SYSTEMIC INNOVATION AND ORGANIZATIONAL CHANGE IN THE CAR INDUSTRY: INNOVATION PLATFORMS IN THE CASE OF ELECTRIC VEHICLES

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ABSTRACT. The design and development of Electric Vehicles (EVs) is a complex and distributed process where large partnerships have been implemented with the scope of learning and acquiring selective technological competencies developed also outside the car industry. The introduction of electric vehicles can be depicted as a collective innovation wherein different actors such as traditional OEMs, automobile batteries producers, utilities and system integrators contribute with complementary resources as well as technologies, and converge towards common goals and incentives. We argue that the integration, coordination and direction of the different strategies and goals of various organizations that take place in such process require a novel form of organization that combines the scope of learning typical of networks, with the coherence of centralized decision making like in the vertical corporation. We identify in the innovation platform, which has recently drawn the attention of numerous studies in the field of innovation, the appropriate organizational solution for such a problem of dynamic coordination.

Keywords: Collective innovation; Electric cars; Industry structure; Organizational change; Platforms.

JEL classification: O31; O32; O33.

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1. INTRODUCTION

The question of electric vehicles (EV) is one that has appeared again and again in the history of the car, since the early post-war period, but has however remained on the edges of the mainstream.

But in recent years macro factors – the recent rises in oil prices and the growing importance attributed to the emissions of carbon dioxide in the atmosphere (the main elements responsible for the greenhouse effect and global warming) and especially technological innovations in sectors complementary to the automotive industry (in particular substantial advances in battery technologies) – have radically changed the picture, opening new development opportunities for this innovation,

However, economic effectiveness does not necessarily correspond to technological opportunities because of a series of factors: battery technology is not yet stabilised, there is no standard, and we thus have unresolved alternatives; the cost of the batteries themselves is still very high, enough to determine a high cost difference for electric cars compared to traditional ones; important public investment is needed in terms of incentives for consumers, support for car manufacturers' research, infrastructure investments. Following from this, the scenarios imagined are not convergent. In addition, the competition of alternative technologies to the electric option starting from innovations on the traditional internal combustion engines should not be forgotten. A further element of uncertainty is the very definition of electrical cars in that we have a series of solutions that go from the simple start-and-stop to the totally electric car, with hybrid vehicles in between.

For these reasons, the introduction of electric cars seems to be a particularly complex innovation in that it demands the co-ordination of a series of heterogeneous yet complementary factors, and which call into play not only the entire automotive sector, but also elements and actors traditionally external to it.

In this context it is worth noting the work of David Teece (1984), in which a radical or "systemic" innovation can be defined as a new product or technology that requires changes in different elements connected together within the system in which it will be located. Systemic innovations require the development of complementary goods, competencies and innovations in order to maximise profit through their commercialisation. This poses two fundamental problems: 1) the problem of dynamic co-ordination, i.e. the need to co-ordinate and integrate complementary competencies in the innovation process; 2) the problem of the reduction of the uncertainty linked to the introduction of a complex technology, complex in that it is based on the interdependency between different elements. Furthermore, systemic innovations can provoke great difficulties in incumbent systems, determining the success of a new entry company or the redefinition of an entire industrial sector, its structure and the relations between the actors.

In this sense, the introduction of the electric car seems to assume the traits of a systemic innovation.

This paper, pivoting around the theoretical contributions that analyse innovation as a distributed and collective phenomenon, argues that the diffusion of the electric car is determined not only, and not so much by, the specific technological choices made by the car and battery producers, but above all by the capacity to organise and manage the integrated action of a series of players, traditional and new (car manufacturers, battery producers, producers of vehicle management systems, transport service management companies, energy distribution companies, energy producers and governments) creating networks, alliances and coalitions explicitly oriented towards the governance of innovation.

Given the growing spread of the phenomenon in various industrial sectors, the notion of innovation platforms in particular have recently drawn the attention of numerous studies of industrial economics and innovation economics (Gawer and Cusumano, 2002; Gawer, 2009a; Gawer, 2009b; Consoli and Patrucco, 2008 and 2010; Patrucco, 2010), which have investigated the nature of these structures and in what way they influence the evolution of industrial sectors and innovation processes. It is now acknowledged, in fact, that the emergence of platforms has a profound impact on industrial dynamics, creating new forms of competition and laying the foundations for the creation of new relations of inter-organisational co-operation in the framework of innovation processes (Gawer, 2009a).

In this sense, the success of the electric car could depend on the adoption of the most appropriate organisational model, that of a network for innovation, co-ordinated by key companies that take on responsibility for the integration of the competencies and technologies of the various players. This model seems to be well exemplified at present by the experience of BetterPlace.

The remaining of this paper is organized as follows. Section 2 articulates the theoretical framework underpinning this work. Section 3 describes the structure and trend of electric cars from both the technological and economic viewpoint. Section 4 appreciates the implications for the supply chain, while section 5 focuses on the role of the so-called "complementers", among which the more relevant for the present analysis is that of the platform leaders such as Better Place. Conclusions summarize.

