovation regards the core business companies usually play safely and follow an M&A strategy for the fear of uncontrolled technology transfer. Acquiring a company allows the buyer to appropriate that technology without sharing its technology to other actors maintaining full control. Technology alliances remain useful for all non-core businesses. Notice that a technology can be not related to the core business in the first instance but then becomes fundamental to remain in the market (Hagedoorn &

Duysters, 2002). According to Hagedoorn, (1993) the three most important reasons to develop a technology alliance are technology complementarity, reduction of the innovation time span, and market access and influence. These three major reasons underline how the alliances are useful to face complexity and uncertainty during a period of technology improvement (Hagedoorn, 1993).

Absorbing knowledge is not sufficient to be profitable, exploiting the technology acquired is fundamental. One way to exploit the technology acquired is leveraging the knowledge that the company has developed by opening the company's boundaries (Gassmann & Enkel, 2004). Companies that do not want to form alliances can increase their profits through out-licensing and selling their patents. The companies that use this strategy in the most effective ways are research-driven firms. This strategy is effective to reduce the fixed costs and share the risks. Moreover, when a company has not a strong brand or a strong commercial experience can be useful to use such a strategy (Gassmann & Enkel, 2004). Another strength of this strategy is the possibility to create a standard sharing the innovation with other players in the market. Basically, it is an option to capitalize on spillovers that can be commercialized in both the company's market or other markets that the company cannot or does not want to reach. A patent can result useful even when it is considered old in a certain industry. Indeed, a technology can be can overcame in an industry but return useful in another generating profits (Gassmann & Enkel, 2004).

It is also possible to combine the outside-in and inside-out processes at the same time, to do that it is necessary deep cooperation with other actors. According to Gassmann & Enkel, (2004) the most important forms of cooperation are consortia, joint venture, and alliances. The actors involved can be enterprises but also universities and research centers for example (Gassmann & Enkel, 2004). The joint venture and alliances can be seen not only as an intermediate level of integration between market and hierarchy but also as a tool to acquire new skills and knowledge. Some skills based on tacit knowledge are more difficult to acquire and a closer relationship like the alliance can provide aid. The value from cooperation can be both created and acquired. The creation is due to the complementarity of the knowledge that has been put together. The acquisition is absorbing the partner's knowledge and capabilities but also assets or money (Hamel, 1991).

2.2 – Gathering knowledge from external sources

As we have seen the open innovation is divided into an outside-in, inside-out process, and coupled process. In this section, we will focus on absorbing knowledge from external sources. This strategy allows the companies to integrate their knowledge with external organizations' knowledge. The fundamental advantage that external sources gave to the firm is the possibility to appropriate of unique knowledge and resources that the rivals do not own. A proper appropriation of resources needs a great effort to transform the company from an entity with solid boundaries to a semi-permeable organization able to move innovation from outside to inside and vice versa. The company should be enough flexible to combine different sources and make that innovation useful for the organization (Gassmann & Enkel, 2004). The desire to acquire this knowledge is one of the major reasons for the internationalization of the R&D centers. In this way, a company can be able to have a faster understanding of the market, in the short term, and accumulate more knowledge from local customers and suppliers, in the long term. The choice to internationalize the R&D center is influenced by is the state-of-art of a company's R&D, if one company thinks to have all the knowledge needed inside would more toward centralization of R&D (Chiesa, 1996). According to Chiesa, (1996) the need to access external sources can vary according to two main different industry variables. One of them is the nature of the innovation. An innovation that has a high-level technology complexity requires more knowledge sources from outside. Since a complex innovation requires knowledge in different fields is more likely that those cannot all be found inside the company. Then we have the product differentiation as a driver to the need of external sources. With a great differentiation both within a market and different market, the company should gather more knowledge from outside (Chiesa, 1996).

According to Gassmann & Enkel, (2004) some characteristics influence the results of opening the boundaries. One of them is the modularity of the product, it plays an important role in deciding to bet on the open innovation process. In fact, companies with modular products are more likely to adopt an open innovation process. Even the knowledge required in an industry can push the companies to go toward an open innovation strategy. For competing in an industry with a high level of technology intensity often the internal resources are not enough and the companies search also outside their boundaries (Gassmann & Enkel, 2004). At the same time, frequently among the companies that develop the ability a put in place an effective outside-in process there are companies from the low-tech industry. Those companies expect spillovers from higher technology industries in order to compensate for their low investments in R&D (Gassmann & Enkel, 2004). The kind of knowledge generated can influence the choice. In fact, external sources can be used as an instrument to generate radical innovation. Since the in-house R&D research is linked with the previous knowledge the internal innovations are path dependent. Gathering knowledge and ideas outside the boundaries stimulate the emergence of radical innovation because helps to break the path-dependent innovation (Coombs & Hull, 1998).

Finally, the stage of the development process may influence the results of the cooperation. The cooperation in the implementational stage is the one that has a more direct effect on innovation success. Instead, the alliances in the concept and product development stage have not a direct effect but are still important and beneficial for the innovation capabilities. The difference is that the latter effect is more influenced by the innovation capabilities of the single entities (Weber & Heidenreich, 2018). Moreover, the companies that participate in collaborations develop the innovation capabilities for future innovations. On the opposite, cooperation in the implementational stage does not help the companies to improve their innovation capabilities (Weber & Heidenreich, 2018).

2.2.1 Supplier Alliances

The cooperation with suppliers often works as a substitute for the company's R&D. If the company has the right capabilities and the ability to deal with the supplier it is possible to gather knowledge and extend the innovation process even outside the company boundaries (Fritsch & Lukas, 2001). The relationship with the supplier can produce both short-term and long-term advantages but at the same time, it is difficult to manage. The potential problems are the lack of communication and trust, the insufficient suppliers' abilities and, the internal resistance from inside. Once a company successfully overcomes these problems in the supplier relationship then would be able to exploit the relationship (Wynstra et al., 2001). One of the advantages to develop a strong relationship with the supplier is that the development process would be integrated since the development phase. This kind of relationship without financial ownership may be more effective for better resource utilization and for developing new technology. In the development of the product, the firms that are not under the hierarchical power of the developing company require more interaction and integration that stimulates innovation (Clark, 1989). The integration with the supplier is useful to compete in a rapid technological change environment. At the same time, the buyer company can be trapped into the developing model of the supplier. To overcome this risk, they should choose the right time to include the supplier in the development of a product(Handfield et al., 1999). In addition to the right time, the supplier's rate of expertise becomes fundamental to avoid this possibility. The supplier should be included early in the process only if it has high expertise in the field. Otherwise, the supplier should be involved only in the last steps of the product development. There are not only cons in involving the supplier in the early, but there are also multiple pros. One of the advantages is the exploitation of the supplier's knowledge on the application of a specific technology, to understand when a technology solution is feasible and when not. Even the risks and the costs of introducing an unknown technology are shared (Handfield et al., 1999). The quality of product development often is connected with problems of manufacturability, fit and finish criteria, effect analysis, and so on. Involving the supplier from the beginning helps feasible product development. The decision that is taken in the first stage of the development process influences a huge segment of the production costs. Indeed, taking some decisions at the product design stage influence most of the final production cost. In this sense, the supplier can provide us important insight to reduce the production costs from the beginning (Ragatz et al., 2002). Working and discussing together lead the two, or more, companies involved to direct the R&D and match their technologies. In a close relationship, the supplier is more willing to share information about the new technologies that may emerge in the market. The cons are not only to be blocked into the supplier's technology but also that the supplier may not have the same incentives to innovate as the buyer company (Handfield et al., 1999). The better access and the application of a technology thanks to the supplier knowledge is more significant when we are talking about complex products. In this case is difficult for the buyer company to develop expertise in multiple fields, to solve this problem the support of the supplier is crucial (Ragatz et al., 1997). Moreover, co-developing in a product with the supplier helps the buyer to influence the supplier's technology path. In this way the supplier would develop better products that fit with the buyer design (Ragatz et al., 1997). Even the time and cost of the process of development will reduce. The involvement of the supplier allows to individuate the problems and solve the problems quickly and less costly. At the contrary, if a company would develop a product by itself may find some problems from the supplier side and be obliged to rethink the whole product design, affecting the time of development, and increasing the costs (Ragatz et al., 1997). The inertia and the resistance to sharing information do not involve only the buyer side, but also the supplier side. When in a relationship there is the buyer with more market-power the supplier may have some difficulty sharing information that can be worried about an unequal treatment (Ragatz et al., 1997). Due to the uncertainty of less predictable product development, the supplier involvement is more effective in more mature technology rather than the projects in which the technology path is not clear (Eisenhardt & Tabrizi, 1995). The technology uncertainty has not a direct impact on the cycle time, but under this condition integrating strategies and team processes are crucial (Ragatz et al., 2002).

2.2.2 Customer Alliances

The ideas that generate a new product development often come from external sources by the recognition of a problem or of a need, while the problem-solving ideas are generated inside the company. The external source of innovative ideas are often the customers or the potential customers (J. M. Utterback, 1971). For this reason, the involvement of the customers is crucial to understand the possibilities in the market. After 2000 many companies tried to involve the customer more directly in the development of production. The customer shifted from being a passive audience to an active audience, proving precious important insights for the companies (Prahalad & Ramaswamy, 2000). Being able to gather information from the customer is not an easy achievement, to reach this goal is necessary to complete some tasks. The first one is encouraging the customer to create a dialogue, in this sense internet is helping the companies to create a contact with the customers. Through the internet, the companies learn a lot about the customer and have the possibility to create involvement thanks to interactive capabilities that become crucial. Another task is mobilizing the customer communities (Prahalad & Ramaswamy, 2000). Even the creation of communities is easier through the internet, these communities are really important because they exercise a serious influence on the market. Dialoguing with the customer requires a further task which is the management of customer diversity. As the company is more involved in customers communities as it would be in touch with different customer groups, that have different needs. Moreover, the company must be careful with the personal data of the customer, which are often a source of profits. In order to provide useful input, knowledge, and ideas the customer should be involved in a continuous dialogue(Prahalad & Ramaswamy, 2000). This can be obtained also thanks to personalized experiences. Personalization gives value to the relationship allowing the companies to continue to learn from the customer. Another aspect the influences the relationship with the customer is the flexibility to respond to its needs. Implementing organizational flexibility is a huge effort for the firm that has to change its structure (Prahalad & Ramaswamy, 2000).

Not all users can provide the same support to the company's knowledge. In fact, the average users are unfamiliar with the technology behind a product and have not the capabilities to understand the potentiality of a technology or a product (Von Hippel, 1986). Instead, it could be much more useful to focus on the lead user. The lead user knows better the product and the technology behind, often they have experience in the field. The lead user feels needs before the average user, anticipating the needs that the mass market would have in the future. Feeling before the others a specific need he has all the incentives to provide support and satisfy its needs (Von Hippel, 1986).

2.2.3 Research centers and universities alliances

Collaborations with research institutes and universities are usually focused on explorative research. The collective research with these institutes is the most important source to develop innovative capabilities rather than to the customer, supplier, and competitor alliances (Faems et al., 2005). The exploration and effectiveness of this kind of research may depend on the primary goal of the institution, which is not commercial but is to increment their knowledge. The alliance with institutions not only increments the company's knowledge but allows the cooperating company to develop new technologies without sharing that knowledge with competitors or suppliers (Faems et al., 2005). Cooperating with these organizations is easier because there is no fear of potential threats. Eventually, the explorative research can lead to radical innovation and be exploited for commercial purposes (Faems et al., 2005). Companies that develop linkages with universities are usually more inclined to develop technological alliances, these links may serve to attract and meet more companies interested in innovation processes (George et al., 2002). University's cooperation led to a more efficient and effective R&D. Since the two authors share the costs, the equipment, and the researchers, that could be absorbed by the company, it is possible to reduce the costs. In fact, the companies that cooperate with the research institutions have a lower expenditure on R&D per employee compared to the companies that do not cooperate. The effectiveness is reflected by the major number of patents developed (George et al., 2002).

The research institutes and university laboratories are similar in many aspects. The reward system is based on scientific publications rather than commercial objectives. Both of them devoted the majority of their time to the publishing activity and minor time to the production of patents and licenses (Bozeman, 2000). The most important difference is students that can be absorbed by collaborating companies and are cheap labor for universities (Bozeman, 2000). For these reasons, in this research the considerations made for universities valid also for public and private research institutes and vice versa.

2.2.4 Horizontal Alliances

When a company wants to learn outside their boundaries and develop new competencies has many options. As we have seen a company cooperate with suppliers, customers, external research organization, and competitors. In this paragraph, we will see the latter type of cooperation, the horizontal alliances. Horizontal alliances are defined as formal collaborations among companies to conduct business activity, included the development of a product (Perry et al., 2004).

The horizontal alliances between competitors pose a series of obstacles to overcome due to the coexistence of cooperation and competition. The challenge here is how to melt together the knowledge without incurring the risk of being exploited by rivals. (Luo et al., 2007). Even though those alliances are difficult to administrate the benefits are several, such as increasing the new product creativity and a faster product development cycle. The horizontal alliances are different from vertical ones both in terms of structure and motivation. Indeed, the companies involved in the horizontal alliances have in common a large part of the technology, that causes redundancy in the alliance's knowledge (Rindfleisch & Moorman, 2001). Moreover, the level of embeddedness and involvement is inferior compared to the vertical ones. The sharing of knowledge is difficult in this kind of alliance because, due to the competence redundancy, the knowledge that the companies do not have in common is few, and often it is their competitive advantage (Rindfleisch & Moorman, 2001). Obviously, sharing their competitive advantage with a competitor with the risk of receiving anything in exchange is very dangerous. Generally, embeddedness and redundancy affect two different kinds of knowledge. In fact, the tendency is that a high level of redundancy would reduce the amount of process information. Instead, instead a low level of embeddedness would reduce the amount of product innovation that emerges from the alliance (Rindfleisch & Moorman, 2001). These two features cause a lower level of knowledge shared compared to the vertical alliances. At the same time, a high level of redundancy creates synergies of knowledge, skills, and capabilities that enhance the level of production creativity and faster speed of development (Rindfleisch & Moorman, 2001).

The external knowledge from competitors can play a different role in incrementing the knowledge. In particular, the effect of the knowledge acquired is more or less useful according to its nature of incremental or radical knowledge. If the company is looking for the stimulation of radical innovation the novel knowledge acquired by a competitor can be one of the best solutions. It is necessary to underline that this exchange of knowledge does not guarantee the creation of radical innovation by itself, a guide by the companies is needed (Xu et al., 2013). The incremental innovation is easier to be acquired because it is linked with the existing knowledge, so the company has all the instruments to acquire this knowledge and understand since the begging the potentialities (Xu et al., 2013). The external innovation from a competitor may act as a substitute for internal development so the company has to carefully balance this equilibrium. This balance is crucial to create the right innovation path. Having strong internal knowledge remains crucial to properly absorb it and reach the desired innovation outcome. It is important to focus on the knowledge related to the core activities of the companies, otherwise, it is more difficult to create synergies (Xu et al., 2013).

Vertical and horizontal alliances address different needs, for this reason, can be used for different purposes. Often horizontal alliances are useful to discover new technologies. In the future, these discoveries can give rise to vertical alliances useful to upscaling and reduce the risks of involving in new technologies and markets (Belderbos et al., 2012). Horizontal and vertical alliances are not substituting but complementary to develop new products. Some alliances give more results if combined with others in particular when the approach is sequential while other work better when simultaneous. The delay between horizontal and vertical alliances increases the propensity to engage vertical alliances rather than reducing them. In this way, the company can evaluate the better vertical alliance to develop its product (Belderbos et al., 2012).

In order to create a strong and effective horizontal alliance, a high level of trust is required. Tools like contractual safeguards, such as termination penalties are useful even with a high level of trust. A high level of trust leads to a high level of commitment which is related to the effectiveness of an alliance. In particular, the combination of commitment and strong termination penalties reinforce the performance of the alliance (Perry et al., 2004). The trust between partners is not the only variable of the success of a partnership, external factors may influence the commitment. One of the most important environmental variables is the technology uncertainty that could affect the commitment (Perry et al., 2004). At the same time, other authors suggest that organizational trust is more effective when there is a low competing environment, so in vertical alliances. While in a high competing environment, so in horizontal alliances, the companies rely on institutional and interpersonal support more than in vertical ones (Rindfleisch, 2000).

There are many reasons to decide to not share information with a competitor. First, the company is trying to reach a market superiority over the rivals. Second, sharing the knowledge rivals may leave to the rivals some potential incidental knowledge not considered ex-post. Third, sharing the technology may reduce the potential profits of the company closer to zero, if the competitors are able to gather this knowledge and to develop faster and better the relative products (Baumol, 1992). On the other hand, there are also many good reasons to share the knowledge with competitors making an alliance. The first reason is to cut the costs of development, that can be allocated to the participants of the alliance. The second reason is that an agreement ex-ante to invest money on an innovative project with competitors would not charge a single company of all the risks of such an innovative attempt. Finally, the components of the alliance have a great advantage against the non-participants, that have to develop the technology by themselves. Especially when the alliance lasts for a long period. In this way, the components can share all the costs and compete with rivals that sustained all the R&D costs by themselves (Baumol, 1992).

