NETWORKING INNOVATION IN THE EUROPEAN CAR INDUSTRY: DOES THE OPEN INNOVATION MODEL FIT?[1]

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ABSTRACT

The automobile industry has entered an innovation race. Uncertain technological trends, long development cycles, highly capital intensive product development, saturated markets, and environmental and safety regulations have subjected the sector to major transformations. The technological and organizational innovations related to these transformations necessitate research that can enhance our understanding of the characteristics of the new systems and extrapolate the implications for companies as well as for the wider economy. Is the car industry ready to change and accelerate its adaptability and pace of innovation? The study investigates the applicability of the Open Innovation concept to a mature capital-intensive asset-based industry, which is preparing for a radical technological discontinuity - the European automobile industry - through interviewing purposely selected respondents across seven European countries. The findings contribute to the understanding of the OI concept by identifying key obstacles to the wider adoption of the OI model in the car industry, and signal the importance of intermediaries and large incumbents for driving network development and OI practices as well as the need of new competencies to be developed by all players.

Key words: open innovation, networks, car industry, SMEs

1. INTRODUCTION

With huge development costs, long development cycles and fierce global competition, the car industry is a traditionally closed industry. Costs must be contained, and yet customers in nearly saturated markets still desire new, cutting-edge products. Moreover, significant amounts of resources have been spent in recent years on lowering emissions and on the development of environmentally-friendly vehicles. The transition to such

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vehicles requires a radical and costly technological and organisational shift in automobile operations.

Under growing pressures from increasingly demanding customers, safety and environmental regulations worldwide, the automotive sector has entered an innovation race. Sustained competitive advantage increasingly depends on the ability to improve and accelerate innovation output continuously (Fallah and Lechler, 2008). Innovation has become largely dependent on the ability to monitor all the latest market and technological developments and integrate various complex technologies.

The constraints of the monolithic, vertically integrated firm in scanning the environment and identifying relevant technological breakthroughs and market changes have given rise to the networked organisation characterised by porous boundaries and numerous linkages with other organisations. In the car industry, large manufacturers, also known as Original Equipment Manufacturers (OEMs), have started to focus on their core competences and outsource other activities to suppliers, forming clusters and wider networks in the process. This shift has driven a deep restructuring of the supply chains, transforming them into supply networks. The number of participants and interdependences within and between these networks, coupled with turbulent business environment and shortening product life cycles generate a high complexity of innovation tasks and decision-making.

The questions that arise are how and why are networks formed and managed in a mature traditionally closed industry like the car industry? How does co-creation occur? These are important questions that have been little investigated in this context and deserve attention not only from scholars but also from practitioners and intermediaries. The management and coordination of networks for innovation require specific competencies, which are not relevant in closed innovation organisations. Moreover, the car industry is preparing for a radical technological shift, which requires a major rethink of its approach to innovation. Are companies operating in the industry ready to embrace a different approach to innovation? The Open Innovation concept provides a relevant framework which can assist the investigation of these questions.

2. THEORETICAL BACKGROUND

2.1. *OPEN INNOVATION*

The Open Innovation (OI) model has become popular through providing a different perspective on how companies can create and profit from innovation (Chesbrough, 2006, Gassmann, 2006). OI has been defined as 'the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and to expand the markets for external use of innovation' (Chesbrough et al., 2006, p.1). Outbound knowledge flows are defined as unused technologies that can be sold or licensed to organizations with better suited for their commercialization business models (Chesbrough and Crowther, 2006). Hence, in contrast to the traditional model where innovation is internally generated and marketed, the OI model recommends utilization of both internal and external sources of ideas.

The idea of sourcing knowledge externally is not new (e.g. Nelson and Winter, 1982, Von Hippel, 1988, Cohen and Levinthal, 1990) but Chesbrough's work provides an overarching concept encompassing various research streams. The basic assumption behind the OI model is that even large enterprises can no longer possess all the capabilities and resources to generate innovation by themselves and need to capitalize on external knowledge (Gassmann, 2006). Indeed, in the car industry the increasing complexity of cars as products reflects the growing number of technical fields that provide new opportunities for problem-solving. The growing importance of deep specialized knowledge in these fields necessitates an upsurge of R&D investment and organisational capabilities that allow absorption and integration of external knowledge. To deal with the tension between the need of diverse specialized knowledge and cost pressures, car manufacturers focus on their core competences and outsource other activities thus forming networks of suppliers.

However, what are the implications of vertical disintegration for core capabilities? Can OEMs maintain superior capabilities to innovate at the architectural level if they have mislaid competencies at the component level? Their role as system integrators in increasingly distributed value networks requires capabilities to specify and test externally produced components, and to coordinate the integration of new technologies. Integrative competencies, however, are not as strongly associated with particular areas of technological knowledge but, rather, relate to application-specific knowledge and adaptability to environmental changes, e.g. emergence of new technologies. Hence, for large organisations like OEMs the adoption of the OI model necessitates organisational innovation and adoption of structures that allow for optimal combination of internal competencies and external knowledge, leading to continuous innovation. Are OEMs willing to change and embrace the OI approach?