2. THE ORGANIZATION OF COLLECTIVE INNOVATION: FROM THE VERTICALLY INTEGRATED FIRM TO PLATFORMS. THE THEORETICAL FRAMEWORK.

This section argues that for a new system of mobility – focussed on battery-fuelled vehicles and linked to the electricity grid – to be conceived and implemented and can express all its potential, a widely shared vision is required, opened through the co-operative and integrated action of a myriad of actors (McKinsey, 2009; Beaume and Midler, 2009) and the creation of specific innovation networks.

The tradition of industrial economics and economics of innovation in the last century supported the thesis of the vertically integrated Fordist company, considered the most efficient organisational model for the production of technological innovation thanks to the benefits from the economies of scale, scope and learning that the vertical integration of R&D activities makes it possible to obtain (Chandler, 1990; Penrose, 1959).

Since the 1990s, however, various factors have emerged that have led to a rapid and radical transformation of the context in which firms compete, raising doubts about the applicability of this model in the new picture. Firstly, the growing turbulence of the situation (for example, in our case, due to the greater instability of oil prices, the uncertainty linked to the cost and stability of the technology of electric batteries, as well as that related to the identification of the different segments of demand for electric cars) and the intensification of global competition reduces the efficiency of management and control planning. In other words, it is more and more difficult for the governance of innovation to predict with a sufficient degree of confidence the evolution of all the variables, thus making it less easy to organise one's activities sensibly and rationally. Secondly, the greater complexity of innovative dynamics, the acceleration of the process of obsolescence of technologies and the significant increase in the development costs of innovation reduce firms' level of autonomy. No company is able to completely dominate all the technological and organisational competencies nor does it have the financial resources needed to develop new knowledge on its own. Lastly, the scientific-technological system has expanded. This means an increase in the sources that companies must investigate to seek out new knowledge to use in their innovation operations. In other words, the potential innovation agents multiply: alongside public research and corporate R&D laboratories, other actors become active in the production of new knowledge, such as science parks, non-profit centres, university and public laboratories linked to intermediate government bodies (regional or supra-national), in addition, naturally, to innovative start-ups, incubators, and major international research networks (Foray, 2004).

The vertically integrated corporation and its R&D laboratories see their margins of autonomy and self-sufficiency shrink. In particular, large companies lose their prime position as the place par excellence for the production of innovation. In fact, in a complex environment, characterised by continuous changes in the features of the products and production technologies, by radical uncertainty and by ever more extreme scientific and technological specialisation, the individual firm has difficulty in managing, purely through the capacities produced internally, all the competencies needed for the process of the generation of new knowledge.

The picture summarised above thus questions not only the model of the integrated corporation, but also the traditional schemes of the organisation of innovation. This implies that the linear and closed model, which saw innovation as a direct and almost automatic effect of the investments in R&D and learning-by-doing processes, must be replaced; not only must firms structure themselves so as to be able to draw advantage from the external knowledge available integrating it effectively with the knowledge produced internally (Chesbrough, Vanhaverbeke and West, 2006), but the industries and supply chains must reconfigure their boundaries and architectures to benefit competencies and technologies developed in other sectors (Jacobides, Knudsen, Augier 2006). For example, as we will see in the next section, the arrival of new entrants in battery technologies, drives car manufacturers to set up joint ventures and vertical, but also horizontal agreements, precisely to be able to face up to the risk of having to depend on battery producers.

As a consequence, consensus has grown in recent times amongst innovation scholars around the idea that, if firms are not able to develop independently a sufficient innovation capacity on their own, they can implement a variety of solutions that goes from one extreme (vertical integration), to another (the market), passing through a variety of hybrid strategies, forms of strategic alliances and inter-organisational relations aimed at minimising the costs of external co-ordination and the maximisation of the creative contribution of the individual companies. This realisation has opened the way to the analysis of the various forms (lesser or more extreme) of decentralisation, specialisation and division of innovative labour and production that emerged following the crisis of the organisational model of the vertically integrated corporation.

Thus on the one hand, a broad thread of studies on the organisation of knowledge and technological innovation has directed its attention to modular systems, based on outsourcing and market transactions as the co-ordination mechanism of the division of labour in innovative activity (Arora, Gambardella and Rullani, 1998; Baldwin and Clark, 1997; Langlois, 2002). When a system is extensive and complex, and the interdependency between the elements and subsystems becomes particularly numerous, co-ordination through an integrated structure is almost impossible, and as is upheld, for example, by Baldwin and Clark (1997) and Langlois (2002) the organisation of production and innovation through modular strategies is the most efficient way to organise and co-ordinate complex technologies and production systems.

According to this approach, companies can decide to adopt an integrated or modular organisational structure on the basis of the technologies and competencies that are the foundations for the introduction of innovation: the more the knowledge and technological competencies needed for innovation are varied and interconnected, the more the adoption of a modular architecture and the recourse to formal contracts and market transactions will be efficient. And *viceversa* (Chesbrough and Teece, 1996).