2.2.4.1 Sharing standards

It is common for firms to join together in order to form standard-setting alliances with the goal to develop and sponsor the adoption of their standard. For example, in the VHS industry, and in the Unix operating systems we have two examples of this process (Saloner, 1990). Standard develops in those markets where there are increasing returns according to the number of firms and customers that adopt a determinate product or process design (P. W. Anderson, 2018). Complementarity and human-capital investment may lock the consumers into their technological choices, for this reason, the cost of shifting technology increase (David & Greenstein, 1990). A standard may emerge in different ways. One of them is by regulators when they force the adoption of a determinate standard through laws. The other way is when in the market emerge one standard that is adopted by the majority of the market. The risk is that companies may be cut off the market because the standard is not compatible with the technology and the capabilities of a company, throwing away all the efforts made to develop their technology (Farrell & Saloner, 1988).

When there is not a strong company able to impose its standard the companies tend to put together their efforts creating alliances, even with rivals, to make their standard the winner one (Saloner, 1990). The alliances allow the companies first to control and take decisions about the development of the standard. Furthermore, alliances are useful share the cost of development with the other members, as the profits. Finally, thanks to alliances there is the possibility to reach more users and adopters (David & Greenstein, 1990). Creating the right alliance is a difficult task in particular in the choice of the better partners. The company requires an alliance to be competitive with the other standard and to be able to appropriate some of the value produced (Axelrod et al., 1995). In choosing the right partners the firms evaluate the history considering their strength in the past and their competitors' strength and assets as standard setters. Moreover, in evaluating those companies the expectations play an important role. The companies search in an alliance the perspective of investing in the winning standard and the possibility of the appropriation of some value produced in the cooperation. The tendency is the aggregation into one single standard alliance when there is not a strong dislike among the group of competitors. On the contrary, when there is a strong dislike among the companies a more than one alliance may emerge (Axelrod et al., 1995).

The standardization through alliances can be seen as a half step between market standardization and policymaker standardization (committee) because it combines features of both of them (Keil, 2002). As the policy maker standardization reduces the uncertainty lowering the number of technologies that compete on the market. At the same time the standardization through alliances maintains a certain level of competition inside and outside the alliance. Standardization alliances are usually semi-opened where there is a limited number of companies that develop the standard and a large number that adopt this standard (Keil, 2002). The more the base of users is large the more the standard is likely to win the competition against other models. Indeed, the externalities play a crucial role in defining the next standards. Which regards direct externalities the value of a product increase with the number of users. In indirect externalities, the process is the same but influences the complementary products (Keil, 2002). When we are talking about standards the competition is both between different standards, and so between alliances, and within the same standard. Even the companies inside the same alliance that support the same standard may compete for the appropriability of the standard's returns. The standard creation has to overcome two different challenges. The first one is the technical solution. A standard has to be developed by a small group, to take rapid decisions and a proper organization, of firms with complementary capabilities. In this period the companies try to deal with different interests which can slow down the process. Then in the adoption phase, the number of participants should increase in order to guarantee a larger user base (Keil, 2002).

2.2.4.2 Catching-up technology leaders through alliances

When a new technology emerges, some companies invest in this new technology trying to gain a competitive advantage. While other companies decide to not invest because of the high uncertainty is high. According to Cano-Kollmann et al., (2018) this heterogeneity in behaviors creates two groups of companies: leaders and laggards. The leaders invest in the early stages, gathering more knowledge and capabilities on the new technology. Their goal is to maintain a technical superiority, therefore, a competitive advantage, so they try to create barriers for the laggards, such as economies of scale. On the opposite laggards, due to uncertainty, do not invest in the early stages and then are behind in the technical knowledge. When they realize that this technology could be an opportunity to try to catch up. Cano-Kollmann et al. (2018) individuate three main strategies for catching up with the leaders, by solo research, through M&A, or with horizontal alliances. The first two strategies are possible but in times of technological uncertainty and several potential technology paths much more expensive. For this reason, horizontal alliances become an advantageous tool because allow the companies to accelerate the gathering of knowledge and at the same time sharing the costs (Cano-Kollmann et al., 2018). This strategy is particularly useful when companies fear that new technology may become dominant but do not know which one would be the winner. In this scenario, the alliance is useful even when the companies do not follow the technology path developed in the alliance. If they decide to follow the technology path developed in the alliance, they would have gathered important knowledge consuming less found and time than alone. Otherwise, they would have excluded a potential technology path, reducing uncertainty, without investing alone but sharing the costs with the partners (Cano-Kollmann et al., 2018).

2.3 Alternatives to the alliances

Even though the alliances are the most common way to build a relationship with an external organization, there are also other ways to share the technologies. In this paragraph the goal is to underline the peculiarities of the joint ventures, and the licensing and patent purchase.

2.3.1 Joint Ventures

An alternative to the alliance is the joint venture. A joint venture, or a joint subsidiary, is the creation of a new organizational entity by two or more companies. A joint venture is something different from a merging or an alliance because imply the creation of a separate entity jointly controlled by the parent companies. This separate organization can stipulate contracts and or incur debt without involving the parent companies (Boyle, 1967). According to Aiken & Hage (1968), the companies are willing to form joint ventures to solve a lack of money, skills, or labor force and creating interdependences among companies. Indeed, the most cited purposes of the creation of joint ventures are the spread of risky industrial development, the establishment of facilities for a greater economy, to accumulate a greater amount of funds, to create programs that are too great for single companies, and to use complementary strengths (Pfeffer & Nowak, 1976).

The ability to combine the distinctive competencies of the parent companies is crucial to create the right complementarity to overcome the resource limitation and create a competitive advantage. If the companies do not choose the partners properly there is the risk of creating a redundancy resource base and the risk of sharing the knowledge increase (Pfeffer & Nowak, 1976). The importance of complementarity leads the parent companies to impose various controls over the transfer of these capabilities (Herbert, 1984). At the same time, it is needed to pay attention to this phenomenon because it can affect the joint venture's performance (Hill & Hellriegel, 1994). The control of the joint venture is a critical point for the performance of this organization. Usually, the companies try to influence the JV in the areas that consider critical (Geringer & Hebert, 1989). Good relations with the partners are one of the most important features for making the JV works, for this reason, the compatibility of the philosophies of the two companies is considered an important factor (Hill & Hellriegel, 1994).

The performance of the control of a JV may change based on the functional area. According to Hill & Hellriegel (1994), a JV that operate in the production of technology is likely to gain more result if its control is influenced by one company. On the other hand, for the research exploration, it seems that the JV benefit more from the multiple influences of all the parent companies. Furthermore, the autonomy of the joint venture increases its performance, especially in the first stages. The complementarity is not only in the choice of the partner but also in the management of the relationship. In fact, these complementarities need to be transferred properly in the JV. When we are talking about JVs, the performances cannot be measured only in financial performances but there are other objectives as gaining technical expertise, testing new technologies, entry into a new technological area, developing a working relationship with a potential partner in the future. Moreover, according to Mowery (1995), the JVs between competitors have been discouraged by the antitrust authorities.

The JV is particularly indicated for stimulating inter-organizational learning (Hennart, 1988). The purchase of knowledge is uncertain because the buyer does not know all the features of the patent, so it is difficult to set a price. Then there is also another problem, tacit knowledge is difficult to be explicated on paper. Once paid, the seller has not so many incentives to continue to support the buyer, and the buyer may have overestimated its capacity to absorb knowledge. Moreover, hierarchical coordination is useful to regulate the exchange of information that is controlled by managerial directives and reduces the incentives to cheat (Hennart, 1988). The joint ventures can be also effective when there are economies of scale that can be reached by putting together the resources of the parent companies (Contractor & Lorange, 2002). According to Kogut (1988), the risk of opportunism is reduced in the innovative JVs compared to the alliances because the partners contribute with specific assets, and the mechanism of supervision incentive the alignment of the objectives.

As we have seen the JVs follow different dynamics compared to the patenting or the alliances. For this reason, it is necessary to evaluate which kind of relationship the companies besides the role of the partners.

2.3.2 In-licensing and patent purchase

Acquisition through alliances with suppliers and customer is not the only way to acquire knowledge from outside. Even the acquisition of patents and the in-licensing are tools to acquire knowledge and technical capabilities (Gassmann & Enkel, 2004). The acquisition of technology and knowledge through a direct purchasing could be saw as a buy option that is opposed to the make decision of through in-house R&D. It is important to underline that buying external knowledge is a complementary strategy with the in-house R&D (Lowe & Taylor, 1998). Furthermore, the companies that buy knowledge outside have not a weak R&D function. In order to exploit the acquisition of the technology, it is needed that the complementary assets help the process of acquisition supporting the technology purchased. It is unlikely that in-licensing can be used for diversification or second-mover strategy, it would be too expensive, and the company would not have the required assets. Usually, this strategy is useful to build or maintain a market share (Lowe & Taylor, 1998). The companies that are more willing to purchase the knowledge are the bigger ones, and the acquisition of this knowledge does not affect internal innovation unless the company has its own R&D infrastructure. Indeed, the firms that have a good absorptive capability are able to capitalize on the technology acquired, and even its expenditure on internal R&D increase with the acquisition. At the same time, the companies that invest more or internal R&D are more likely to invest in external cooperation (Veugelers, 1997).

Chapter 3 – Open innovation in the automotive industry: an empirical analysis

3.1 The empirical setting: an overview of the automotive industry

According to the description made by Binder & Rae (2020), the automotive industry comprehends all the companies involved in the development and production of motor vehicles and their components. The principal products of the industry are passenger vehicles and commercial vehicles. The industry is important in the technological advances since introduced concepts such as full-scale mass production which includes standardization, interchangeability, synchronization, and continuity (Binder & Rae, 2020). The automotive industry is huge, in the US is the largest industry in terms of the value of products, value-added by manufacture, and the number of wage earners employed. This sector is important also for countries like Japan, South Korea, and the European western countries. The industry is characterized by few large firms which make heavy investment in equipment and tooling, for this reason, is sustainable only for large organizations. The economies of scale give to the large organization a competitive advantage that is difficult to overcome for small organizations (Binder & Rae, 2020).

The automotive industry is both capital and labor-intensive. The companies face many costs associated with raw materials, components, and labor. Besides, we have to consider also marketing, advertising, and R&D costs. The seasonal nature of the demand and the launch of new products emphasize cost control. Since the driving habits change overtime the OEMs should be ready to satisfy customer needs developing new models with the required innovations (Ferro, 2015).

3.1.1 Key trends in the automotive market

According to a market research made by KPMG (2020b) the four most important trends of the last four years are battery electric mobility, fuel cell electric mobility, hybrid electric mobility, and connectivity and digitalization. For the moment, autonomous driving is not perceived as a top priority in the short term. The major problem remains the mixed traffic between autonomous and non-autonomous. Even the shared mobility has a higher relevance at this moment. The situation is more complex because there are not global strategies that go in only one direction. The companies choose different strategies and different priorities, that have to be adapted to different markets. Moreover, traditional economic factors are influenced by Information, Communication and Technology (ICT) companies which are creating technological ecosystems changing the lifestyle of consumers (KPMG, 2020b).

The top priority for incumbents is the new powertrain technologies. For which regards the powertrain technologies the companies are focusing on different powertrains according to their geographical proximity. Executives of OEMs from west Europe are focusing on Battery Electric Vehicles (BEVs) for 83% and Hybrid Electric Vehicles (HEVs) for 80%, at the contrary in the US the OEMs are still focusing on the further development of ICEs engines for the 89%. It is important to take into account that the powertrain technology which is favorite by the customer for the next purchase is the hybrid model (KPMG, 2020a). For which regards the battery electric vehicles the most important limit to the spread of EVs is the cost of the car, followed by the charging infrastructure, the range, the uncertainty of the future technological development and finally the image, in this order. The major limit, so the cost, can decrease due to the higher production volumes. One example is China, where the cost of EVs is reducing thanks to the increase of volume production, as result, the customer puts the price in third place as the driven factor for choosing the EV. Instead in western countries, the price remains the first barrier for an EV purchase (KPMG, 2020a). Another issue is the charging infrastructure. During the year 2020, 69% of executives thought that that issue will lead to the failure of this system, 14% more than in 2019. Another important theme is the raw materials that are likely to play an important role in determining the future of the automotive industry. Indeed, it is another factor that influences a lot the price of the batteries for electric vehicles. The Fuel Cell technology can be an electric alternative to battery electric vehicles because does not have problems with the charging structure. On the other hand, this solution has unresolved problems in terms of costs and does not have sufficient maturity to penetrate the market. At the moment, the challenges regarding this technology are the hydrogen, cooling, storage, and pressure system. Nevertheless, 84% of executives think that fuel cell technology will have a breakthrough in commercial mobility in the long term (KPMG, 2020a).

For the first time, the executives expect that in 2030 we will see different powertrain solutions sharing the market. Many solutions would coexist and complement each other. For example, it is expected that the mobility between rural and city areas would be different. Some solutions may be much more efficient than others according to the features of the territory and the needs of the customer. For example, the electric powertrain solution is more useful in urban areas while in other applications the situation changes. In the long-distance for the state-of-art of the battery-electric technology, there are difficulties to cover all the needs of the customers (KPMG, 2020a). This situation leads to exacerbate the uncertainty over the product portfolio mix. The OEM must choose which product to offer and how many models for each product. The choice does not depend only on the OEMs and the customer market. The policymaker is having a huge impact on the technology path (KPMG, 2020a). Moreover, the OEMs are dependent on the sales of a specific region of the world, for this reason, they may focus on the preferences of the customers and the regulation in their main region. For the Chinese OEMs instead, the situation is different since they depend in large part on their internal market, this excludes the concerns about the situation of the other countries in the short term. Furthermore, the availability of resources influences the policymaker. Indeed, the electrification process is much more convenient for those countries that have a high dependency on oil and a positive electricity balance of trade. There is a positive correlation between the electricity balance and the adoption of EVs. For example, France and Germany have more incentive to electrify than Italy and Spain, this means that we would have a different level of EVs adoption in the future (KPMG, 2020a).

The pressure of introducing autonomous drive is decreasing since there are unresolved problems that may postpone the introduction of this technology. The executives are experiencing the major constraints of the autonomous drive due to the mixed traffic. Witnessing a real autonomous drive experience is possible only in the "island of autonomy" where all the cars are powered by the autonomous drive and are isolated by the non-autonomous drive cars (KPMG, 2020a). Furthermore, it is necessary to develop an effective software platform and the building of a 5g infrastructure to make the autonomous drive possible. Both customers and executives agree on considering autonomous driving as something that would impact the future rather than in the immediate, differently than originally predicted. (KPMG, 2020a).

Then we have the threat of the new model of mobility, so the mobility as a service. This business model may threaten the incumbents. The risk is that new entrants would focus on the industry's segments that are more profitable reducing the margins of OEMs. Some examples are Tesla, Uber, Google, Apple, and Baidu. These companies may influence the consumers and the regulators. Moreover, there is a threat from the Chinese OEMs that are becoming more and more important stimulated by their home sales (Gao et al., 2016).

Anyway, the powertrain alternatives are at this moment the major source of uncertainty and the priority for OEMs. For this reason, this thesis will focus on the three technologies in which the OEMs are putting more emphasis, the hybrid, the battery-electric technology, and the fuel-cell technology. The first would have more emphasis because can be useful to develop the battery-electric one and is the most considered by the consumers. Moreover, since the hybrid does not require a charging infrastructure the technology is more flexible, it can be used in different environments. Another key point is that all the previous knowledge on the thermic engine of incumbents would not be loose and may contribute to maintain a competitive advantage. We will go deeper analyzing the two technologies in the next chapter.

3.1.2 Facing the new entrants

Overcoming the barriers to entry into the automotive industry may be a difficult task. The automotive industry is capital intensive, shifting to an alternative powertrain system would require creating a new capital-intensive system, abandoning the existing one (Zapata & Nieuwenhuis, 2010). This would lead to intensive resistance by the incumbents and all the players involved in the existing system. The choice between alternatives fuels and alternative powertrains became crucial. Indeed, alternative fuels would not require to change the entire industry, but only a minimal modification of the existing system (Zapata & Nieuwenhuis, 2010).

In the past, some attempts with EV technology have been made. EV technology was born a long time ago, in the middle of the 19th century. During the 1890s many OMS produced EV cars but in the 1920s the production almost disappeared. On the opposite, the ICE technology increased exponentially the production thanks to the Ford-T, the first mass-production car. This popularity allowed the industry to build a strong economy of scale (Midler & Beaume, 2010). Another attempt to introduce EV cars was made in the 1970s, even at that time the market did not answer as expected and OEMs reduced their production. Finally, the last attempt was made in the 1990s in California because of the emissions legislation (Midler & Beaume, 2010). The EV did not take so much market because the OEMs put pressure to reduce the emission laws requirements (Pilkington & Dyerson, 2004). These examples are useful to understand that technology can fail to enter into the market and became a dominant design, but it may find the right economic environment later as we will see later in for the Tesla experience. Furthermore, how technology paths can be promoted or hampered by policymakers, actors in the industry, or economic factors.