Moreover, what is the role of SMEs and entrepreneurs in the generation of innovation in a mature industry preparing for a radical technological change? The ability of SMEs to innovate is becoming increasingly important in the light of deepening trends for specialisation. However, while some studies have reported that entrepreneurs and SMEs are great idea hunters because they are skilled at opportunity recognition (O'Connor, 2006), it has been also argued that many SMEs lack the capability to innovate (e.g. Vermeulen, 2005). Lack of resources and limited access to qualified labour are often cited as the main obstacles to SMEs' ability to innovate (Amini, 2004). One way to overcome these deficiencies is through engaging in interorganizational networks, which reinforce SMEs' innovative ability by providing them with a window on technological and market change, and sources of technical assistance and potentially available resource flows (Vermeulen, 2005, O'Regan and Kling, 2011). SMEs can reap greater benefits from OI than their larger counterparts because external collaboration can offset the limitations of internal resources and competencies (Lichtenthaler, 2008).

The question that arises and has been inconclusively answered by previous research is how effectively SMEs engaged in networks exploit the potentially available external scientific and technical knowledge to support their innovation. Some authors argue that SMEs have a good ability to create and make use of network relationships due to their size (Massa and Testa, 2008) while others claim that SMEs have weak external contacts precisely because of their size (Srinivasan et al., 2002). Moreover, SMEs are generally short of managerial resources and find it difficult to manage a broad network due to a very high opportunity cost of management time (Lowik et al., 2012).

Technological change tends to reinforce vertical disintegration through reducing the minimum efficient scale thus making it possible for SMEs and entrepreneurs to drive technological innovation (Langlois, 2003). SMEs and start-ups can build a strong regime of appropriability in the early stages of the technology life cycle through establishing deep and complex technology knowledge base, generally unrelated to the knowledge bases of the large players, and a combination of patents (Christensen, 2006). Moreover, SMEs should take advantage of OI and make this technology base attractive to incumbents through codification, documentation, and communication, and engage in cooperation with incumbents to create functional solutions and test market potential (ibid.) or sell the technology to complete its commercialisation (O'Connor, 2006). Thus, one way or another, entrepreneurs and SMEs are bound to become involved with large incumbents (Christensen et al., 2005, Teece, 1986). However, do SMEs possess the managerial and organisational capabilities to secure rents from technological knowledge when collaborating with large incumbents?

In sum, the OI perspective suggests that entrepreneurs and SMEs deliver innovative ideas and technologies, which large enterprises integrate in product architecture in exchange for complementary assets (Christensen, 2006). While SMEs and entrepreneurs concentrate on exploration and perhaps some experimentation, large incumbents step into the final stage and take over experimentation and exploitation, instituting repeatable processes such as manufacturing, delivery and customer contact and support (O'Connor, 2006). Such symbiotic relationship can compensate for the cumbersome structures of large enterprises as well as for the resource shortages of SMEs and entrepreneurs.

Last but not least, the OI model is highly dependent upon intermediate markets where entrepreneurs supply new discoveries and highly specialised technological capabilities, possibly in collaboration with research institutions, to large companies, like OEMs, who in turn provide integrative capabilities, transform technologies into application-specific use, and complementary assets for large scale commercialisation of innovation (Teece, 1986). Thus the OI model highlights the prominence of market-supporting institutions in promoting technological entrepreneurship as well as the importance of multiple ties among organisations and various types of institutions, e.g. universities, research centres, government and regional institutions (Simard and West, 2006). It is important to explore to what extent intermediate markets and institutions facilitate interorganisational interactions in the car industry.

2.2. *OPEN INNOVATION IN THE CAR INDUSTRY*

To have external validity, a paradigm must explain evidence beyond its initial area of enquiry (Yin, 1988). However, the evidence to support the OI concept is taken almost exclusively from evidence in the context of high-paced industries, such as computers, software industry and pharmaceuticals (e.g. Chesbrough, 2003a, 2003b, 2003c, 2003d, West and Gallagher, 2006, Gardet and Fraiha, 2012). Whether the OI concept can be applied in lower tech or more mature industries, remains an open question. Mature industries display very different characteristics in terms of types of innovation, handling of intellectual property rights (IP), patterns of innovation diffusion, risk management as well as strategies for exploiting innovation. Hence it is important to examine whether the OI model is appropriate in other industry settings and what obstacles prevent the wider adoption of the model.

As in many other industries (e.g. Coombs & Richards, 1993, Christensen, 2002), in the 1980s, the car industry witnessed a move from the prevalent central-R&D-lab model towards a more distributed R&D model through supplier involvement in new product development. While this may be seen as a move towards OI, suppliers were still working under strict guidelines and specifications provided by OEMs. Although specifications vary in the level of detail (Ge and Fujimoto, 2006), their prescriptive nature make it problematic to see the resulting output as purposive knowledge inflows intended to accelerate internal innovation in OEMs. OEMs still maintained powerful central laboratories while experimenting with ways of coordinating R&D at different levels (Tidd et al., 2005, Argyres, 1995). The move in the 80s has been branded 'a dismal failure' by industry practitioners and resulted in transferring the design control and product validation back to OEMs in the 90's.