The so-called *loose coupling* strategy does, however, show some limits. In particular, activities that demand exchanges of complex technological knowledge require the presence of integration mechanisms much more rigid, frequent and long term than a modular organisation usually manages to guarantee (Schilling, 2009). If the activity demands an intense form of co-ordination and continuous in time, the development process is conducted more efficiently within a more integrated and hierarchical organisational structure, which maintains closer integration between the partners involved.

Furthermore, complex systems, by definition, cannot always be broken down into discrete and distinct components as the modular structure suggests (Patrucco, 2010). One of the main characteristics of complexity lies in the recognition that the system cannot be reduced to its individual elements and sub-systems, in that changes in the conduct or the characteristics of a company also determine – through feedback processes deriving from the interaction between the elements – transformations in the other organisations belonging to the system. Lastly, empirical evidence shows that, in tackling choices linked to the organisation of their own innovation activity, companies do not have to hand purely modular or purely integrated solutions. Instead, the characteristics of the two alternatives co-exist and firms are able to use a broad spectrum of inter-organisational solutions in order to combine the advantages of both options (Brusoni and Prencipe, 2001; Consoli and Patrucco, 2010; Zirpoli and Camuffo, 2009).

In this direction, a growing literature has put increasing emphasis on networks as the place of production of innovation: the networks facilitate the co-ordination and integration of complementary technological competencies in contexts characterised by complexity, uncertainty and the dispersion of these competencies between heterogeneous sources, avoiding the costs and inefficiencies of full integration (for example, Powell, 1990; Uzzi, 1997; Burt, 2000; Kogut, 2000; Helper, MacDuffie and Sabel, 2000; Ozman, 2009).

In particular, innovation studies have progressively asserted the idea that inter-organisational links and hybrid forms of integration and modular organisation are the most effective solutions for the management of innovation, in that collaboration aids the access to a wide range of complementary technological competencies, representing an opportunity to recombine existing resources and competencies developed by the individual company in new knowledge. The efficiency of these organisational forms lies in particular in the fact that it enables learning and innovation by exploiting the mixture of resources from different companies.

Innovation and the creation of new technological competencies are more and more frequently seen as a collective and distributed phenomenon, based on a high degree of complementarity between internal investments in R&D and the learning of technological resources acquired externally from other companies (for instance, customers and suppliers, competitors), and from research bodies (e.g. universities, public laboratories, technology transfer centres) (Allen, 1983; Cowan and Jonard, 2003; Patrucco, 2008).

In line with the pioneering contribution of Nelson and Winter (1982), in which economic change is the product of the action of actors who possess idiosyncratic and highly specialised abilities, technological competencies, because of the high level of specialisation and differentiation, are therefore characterised by rather limited degrees of interchangeability and substitutability, and hence high complementarity.

External competencies may differ considerably from those possessed internally by the firm (Pisano, 1996) and the implementation of the processes of screening and learning strategies is a condition required for access to existing external knowledge and to render the exploitation of externalities efficient in the creation of new knowledge and its dissemination within locally-based innovation systems.

Some authors (Cohen and Levinthal, 1989) talk on this point of the ‘two faces’ of R&D and of the importance of investing in internal R&D so as also to be able to use knowledge arriving from outside. This implies, for instance, that R&D activities run internally assume new functions: their role is no longer limited to the production of new technological knowledge, but includes the identification and comprehension of the external knowledge available, the selection and integration of the significant portions with internal knowledge in order to produce more complex combinations, as well as the production of further profit through the sale of in-house research work to others so as to be able, in the same way, to integrate and use it in their own innovation process (Cohen and Levinthal, 1991).

Much analysis on the effectiveness of the networks as models of governance of innovation has focused on the nature of the relations and roles played by the various actors within the networks. The structure of the network influences in fact the learning and technology curves of firms; in particular, the relations of a collaborative nature that are established within the networks influence the behaviour of the members by creating the conditions for the generation of new opportunities for research and innovation.

The analyses concentrated on the respective advantages of the various structures of relations that occur within a network, and in particular for two contrasting configurations: on the one hand networks characterised by strong and abundant ties, and on the other networks characterised by structural holes and weak ties.

According to Coleman (1990), for instance, the networks characterised by strong ties would generally be associated with an intense exchange of information, effective mechanisms of transfer of tacit knowledge, and reciprocal trust between partners. For this reason, these links would be more efficient for the exchange and communication of complex knowledge, in that they would allow the establishment of more efficient co-operative attitudes thanks to the repeated exchanges and a balanced distribution of power within the network. In contrast, according to some authors, the networks characterised by weak connections and by structural holes that play a role as broker, directing and co-ordinating the flows of knowledge between companies or groups of companies not directly linked to each other, would represent more efficient solutions due to the advantages stemming from a partially hierarchical organisational form (Burt, 1992).

The empirical evidence demonstrates that both the configurations are correlated to an improvement in the innovative performances of companies and it is in exactly this context that the concept of innovation platforms expresses all its potential for interpretation. The innovation platforms are in fact characterised by system integrators or platform leaders, who through a hierarchical structure govern and co-ordinate the interactions between organisations not directly connected with each other.