Nowadays thanks to the technology improvements, especially on batteries and charging systems the EV and Hybrid technologies are more competitive. The emergence of these new technologies needs a rethink of the key performance criteria, for example, emission product architecture and to adapt to new constraints (Midler & Beaume, 2010). Those peculiarities will redefine the technology paths that drive the transition to new dominant design. The whole system should be oriented to the new paradigms to lead to a shift in the dominant design (Midler & Beaume, 2010).

Tesla is an example of all the difficulties of entry into the automotive industry. The first difficulty is the cost advantage of incumbents based on the economies of scale. Tesla avoided this problem by focusing on the luxury market and proposing a model of car that can be profitable even with low volume. Then achieved the level of production required with partnership and alliances. For example, Lotus was the first assembler helping Tesla to produce its first cars. Moreover, Lotus provides support for engineering, design, and technology, in this way Tesla was able to absorb know-how on automotive technology (Stringham et al., 2015). Even the components, such as the drivetrain and the batteries were provided by partnerships with Daimler, Toyota, and Panasonic (Stringham et al., 2015). In this way, Tesla was able to avoid the barriers of the economies of scale, the relationship with the supplier, the resistance from the incumbents, the know-how of the incumbents. But, as said this strategy worked only for luxury cars, entering the market with cheaper cars, and so higher volume, would be more difficult.

For which regards the network effect Tesla tried to overcome this barrier creating a huge charging infrastructure. Tesla focuses on creating charges in hotels, restaurants, and resorts. As of June 2015, Tesla built 445 stations at zero marginal cost to the user. Furthermore, they provided all their patents to push other companies to enter into the electric market and benefit from the network effect. Building this charging infrastructure at zero costs to the users has the object to reduce the network barriers that influence the purchase choice of the users (Stringham et al., 2015). For which regards the dealer store Tesla bet on the multichannel solution involving retail stores and online stores. The price of the vehicle is not negotiable in this way purchasing online or on-site is the same in terms of price. The onsite dealers are located in crucial dense traffic locations (Chen & Perez, 2018).

In the automotive industry, the purchase should pass a long process of evaluation and comparison before being chosen. In this sector, customer satisfaction is particularly important because led to higher brand power, while customer dissatisfaction can damage a lot the brand. In this sense the quality and reliability of a car influence 40% of the customer satisfaction (Chougule et al., 2013). In this scenario for new entrants, it is important to face the brand reliability of the incumbents and to create a high level of customer satisfaction that is crucial to improve the image of the brand.

Nowadays thanks to the technology improvements, especially on batteries and charging systems the EV and Hybrid technologies are more competitive (Midler & Beaume, 2010). The emergence of these new technologies needs a rethink of the key performance criteria, for example, emission product architecture and to adapt to new constraints. Those peculiarities will redefine the technology paths that drive the transition to new dominant design. The whole system should be oriented to the new paradigms to lead to a shift in the dominant design (Midler & Beaume, 2010). This shift may help the new entrants to avoid the high barriers to entry in the automotive industry.

3.1.3 The policymaker as the driver for innovation

The policymakers are now seen as the major force that drives the innovation, rather than the market (KPMG, 2020a). Indeed, one of the reasons why the automotive industry has become more focused on innovation, both radical and organizational is the intervention of the governments. The intervention of governments and regulators, both direct and indirect, has the goal to reduce emissions by introducing new green powertrain solutions (Story et al., 2011).

It is important to take into consideration that the automotive industry has its own features that influence the environmental policy instruments. The automotive industry has few incumbents without the incentives to invest in disruptive innovations. Nowadays the entire supply chain is based on the production and the distribution of the current technology. The governments are the actors that may accelerate the introduction of technologies like hybrid or EV (Weyant, 2011). Generally, we can say that in this industry standards are more effective than taxes. There is a political difficulty to reach the desired level emissions through taxes are difficult to implement (Clerides & Zachariadis, 2008).

Now we will take a look at some of the most important regulations and their impact on innovation in the automotive industry by the Bergek & Berggren (2014)'s work:

- In the US the Congress in 1970, after a period of criticism for automotive pollution, introduced a new law called Clear Air Amendment Act (CAAA). The goal was the reduction of HC, CO, and NOx of 90% by 1975/1976 compared to the level of 1970. Then the legislation became more stringent in 1990, 2004, and 2009.
  After an initial period of resistance, the companies increased their efforts. The average was 100 patents per year in the mid of 1970s, moreover, the innovations were quickly brought to the mass market. During the 1980s there was a slowdown in the patent rhythm that then increased again with the new restrictions. The law was effective in increasing innovation and

reduce pollution. Companies focused on modular innovation, such as catalysts, without modifying the architecture (Lee et al., 2010).

- Another important legislation was made by the EU that introduced a framework for reducing the pollutant of the diesel engine. The legislation is inspired by the previous one, it was introduced in 1990 but became more stringent during the years. It is divided into classes that gradually tightened. The legislation was effective with a reduction of 90% in the new vehicle. The aspect really interesting is that it had a side effect on the improvement of combustion diagnostics, sensors, electronic control, and engine management systems (Bauner et al., 2009).
- In 2008 EU made a new regulation of the reduction of CO2 emissions. The regulation was useful to promote the use of existent technology in the mass market such as turbocharging, start/stop system, and so on. Those technologies anticipated the regulation that would have been fixed in the next few years (Berggren & Magnusson, 2012).

Even technology-specific economic instruments have been made in the past to promote more ecologic mobility. One example is the public procurement (a long-standing research in innovation) put in place by the UK government, the Transport for London (TfL). The goal of the research was to understand which was the most efficient hybrid powertrain for London's transportation system. They were able to test eight different hybrid powertrain solutions and analyze the best solutions. The research was very useful to the bus manufacturers in order to direct the efforts and clarify the best technology path to follow (Sushandoyo & Magnusson, 2014).

One of the most important technology-forcing regulations that influenced the future approach of the policymaker was the Californian Zero Emission Vehicle (ZEV) rule. The born of this environmental rule is due to a climate of urgency to reduce the air pollution in California in 1990 (Collantes & Sperling, 2008). The ZEV-rule was part of a larger program the Low Emission Vehicle and Clean Fuel program. This rule imposed the sale of ZEVs in a percentage of the sales of each manufacturer in California. It was effective for all the manufacturers that sell more the 35000 vehicles or more per year, all the smaller manufacturers were benefiting from a lighter treatment. The law was not explicitly referred to battery-electric technology but the zero-emission vehicles enough mature to reach the market exploit that technology. It is important to underline that the introduction of the rule was influenced by the progress in the battery-electric car of GM and their optimism about the possibility to effectively develop this technology (Collantes & Sperling, 2008). After the introduction, the OEMs had different reactions. GM sow the rule as an opportunity to differentiate and show their technological superiority. Others like Ford and Chrysler showed their concerns in public. The OEMs were familiar with technology-forcing low but, on this occasion, there was not a collaboration as usual. Moreover, in their opinion the law was too extreme, and that the costs were not taken into consideration properly. Most OEMs thought that since the rule was technology-forcing should not be mandatory but rather should set a goal (Collantes & Sperling, 2008). This rule is unique for importance because it is not common to propose a non-incremental law. In fact, there is a disruption of the status quo presenting a new and difficult challenge to face. The reaction of the oil industry was not strong as expected in the first stage, they do not react immediately to ZEV. In the first place, they sow as a threat more the biofuels rather than the electric cars. The oil industry reacted to this law only lather during the review in 1996, making pressure on political forces. In this case, the policymaker created a new technology forcing rule but was influenced by the technology research of one OEM that influence the choice to adopt this rule (Collantes & Sperling, 2008). Due to this rule, the OEM has to increase the performance of their EV sales on the total sales, forcing the EV technology to compete with the ICE one without any intermediate step (Collantes & Sperling, 2008).

In the automotive industry, the instruments that operate on the price may not be the optimal choice. In fact, the buyer carries only a fraction of the price of a product, due to the second-hand market the cost of the product is not limited to the first owner. In this way, the first customer considers only the savings of the first years when buying decision comes, and not the life of the product (OECD & Greene, 2010).

3.1.4 Alliances as a tool to boost the innovation

The uncertainty situation of the future of the automotive industry is the results of the market trends that are emerging. There is the awareness that the industry is changing and to survive was necessary to shift toward an open ecosystem made of partnerships. The OEMs need to form alliances with suppliers and service providers to participate in an ecosystem that addresses the new trends, for example building a charging infrastructure (Gao et al., 2016). Since there are many challenges to face for OEMs, such as autonomous technologies, connectivity, electrification, and shared mobility the incumbents are more inclined to work together rather than working alone since have not all the competencies face these trends (Hofstätter et al., 2020). One of the major needs for OEMs is to share costs of electric and hybrid infrastructure. Moreover, the partnerships are useful not only to share costs but also to talk with governments about future policies, reducing uncertainty. At the same time the OEMs should pay attention to maintaining control over their value creation otherwise would lose their competitive advantage. To reach this goal the organization should change, facilitating internal collaboration. New knowledge and expertise have to be acquired, it can be made by building internally or outsource to external companies (Gao et al., 2016).

The OEMs try to absorb knowledge to create radical innovation from both stable and emergent networks. For this reason, they need to look for partners with different and emergent technology capabilities (Story et al., 2009). One of the major limitations for the OEMs is the funds which are crucial for gaining new knowledge and start a process of trial and error, in particular for physical development and the market launch of new prototypes (Baker & Hart, 2007). Nowadays, it is more difficult for an OEM to finance its R&D by itself. The competition is increased, and the funds are becoming thinner than in the past. (Story et al., 2001). In this scenario, the governments play an important role even in the financial side of innovation. For instance, in the UK the government is financing through the Technology Strategy Board, Regional development agencies (RDAs), or Research councils, supporting the efforts of the OEMs and incentivizing the research (Story et al., 2011).

The alliances are a tool to develop the powertrain technology efficiently and effectively. For this reason, the thesis is focused on the alliances and partnerships that emerged to develop the key technologies required in the market.

3.1.5 Automotive supply chain

Some automotive OEMs decided to try to implement a modular system of supply. One example made by Doran (2004) is Mercedes that created a modular concept for its facility plant. In this case Mercedes shift from relying to 100 first tier supplier to 25. A supply chain that is able to exploit modularity requires the right suppliers with specific capabilities and knowledge. Each OEM has its own concept of modularity. A supplier which is crucial for one OEM may be not as important for the others. The OEM is crucial because has the role of integrator if remains in control of the supply chain or the modulaiser role when the pass the control of parts of the supply chain to the better suppliers. In both cases, the OEMs manage the supply chain (Doran, 2004).

In the automotive industry, the OEMs should be able to adapt quickly to the change and this ability depends also on their supply chain. There is a need to respond to an increasing number of customer segments and car models (Veloso & Kumar, 2002). The OEMs are gradually passing the responsibility to manufacturing, developing, and assembling an important section of the car to the suppliers. There is a focus is on building a relationship with key suppliers around the world. These key suppliers are becoming more global and larger, being able to manage the complex system and integrate sub-suppliers. The suppliers' requirements should be: high quality and cost competitiveness, R&D capacity, and be close to the headquarter (Veloso & Kumar, 2002), global presence, and control of the key areas of the supply chain (Doran, 2004).

In this paper the interest is not arguing if the car and the supply chain is modular or not. On the contrary, we are interested in understanding if building a relationship with the new supplier would become fundamental. The OEMs should be able to manage groups of suppliers from different industries and with different knowledge and capabilities. Creating strong ties with new suppliers like battery producers may be crucial to increase the pace of the development of products and the efficiency of the production.

Nowadays, in the automotive industry, according to Carlsson & Stankiewicz (1991) we can consider EV and hybrid technologies as technology discontinuities, although of different intensity. Indeed, in 2019 the Internal Combustion Engine (ICE) cars are responsible for 90% of the market share (JATO, 2019). The two technology discontinuities are in a different stage of maturity, the hybrid technology is in a more advanced stage (Hekkert & van den Hoed, 2004). The automotive industry includes very complex products and supply chains, involving many actors on different sides of the world. For this reason, we should think in terms of technology systems. The technologies systems are defined as a "*'network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure for the purpose of generating, diffusing and utilizing technology*" (Carlsson & Stankiewicz, 1991:111). The automotive industry's dominant design, the ICE system, includes actors that have a great influence on the market, such as the oil industry.

A shift to hybrid or EV technologies could change the entire technology system. With the new technologies, each OEM should increase their knowledge, skills, and expertise to the new system and adapt the organization. It could be extremely costly in terms of money and time (Hekkert & van den Hoed, 2004). Moreover, a substantial portion of the supply chain would likely change. One example of actors that would be harmed by this change are the fuel suppliers and the repair facilities. It is clear that hybrid technology would have less impact on the architecture of the supply chain (Hekkert & van den Hoed, 2004). On the opposite, EV technology would cut a huge part of the supply chain. Likely, the oil companies would play an important role. They have the interest to maintain the actual energy infrastructure and the power to influence the development of the innovation path. Even though their interest is in gasoline, maintaining the actual infrastructure, they are trying to invest in alternative fuels. The alternatives fuels could be not considered as disruptive technologies because are competence enhancing and do not change so much the current technology system (Hekkert & van den Hoed, 2004).

During the competition for increasing the margins and competing inside the boundaries of the dominant design, companies should pay attention also to all those factors that may threaten their business model to prevent their previous investments.

3.2 Collecting data

The objective of the research is to understand how the alliances helped the OEMs in the automotive industry to develop new technologies. The data are useful to create a framework of the alliances and understand the patterns that drive the behavior of the OEMs. The data analysis will be descriptive in order to understand better what happened and contextualize the data. Understand the past behavior of the manufacturers could be useful to interpret the current results.

In order to discuss the open innovation in developing the knowledge and capabilities in electric and hybrid technology, it is necessary to map all the activities undertaken by the most important Original Equipment Manufacturer (OEM) in the automotive industry. The OEMs selected for the automotive industry are the most important producers in the market. The list is composed of the top 24 OEMs in the automotive industry taking into consideration features like revenues, capitalization, production, and inventions: Honda, General Motors (GM), Chang'an, Daimler, Fiat, Tesla, Peugeot, BMW, Renault, Mazda, Nissan, Toyota, Mitsubishi, Suzuki, Great Wall, Ford, BAIC, Hyundai, Volkswagen, Tata, Kia, Dongfeng, Saic, Geely. The time of the data is between 2005 and 2014. Those OEMs represent the majority of the automotive market share. The time-lapse taken into consideration is the period that goes from the firs of January of 2005 to the thirty-one of December of 2014.

To achieve this goal, it was useful to gather data from two important sources. The first one is Orbis which is the bigger global database on companies' data. The second is Lexis Nexis a full-text database on juridic and financial sources of international relevance.

3.2.1 Orbis data

The first data that could be useful for the purposes of this thesis are the information on the investment, M&A, and joint ventures made by the top OEMs. The data has been downloaded from Orbis and then elaborated.

The first step was to collect all the title news of the Bureau van Dijk about the M&A deals made by all the OEMs considered in our research. Then all the data gathered has been elaborating splitting all the news into different archetypes that define kind of deal. The data were useful to find all the joint ventures that included at least one of the OEMs selected comprised in the time-lapse considered. Then all the data has been put together and cleaned from the duplicates, for example, if PSA and GM established a joint venture together the data would be reported only one time and not one time for the PSA data and one time for the GM data.

3.2.2 Lexis data

Another source of data is the Lexis database. The lexis data are useful to analyze the alliances put in place by the 24 OEMs. The research is set-up as follows. The first step was to select the right keywords to individuate the majority of the alliances made in the time-lapse considered. A list of seven keyword was made, then ordered in base of the number of results that produced. The first three keywords of the list partnership, alliance, and collaboration produced different results while the other words did not produce extra material so only the first three were considered in the research. The research included all the news that included in the title the name of at least one of the OEMs and at least one keyword among partnership, alliance, and collaboration. The news selected was only in the English language and related to the automotive industry.

Then the data were elaborated selecting one article for each potential alliance, in this way the duplicates were removed. Then for each alliance, according to the information gathered reading the article, were assigned one or more function that has been involved in the alliance. The functions are marketing, supply, R&D, production and not defined. Those functions allow to understand if the alliance has been created to promote products, to increase production, or for incrementing the capabilities in one field. Moreover, each alliance has one or more topics, which is the focus of the alliance. The topics are components, autonomous vehicles, design (included the car architecture), electric vehicles, fuels and lubricants, hybrid engines, IT, marketing, mobility, motorsport, other (when not comprised in this list), manufacture, safety, sustainability, thermic engines and not defined. Since the object of the thesis is focusing on the innovation aspect of the alliances some functions may not have explicated the topic, but all the R&D alliances have at least one topic.