The only previous study examining OI in the car industry (Ili et al., 2010) is focused on the German car industry. Building on Gassmann (2006), the authors demonstrate that the car industry displays all the relevant properties suggesting that the OI model would be appropriate, i.e. it is highly globalised, technology intensive, characterised by high levels of technology fusion and open to identifying and implementing new business models. Yet, it tends to the closed innovation paradigm (Ili et al., 2010). The one idiosyncrasy that does not fit the model is the low level of knowledge leveraging.

However, no attention has been devoted to the question whether OEMs possess the capabilities needed to become the leaders of OI networks, i.e. supporting and accelerating inflows and outflows of knowledge to facilitate innovation and efficiency within the networks? For mature traditional companies like car manufacturers, OI is a marked departure from previous vertically integrated 'industrial' models. Have they developed the integrative competencies needed to explore opportunities emerging from technological breakthroughs outside of the firm, to coordinate and benefit from external developments?

2.3. *RESEARCH PROBLEM AND OBJECTIVES*

Against this background, our study aims to explore the applicability of the OI model to a mature industry – the European car industry - in the light of the radical technological discontinuity taking place in the sector.

More specifically, we aim to investigate:

- How and why networks are formed and managed;
- How flows of knowledge circulate in the networks;
- How companies in the industry make use of the potentially available external knowledge;
- What is the role of the different payers in the generation of innovation;
- How intermediate markets and institutions facilitate interorganisational interactions.

3. RESEARCH METHOD

We applied a qualitative inductive approach because variable-oriented techniques would not allow, for example, to address questions about motivation or to observe causal processes (Rueschemeyer & Stephens, 1997), particularly with regard to sensitive issues such as interorganisational relationships, interaction problems, intellectual property (IP) rights, and perceived risks.

3.1. *SELECTION OF RESPONDENTS*

The study applies the principle of data source triangulation, whereby the phenomenon of interest is studied at different places (Stake, 1995), e.g. across organizations, which vary in terms of size, locality, or industrial background, in order to achieve validity of interpretation, explanation and generalization. The respondents in our study come from seven European countries - Germany, Hungary, Italy, Romania, Slovenia, Spain, and UK.

It is often problematic for the researcher to identity key informants who can provide the most relevant information (Fontana & Frey, 1994). Consistent with the logic of Huber and Power (1985), who argue for selecting knowledgeable informants, the respondents for this study were purposely selected to represent car industry stakeholders from one of the following groups: OEMs, large suppliers also known as Tier 1 suppliers, SMEs, regional authorities, cluster management, regional universities or research institutes involved with the automotive industry, and regional support agencies (description of the respondents in Appendix 1).

This approach allowed examination of the experiences and perspectives of a diverse selection of individuals who were directly involved with the studied phenomena hence ensuring the research problem was approached 'in a rounded and multi-faceted way' (Mason, 1996, pp. 149).

3.2. *DATA COLLECTION*

The employed research instrument was semi-structured, open-ended interview for its potential to generate rich and detailed accounts of the interviewed individuals' experience. This research instrument allows the discussion to lead into areas which may not have been considered prior to the interview but may be potentially relevant. This flexibility was particularly important in our study due to the different professional background of the respondents and the need to make full use of their individual experiences, while ensuring consistency and comparability across the interviews.

A set of directional topics and guiding questions was prepared, reflecting the insights gained from the review of the relevant existing literature. The questions were designed in most general terms to allow multiple site research and collection of data comparable across country boundaries and organisational settings. The specific questions and their order varied between interviews depending on the conversational flow while the common topics ensured comparability across interviews.

The data collection was completed over a three-month period (January – March 2012). Each interview began with a brief professional history of the interviewee. These narratives lasted approximately 5-10 minutes and were used as a basis for follow-up questions for the remainders of the interviews. The interviews ranged in length from 50 to 90 minutes.

The interviewees were encouraged to develop their views around the open-ended questions. The interviews captured a broad picture of the automobile industry and the processes taking place in the sector because most of the respondents had occupied different positions or worked in different companies in the industry over a number of years. These individuals were able to reflect on their experiences and provided valuable insights into the studied problems.

Thirty interviews were conducted until it was felt that theoretical saturation was reached and we felt confident about the meaning and importance of the findings (Bryman and Burgess, 1994). The diverse selection of respondents ensured that patterns of reoccurring events and behaviours were accounted for, while maximizing the underlying country variations.

3.3. *DATA ANALYSIS*

The data was analysed with NVivo9 software package. Since most of the respondents requested anonymity, all the data were coded and cross-referenced to ensure that, if necessary, it would be possible to trace it back to the original data. The data were initially broken down into fifteen categories (nodes) corresponding to different aspects of the main themes of the study for each country (nodes description in Appendix 2). In those cases where the respondent's reply addressed more than one node, the data were coded into both categories. Subcategories emerged within the main nodes and assisted a more precise categorisation of the data.

The nodes were searched for patterns and reoccurring events in order to establish underlying concepts (Gephart, 1993, Turner, 1994). This approach is underpinned by Kolb's learning cycle model (Colombo et al., 2012, Kolb, 1985), consisting of four stages: data collection, reflective observation, abstract conceptualisation and active experimentation. The discussion section of this paper contains a summary of the latter stage, where the identified patterns are checked for a fit with concepts suggested in the existing literature.