In this sense, firms that act as system integrators represent specific forms of structural holes at the centre of the flows of different portions of knowledge that are at the base of complex technological innovations.

On the other hand, the growing division of labour produced by the complexity of both products and knowledge generates an increase in the number of components and types of knowledge required to fine tune the final product. Abundant links in this context are often necessary to obtain specific complementary competencies and share the relevant knowledge with other companies in the system. Direct collaboration – i.e. not mediated by structural holes – for instance between two specialist suppliers can, therefore, be necessary to co-define a new component or a sub-system of a complex product. In this case, the network assumes some of the properties of the flat and dense structures described by Coleman (1990).

Innovation platforms are specific governance forms through which economic players and their organisations acquire and co-ordinate innovative capacities and new knowledge (Patrucco, 2010). The notion of platform expresses the vision that innovation occurs efficiently and successfully when partnerships are implemented based on the convergence of incentives and structured complementarity of the competencies of a variety of heterogeneous actors, so as to grow the cohesion of the group and organise the intrinsic complexity of the system around a common purpose and shared goals.

Efficient platforms emerge, in fact, when the various incentives and the complementary capacities of a multitude of heterogeneous actors involved in a network are organised and aligned so as to ensure the cohesion of the network and the co-ordination (which occurs through a complex network of high-quality interactions) of the division of technological knowledge and labour in the innovation process.

Empirical evidence shows the emergence of this type of structure of co-ordination in many sectors in which innovation and the production of new technological competencies are to a growing extent the effect of the integration of diverse and complementary competencies, diffuse and scattered between specialised and heterogeneous actors (such as the automotive, banking, electronics and software sectors). One of the key points of the rationale at the basis of the creation of platforms is in fact the maximisation of the variety of contributions from mixed sources of knowledge, combined however with the maintenance of global coherence through a hierarchical structure (Consoli and Patrucco, 2010).

In this sense, the platforms represent a significant organisational innovation, different to the integrated company, the market and the networks themselves. The platforms appear rather as a new and specific form of governance of knowledge that emerges as an effect of the dynamics of complex systems (Consoli and Patrucco, 2010). In particular, they can be defined as hierarchical networks, i.e. as networks in which the interactions do not emerge and evolve spontaneously, as in the traditional literature on the industrial districts, or as hypothesised by complexity theory, but in which the key nodes (the companies) exercise a guiding role on the behaviour of the other actors, thus influencing and directing the behaviour and the evolution of the system as a whole (Consoli and Patrucco, 2008).

The distinctive element of these organisational forms is represented by the active search for complementarity (compared to mere agglomeration) between different activities; in other words, the innovation platforms are structured and designed with a view to precise and pre-determined innovation objectives (in contrast to spontaneous phenomena such as the networks). In this context, as has been said, the platform leaders play their role.

In this framework it has recently been highlighted that the platform leaders play a crucial role in the success and efficiency of the innovation process. Concepts like *architectural knowledge*

(Henderson and Clark, 1990) or *architectural capability* (Jacobides, 2006), or that of *system integrators* (Prencipe, Davies and Hobday, 2003) have been introduced recently to describe precisely that decisive capacity, possessed by the network leaders, to co-ordinate and manage the work of complex organisations, and more precisely to combine elements typical of the integrated models (such as authority and control), with characteristics typical of modularity (such as a sufficient degree of openness) in order to select the significant competencies and knowledge to include in the network (Consoli and Patrucco, 2010).

As will be argued later, the business model brought forward by Better Place, by combining elements of hierarchical co-ordination with elements of decentralisation of innovative and production capacities and activities, seems able to be configured as a platform for innovation and situate itself at the centre of the innovation process – that regarding the introduction of electric cars – in which innovation is the result of processes and activities conducted collectively, and that sees new players take position at the centre of the innovation process both as suppliers and as integrators.

The arrival of new entrants from other sectors entails not only the introduction of new competencies and technologies, but also the redefinition of roles and power relations within the sector. The analysis of the supply chain becomes fundamental at this point to understand how the introduction of electric technology can change the architecture of the relations between OEMs and suppliers of various levels, and consequently the structure of the relations of collaboration between different actors, which we have seen is decisive for the success of the introduction of new technology.