This work produced a data set of 875 records, 44 of them refer to the end of alliances. The new alliances individuated are 831, 29 of them are not verified. We have a not verified alliance when the source think that the agreement is close, but it is not official and there are no other sources that confirm it. which means that in the news the creation of the alliance was not sure. Furthermore, there are 82 are extensions of old alliances.

Chapter 4 – The empirical analysis

4.1 – Hybrid and electric vehicles overview

In the automotive industry there are many technologies that are going to compete with the ICE for the future dominant design in the next few years. Nowadays the ICEs dominates the market, in the first quarter of 2019 the 91% of the car sold were equipped by an ICE engine (JATO, 2019). The ICE engine is still the dominant design, but the electrification process is changing the industry. The incumbents are now threatened by hybrid and electric engines. The electrification process is caused by many features like environmental policies, declining battery costs, and advances in electric technology (Automotive Logistics, 2020). The growth of hybrid and electric vehicles is forecasted to increase from 8% of the total market share to 55% by 2030. Likely, the growth of the new powertrains will not be uniform all over the world. Indeed, the diffusion rate is characterized also by peculiar factors typical of the different regions of the world. The rate of adoption depends on regulatory differences, purchase subsidies, changing infrastructure, and consumer preferences. For example, Europe and China can grow seven-time by 2030, while in the US the situation could be different. Indeed, in the US we have different environmental policies and lower population density that can lead to a lower adoption rate (Automotive Logistics, 2020).

The carmakers need to be ready for the change, but the risk is to invest in the wrong technology that would not win the dominant design competition. This risk increases if we consider the divergences in the environmental policies that may emerge. Some countries may promote a standard while other countries other standards. This uncertainty condition allows the new entrants to threaten the incumbents by focusing directly on electric vehicles. Since the new entrants do not have previous investments to protect (Automotive Logistics, 2020). Another aspect to take into consideration regards the supply chain. The relationship with the new battery suppliers becomes central in the production of EVs and hybrid vehicles. They may gain more and more importance in the development and production of the new vehicles, eroding the margins of OEMs. The importance of battery suppliers is confirmed by the cooperation between them and some OEMs. For example, Volkswagen and Tesla are creating joint ventures with battery suppliers, in this way they can purchase and develop the best batteries for the new cars. The costs of developing electrified cars would lead the incumbents to share R&D costs and production platforms (Automotive Logistics, 2020).

Notice that for the single OEM it is difficult to make the difference by itself. In fact, electric and hybrid vehicles are eco-innovation so incentivizing their application is complicated. These innovations reduce the pollution levels improving the health of the people that live in a defined area. The benefit produced cannot be charged at the price of purchase since are positive externalities. On the contrary, the cost of the ICE cars and the fuel does not include the negative impact on the environment (Brown, 2001). The new powertrains have better performances in terms of emission levels, but this performance is a positive externality and depends on the community. So, the consumer has not a better performance buying an eco-car. The policymaker has the goal to internalize the benefit and the costs, but it is not a simple task (Brown, 2001).

The rate of adoption of the new technologies depends also on the country of origin of the OEM (Sierzchula et al., 2014). In countries in which the home OEMs invested heavily in green powertrain technologies, the rate of adoption is higher, such as France and Japan. While countries in which the national manufacturers did not invest so much in these new technologies the rate is lower, like Italy and Germany (Sierzchula et al., 2014). This tendency is reflected also by the strategies of the OEMs that are more willing to put out their products before in the home market and then abroad. The policies of the different countries have a huge impact on the adoption of level. In fact, the number of EVs in a market is more influenced by specific EV factors such as the charging infrastructure rather than the socio-demographic factors like the educational level (Sierzchula et al., 2014).

4.1.1 - Hybrid Vehicles

As we have seen in the first chapter the hybrid intergenerational products can be useful for many reasons. In the automotive industry, we can consider the hybrid engine as a hybrid intergenerational product. In fact, it is the combination of two technologies of two different generations, the internal combustion engine (ICE) and electric engine.

The internal combustion engine that is linked with the electric engine could be fostered by different fuels, the most commons are gasoline or diesel. There is not only one kind of hybrid but several hybrid models that are different according to the role of the electric engine and ICE. The connection to the transmission is one of the features that characterize several hybrid engines:

- Parallel hybridization: In this kind of hybrid engine the two engines are both connected to the transmission. This allows the engine to switch the powertrain according to the speed. Usually, the electric engine works by itself until 30/50 km/h then the thermic engine would operate (Groupe PSA, 2020).
- Serial Hybridization: the serial hybrid engine is a quite rare solution. In this model, the electric engine is the only one that provides power to the wheels. The thermic engine is not connected to the car's transmission but is useful to charge the batteries of the electric motor. In other words, the thermic engine works as a generator for the electric one. In this model the driver experience is much closer to the pure electric car (Groupe PSA, 2020).
- Mixed or Power-Derived Hybridization: this typology is the combination of the previous two. It allows both engines to give power to the wheels and the thermic engines can also recharge the battery (Groupe PSA, 2020).

Then the hybrid vehicles can be classified according to the different roles and importance of the two engines. Possible combinations lead to a high number of different models:

- The mixed hybrid cars, or mild hybrid, have a small battery that helps the car to save fuel in situations of traffic or to maintain a constant speed, the saving of fuel is 0,5/100km compared to a traditional thermic car. This model does not allow the electric engine to push the car by itself (Groupe PSA, 2020).
- Another solution, one of the most common, is the full hybrid. In this solution, the electric engine generally works by itself usually until 50km/h. Once the car overcomes the speed reached by the electric engine the propulsion relies

on the ICE. Even during the ICE propulsion, the electric engine helps the thermic one to save fuel (Groupe PSA, 2020).

- Finally, there is the most electric model is Rechargeable Hybrid Car, or Plug-in Hybrid. In this model, the car is equipped with more powerful batteries that can be charged by the user and have a higher electric capacity. It guarantees lower fuel consumption (Groupe PSA, 2020).

Thanks to the spectrum of possibilities the consumer has a great number of options that are summarized in the table below.

Table 1: Comparison of different levels of Hybridization

Type	Start-stop systems	Regenerative braking Electric propulsion	Charge-depleting	Rechargeable	Fuel efficiency gain
12V Micro Hybrid	Yes	No	No	No	5%
48V MHEV	Yes	Yes	No	No	5% - 15%
HEV	Yes	Yes	Yes	No	23% - 34%
PHEV	Yes	Yes	Yes	Yes	50% - 70%

Source: Automotive Logistic Forecast to 2030

It is important to do not to confuse the "micro-hybrid" model as a hybrid engine since it is not equipped with an electric engine. This model is equipped with a battery that turns off the engine when the car is stationary and turns on when the car re-start lowering the fuel consumption, basically the start-and-stop system (Automotive Logistics, 2020).

The market of the hybrid car is assessed to grow in the next years. The mild-hybrid vehicle (MHEV) is expected to grow from 4.2m units in 2020 and dramatically rise to 28.2m units in 2030. For full hybrid, or hybrid electric vehicles (HEV), the growth would be from 1.9 million in 2020 to 9.2 in 2030. Instead, for the plug-in electric vehicles (PHEV) model it is forecasted a better growth. This model is about to increase the market share from 2.1 million in 2020 to 10.4 million in 2030. The strength of this model is the flexibility since it allows the user to change his behavior according to the availability of electricity (Automotive Logistics, 2020).

The basic idea of the hybrid engine is to exploit the strength of both of the two engines eliminating the weaknesses thanks to their cooperation. The ICE engine works at its optimum level only in a certain operating range, otherwise is less efficient. The non-optimum operational range emerges when the user is driving at low speed in particular in the city drive. When this happens, the electric engine should help the vehicle to be more efficient. At the same time, we can see the hybrid in a different way. Indeed, the electric vehicle can be considered as a solution to solve the range problem of the electric vehicle. In these terms, the ICE engine solve the bottleneck of the EV increasing the energy storage and the length of the range (Chanaron & Teske, 2007). Then we have also to consider the weak points of hybrid cars. The first is that the fuel consumption is limited by the weight of the two engines. If we run with a hybrid car only with the ICE engine it would spend more fuel than a car equipped with a classic ICE engine alone because of the weight. Basically, it lowers the potential. Another issue is the challenge of combining the two technologies, this combination requires a complex architecture. Finally, that the hybrid cars are not zero-emissions vehicles, this technology may be harmed by the zero-emission regulation. Moreover, in long-distance, hybrid engines have less fuel efficiency than modern diesel (Chanaron & Teske, 2007).

According to Chanaron & Teske (2007), it is necessary to underline the limitations from the consumer side. One of the major limitations for the customer is the price of the car. Even in this case depends on the country that we are considering. In some countries, the difference between the same model of ICE car and the hybrid car is high, while in others is low. The spread of hybrid cars depends also on many other drivers. The customer takes into consideration not only the price for itself but also all the advantages and disadvantages that influence the cost of a hybrid. The most important are the tax reduction, the uncertainty over the expected resale price, and the low cost of maintenance due to the long-term warranty. Even the macroeconomic factors influence the spread of these vehicles. Such as the fuel prices, the availability of the resources, and the regulations or the tax regime, which are exogenous to the OEMs but have an impact on the customer choice. Then we have the supply-side drivers, which include the variety of models, the cost of production, the technical features, and the emissions. These last drivers are endogenous and can be influenced by the behavior of the OEM (Chanaron & Teske, 2007).

For which regards the hybrids from the point of view of the users this technology is seen as an incremental innovation as it allows to maintain the same infrastructure (fuel distributors) and behaviors (Hekkert & van den Hoed, 2004). Instead from the OEM perspective, the production of these vehicles needs new technologies and capabilities that must be reintegrated with their current capabilities (Geels, 2002). For this reason, even hybrid cars can be considered a technological discontinuity. Even though, it is a not typical discontinuity since it does not replace the old technology but integrates it to reach a superior result. The new technology is modular because it changes the components and architectural since it changes the configuration of the product. One example of modular innovation in the automotive industry could be the diesel engine that changed some components but not the architecture. The new system may attempt to the OEMs profitability as system integrators because become dependent on a limited number of suppliers that will have more market power. (Magnusson & Berggren, 2011). Hybrid cars are supposed to gain a wider acceptance from the customer. The customer must not change its behavior since they have the ICE that can support them even in longer distances and not rely on charging infrastructure (Chanaron & Teske, 2007). On the opposite, the EVs lead the customers to change their habits because they can rely only on the charging infrastructure paying attention to the distance length. Notice that for OEMs the hybrid system does not mean only adding an electric engine to their existent architecture. They have to integrate the two engines and facing high costs due to the complexity of the product (Chanaron & Teske, 2007).

Finding the right balance between the power of the ICE engine and the electric components for hybrid products is difficult. Increasing the power of the ICE engine would help the performance of the car but reduce the fuel efficiency. At the same time increasing the electronic part would help the fuel efficiency and the performances but the costs increase. The challenge is to make the electric components needed for lowering hybrid car costs cheaper (Magnusson & Berggren, 2011).

4.1.2 - Electric Vehicles

The battery-electric vehicles are supported by an electric motor powered by a battery. Those vehicles have not ICE nor fuel tanks and pipeline, for this reason, are zero-emissions vehicles. In order to fill the battery, it is needed the charging to a power station. The several charging stations have been classified by the Society of Automotive Engineers and by the International Electrotechnical Commission according to the different power levels and different power models (Das et al., 2020). Although, the lack of a universal charging model remains a problem. Actually, there are different models that vary according to the country, manufacturer, power level shape, size, ext. (Foley et al., 2010). The improvement on the charging infrastructure suffers from low investments. Private and public investments hesitate because there are not many EV vehicles, at the same time there are fewer vehicles because the infrastructure is not adequate in many regions of the world (Haddadian et al., 2015). Indeed, the creation of a charging station for every 1000 habitants would help more than a 1000 dollars subsidy for each purchase (Sierzchula et al., 2014). The location of the power station plays an important role, they should be located near to the electric substation to not waste electric energy. At the same time power station should be located near the users to be economically feasible for the economic choice of EVs (Kim, 2019) (San Román et al., 2011).

Electric vehicles are forecasted to grow from 2.7 m in 2020 to 17.8 m in 2030. It is necessary to underline that these vehicles are often sold at cost or even below thanks to environmental policies. If the OEMs will not be able to reduce the costs, there is the possibility to damage their profitability in the long run. Moreover, the growth is heavily dependent on the price of batteries, in 2018 the price of the battery was $180-200 per kWh. It is assumed that only when the cost of the battery would drop to $100 per kWh the electric vehicles would be able to compete with the ICE vehicles in terms of margins. Actually, the main obstacle that reduces the spread of EVs and increases the uncertainty is the lack of charging infrastructure and the length of the charging process (Automotive Logistics, 2020).

Then the tastes of the consumer are critical for the future of EVs. At this moment it is difficult to attract a huge audience due to the lack of EV models. An increase of models and variation of styles, appealing features, and functionality can attract more users (Haddadian et al., 2015). Finally, it is important to underline that at this moment the EV engines can compete in terms of cost to ICE engines only if tax reductions and subsidies help them to remain economically feasible (Ghosh, 2020).

Other barriers that limit the purchase of an EV are the range anxiety, the long charging time, and the high purchase price. Surprisingly, the income does not play a great effect as we can expect. Notice that, the customers that are willing to buy an electric car in the future are the ones who are interested also in hybrid cars for the next purchase (Hidrue et al., 2011).

An electric alternative to battery electric vehicles is the Fuel Cell Vehicle. The Fuel Cell technology exploits hydrogen to produce electricity. This kind of vehicle is not provided by a battery pack but by a tank of hydrogen. It is a zero-emission vehicle and environmentally friendly as long as hydrogen is produced by a renewable source. Many companies are investing in this kind of technology as Honda and Toyota for example (Automotive Logistics, 2020). Furthermore, even the governments of China and Japan are encouraging the development of these engines. Anyway, at this moment many technical challenges block the spread of these vehicles. The first is the high compression needed to provide a significant amount of hydrogen increases the risk of explosion. Moreover, the price of this vehicle is very high, around 100 000$, due to the cost of manufacturing the fuel cell unit. Finally, there is a lack of a refueling infrastructure, which is very expensive due to the cost of delivering hydrogen. An alternative should be generating the hydrogen on-site for example through solar panels. In both cases, it is a huge challenge. This kind of technology may be particularly useful for commercial vehicles. For example, the trucks may require enormous batteries that are not feasible. On the contrary refueling in an isolated station would not be a problem thanks to the dimension of the tanks (Automotive Logistics, 2020).

The forecast for fuel-cell vehicles is 22 000 in 2020 that become 984 000 in 2030. These numbers are not comparable with the battery-electric one which remains the pure electric powertrain more mature for penetrating the market (Automotive Logistics, 2020).

4.2 - Incumbents' strategy

In this paragraph, we will analyze how the incumbents are trying to face the new technology challenges.

In order to shift toward the electric and plug-in hybrid technologies, new elements have to be added into the new ecosystem. These elements are electric and hybrid vehicles, the infrastructure such as the charging stations, software able to find charging stations, a software that connects users to the charging stations. The OEMs cannot provide all of these requirements by themselves, and integration with other companies is needed. All of these components have little value alone and the skills and capabilities to create them are very different (Hodapp & Dao, 2019). Since the companies have not the expertise to produce all these elements alliances and cooperation are needed

A useful example could be the strategy adopted by Toyota, one of the first companies to successfully introduce a hybrid vehicle into the market. The Toyota Prius was one of the first hybrid cars to have success in the US market. When this car entered into the market the other incumbents do not pay too much attention. Only when the price of fuel increased the Americans started to take into consideration the hybrid option, and the incumbents started to pay attention. During these years in Europe, hybrid cars did not reach the same success as in the US, even this result may be linked with the price of fuels. In Europe the price of fuel is higher than in the US but stable, on the contrary, in the US the users witnessed an increased price in 2004-2008 that pushed the US citizens to find attractive this alternative. In Europe, there was already an option to face the high fuel prices, the diesel engine. It is not a radical innovation so the incumbents were more willing to adopt this technology (Magnusson & Berggren, 2011). Moreover, the research for incremental innovations of the European manufacturers, such as the start-and-stop function, was useful to make a step forward in the reduction of emissions without making a step toward the new powertrain technologies (Chanaron & Teske, 2007). In order to create the Prius, Toyota relied on the same supplier that produces its EV batteries, Panasonic. Since hybrid cars require an effective integration between ICE engines and electric components it was necessary to combine their knowledge. For this reason, they formed a joint venture to develop together the new technology. As the joint venture produced an important improvement in the field Toyota acquired the control of the company to improve its knowledge in the field (Magnusson & Berggren, 2011). The first step was to launch the Prius only in the home market acquiring expertise investigating the potentiality and the weakness of the hybrid car. The hybrid car became a knowledge platform even for EVs models. Indeed, electric motors, batteries, regenerative brakes would be useful even in EV production. In this way, Toyota is able to gather knowledge not only on the technology but also on the critical component manufacture, combining effectiveness with efficiency. Many components have been developed for a low-volume application, using them for higher volumes allowed Toyota to gain knowledge and make them feasible for the mass market (Magnusson & Berggren, 2011). Another important aspect was the ability of Toyota to reach those customers that are more sensible about an environmental issue and that are more willing to pay an extra price. Even though the Prius was a loss-making product allowed them to reach more knowledge about the technology and the market that could never be reached only by R&D. The difficulties of the competitors is to assess the cost of production in the mass market, that information is difficult to be acquired so every competitor needs to create its own knowledge (Magnusson & Berggren, 2011).