3.4. *VALIDITY AND RELIABILITY*

To ensure reliability of the findings, all the interviews and consequent comments were tape-recorded and transcribed, and consistent data coding and sorting were deployed and documented.

In qualitative research, the primary checks on validity are internal checks on the validity of the data (Kirk and Miller, 1986). Hence, the emerging categories were continuously refined in parallel with the process of interviewing. As the research progressed and new or inconsistent data were collected, the categories were constantly compared and modified. Moreover, all the interviewees agreed to follow-up calls and emails and, where necessary, elaborated on unclear points. To assist the validation of the findings, the interviewer summarised the key points for each section of the questionnaire and asked the respondents to comment on the truthfulness of the interpretation. The identified inconsistencies were recorded and used to support the data analysis.

4. FINDINGS

It is not possible within the limits of this paper to show the full rich evidence the study has collected. Nevertheless, in the following sections we summarise the key findings and illustrate them by short interview quotes.

4.1. *NETWORKS IN THE EUROPEAN CAR INDUSTRY*

In all the countries covered by this study, the regional companies working in the automobile sector have formal network organisations, typically funded by the industry and the regional authorities. These regional networks are seen as important platforms for exchange of ideas, critical for innovation, and are often referred to as clusters for the spatial proximity of the member organisations.

> 'I think a network is critical. Otherwise your horizons for innovation are going to be very limited.' Respondent (R) 21

The cluster networks differ between countries in a number of characteristics, e.g. size, variety of membership, method of funding, level of organisation, level of support and type of services for member companies. However, the better developed clusters typically involve 'a cross-section of the industry' (R20). Research centres also play a role in forming innovation networks.

> 'Normally you get a couple of universities in the cluster, some key stakeholders from the Tier 1s, and the SMEs. The mainstream car manufacturers are also involved in clusters.' R20

> 'We have around 100 companies as well as research institutions, universities, labs, public authorities.' R16

Clusters support the regional automotive SMEs through facilitating their relationships with OEMs and Tier 1 suppliers, as well as with public authorities and research institutions. While the evidence shows that OEMs may not necessarily see benefits in network membership, it also shows that large enterprises are interested in networking per se:

> 'Bigger enterprises tend to underestimate the potential of innovation networks. They have big research departments on their own and do not need any research from us. The networking aspect is for OEMs much more important than the actual innovation.' R12

4.2. KNOWLEDGE FLOWS IN THE NETWORKS

The key characteristics of a network are the participating actors, the relationships between them, and the resources exchanged through these relationships. In the context of OI, the existence, intensity and direction of the knowledge flows circulating between the participating actors in the network indicate whether and to what extent OI practices are employed. We distinguish three types of purposive knowledge flows, namely between (i) OEMs/Tier 1s and knowledge institutions, (ii) OEMs/Tier 1s and SMEs, and (iii) SMEs and knowledge institutions. Problems and barriers exist at all levels.

A key feature of the better developed clusters is the good relationship between OEMs and the knowledge institutions, including ‘involvement of students into production for training purposes’ (R25) and ‘contribution to research development’ (R16).

OEMs work more actively with research institutes and outsource R&D, ‘or rather D’ (R17). They use a twofold mixed approach, which ensures that internal capabilities are maintained. Research institutes – like suppliers – work to strict specifications.

> ‘OEMs have the architecture, and certain things coming from other suppliers, and they need us to develop basic modules and components. You have a specific task, so tactically you are replacing an internal department.’ R17

The key considerations behind the use of research centres by OEMs are cost, time to market, diversity of knowledge and speed of technology advance.

> ‘You have a task which requires specific knowledge; you need someone to have it done in 3 months. So you buy the skills that you need for the time being […] If you have employees, you would have to retrain them every couple of years.’ R17

The key barriers to the use of external knowledge by OEMs are the capital intensity of the industry, the related cost and risk considerations, resistance to external ideas, and limited accessibility.

> ‘You have to trust in others’ knowledge, that is a learning process. You need to change the mindsets of the guys doing the actual R&D within the company to see that they add value if they make use of external knowledge.’ R16

> ‘If an SME came to me and said “we have a telematics idea”, I wouldn’t know who to direct them to. Somebody who is sitting over in [another country] may be responsible for the development of telematics.’ R22

All in all, our data strongly indicate that knowledge flows are interrupted in both directions. OEMs’ incoming and outgoing knowledge flows are strictly controlled and SMEs are reluctant to tap into external knowledge and tend to be passive members of the regional clusters. The challenge of inefficient use of external knowledge by SMEs can be observed even in the most developed clusters:

> ‘There are many networks and opportunities for networking for the SMEs, but the majority do not use these opportunities.’ R13

> ‘It is not easy for SMEs to work with research centres and universities because usually they do not have so much resources, skilled people and also financial resources.’ R2

Universities are seen as having a different agenda reflected by their approach to knowledge generation and project management.