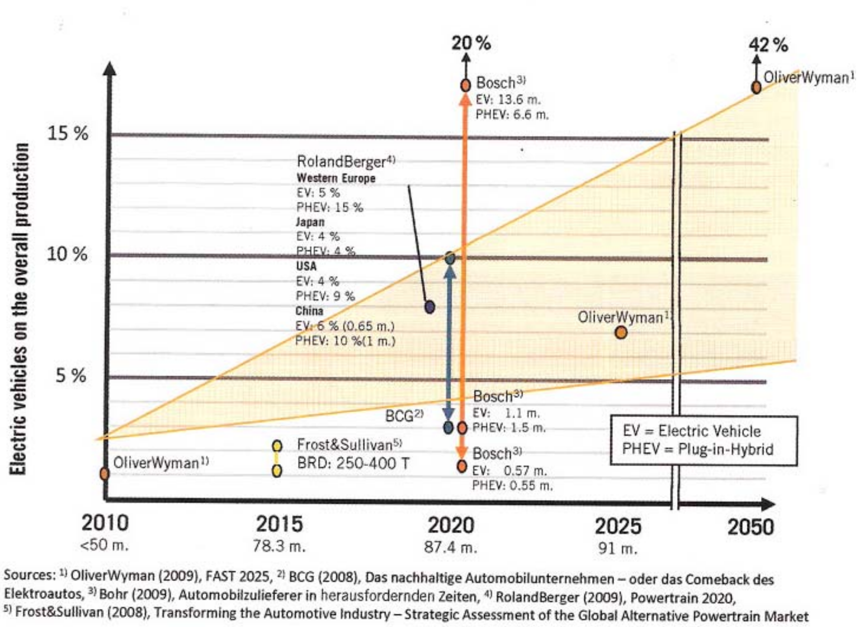
3. CHARACTERISTICS AND DYNAMICS OF THE ELECTRIC CAR: AN ETERNALLY EMERGING TECHNOLOGY

As some recent studies have underlined (Beaume, Midler, 2009; Frery, 2000; Kirsch 2000; Hoyer, 2008), research on electric and hybrid vehicles is not new in the transport sector, but is a recurrent question that has re-appeared many times in the history of the automotive market, so often in fact that it represents a perfect example of a 'technologie éternellement émergente' (Frery, 2000). This is therefore a technology whose development has been discontinuous, characterised by great acceleration at the beginning of the 20th century, and repeated stops and starts compared to expectations.

With the undoubted success of internal combustion engines, research into EVs was virtually abandoned until the 1970s, when the emergence of environmental issues and the oil crisis of 1973 brought the energy question to the forefront of public attention. Thus, from the mid 1970s to the mid 1990s the EVs were the cause of successive waves of enthusiasm, so much so that more than once authoritative studies had forecast as highly probable the development of a market on a vast scale, growing so fast that in just a few years it would reach a market share between 10 and 25%[1]. The reality is very different: according to two consultancy companies, in 2010, the market share of completely electric and hybrid cars would be between 1.6% (Analyst Note of Autofacts)[2] and 2.2% (J.D. Power)[3].

In fact, the production (or the play) of forecasts still continues today with diverging results (figure 1).

Figure 1: Market forecasts for electric cars[4]



Source: Kampker, Burggraf , Deutskens , 2010

To make the picture even more complicated we can add the fact that, talking of electric vehicles, in reality we are talking about a fairly wide range of vehicles as, more than a product, an

[1] An analysis of the various estimates of the 1990s is contained in Beaume, Midler (2009)

[2] http://www.autofacts.com/content/an/PwC_Autofacts_Electric_Vehicle_Outlook_Nov_10.pdf

[3] http://www.prnewswire.com/news-releases/jd-power-and-associates-reports-future-global-market-demand-for-hybrid-and-battery-electric-vehicles-may-be-over-hyped-wild-card-is-china-105857988.html

[4] EV: Electric Vehicle; PHEV: Plug In Electric Vehicle (electric cars that can be recharged from the electricity grid).

‘electrification path’ lies ahead (BCG, 2009). At one extreme are vehicles that allow limited savings in terms of emissions and a lower use of electricity, while at the other extreme there are those that offer significant increases in efficiency and show lower levels of emissions. In this range, the vehicles present higher and higher costs, as the higher is the use of electricity, the higher is the power demanded of the battery, thus raising its cost.

A possible classification is as follows.

Hybrid-electric vehicles (HEVs) combine an internal combustion engine with a supplementary electric engine. The first is generally the main system and works at higher speeds, while the electric engine is used to power the vehicle in the city and over short distances (the example is the first series of the Toyota Prius).

The **plug-in hybrid electric vehicles (PHEVs)** and the **range-extended hybrid vehicles** (respectively like the new Toyota Prius and Chevrolet Volt from General Motors) are hybrid vehicles with rechargeable batteries that can be restored to full charge by connecting a plug to an external electric power source. A PHEV shares the characteristics of both a conventional hybrid electric vehicle and of an all-electric vehicle, having a plug to connect to the electrical grid.

The **fully EVs** or **battery electric vehicles (BEVs,** such as the Mitsubishi i-MiEV and the Nissan Leaf, soon to be released) do not possess on-board electricity generation devices, and the battery can therefore be recharged only by connecting the vehicle to a socket (and so to the electricity grid) or by changing the discharged battery with a fully charged one.

In this context of technological variety, adopting a prudent scenario (PFA, 2010) it is forecast that for 2020 around 95-98% of vehicles will still continue to be fitted with internal combustion engines, of which a non-negligible share will be equipped with a certain degree of hybridisation; that the "full hybrids" remain essentially limited to the high-range vehicles; that the emergence of completely electric vehicles will be concentrated in mini local markets as cities thanks to public support. It thus seems evident how the different types of electric cars could co-exist for a long term on the market with traditional internal combustion vehicles: a massive conversion to pure electric cars, the only one that can represent a true turning point in the conception of the architecture of the car product is credibly imaginable only in the long term (50 years) (PFA, 2010; BCG 2010).