The effectiveness of the strategy depends also on the market of destination, there are many differences among countries. The countries that were able to promote the EVs like Israel and Denmark have the right specific features. One important factor is the ability to offer economic support to EVs. The hybrid or EVs should be competitive in comparison with the ICE engine in terms of costs for a period of lifecycle which is at least 10 years. Another important feature is the customer's use of the vehicles. Both of the countries taken as an example are small countries in which the users use the cars every day to make short trips (less than 100km). Moreover, the market should be enough large to justify a strong commitment (Beaume & Midler, 2008). The improvement in specific countries leads to an increase in the economy of scale, reducing the production costs allow the companies to spread the innovations into new markets. Usually, the countries that adopt for first these innovation benefit from the creation of a new value chain in their territory, making agreements with the companies (Beaume & Midler, 2008).

In the automotive industry, the incumbents were able to develop radical innovations such as Toyota Prius and Nissan Leaf (Sierzchula et al., 2012). The goal of these companies was to gain a competitive advantage over their competitors, at the moment the consumers still prefer the old thermic technology. This process should push the incumbents to focus on incremental innovation on the ICE engine but they see improvement on the alternative powertrains as a necessity because is driven by policymakers and not by the market (Sierzchula et al., 2012). These efforts in focusing on radical innovation even in a period of strong uncertainty are not unformed for all the companies. The OEMs focused on different technologies. Some of them were more specific like Toyota that focused on hybrid cars or Nissan on EVs, while others develop several technologies at the same time without focusing on one specific technology. In any case, most of the technologies developed are competence destroying (Sierzchula et al., 2012). Three main scenarios may emerge in the next years. The first is that the ICE engine continues its predominance, the second is the emergence of a new dominant design and the third is the coexistence of multiple designs. The third scenario can emerge only if the demand is heterogeneous. The heterogeneity of demand may depend on the existence of different regulations in different countries, on the division among urban mobility and non-urban mobility, and on the different availability of the resource in different countries, e.g. in the US the gasoline is cheaper (Sierzchula et al., 2012).

The early adopters are crucial to increase in this market to gain market share in the future. This kind of customer is driven not only by fuel consumption but also by environmental concerns and the social standing that these types of vehicles guarantee. The management of the expectation of the early adopter then becomes fundamental (Sovacool & Hirsh, 2009). The initial phase of excitement can easily turn into disappointment if the expectations are not achieved, in particular in terms of fuel efficiency. A proper communication is necessary to not start this process. In fact, if the users that do not adapt properly to the features of new products would be disappointed. For example, when the consumer does not change his style of driving and drive the hybrid and electric vehicles as a traditional car the effect is that he would not see a great advantage in terms of consumption. Also, small expedient, like charging the vehicle during the night, influence the experience, if a customer does not do so he would not see the advantages and would be disappointed (Sovacool & Hirsh, 2009). Companies have to pay attention to how they promote hybrid and electric vehicles to avoid this risk. When the companies understand that they may assault the mass market it is necessary to change the perception of hybrid and electric vehicles. Drawing these products as equipped of revolutionary technology is appealing for early adopters but not for the mass market. The majority of the customer may perceive that these technologies would not reach a huge market share that would lead to less investment in complementary products. This process would happened even if this technology is cheaper (Sovacool & Hirsh, 2009). Moreover, when an OEM is outlining the strategy, it is necessary to take into consideration that some OEMs and the oil industry may make resistance to these new trends, as happened in the past for alternative fuels. This may happen because the new technology is competence destroying and require a new set of suppliers. Changing toward electrification of cars means also harming many other markets, for example, the repair and maintenance market. In other words, most of the actual actors in the automotive industry have the interest to not change toward hybrid or EVs (Sovacool & Hirsh, 2009).

The uncertainty over the alternatives to the ICE engine is high. The feedbacks of the early adopters are crucial, including word of mouth and social exposure. Then we have the economic factors as the economies of scale and scope, the trial-and-error process, the fuel and service infrastructure, and the lack of a unique standard. The choice of the car depends also on social status and personal identity, for this reason, there is also a component of emotions linked to the choice. Since the vehicles have a long lifecycle the increase of the installed base will increase slowly (Struben & Sterman, 2008). Moreover, as the users switch from ICE cars to hybrid or electric cars the price of the used car would diminish playing the opposite effect. This effect can be limited by public policies or by the subsidies that may promote the demolition of old ICE cars with the purchase of new ones. The incumbents have some advantage in the actual automotive industry, such as the economies of scale, market knowledge, huge R&D centers (Struben & Sterman, 2008).

As we have seen the need to diminish the costs but at the same time to explore in a different direction because the choice of the regulators could be different and could change over time. For this reason, they created partnerships with the actors in the industry, and with is crucial to pursue different technology paths without the risk to invest in the wrong technology and spending too many funds.

4.3 Joint ventures on electric and hybrid vehicles

In this paragraph, we will take a look at the different joint ventures created from 2005 to 2014 in order to enhance the technical knowledge on hybrid and electric vehicles. For first we will see the joint ventures among OEMs and the with other companies.

4.3.1 Joint venture between OEMs

The first joint venture was created in November 2011 by BMW and PSA that launched the BMW Peugeot Citroën Electrification. The joint venture is divided equally between the two companies, each of them has the 50% of the quotes. The goal of the project is to develop and produce together components useful for the production of hybrid vehicles, such as battery packs, E-machines, generators, power electronics and chargers, and also developing software for hybrid systems. Another object is the creation of common standards in Europe for the components useful for the electrification of vehicles. The joint venture can sell its components to other companies and can cooperate with other suppliers. The joint venture aims to achieve economies of scale for hybrid components (BMW group, 2011)

The second joint venture was born in June 2006 between the companies Nissan and Mitsubishi that created a joint venture called NMKV. The joint venture's object was to produce mini cars for the Japanese market. The two companies think that the standard cars would be replaced by mini cars in Japan. For this reason, they are working together to create electric minicars for their home market (Bloomberg news, 2011).

There is a third horizontal joint venture between Mitsubishi and Guangzhou Automobile Group called GAC Mitsubishi Motors created in 2012. The joint venture aims to create a new SUV in two versions, electric and hybrid, destined to the Chinese market. Guangzhou Automobile Group is not among the group of the 24 OEMs taken into consideration but it still a Chinese OEM (Mitsubishi news, 2018).

The OEMs created only three horizontal joint ventures. As we will see in the next paragraph they preferred to focus on joint ventures with suppliers.

4.3.2 Joint ventures between OEMs and other companies

Then we have the JVs stipulated between the 24 OEMs considered and the other companies:

- Suzuki and Intelligent Energy holdings formed a joint venture to develop batteries for electric fuel cell vehicles in 2012. Intelligent energy is a company focused on fuel cell technology for many markets included the automotive one (Green Cars, 2012).
- Sumitomo, Nissan Motor, NEC, and Showa Shell Sekiyu established a joint venture in 2011. The goal of the joint venture is to develop and manufacture battery charging services for electric and plug-in hybrid vehicles. The Nissan's partners are a trading company, a semiconductor company, and an IT company (Fuels and Lubes, 2011).
- Daimler created a joint venture with Bosh, an electric motor producer, in 2011. The joint venture aims to develop and produce electric motors (Dumitrache, 2011).
- BYD, a battery producer, created a joint venture with Daimler, in 2010. The joint venture has been formed in order to create a research center in China for the improvement of electric vehicle technology (Mercedes-benz media, 2010).
- In 2009, Volkswagen and Varta Microbattery created a joint Venture to develop lithium-ion batteries for electric vehicles. Varta Microbattery is a battery supplier that is focused on supply miniature battery technologies for mobile communication, medical and electronic equipment (Green Cars, 2009).
- Daimler created a joint venture with the supplier of lithium batteries Evonik, the goal is to develop and produce the best batteries for electric vehicles that can be used both in passenger cars and commercial vehicles. The joint venture has been created in 2008 (Evonik media, 2008)
- The battery producer NEC corporation formed a joint venture with Nissan in 2007. The goal was to develop and produce lithium-ion batteries both for hybrid and electric vehicles (Nissan news, 2007).

- Mitsubishi formed a joint venture with the Japanese battery producer GS Yuasa Corporation in 2007. The joint venture aims to produce batteries useful for electric vehicles and plug-in hybrids (Green Cars, 2007).

As we can see the major concern of the OEMs is the batteries. The OEMs have chosen to collaborate with the supplier of batteries rather than creating many horizontal alliances except for PSA and BMW, Nissan and Mitsubishi, and Mitsubishi and Guangzhou. The companies that decided to make horizontal JVs to boost the electrification process are geographically and so culturally close. PSA and BMW are both European while Nissan and Mitsubishi are both Japanese and, Mitsubishi and Guangzhou Automobile Group are both Asian. We can notice that Europe, Japan, and China are focusing on electric mobility more than other countries. Maybe the three joint ventures are used as a way to explore and penetrate their internal market.

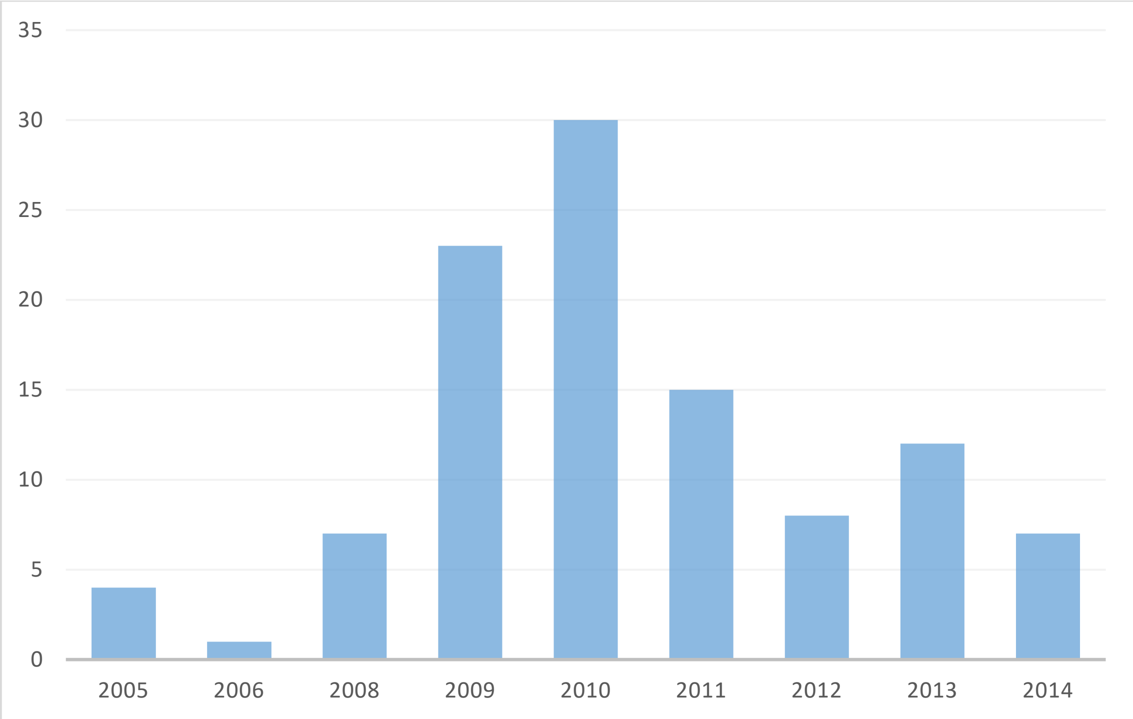
All the companies that created a joint venture with a battery supplier are likely to focus on their own batteries that are adapted to their own model, creating different standards. The battery producers are the ones who are more likely to increase the knowledge of the OEM.

4.4 Alliances on hybrid and electric vehicles

In this chapter, we will analyze the alliances created to gather knowledge on hybrid vehicles, electric vehicles, fuel-cell vehicles and charging infrastructure. The purpose of our research is to understand how the OEMs developed new powertrain technologies, for this reason, we will take into consideration only the alliances that aim to develop these technologies.

For first we need to understand the time-frequency of the alliances. The graph below registers the higher number of alliances in the three years 2009, 2010, and 2011, with the peak in 2010. Then there is a return in 2013 and finally a drop in 2014. The number of alliances is quite similar for each technology as we will see, except for the fuel-cell technology where we have little data.

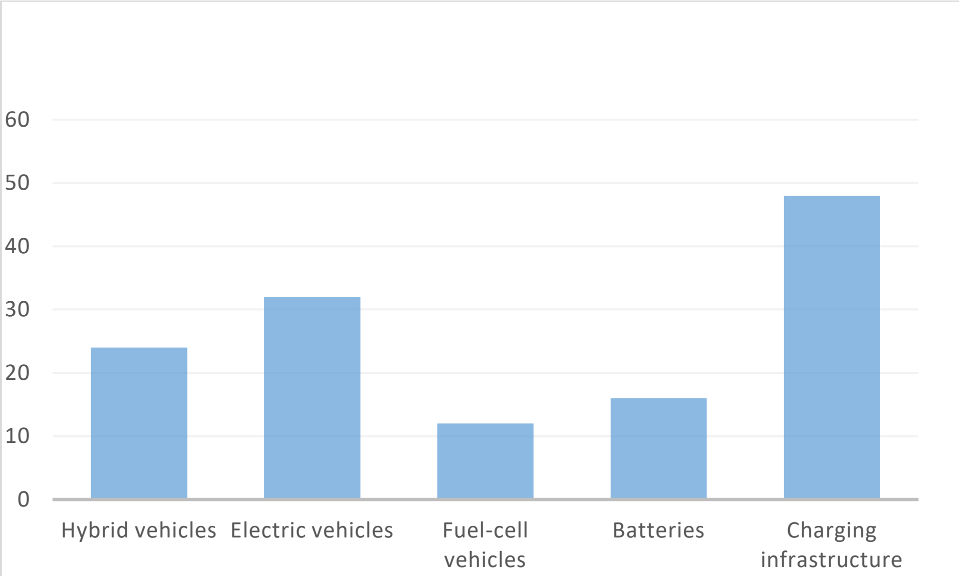
Figure 1: Number of alliances per year



Source: Elaboration on Lexis data

When we are looking at the technology objectives of the alliances it is needed to clarify that one alliance can have as an object more than one topic. For example, an alliance can aim to develop at the same time hybrid and electric vehicles. In the next graph we can see the distribution of the alliances per technology.

Figure 2: Number of Alliances per technology

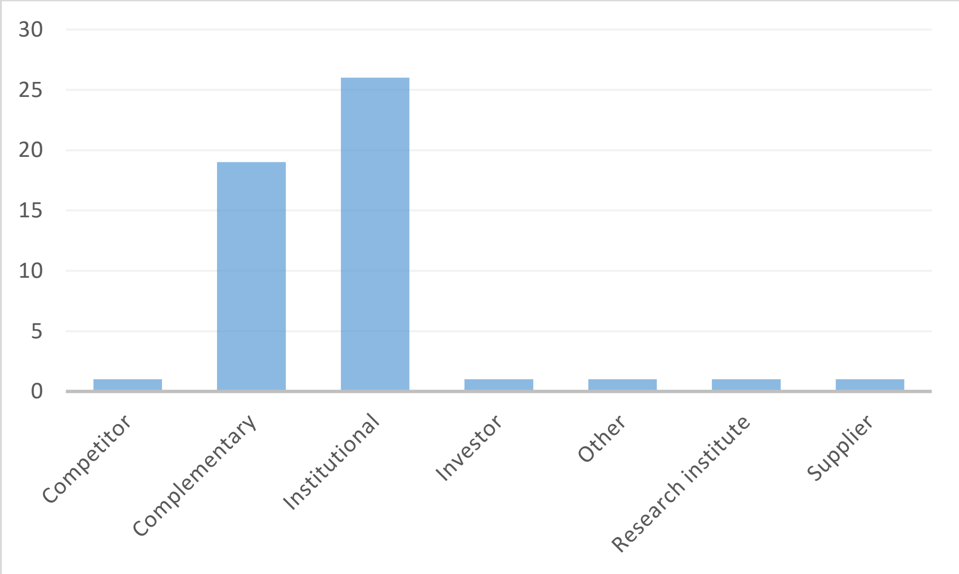


Source: Elaboration on Lexis data

As we can see, most of the alliances aimed to develop a proper charging infrastructure. Notice that the charging infrastructure could be useful both for Plug-in hybrid and electric vehicles. Even though the charging infrastructure has a higher impact on electric vehicles because this technology cannot prescind from the charging stations. Then we have the electric vehicle alliances followed by the hybrid alliances and the batteries. Even the development of lithium batteries can be associated with both hybrid and electric vehicles. Finally, we have the fuel-cell technology which compared to the hybrid and electric is far to be launched in the market.