> ‘The timeframe of the academia seems to break up the project into small elements. Maybe it is ok for research, but if you are looking for product

> development, we have struggled to get those guys to work in the same timeframe that we are expected to serve that customer base.' R19, SME

Ultimately, the intensity and quality of participation and knowledge exchange are contingent upon the beliefs and drive of the individuals involved. Existing mindsets and lack of trust are cited as key communication barriers.

4.3. DIVISION OF LABOUR IN INNOVATION

Key product innovations are driven by the OEMs and executed by Tier 1 suppliers who are expected not only to generate most innovation but also to 'manage' the rest of the suppliers. The role of car manufacturers is seen as integrators and 'market masters'.

> 'Collaboration between car manufacturers and suppliers is very important in terms of accessing and forecasting what is going to be coming in the future. We do rely on our suppliers to bring new ideas to us. We are experts in building and selling cars, and we are not necessarily experts in things like telematics for example.' R22

> 'OEMs do not have the deep understanding of the factors that influence the design side, and then probably we do not understand exactly what the customers want. We need to discuss and compromise.' R25

Views diverge over the role of SMEs in this large scale innovation model. Prohibitive industry structure is seen as preventing SMEs from engaging more actively in innovation.

> 'I do not think so [SMEs innovate]. It is not simply a matter of resources. That is a matter of the functioning of the value-chain. OEMs and Tier 1s require innovation from tier 2, 3 and 4. But it makes no sense if tier 3 or 4 companies are innovating but there is no idea at the OEM at the end of the value-chain.' R16

Most of the respondents shared the view that smaller suppliers do contribute significantly to the innovation and expertise of Tier 1 suppliers. However, scarcity of resources typically prevents them from taking their inventions to the market.

> 'Most of the new car innovations come from other [smaller] companies but it is very complicated for them to get finance, and to get investment, and therefore a lot of innovations could not go into production.' R8

> 'I have seen a number of them, technologies that have been developed in a small organization, which have then been bought up by the Tier 1 suppliers going into the OEMs. This small organization is then bought up by the Tier 1.' R19

Once again, the strong position of OEMs and Tier 1 suppliers in selecting which technologies and which products reach mass commercialisation comes into view. Smaller suppliers are provided technical specifications and aggressive cost targets within which they must deliver.

On the other hand, opportunities are emerging and spaces are opening up for innovative SMEs in the new segments around environmentally friendly vehicles, e.g. IT, electronics, software and mobility services, telematics, car entertainment, as well as the development of relevant infrastructure. While the car industry is still closed in its traditional segments, some OI practices can be observed in these emerging segments, which display all the signs of an emerging industry, e.g. lack of dominant design, low rate of market penetration, focus on technology and design, etc., hence creating space for innovation-potent SMEs.

> 'There is still a quite broad field [around eMobility] which is not so much defined and could develop into a big market in the future. SMEs could position themselves and it is pretty open still.' R12

However, the opportunities in the emerging sectors are limited in terms of potential market success in the short run. This uncertainty is a significant drawback in the context of SMEs who typically suffer low survival rate in the first five years after establishment:

4.4. INTERMEDIARIES

In the context of OI, intermediate market-supporting institutions can promote entrepreneurship through reducing coordinating costs, increasing the scope for secure IP, and developing ties among the various players. They are the critical drivers of enhanced effectiveness in technological markets.

Although there were differences in the level of development, we have observed attempts to establish intermediate market-supporting institutions across all the countries in our study. Cluster networks are themselves key intermediaries. 'We have also an area devoted to innovation management. We support the companies in getting support from public institutions, or identifying possible partners to share technologies.' R29

> 'We do common marketing and push innovation and research. We work consistently on upgrading R&D competencies and buy equipment for our technology centres, which the companies use together. We support SMEs with training that is not available but is needed, especially resource management, project management, quality management.' R6

However, the key role of intermediaries in the OI model is linking highly specialised suppliers of technology and technological capabilities with the OEMs and Tier 1s that possess the integrative capabilities and complementary assets needed for large scale commercialisation. The examples of the well-developed regional clusters illustrate the importance of close interaction and exchange between SMEs and the large players. The absence of OEMs and Tier 1 suppliers typically has negative impact upon the achievements. In the clusters where healthily-funded intermediaries have assisted the establishment of robust multiple links between the players, SMEs demonstrate marked improvement in technological and managerial capabilities.

> 'The cluster could be a solution because you have to find the trust at some level. You need to have a number of companies willing to say "that is how it could work, and our bundle will act as a partner to Daimler, and this is who will do the job, but if he fails we are going to jump in and save the game." It is all about trust and the intermediary organizations could plant the seed of this trust, feed it,

> water it and try to be the gardener of it. They can ensure that all the frictions that exist in the networks are managed.' R17

Different types of intermediaries have emerged to serve the technology markets. Some provide managerial support, link enterprises according to their needs, and coordinate the innovation efforts, e.g. clusters, while others link universities to enterprises, fundamental research to applied research, and become directly involved with the innovation processes, e.g. research centres.

5. DISCUSSION

Our findings show that two types of networks can be distinguished in the EU car industry: formal (clusters), informal (strictly based on trust and credibility) and project-based. The latter are typically networks initiated by research centres.