If in percentage terms the electrification process seems to be a relatively limited phenomenon, in the mid term, it is important not to ignore its dimensions in absolute terms: using the forecasts contained on the horizontal axis of fig. 1, in 2020 the forecast is for over 87 million vehicles sold (cars5 and other vehicles) compared to a little less than 50 million in 2010 (44.7 of cars alone): an increase of 74%, or 37 million in absolute values (about 26 million of cars alone). Therefore electric cars (including hybrid cars and mild hybrid) could vary from seven to 21 millions, leaving space to 50 or 64 millions of traditional cars.

If the estimates cited are credible, we are effectively faced by a coexistence of technologies yet without heavy crowding-out effects, given the substantial growth of the market as a whole. This dynamic is also significant for the supply chain, in particular for the role of components suppliers: the change of the technological paradigm does not seem to have significant effects on the components manufacturers in the short-mid period.

In summary, the success of the introduction of new electric vehicles and the speed of their spread thus depends on a series of interdependent technological, institutional and social factors, such as the elasticity of demand, the diffusion of recharging infrastructures, the achievement of critical production capacity, the form of the learning curves of battery producers, the creation of market niches and the role of governments (Hensley, Knupfer and Pinner, 2009).

In any case, the element that seems to be decisive in the various analyses is the need to develop networks of the many players (incumbents and newcomers): this reflects one of the four conditions identified by Freyssenet (2011) for development, in the historical sense, of the automotive industry.

[5] According to the estimate cited earlier of J.D. Power, the sales of cars alone should be almost 71 million.

This means the formation of coalitions and alliances of diverse actors and organisations in order to tackle uncertainty and reach a specific solution to a given problem.

4. THE SUPPLY CHAIN

The forecasts for the timing and dimensions of the electric car market also influence the components makers and all the other complementary actors involved in the industry, such as the suppliers of energy and services, defining for each of them opportunities and risks (figure 2).

Figure 2: Opportunities and risks along the value chain

	Energy Delivery	Conversion and Propulsion Systems	Services
Value Gains	▪ Incremental electricity and charge-point sales ▪ Capital investment avoidance	▪ Sales of EV cells and packs	▪ New service/ content channel co-branding ▪ Revenue white spaces
Companies With Opportunities	▪ Utilities ▪ Charge hardware and software providers	▪ EV-based suppliers ▪ Battery suppliers ▪ OEMs	▪ Telecom ▪ E-Mobility service providers ▪ Municipalities
Value Losses	▪ Reduced gasoline sales ▪ Underutilized infrastructure	▪ Technology obsolescence ▪ Underutilized ICE assets	▪ Reduced vehicle service demand ▪ Underutilized service assets
Companies at Risk	▪ Oil companies ▪ Fuel distribution companies	▪ ICE-based suppliers ▪ Traditional OEMs	▪ ICE-based services

Source: Hazimeh, Tweadey and Chwalik, (2010)

The theme of the effects on the supply chain of the electrification of cars can be examined in two ways and both views put the issue of networks and collaboration at the centre.

4.1.A long-term view, that also includes new entrants

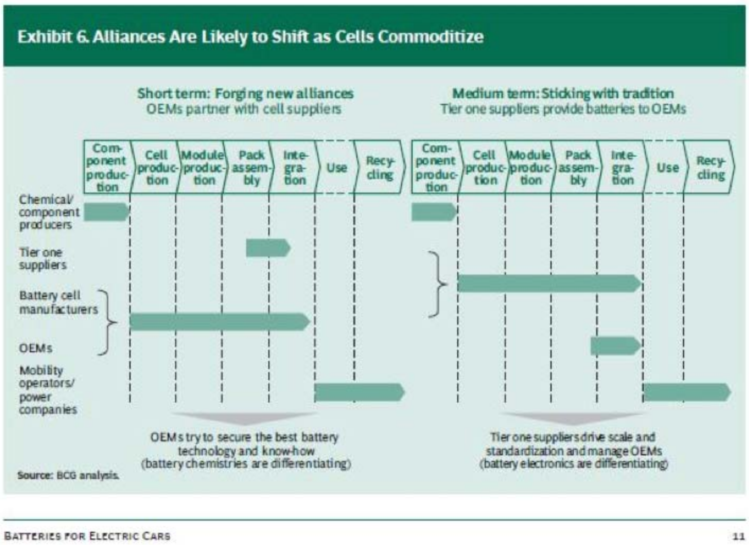
In the long term the centre of attention is the battery that, representing over one third of the cost of the vehicles, constitutes a significant part of the cost difference between electric and traditional cars (BCG, 2010), and a decisive component in the adoption of these vehicles. According to an estimate made by the BCG (2010) the current cost of a lithium ion battery pack of the NCA type (nickel, cobalt, aluminium) for car manufacturers swings between 1,000 and 1,200 US dollars per kWh; considering that for an average car batteries are needed to provide power of 15kWh, their cost is around $16,000. The United States Advanced Battery Consortium has set a target cost of $250 per kWh that could not be reached by 2020 without a radical innovation in battery technology (BCG, 2010).