4.4.1 Charging infrastructure

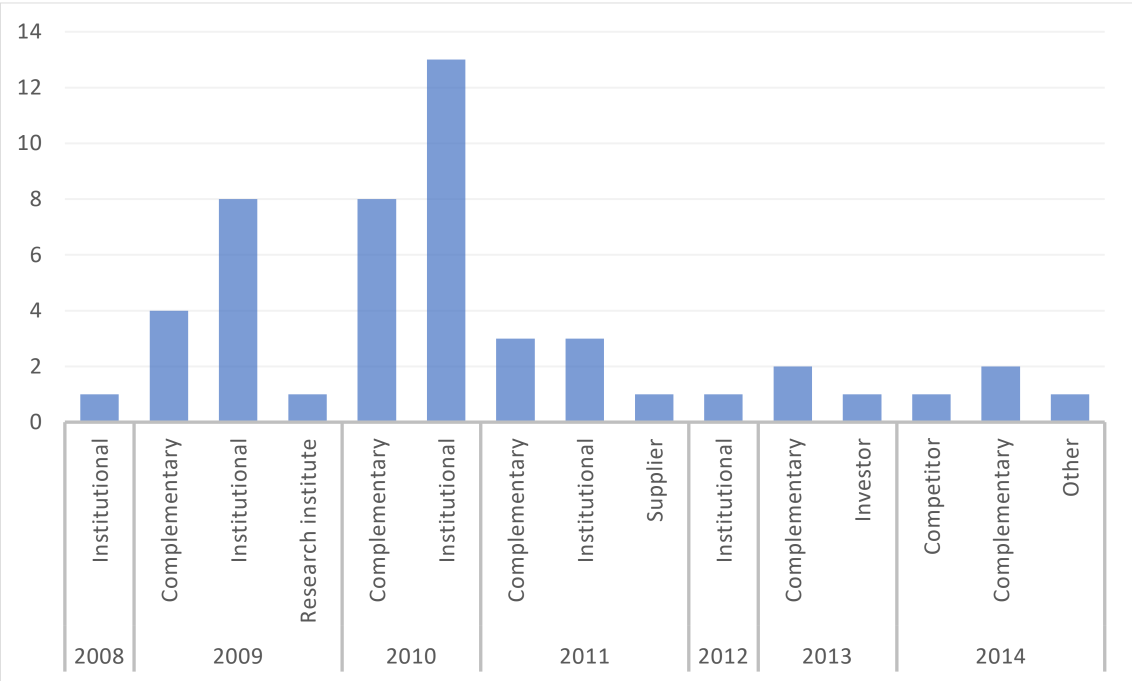
Figure 3: Charging infrastructure alliances



Source: Elaboration on Lexis data

One of the major concerns about electric and hybrid vehicles is the charging infrastructure. For which regards the charging infrastructure this data is surely heavily influenced by the Renault-Nissan alliance. The alliance is really committed to creating an efficient infrastructure since stipulates 35 alliances over a total of 47. The Renault-Nissan alliance, unlike the other, focused a lot on institutional partners. The Renault-Nissan alliance is trying to create boundaries with local governments to create a proper charging infrastructure, the goal may be to stimulate the growth of a complementary asset needed to sell their products and/or to absorb knowledge about the city viability, these alliances are 22 over the total of 37 alliances promoted by the Renault-Nissan alliance. These institutional alliances are not focused only on one precise location but distributed in many locations all over the world, including Spain, France, Turkey, Italy, United States, and so on. Basically, they did not focus on one market but explored the situation over the creation of the charging infrastructure in the western countries. In terms of the number of alliances, the Renault-Nissan alliance relied also on many energy suppliers stipulating 12 alliances with them. The energy companies are the actors who are supposed to create these infrastructures so producers of complementary products. Even in this case, the object of the partnership can both stimulate the charging infrastructure and gather knowledge on the field of electric energy and charging. Finally, to complete the overview of the Renault-Nissan alliance they made 1 alliance with a research institute to boost their knowledge on the charging infrastructure. Then the other OEMs that made alliances for developing the charging infrastructure are Mitsubishi, Toyota, Peugeot, Tesla, BMW, and Tata. These OEMs together made 14 alliances, 2 institutional, 1 with an investment company (to install the charging station in their offices), 1 with a Hotel (to install the charging station in their hotels), 9 with energy companies and 1 single alliance is between two competitors. The only alliance between two competitors in the automotive industry is between Tata and Mahindra & Mahindra. For which regards the charging infrastructure we can say that 8 out of 24 OEMs decided to push the development of the charging infrastructure with the alliance Renault-Nissan that committed a lot on the goal. For the development of this technology, the OEMs did not work so much together or with the suppliers, they rather preferred companies outside the supply chain and institutions. These results may depend on the fact that they do not feel like the ones who have to develop this asset but at the same time, they want to stimulate the growth of the infrastructure since it is crucial for the development of their products.

Figure 4: Charging infrastructure alliances detailed

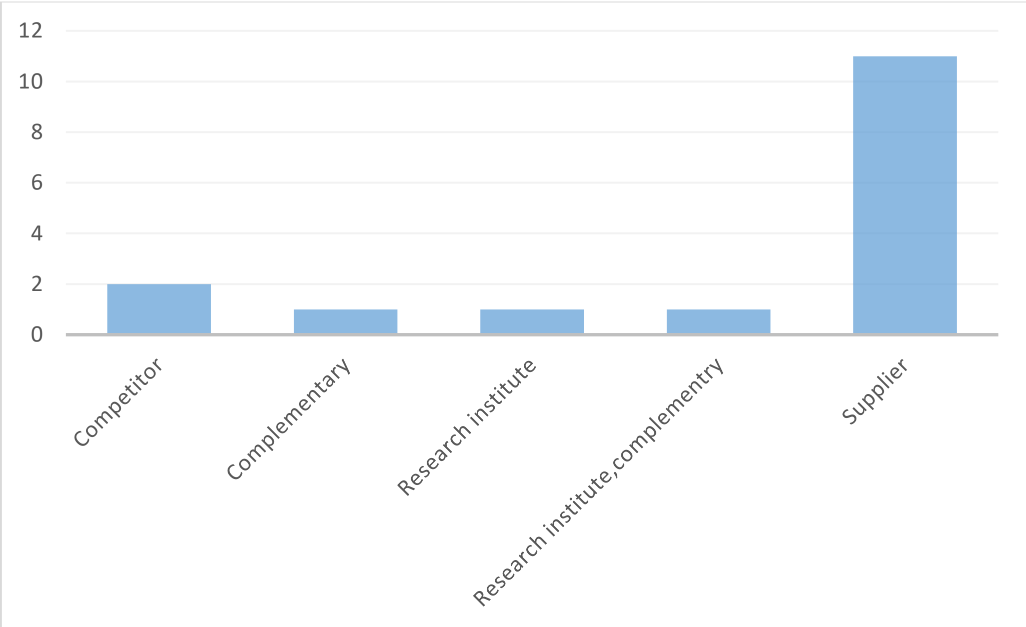


Source: Elaboration on Lexis data

The OEMs, in particular the Renault-Nissan alliance, focused on the charging infrastructure mostly during 2009 and 2010 then the effort reduces over time, in particular for which regards the institutions and the complementary assets. Likely in those years, they gathered enough knowledge and information on the state-of-art in the building of the charging infrastructure.

4.4.2 Battery technology

Figure 5: Battery alliances

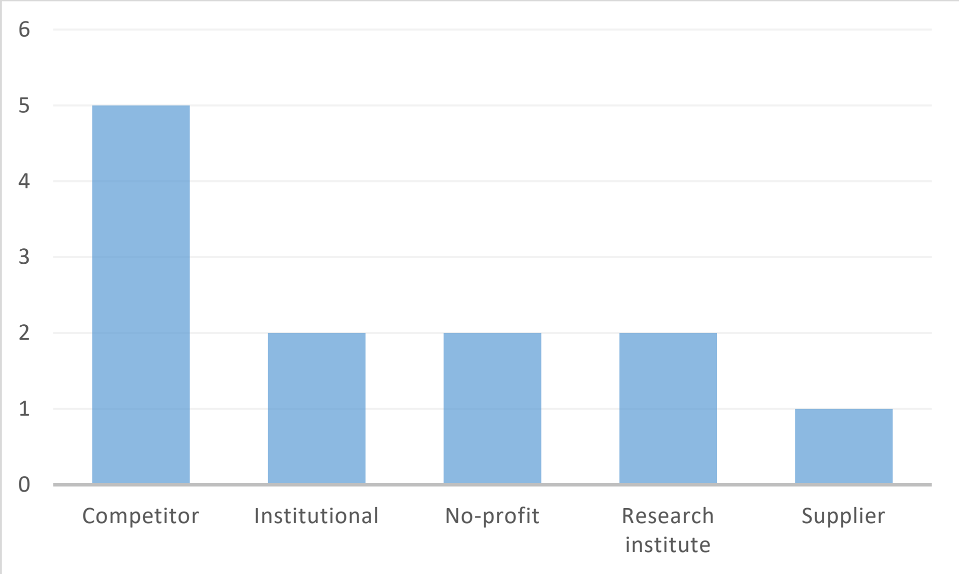


Source: Elaboration on Lexis data

Even the battery technology can be useful for both hybrid vehicles and electric vehicles. The companies that are committed in alliances for the development of batteries are Volkswagen, Daimler, Ford, Renault, Nissan, Tesla, Saic, General Motors (GM), Honda, Toyota, and BMW; so, 11 out of our 24 OEMs. All together all these OEMs made 16 alliances for this purpose. Most of these alliances are made with battery suppliers, 11 in total, and all of them are comprised in the time-lapse from 2008 and 2012. The collaboration between OEMs for the development of batteries is only 2. The first one is between Tesla and Daimler and it aims to the development of battery for electric cars. Daimler aims to develop and produce batteries through the joint venture created with Evonik, becoming the first OEM automotive to produce batteries (Telsa, 2010). Then we have the partnership between BMW and Toyota that instead aims to the development of batteries for hybrid vehicles. The goal is to produce a diesel-hybrid engine vehicle with the expertise of BMW in diesel engine and the knowledge of Toyota on hybrid technology. The chief executives of Toyota Motor Europe said that the alliance would boost efficiency, increase the scale economy, reduce the cost of development and bring the product faster into the market (Tabuchi, 2011). Then we have alliances with suppliers and research institutes. It is interesting also an alliance that includes both a supplier and a research institute. It is the one between Ford, the Electric Power Research Institute (EMPRI), and Jonson Control-Saft. EMPRI is a research institute and Jonson Control-Saft is a battery supplier, the objective is to create batteries for hybrid vehicles. The research with EMPRI is focused on battery technology, vehicle systems, customer usage, and grid infrastructure while Jonson is proving all the materials and the expertise on the production of batteries. Among the companies that allied with research institutes, we have also Honda that formed an alliance with the University of Delaware and NRG Energy, an energy company. The mission is to produce a battery for hybrid vehicles able to discharge electric energy. This can allow the car to send a message to the grid when the power exceeds the demand, using a smart charging system. Finally, there is an alliance between the Renault-Nissan alliance with Enel and Endesa to study the lifecycle of the battery and even a potential use of the battery as energy storage for renewable sources after being used as a battery for a car. About the battery development through alliances, we can say that half of the 24 OMEs created an alliance with a battery producer to develop and increase their knowledge in the field in the same years. Some of them went further as Daimler that aimed to produce batteries or Ford, Honda, and the Renault-Nissan alliance that committed to more ambitious projects. Notice that the only companies to cooperate for the creation of batteries are Toyota, Tesla, BMW, and Daimler, excluded the Renault-Nissan alliance.

4.4.3 Fuel-Cell technology

Figure 6: Fuel-cell alliances

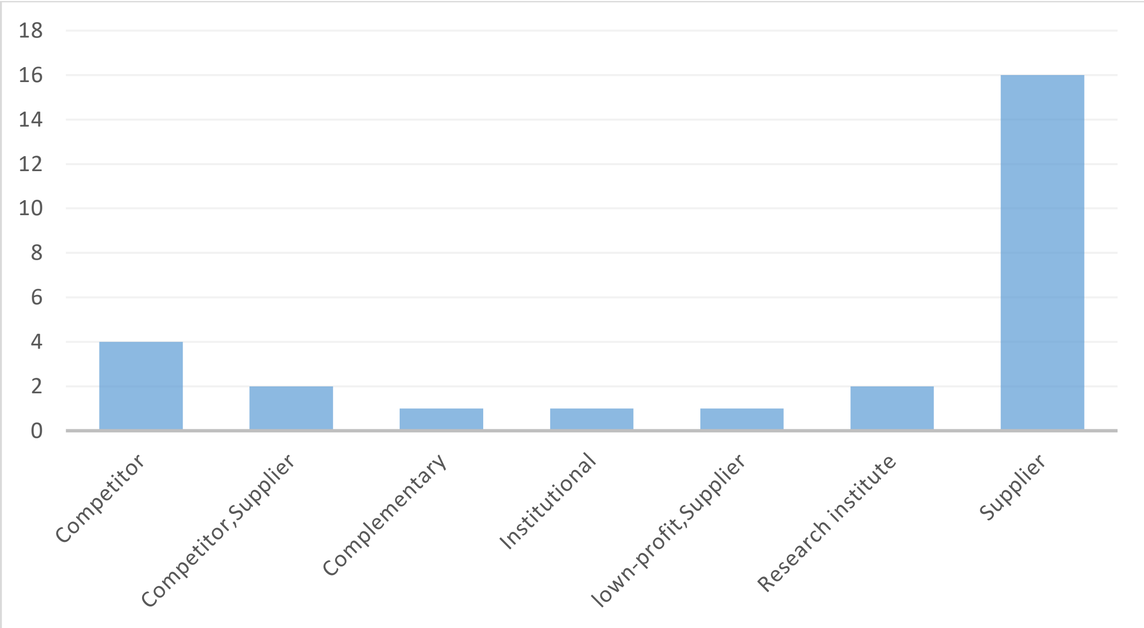


Source: Elaboration on Lexis data

The fuel-cell technology has been supported only by 12 alliances. The most popular kind of alliance to develop this technology is the horizontal collaboration between the OEMs. Toyota and GM stipulated an alliance in 2005 to share the costs of the development, then GM in the same years collaborated even with BMW and Honda for the same purpose. Some years later, in 2013, another alliance among competitors involving the Renault-Nissan alliance, Ford and Daimler, even in this case the companies aim to a faster development with lower costs. In the same year, 2013, BMW worked also with Toyota with the goal to bring into the market a fuel-cell vehicle in 2020. Again in 2013, Honda and GM made an alliance to develop the fuel-cell technology and the hydrogen storage technique which is one of the major issues of the fuel-cell technology. There are also alliances with Research institutes like GM which worked with the Energy Department's National Renewable Energy Laboratory (NREL), the goal is again to break down the costs of the fuel-cell vehicles. Another alliance with a research institute was made by Hyundai that collaborated with House Hydrogen and Fuel Cell Caucus to develop a hydrogen infrastructure. One company to develop an alliance with an institutional organization was Hyundai that collaborated with the city of London and the Energy Department of New Delhi. In both cases, the goal was the development of a hydrogen infrastructure. The only company that made an alliance with a supplier is Honda. Reassuming we can say that several OEMs are developing this technology and the main strategy is to create alliances among them to share the costs of development which should be very high. Some companies like BMW, GM, Honda, Hyundai, and BMW focused on this technology through alliances, the other did not involve so much in this kind of alliance.