Clusters are formal networks, typically established by industry initiative and supported by regional authorities. They differ between countries in a number of characteristics, but typically involve a cross-section of the industry and relevant institutions. Large incumbents participate in the better developed clusters mainly to secure a window on potentially innovative developments. In the less developed clusters, the member base is typically limited to SMEs, and knowledge–generating and support institutions. SMEs participate in the networks to gain bargaining power, access to technology and expertise, managerial and administrative support. Most importantly, SMEs use networks to gain access to large incumbents and knowledge-generating institutions. The clusters, in which large incumbents are absent, tend to be under-resourced and often dissolve over the course of several years.

The definition of OI suggests that the readiness of an industry for OI can be assessed by examining the purposive inflows and outflows of knowledge that circulate between the players. Our findings strongly indicate that knowledge flows in the car industry are, although to a different degree, largely disrupted. In the traditional segments, the direct incoming knowledge flows of car manufacturers are limited mainly to large suppliers and research institutes. In the better developed clusters, limited in scope relationships with universities are present but direct relationships with SMEs are rarity in all settings. Outgoing knowledge flows are completely severed.

OEMs have the technological competencies to evaluate and integrate breakthroughs emerging outside of the firm. However they lack the organisational capabilities to select, coordinate and benefit from unplanned external developments. The key problems obstructing the inbound knowledge flows from SMEs and entrepreneurs are credibility and risk aversion grounded in the capital intensity of the industry, resistance to external ideas and coordination costs. Moreover, the cultural and organisational barriers to OI identified by Ili et al. (2010) in the German car industry - 'not-invented-here' syndrome, lack of appropriate processes, and top-down integration – do apply to the national settings in our study. Last but not least, we have identified a problem of accessibility caused by the lack of efficient communication interface between OEMs and the rest of the industry.

The large Tier 1 suppliers appear to be well connected both upwards with the OEMs and downwards with the SMEs. They are also the ones who appear to be most open –

not only they actively scan and select external ideas and knowledge, but they also attempt to maximise the exploitation of their own innovations by offering them to other industries.

SMEs, on the other hand, find it next to impossible to exchange direct knowledge flows with OEMs and difficult to work with large suppliers due to the reasons discussed above. Hence, the paths for taking advantage of OI and making their technology base attractive to incumbents (Christensen, 2006), boil down to two: via the large Tier 1 suppliers or via the regional clusters. If SMEs do engage in collaborative work with large incumbents, they typically lack the managerial and organisational capabilities to secure rents from their technological knowledge. Cluster membership offers better chances of benefiting from own innovations. All in all, while SMEs and entrepreneurs may reap greater benefits from OI than their large enterprises (Lichtenthaler, 2008) in dynamic, knowledge-based, labour-intensive industries like the software industry, in mature capital-intensive asset-based industries like the car industry, they have limited options.

Extant studies have argued that SMEs can counteract the liability of size and enhance their ability to innovate by engaging in networks and OI practices (e.g. Vermeulen, 2005, Lichtenthaler, 2008, O'Regan and Kling, 2011). However, our analysis suggests that SMEs in the car industry are slow to engage in networks and do not take a full advantage of the opportunities to tap into external knowledge. The key barriers are IP issues and resource limitations. Beyond financial and human resources, SMEs are also short of managerial resources and find it difficult to manage broad networks due to high opportunity cost of management time. Knowledge flows between SMEs and knowledge-generating institutions are obstructed by resource limitations as well as differences in management style and priorities.

The observed industry structure consists of 'fishnet networks' of SMEs and entrepreneurs providing absorptive capacity to larger incumbents by identifying and implementing new technologies, including from other industries, in their products and processes. By doing this, SMEs facilitate technological innovation in client companies (Wood, 2006), and enhance their adaptability to the rapidly changing environment, including technological change and increasing knowledge diversity. The Tier 1 suppliers act as a filter at the end of the funnel by selecting the most viable innovative ideas, developing them to a marketable stage, often integrating with own developments, and passing them on to the OEMs. SMEs have become part of the OEMs' wider resource.

While SMEs and entrepreneurs concentrate on the selection and exploration of knowledge, large incumbents take over experimentation and exploitation (O'Connor, 2006). This is not a linear process because diversity of knowledge drives innovation and necessitates dense networks (Cowan et al, 2004). However, this study demonstrates insufficient and irregular development of links in the networks which results in underutilization of their potential. We observe pyramid-shaped regional networks, stratified according to organisational size, with predominantly bottom-top knowledge flows, consisting of horizontal and vertical sub-networks with limited scope, the links within and between which are mediated by research centres, cluster management and support institutions. The need of close simultaneous interdisciplinary development glues the pyramidal structures. This large scale innovation model has implications for decision making and suggests that the management of innovation in the sector needs to be built on an integrative system along the innovation processes rather than on isolated players if it is to reap the benefits of continuous innovation and minimise knowledge spillovers.