In addition to cost, the batteries also have a technology problem: if it is true that the lithium ion is indicated as the winner in the long term we are faced with different alternatives within the same technology and none at the moment and in the short term appears dominant in the six dimensions that characterise the batteries themselves as a whole[6]. In fact, without a significant technological leap in batteries it is unlikely that the full electric vehicles could be available for the mass market by 2020 (BCG 2010, page 5). To this we have to add that "within the technical community there is still considerable doubt as whether the new batteries will match performance expectations over the entire life of the vehicle" (Barkenbus 2009, page 404).

In this context, car manufacturers do not intend to depend totally on battery makers and they therefore stipulate agreements to control both the development of the technology and production operations. The alliances and joint ventures give car manufacturers exclusive access to the know-how, technology and production capacities of the battery suppliers, enabling them to differentiate their vehicles on the basis of the battery technology. However, the advantage is accompanied by the risk of limiting the capacity to react quickly to the results achieved by other battery producers and also to limit the scale effects.

But the alliances also involve battery producers and first-tier suppliers and this type of collaboration could grow in the mid term, according to the forecasts of BCG (2010) (figure 3): the question for components makers is to take note that cost control in electric vehicles shifts towards battery manufacturers, but they can offer their competency in the car integration process. For car producers, this trend entails less control of technology and knowledge of batteries but offers both the benefit of the exploitation of economies of scale, and that of the reduction in the costs of switching in the event that new alternative technologies were to emerge. These advantages would be increased with the standardisation in battery technology.

Figure 3: Dynamics of alliances



Source: BCG 2010

4.2. A mid-term vision, or the transition to the future.

If the spread of the electric car is not a short-term question (i.e. it goes beyond 2020), it is still true that the electrification of vehicles will constitute an inescapable mutation in the mid-long term. If it is held that the transition cannot be an exclusively spontaneous process between the companies involved, the role of governments becomes crucial as the organising element of transition itself, with action to support the emergence of a supply chain for electric vehicles.

[6] Safety, duration - such as the number of cycles of charging and recharging -, performance, energy stored, specific power and costs (BCG 2010).

Many countries have moved along this road, but the most interesting case is that of France, in that the country's government is one of the few that, after having assumed the intermediate hypothesis (which is the most probable evolution) (PFA 2010), explicitly set the goal of building a supply chain for the electric car defining a project defined PFA (Plateforme de la Filière Automobile), set up in 2009 and which have worked to:

- enhance the potential for the improvement of engines suggesting to continue to support the competitiveness of the diesel supply chain in France, but also of launching a petrol supply chain with a major national project to develop a small universal engine and with the possibility of being hybridised, with a consumption from 2 to 3 litres per 100 km;
- create a French supply chain for the electric and hybrid car, positioning itself on technological solutions already defined for 2014-2015 but with the objective of widening their perimeters to new technologies such as heat management (from 30 to 50% of the range of an electric vehicle is influenced by air-conditioning and heating), braking with energy recovery (that can allow a doubling of the range) and the development of auxiliary low-consumption functions. Other initiatives for the electric supply chain go in the direction of: structuring university and laboratory competencies in electronics and electromagnetism; developing batteries aiming at system integration; developing the aggregation of French competencies in a European context.

The development of the French supply chain then also depends on the initiatives that can be set in motion to give an economically significant dimension to the production of electric vehicles. This is the direction taken with the decision by 20 private and public companies[7] to establish a grouping for the purchase of 50,000 electric vehicles starting in 2011, but which could reach 100,000 if other players were to join the scheme.

From the point of view of the individual components firms, their current competencies need to be extended, in particular to cover entire systems so as to achieve cost and function optimisation. While for large companies this expansion can be handled with internal growth, medium-sized firms need to establish networks of companies able to create and manage a system of competencies to develop integrated systems and integrated products (Kampker, Burggraf and Deutskens, 2010).

5. THE ROLE OF COMPLEMENTARY ACTORS

As noted in the introduction, the success of the electric car requires the contribution of other players outside the automotive supply chain, such as electricity producers and the suppliers of services: for the purposes of this paper, that concentrate on the organizational implications of technological change, we focus here on the latter.