4.4.4 Battery Electric Vehicle technology

Figure 7: Electric vehicles alliances



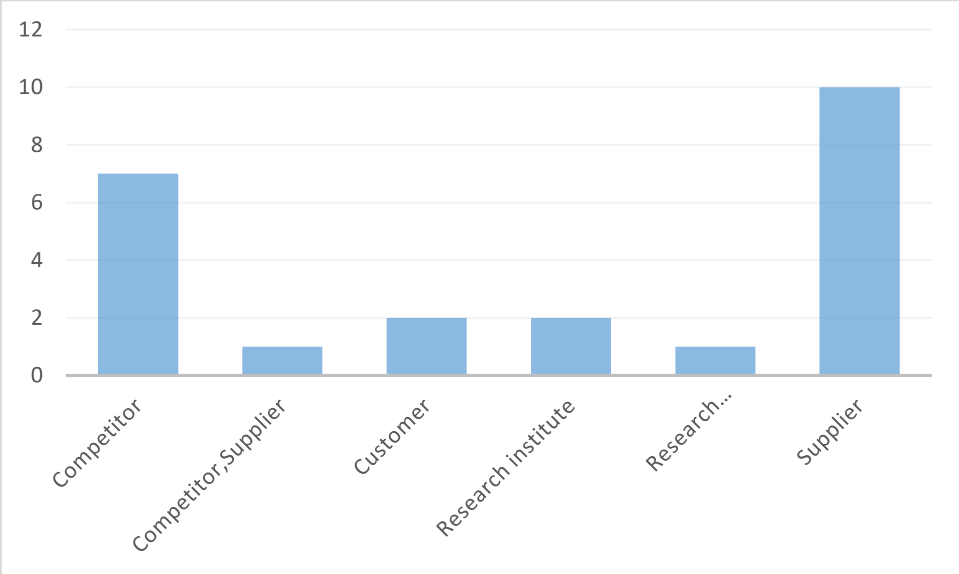
Source: Elaboration on Lexis data

The majority of electric vehicle alliances are made with suppliers. Those suppliers are companies that provide components, energy companies that are developing batteries or other electric components, IT companies, and semiconductor companies. For which regards the alliances between competitors there are four alliances. The first alliance is between Peugeot and Mitsubishi in 2008, that aim at both electric and hybrid vehicles. The goal of the alliance is to develop, produce and make research on motors and other components for electric and hybrid cars producing the new pieces in Russia together. Then we have the partnership with Daimler and Tesla that we analyzed in the battery section, but the alliance aimed not only to develop batteries together but also to integrate the Tesla technology into the Daimler cars (Telsa, 2010). Another collaboration between automotive manufacturers is the alliance between Great Wall Motors and Coda Automotive. Coda is a small American automotive company that produces electric cars but also batteries for EVs, for this reason, can be considered both as a supplier and a competitor. In this this research, it has been considered as a competitor since the alliance's goal is to co-develop and produce the cheaper electric car. Among the collaboration for electric vehicles between automotive manufacturers there is also the Geely and Detroit Electric. This allice has much in common with the previous one because there is one big Chinese manufacturer with a small American automotive manufacturer focused on electric cars that aim to develop and produce together a cheap electric car. Finally, we have an alliance between Dongfeng, Citroen, and Jiangsu Xinri, one of the largest electric bike producers that want to shift to the automotive industry. The purpose is to jointly make research and development together on electric vehicles. We have also two alliances with the research institutes. The first one is between Daimler and Karlsruhe Institute of Technology which developed a program that would treat topics as power electronics, motor research, energy storage, and the control software that should put all these elements together.

As we have seen the electric technology has been developed by our OEMs through the alliance with suppliers and few alliances with competitors. The suppliers that have been involved are mostly energy companies and a few components suppliers. The major concerns of the OEMs remain the battery technology.

4.4.5 Hybrid Vehicle Technology

Figure 8: Hybrid vehicles alliances

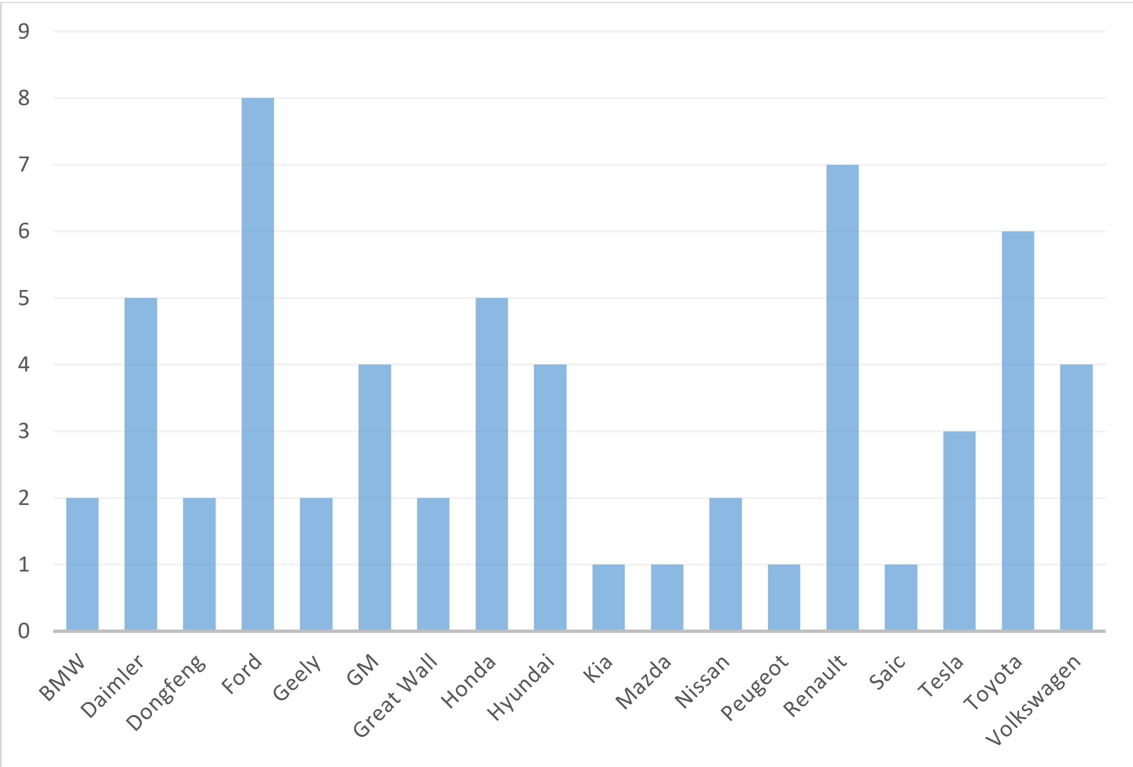


Source: Elaboration on Lexis data

For which regards the hybrid alliances there is a majority of alliances between our OEMs and suppliers, in the second place we have the alliances among competitors. The difference is that the alliances with competitors are more compared to the ones for developing electric vehicle technology. The first alliance is between BMW, Daimler, and GM back in 2005. The alliance aims to co-develop and produce hybrid vehicles to catch up with Toyota creating a shared platform to integrate the technologies of the participating companies. Another alliance is the one between Toyota and Mazda. The two companies would cooperate to integrate the Toyota hybrid technology in the Mazda vehicles, in this way Mazda have not to develop the technology on its own and Toyota can benefit from more economies of scale. In 2010 GM worked with Bright Automotive an American start-up that specialized in hybrid vehicles. The goal of the partnership was to create a hybrid commercial vehicle. Another alliance is the one between Ford and Toyota to develop and produce hybrid SUVs and pickups, two companies that have experience in small-cars hybrid but not in heavier vehicles. In the same year, 2011, Toyota made a partnership with BMW that we treated in the batteries section since they decided to develop batteries together. The alliance can be considered also in the hybrid section since they would share the hybrid technology of Toyota and the diesel technology of BMW do create a diesel-electric hybrid engine. Even in this section, there is the Peugeot and Mitsubishi alliance of 2008 to create electric and hybrid vehicles and components. Then we have the alliance between Honda and the Delaware University and NGR to develop batteries for hybrid cars. For the development of hybrid vehicles, the OEMs relied on suppliers of batteries, automotive components, and electric motors. Then they made also alliances among the bigger OEMs to create more scale economies, sharing the costs and shorten the developing process.

4.4.6 Considerations over hybrid and electric alliances

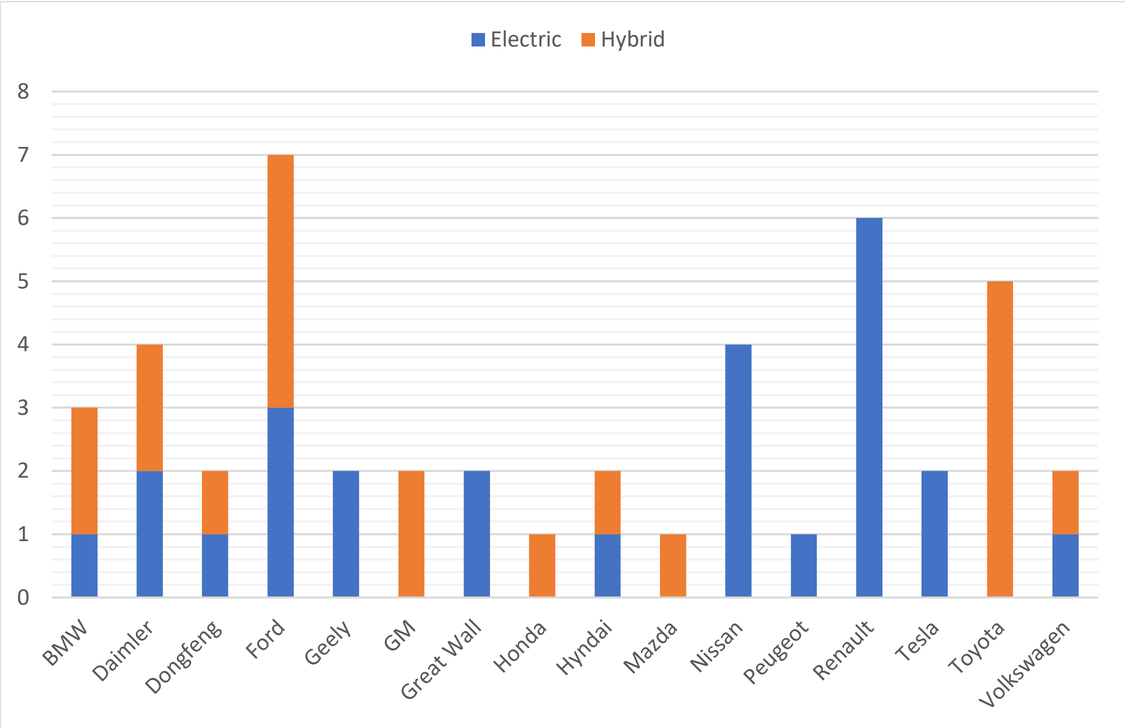
Figure 9: OEMs alliances (no charging infrastructure)



Source: Elaboration on Lexis data

In the graph, we can see the OEMs that stipulated more alliances. Since the charging infrastructure should be in charge of governments and energy companies these alliances have been excluded by this evaluation. In this way, we can notice how these companies are focusing on the new powertrain solutions. Both the North American companies GM and Ford are quite committed in the alliances with respectively 4 and 8 alliances. Tesla committed to 3 alliances, but the situation is different since the company is born as an electric car producer ignoring the hybrid solution and has no previous knowledge to protect. On the opposite the Chinese companies are not looking at alliances Dongfeng (2), Great Wall (2), Geely (2), Saic (1), Changan(0), and BAIC (0) are not so committed to this kind of development. The Japanese companies witness different strategies with Toyota (6) and Honda (5) highly committed while Mazda (1) and Nissan (1) with few alliances. Nissan can be considered as an exception because of its alliance with Renault which is highly committed. The South Korean companies have different strategies since Hyundai is willing to do alternative powertrain alliances (4) and Kia not (1). The European manufacturers like the Japanese ones have different strategies. There are companies like Volkswagen (4) and Renault (7) which are willing to make alliances and others like BMW (2), Peugeot (1), and Fiat (0) that are less willing. Finally, there is the Indian Tata that did not invest in this kind of relationship or technology.

Figure 10: Electric and Hybrid alliances per OEMs

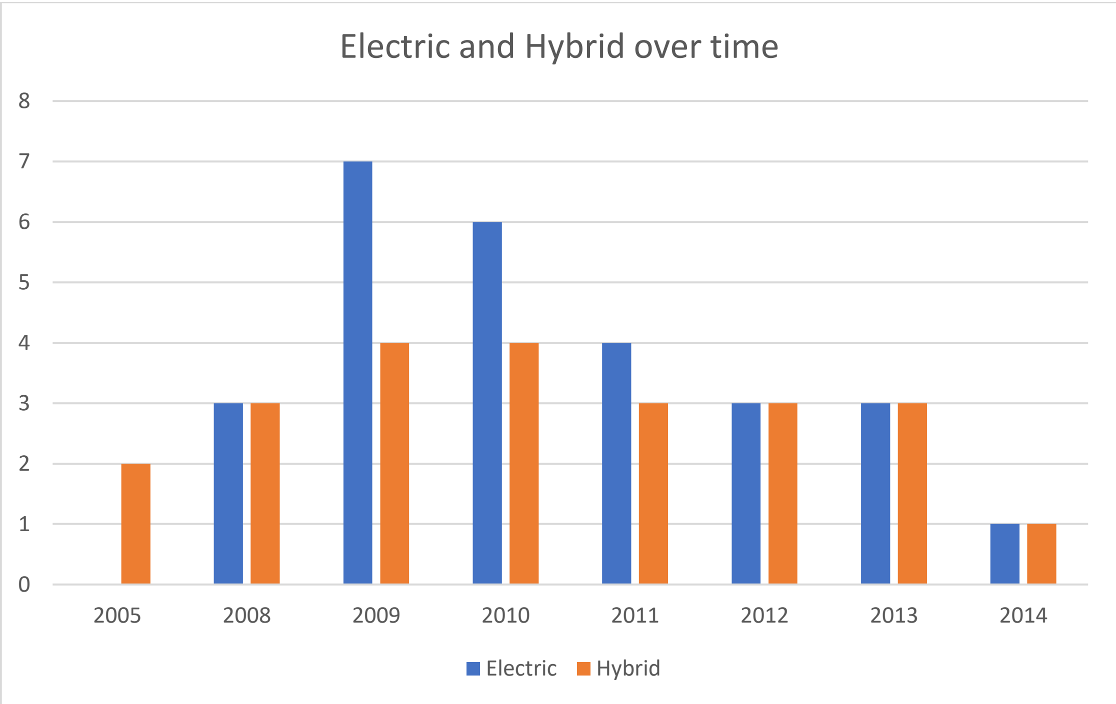


Source: Elaboration on Lexis data

The graph above represent the alliances per OEM and per technology. As we can see some companies focuses mostly on one specific technology, like for example Nissan and Renault who invested only in the electric vehicle, which is consistent also with their commitment to the charging infrastructure commitment. Other companies that focused on electric vehicles are Peugeot, Hyundai, Great Wall, and obviously

Tesla. Then some companies decided to focus mainly on hybrid vehicles, such as Toyota which is the market leader, Honda, Mazda, and GM. As we can notice mainly Japanese companies and GM. Finally, we have the companies that decided to pursue both technology developments which are BMW, Daimler, Ford, and Volkswagen, mostly European. The differentiation of the strategies may depend on the reference markets on which they rely more. For example, the GM group is heavily dependent on the North American market which absorbed 51% of its market share in 2015 (KPMG, 2020a). For this reason, the GM would follow for first any technology path that will emerge in North America.