All in all, the findings show that the car industry is still a closed industry in a pressing need of cultural change if it is to accelerate innovation rate and adaptability. At present, the sector uses mainly its own direct environment as a trigger for innovation: the handling of IP is defence-oriented (Ili et al., 2010), while the most important drivers of innovation are legislation and regulations, followed by customer demand. However, the expected shift to electrical vehicles is giving rise to OI practices in the emerging sustainable segments, where SMEs incubate radical innovations. While large enterprises are proficient in managing existing markets, SMEs and start-up organisations act as engines of radical innovation because they do not suffer the bureaucracy of incumbents and can be flexible in structuring appropriate business models (Leifer et al, 2000, O'Connor and Rice, 2005). The new sustainable mobility paradigm opens up niches for SMEs to identify new kinds of needs and satisfy these through innovative adaptation of deep specialised knowledge, including from cross-industry linkages.

Last but not least, the study demonstrates the importance of intermediaries and large incumbents for driving network development and OI practices. However, OEMs have not yet developed the capabilities needed to become the leaders of the networks, i.e. supporting and accelerating inflows and outflows of knowledge to facilitate innovation and efficiency. New competencies need to be developed by all players to achieve and manage the optimal combinations of internal competencies and external knowledge leading to continuous innovation, particularly adaptive integrative competencies, efficient management of IP and radical cultural change.

6. CONCLUSIONS

Perhaps the most important deficiency that has surfaced from our analysis is the lack of links between SMEs and larger companies as well as weak links with various institutions. Despite evident attempts by regional authorities, the desired links have been slow to develop. Further efforts in this direction can improve the performance of the automobile clusters and networks. The research points to the significance of policies and support infrastructure for the economic gains from clusters and networks, including intermediary institutions that facilitate interorganisational exchanges, create accommodating environment, facilitate joint problem-solving between different stakeholders, and support and motivate the innovation efforts of firms.

Yet, the problems of accessibility and disrupted knowledge flows can be only resolved if appropriate mindset exists. Regions that seek to participate in global technology networks must devote as much attention to expanding education and training, creating institutions to support entrepreneurs and SMEs, and building ties and trust, as to attempting to attract investment. The trust and local knowledge that exist within regions can provide competitive advantage in continuously introducing new products and services in concert with the evolution of technology and customer requirements.

This study contributes to the understanding of the OI concept by examining its applicability in a mature capital-intensive asset-based industry, which is preparing for a radical technological discontinuity. Such industries may be less dynamic but with more momentum, thus manifesting very different characteristics in terms of patterns of innovation diffusion, risk management and strategies for exploiting innovation. We identify key obstacles to the wider adoption of the OI model in the car industry and demonstrate that the OI model, although very attractive, may be not be equally applicable to all industry settings. The dependency of the model on IP management and intermediate markets deserve more attention from scholars as well as from policy makers.

Finally, it seems that the adoption of the OI model may not be necessarily a one-way road. Cyclical adoption of OI practices appears a plausible proposition for mature asset-based industries. Incumbents may adopt OI strategy in the beginning of the technology life cycle to deal with a radical technological discontinuity, e.g. the adoption of electrical vehicles, followed by internalisation of the consecutive innovations as the technology matures, and then by re-externalisation of components as interfaces become standardised (Chesbrough & Kusonoki, 2001, Christensen, 2006). This proposition provides an interesting line of enquiry for future research.

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APPENDIX 1: Description of the respondents

	Respondents' job title, education & experience	Organisation
1.	Professor, and Founder and Manager	SME, spin-off of a cluster member university
2.	Technical coordinator	Intermediary providing foreign buyers with support in outsourcing activities through linking them with suppliers, selected on the strength of their technical, qualitative and logistic capabilities. The member companies are together potentially able to manufacture a vehicle from the drawing board to mass production
3.	[Dr] Head of the Secretariat of the regional financial institution; an Engineer, Ph.D. in Economics and the Management of Technology	The regional financial institution is the bank of the regional government devoted to policy operations. The institution takes care of the car sector with specific instruments.
4.	[Dr] researcher in material engineering, working on power sources	University - a cluster member
5.	Founder and General Manager	An engineering SME (40 staff), focused on R&D in the field of Electronics. The company provides highly specialised engineering services in different sectors: automotive, railway and military.
6.	Managing Director of a regional automotive cluster	The cluster is a business interest association of automotive industry suppliers.
7.	HVEC cluster manager, and project manager and partner	An engineering SME (micro – under 10 staff) originally providing services in the field of CAD/CAE, dedicated as a supplier partner to support engineering activities in development of vehicles mostly in designing of passenger cars; offers services in BIW design and simulation]. The cluster deals with national and international R&D projects in the vehicle sector, from bicycles up to buses and trucks
8.	[Dr] Partner; an engineer and an entrepreneur for about 15 years	An SME (40 staff) developing innovative technical development and background services; construction of prototypes of alternative and hybrid vehicle models, preparations for manufacturing, series production
9.	Innovation Manager	Regional innovation agency
10.	Project and PR manager in the Regional Knowledge Centre for Vehicle Industry,	University - a cluster member
11.	Manager	A large supplier providing a broad range of services to the automotive industry in mechanical engineering
12.	Project Manager in the Competence Centre for Mobility Technologies	Research institute
13.	[Dr] a researcher and Project Manager	Research institute
14.	Project Manager for development projects; mechanical engineer; 10 years experience in the current consulting company, 10 years in another company providing engineering services to the automotive industry	A large (over 600 employees) specialized engineering and consulting company in the fields of electronics and information technology, developing software and hardware for electronic car units
15.	Manager Infrastructure Development for Fuel-Cell and Battery-Electric Vehicles; Previously 'started in the production of condenser powertrain, then worked on hybrid vehicles in the development centre in Michigan, US, then worked on software development for production vehicle which is	Major car manufacturer