As already mentioned, the cost of the batteries is an issue that does not regard only the OEMs. In fact, it also has an important impact on the purchaser of this type of vehicle in that the high cost difference depends precisely on the cost of the batteries. This constraint leads towards a new type of ownership and a new business model for companies offered by a new type of company: this would mean not buying a whole vehicle, but purchasing only the car without the battery, in that it would be paid only for real consumption, or the 'pay-per-mile' system. In this case, a new actor joins the consumers and carmakers, the company that manages the recharging and replacement of the batteries. The adoption of this radically new business model is defined as a disruptive strategy (Barkenbus, 2009) that can more easily be proposed by new entrants rather than incumbents, such as the car manufacturers: it would be able to modify/alter the preferences of consumers, presenting

[7] ADP, Air France, Areva, Bouygues, EDF, ERDF, Eiffage, France Telecom, GDF Suez, Suez Environnement, GRT Gaz, GrDF, La Poste, RATP, SAUR, SNCF, SPIE, UGAP, Vinci, Véolia

a more appealing offer of electric cars (for example, lower price, comfort and ease of use). In reality, this is the model proposed by Better Place and adopted by Renault for the pilot experiments in Israel and Denmark. With this model, the purchase of the vehicle is separated from that of the battery: transferring the possession of the battery to an electric car network operator (like Better Place), consumers' concerns about the cost and life of the battery could be eliminated.

5.1. Better Place[8]

Just as the electric car model comes from afar, so does the business model brought forward by Better Place. The Better Place model has found applications in some countries, first of all in Israel and Denmark, but also in Australia, California, Portugal, Hawaii, Ontario, Tokyo. Look at the case of Israel. In 2008, the Israeli government decided to launch, together with Renault-Nissan and Better Place, a vast programme of diffusion of a cheap, ecological electric car, easy to use and to recharge, thus becoming the first country in the world to commit itself to a fully electric car project with the priority goal of abandoning dependence on oil.

What are the traits that make this country a true case study?

− A country with a limited area (250 km apart from the Negev desert), and therefore suitable for the range of electric vehicles.

− A population concentrated in the large cities (in particular Tel Aviv). Most drivers (90 %) travel less than 70 km per day and the distance between the towns is no more than 150 km. These regard essentially urban trips.

− A country able to produce vast quantities of electricity, thanks to renewable energy forms, especially solar power.

In this context, Better Place has the objective of investing in the infrastructures: recharging points (for at least the partial recharging of batteries) and service stations for the rapid replacement of batteries in a few minutes or for a complete recharge in 4 or 6 hours. But the central point is that the ownership of the electric vehicle and of the battery are separate: the ownership of the battery concerns in fact exclusively the firm that manages of the infrastructure (Better Place) and this is for many reasons (CDS 2009): i) first of all, the development of the batteries is part of a short innovation cycle that could create uncertainty in the consumer. Thus, as the technological evolution of the batteries does not put in question the purchase of the car, one solution is precisely to separate the two ownerships; ii) furthermore, it is indispensable in order to lower the vehicle purchase cost; iii) lastly, the range of the vehicles and their reliability can be improved with the mere change of the batteries.

The originality of the model lies above all in the public-private partnership, in other words what has been defined as "collaborative innovation" (CDS 2009) as a number of actors make their contribution:

− the Israeli government offers tax breaks to consumers and helps to make the investment appealing to the partners through support for research;

− Renault runs the technical development and provides the electric vehicle;

− Better Place (i.e. the mobility operator) constructs a network of battery recharging stations and a network of battery replacement stations thanks to various sources of finance;

− public and private companies have stipulated contracts with Better Place for the conversion of their fleets with electric vehicles and for the installation of an adequate infrastructure network (for example the municipality of Jerusalem and Israeli Railways take action for the installation of recharging stations in the capital and in the vicinity of the main railway stations);

− most Israeli citizens are open to buying electric cars.

While this is the scheme of the project, a series of obstacles remain to be solved in practice, including the air-conditioning of the vehicle and the need for supplementary energy when the

[8] For the history of the company, see the site http://www.betterplace.com/.

batteries have a limited charge, the infrastructure network, and the unpredictable times to run the tests and to adapt to the constraints.

6. CONCLUDING REMARKS

We described the development of electric cars as a complex and distributed innovation in that it is the result of the interaction of a variety of diverse and interdependent factors.

We argued that the successful governance of these factors, and therefore the success of the introduction and diffusion of electric cars, requires the coordination of a diverse range of complementary players, not only internal to the traditional auto industry (i.e., carmakers, suppliers), but external to it (i.e. new entrants like producers of batteries from the electronics sectors, electric utilities, public government).

The paper put forward the notion of innovation platforms as the appropriate organizational form for the coordination of such different resources and actors. Innovation platforms combines the benefits of large coalitions implemented with the scope of mutual learning and the acquisition of technological and productive competencies sourced externally, with those of centralized decision making. As a matter of fact, some elements of a hierarchy characterize such models since some directedness is required in order to both guarantee the cohesion of the network and the convergence of the complex system of goals, incentives and interactions that are typical of such articulated innovation processes like the development of electric cars. We identify in the experience of Better Place an original application of the notion of innovation platform to the case of the introduction of electric vehicles.

Clearly much research needs to be done in order to provide a better understanding of the possible introduction of alternative technologies in the car industry, and further research topics that ought to be addressed should include: the characteristics and dynamics of the process of technological standardization; the role and modes through which national and supra-national government institutions can support the development and diffusion of new engines technologies; the effect that technological change has on the industry structure and dynamics. These topics go well beyond the limited scope of this paper and deserve dedicated investigation.

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