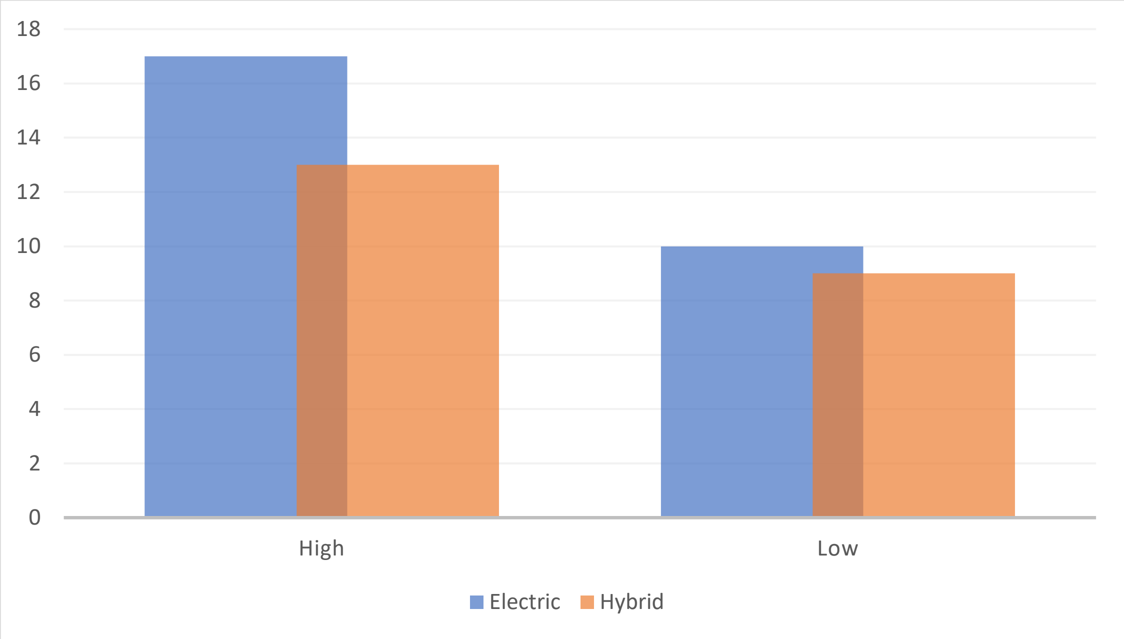
Figure 11: Electric and Hybrid alliances per year



Source: Elaboration on Lexis data

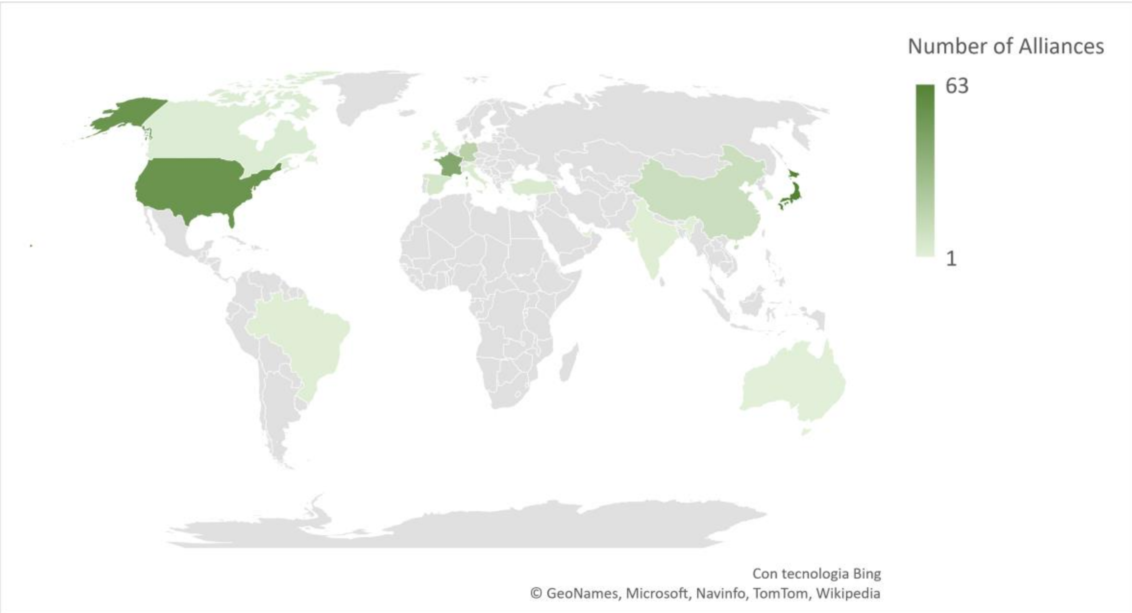
The alliances for the development of hybrid and electric vehicles are more frequent in the two years 2009-2010 in both technologies. The distribution over time of the alliances is different since the EV alliances are more focused on one single period while the hybrid alliances are more constant over time. Moreover, we have the first hybrid alliances in 2005 made by BMW and Volkswagen which seems to anticipate the other OEMs.

Figure 12: Alliances' cultural complexity



Source: Elaboration on Lexis data

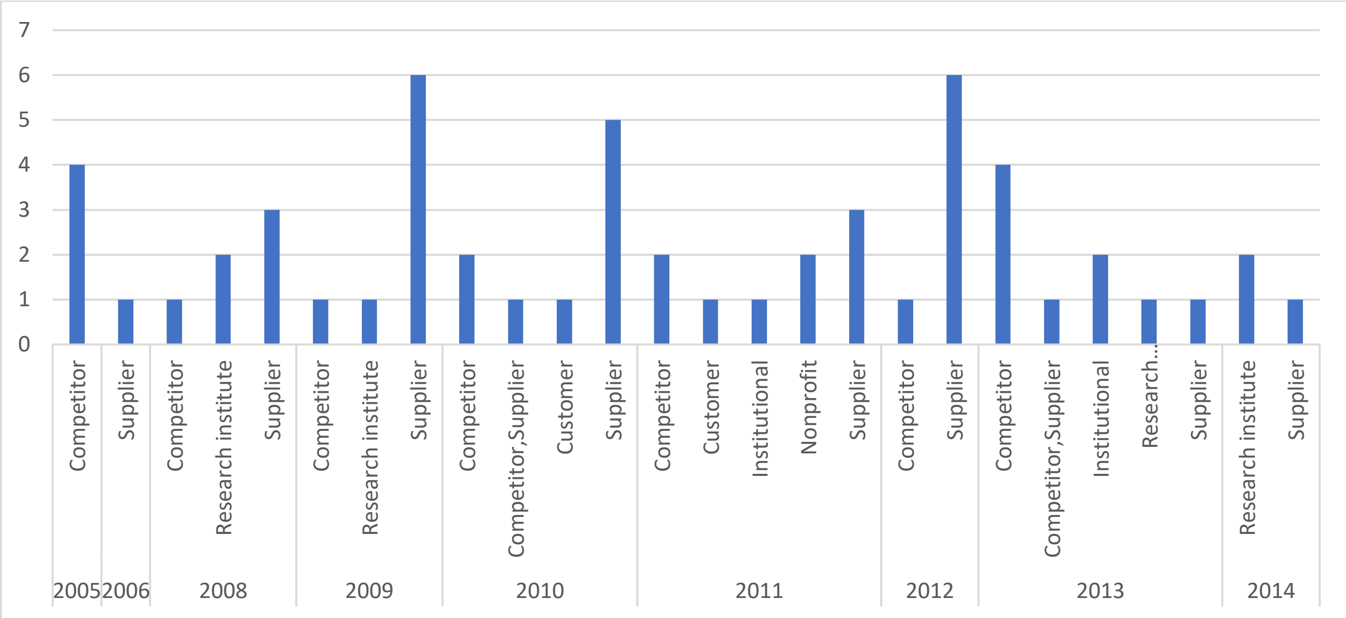
Figure 13: Alliances Map



Source: Elaboration on Lexis data

Another consideration that can be made between the two technologies is cultural complexity. We have a cultural complexity when the alliances are between two companies that come from different regions of the world. The regions taken into consideration are North America, Asia, Europe and Other. If in an alliance we have at least two companies that come from different regions we have high complexity, otherwise we would have low complexity, then we have n.d. when it was not possible to find the country of origin of the one company. As we can see both of the technologies have been developed with a preference over a higher cultural complexity alliance and with a similar ratio between high complexity and low complexity.

Figure 14: Actors included in the alliances

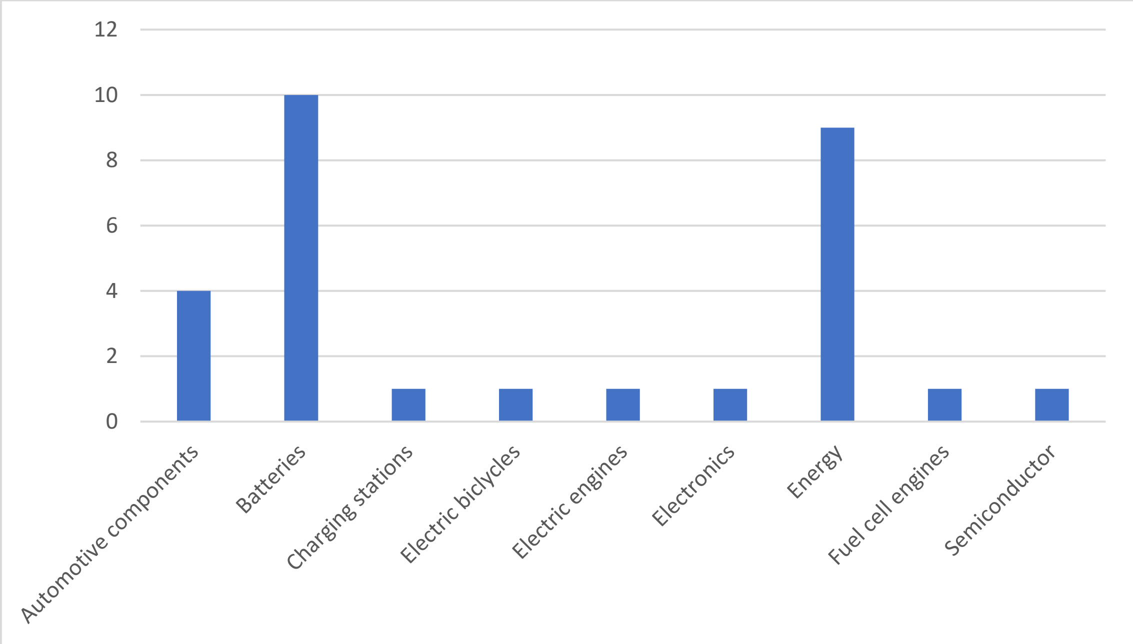


Source: Elaboration on Lexis data

In this graph, we can analyze the incidence of the actors included in the alliances. In 2005 we have four alliances among competitors, then there is an increase in the variety of the actors involved. Including suppliers, competitors, and research institutes. As we can see the suppliers are a constant from 2008 until 2012, then the number of alliances that include suppliers diminished. In 2012 other kinds of alliances emerged, in particular with the competitors that played a major role. Then in 2014, we have a strong reduction of alliances that involved only one supplier and two research institutes.

4.4.7 Suppliers

Figure 15: Suppliers involved



Source: Elaboration on Lexis data

The new actors in the automotive industry are the energy companies and the battery suppliers. As we can see the large majority of the alliances with suppliers includes companies that do not use to work with the OEMs. The lexis data shows how the battery suppliers and the energy companies are becoming crucial in the supply chain for the development of the new competencies required for penetrating the market with the new powertrain solutions. Building the right relationships with the new battery providers is crucial since the performances of hybrid and electric cars depend on battery performance. As we have seen one of the major constraints for electric cars is the range that depends heavily on the battery performance and the ability to use efficiently the electric energy. For which regard the hybrid vehicles the fuel efficiency that remains and consequently the emissions are weak point compared to the electric vehicles that produce zero emissions. Even in this case the batteries and the ability to recharge the batteries through the ICE engine is fundamental. To develop these abilities, it is necessary to increase the knowledge on batteries and electric components and these partnerships go toward this direction.

4.5 Discussion

The purpose of this research is to make an overview of the relationship in the automotive industry that aimed to develop the new powertrain technologies. We can divide among the Joint Ventures (JVs) and the alliances. The JVs were not so common among the OEMs taken into consideration. Only three JVs over the time-lapse considered aimed to develop together with the new powertrain technologies with competitors. On the opposite was quite common for many OEMs to form JVs with battery suppliers to develop the new batteries that should have specific technical requirements. This result shows how the companies are willing to create strong bonds with the supplier but not with the competitors. This may depend on the OEMs' fear to share their knowledge with a competitor and lose their competitive advantage on the new technologies. Moreover, the JVs show that some companies choose to develop jointly batteries for hybrid and electric vehicles. This may influence the economies of scale and scope. Producing a high number of hybrid vehicles imposes a high production of batteries that may result in more expertise and the possibility to exploit economies of scale and scope. Notice that improving in the battery sector may be important even for electric vehicle development.

For which regards the alliances the research underlines how the years of major commitment in powertrain electric solutions through alliances are concentrating in the years 2009, 2010, and 2011. One of the major concerns of the OEMs was the charging infrastructure, especially for the Renault-Nissan alliance that focused a lot on the electric vehicle infrastructure. The Renault-Nissan alliance is the only organization that invested heavily in institutional partnerships to increase the spread of the charging infrastructure. The charging infrastructure is fundamental for the spread of electric vehicles, but it can boost also sales of plug-in hybrid vehicles. This behavior is interesting because the Renault-Nissan alliance is the only organization that committed at this level for the development of the charging infrastructure underlining a different strategy compared to their competitors.

The fuel-cell technology is seen as a technology that can avoid the problem of the charging infrastructure but far away from commercialization. The OEMs did choose from many alliances for the development of this technology. The few alliances created to develop this technology are made among OEMs maybe for sharing the development costs and to increase the speed of the commercialization for the fuel-cell vehicles.

As we have seen the knowledge about batteries becomes crucial to increase the performances of both hybrid and electric vehicles. The battery alliances, as the JVs, have created a link between the OEMs and the battery lithium battery suppliers that are the most important actors for improving their knowledge and develop the best batteries. Then even the energy companies are that similar to the battery suppliers because are new in the industry. We can say that even for which regards the alliances the batteries are developed primarily with battery suppliers then with energy companies. These results underline the increasing importance of the new suppliers in the automotive industry that may threaten the OEMs to catch value in the supply chain.

Then we have the alliances to develop hybrid and battery-electric powertrains. Even in this case, we have a huge involvement of suppliers but there is an increase of the horizontal alliances, especially for hybrid vehicles. The difference in the development of these new technologies through alliances is the willingness of the OEMs to cooperate with competitors. Since hybrid vehicles do not require an effort from government and energy companies to build an infrastructure depends on the performances of the OEMs. For this reason, the OEMs may be more willing to pursue alliances with competitors in order to reduce the time to penetrate the market before producing economies of scale and scope and gain a competitive advantage. Penetrating the market, thanks to the hybrid model, as soon as possible allows also the OEMs to increase their knowledge about the market and build a relationship with the policymakers. In both technologies, hybrid, and electric, the major reasons for the involvement of competitors are sharing the development costs, create standards, and decreasing the time to launch in the market the new technologies. I suppose also that for developing the hybrid technology the alliances with competitors are more useful rather than in the electric technology. The reason could be that the hybrid technology modifies the architecture and needs a complex integration with the thermic engines and only a competitor could have the right competencies to make this process.

The OEMs created partnerships all over the world even with cultural complexities to overcome. We cannot notice strong differences in terms of cultural complexities among the development of the different technologies.

One of the most important aspects that emerge from the data is that not all the OEMs decided to go for the same strategy. Some companies focused only on one hybrid technology such as Toyota which is the one of first companies to offer a hybrid vehicle in the market. While some companies instead focused exclusively on electric technology one example is Renault and Nissan, which were the most active companies in promoting the charging infrastructure development. The reason should be that Renault and Nissan bet all on the electric vehicle technology and the success is highly influenced by the development of the charging infrastructure, which is not under their control. An alternative that some OEMs followed was not to specialize in one technology development but follow at the same time both the development of hybrid and electric technologies. Notice that allying to developing a technology does not mean that this OEM would launch into the market a product with that technology. The alliance could be useful also for increase the knowledge in the field and make a better decision about which path to follow sharing the costs with other companies. Finally, we have all those companies that did not made alliances for the development of new powertrains. These companies may have decided to bet on the ICE engine or to develop the new technologies by themselves, even though the first strategy is more likely.

Given the interest of the OEMs to the batteries for both hybrid and electric technologies, the battery suppliers will gain more importance in the automotive industry rather than the components suppliers for the thermic engine lowering the OEMs margins. The policymakers and the OEMs are following different strategies so it is likely to see more than one standard in the future where hybrid and electric vehicles will share the market. The fuel-cell technology has not been abandoned by the OEMs and could gain more importance in the future, in particular by commercial vehicles that have different requirements.

Conclusions

In the first chapters of this paper, we have explored the theory under concepts as dominant design, technology transition, and intergenerational hybrid technologies. Since the change in this industry has been triggered by the policymakers, their influence on the industry results decisive in outlining the behavior of the OEMs. Then we have analyzed more in-depth the automotive industry and its trends, focusing on the new powertrain solutions, and on the OEMs strategies for innovating and gather knowledge about the new technologies.

In order to reach the goal of developing the new technologies reducing the costs and the time of development, many OEMs stipulated several alliances and JVs. The analysis of the alliances can help to better understand in which direction the OEMs are moving. The principal technologies developed through alliances result being fuel-cell, hybrid, and electric batteries vehicles. According to the analysis, fuel-cell technology is gaining less attention compared to hybrid and battery electric technology ones. In fact, hybrid and electric vehicles are forecasted to gain more market share in the next years. The strategies of the OEMs are various, some companies focused on hybrid while others on electric vehicles, and others again on both. The Renault-Nissan alliance followed a peculiar path trying to keep in touch with institutions and governments to build an adequate charging infrastructure. Indeed, according to this research, the charging infrastructure has been individuated as crucial for the future spread of the battery electric vehicle. Furthermore, the research underlines the increasing role of the new actors in the industry, the most important resulted to be the battery suppliers. The OEMs created many JVs and alliances with the battery suppliers that can be fundamental for the development of hybrid and electric cars. Notice that the batteries are one of the most expensive components of hybrid and electric cars.

At the end of the analysis, we can say that there are new actors that are going to acquire more importance as the battery suppliers and the energy companies. The industry features which are not controlled by the OEMs, such as the regulation and the charging infrastructure, increase the uncertainty in the industry. This uncertainty may be a reason that led the OEMs to follow different strategies and promote alliances. The strategic choice of alliances to implement depend also on the technologies that the OEMs are developing. Some technologies have been developed mostly through vertical alliances, such as electric vehicles, in particular for what concerns the batteries. While others mostly with competitors, like the fuel-cell engines. One of the reasons that led the competitors to cooperate for that technology is that may be far to be launched into the market. Then we have the hybrid technology that has been developed both with suppliers and competitors. The reason may be that it requires not only new competencies for which regards the electric components but also the ability to integrate them with the old technology.

Hopefully, this paper can help the reader to have an overview of the strategies and the technologies that the OEMs are developing through alliances. This can be useful to evaluate the future behaviors of the OEMs and the choice and the results that they are going to make.

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