	now sold in US'	
16.	[Dr] Cluster manager for two organizations	Regional automotive clusters
17.	[Dr] Project Manager; background in mechanical engineering and software services for the automotive industry, experience with the Regional Economic European Cooperation	A large (over 600 employees) specialized engineering and consulting company in the fields of electronics and information technology, developing software and hardware for electronic car units
18.	Head of Powertrain Engineering and Advanced Propulsion; 28 years experience in the current company; background in automotive test and development particularly powertrain emissions and fuel consumption.	A large service provider, operating as an independent test development facility for the whole of the automotive and related industries
19.	Founder and Managing Director; 41 years experience in the industry, started at 16 on a mechanical apprenticeship, worked for Lotus for 19 years managing a project team with more than 36 people, introducing 8 engines, which have resulted in 8 million cars in and around Europe and America.	An engineering design SME (42 employees) working closely with clients (OEMs globally) to develop new products and technologies in all areas of mechanical engineering; clients span aerospace, automotive, industrial, marine, renewables and oil & gas and others; active in the renewable energy sector through anaerobic digesting, solar PV and wind energy.
20.	Technical Director; also working as a consultant on some automotive based programs; technical lead on a major EV infrastructure development project; formerly Chief Electrical Engineer at Lotus for a period of 18 years; in the automotive business for a period of 32 years; also worked on some energy storage projects; Chair of the EDITC of the Institute of Engineering and Technology	An SME providing consultancy and project management for electric vehicle and infrastructure projects; focus on integrating transport and infrastructure (incl. infrastructure design and implementation), managing a very large scheme for electric plugging for hybrid vehicles and running a fleet of 45 vehicles on behalf and in close cooperation with a number of vehicle manufacturers.
21.	Director of Mergers and Acquisitions	Tier 1 Supplier, delivering climate systems, electronics, interiors, lighting, engine induction, powertrain controls, mobile applications; origin: 'the components manufacturing segment of Ford Motor Company'
22.	Manager Environmental Strategy; worked for another major car manufacturer in a variety of roles in Europe and around the world for 21 years	Major car manufacturer
23.	Professor, specialist in the programming and operation of CNC machine tools	University - a cluster member
24.	Process Improvement Consultant; 16 years experience in the automotive industry (multinational corporation environment) working as process engineer, production manager, plant manager. Participated in the cluster establishment and development.	Consultancy (SME) in the automotive industry for projects improvement or training for lean manufacturing, six sigma, quality, ISO/TS 16949
25.	General Manager	An SME (36 people); provides engineering services to OEMs in a variety of engineering disciplines in the development of electronic automotive products
26.	Project Consultant and Project Coordinator	Regional Development Agency and Regional Center for Innovation and Technology Transfer
27.	General Manager	A regional foundation – part of the regional cluster - that governs all the regional automotive industry and brings together all of the sector: the manufacturer; the components and support services companies; and the technological centre.

28.	Coordinator	Corporate university of the regional automotive foundation (see above); provides 'a more specific training, not only to respond to the needs of the present, but also to the future needs'; 'we do not only hire people, who are professionals in training, but who are professionals in the clusters, so that they could bring all their knowledge and experience'; the training is 100% adapted to the needs of the industry.
29.	Director of the Research Department at Automotive Technological Centre	[Automotive Technological Centre] (more than 300 people) is an initiative launched by the automotive sector. It provides local automotive companies with technological support for their activities. It has been established to bridge the gap between universities and industry.
30.	Partner and COO in an SME, many years of experience in the automobile industry	SME developing and installing the infrastructure for EVs

APPENDIX 2: DATA ANALYSIS - NODES AND 'CHILD NODES'

- Type of organisation
- Respondents' experience

- What is innovation
- Innovation in the car industry
    - Who innovates in the car industry
    - Drivers of innovation
    - Innovation in SMEs
    - Expectations for the future

- Opportunities for SMEs in the emerging sustainable transport
- Outsourcing
    - Expectations for the future
    - Barriers to a more intensive use of external suppliers
    - SMEs

- Collaboration
    - Importance of geographical proximity
    - Suppliers-clients relationships
    - Face-to-face communication
    - Problems
    - How it could be further facilitated
    - SMEs
- Networks

- Relationships or collaboration with other sectors (outside of the car industry)

- Relationships or collaboration with universities or research centres or other institutions
    - Benefits
    - Problems
    - SMEs

- Openness towards ideas that come from outside the company
- Willingness to share ideas or innovations with other companies

- Importance of geographical location
    - Importance of local contacts and interactions

- External support (incl. funding)
    - From Government

    - From Europe + Industry
    - From Regional authorities
    - For SMEs

- Need of further support
    - SMEs