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Beyond product architecture:

Division of labour and competence accumulation in complex product development

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ABSTRACT
This paper considers the trade-off between leveraging external sources of innovation by outsourcing design and engineering activities and the ability to develop internal product development competences. The trade-off arises because the division of labor within and across firms' boundaries has a crucial role in shaping competence development processes, especially because the division of labor also influences opportunities for *learning by doing*. In new product development projects, learning by doing appears to be both a key determinant of competence development and a difficult-to-substitute form of learning. While the division of development tasks is often considered as guided by product architecture, we show that by *decoupling* the decisions concerning the product architecture and the allocation of development tasks, firms can realize the benefits of outsourcing such tasks while developing new internal competences. Drawing on a longitudinal case study in the automotive industry, we also identify a new organizational lever for shaping competence development paths and for designing firm boundaries. This lever consists in alternating different task allocation schemes over time for different types of development projects. We show why this is a novel solution, what its underlying logic is, and how it enables alleviating the trade-off between the benefits of leveraging external sources of innovation and the opportunities for competence development provided by in-house design and engineering. We discuss implications for theories of organizational boundary design and innovation management.

Keywords: *innovation management, organizational boundaries, outsourcing, product architecture, modularity, new product development, template process, automotive industry, Fiat.*

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1. Introduction

A key question for firms that develop complex products is what type of competences they should retain in-house and what rationale they should follow in taking this decision. Since complex products such as automobiles, software, or PCs embody heterogeneous and rapidly changing technologies, involving external sources of innovation has become a necessity for innovating firms. Pressures to increase strategic flexibility and reduce development costs have made involving external sources of innovation even more attractive. Firms that produce complex products, such as Toyota, Microsoft, or HP therefore have to choose what technological competences to build up and maintain in house and which ones to outsource.

In considering this question, literature has used many different analytical lenses and different rationales, leading to different prescriptions. Transaction cost economics, the resource based view and the knowledge based view, to cite just a few, have developed thorough insights into this fundamental choice. More recent contributions have systematically considered the interdependences between vertical scope and competence development: in choosing their boundaries, firms not only influence the division of labor in their industry but also the trajectory of their competences development (Argyres, 1999; Teece, Pisano & Shuen, 1997; Jacobides & Winter, 2005; Teece, 2007).

Despite their differences, a common thread runs through these different literatures. It is represented by the assumption that the decisions concerning the product architecture (Baldwin & Clark, 2000) guide and constrain the decisions concerning the division of labor of innovation tasks within and across firms' boundaries (henceforth 'task allocation'). Given a particular decomposition of the product in different systems and modules (e.g. the safety and entertainment systems in a car or the motherboard and the storage system in a PC), firms decide which of those systems and modules to develop in house, and for which ones the development will be outsourced to system and module suppliers. This approach is particularly common in the innovation management literature, where product architecture is considered the dominating criterion for the allocation of development tasks (Baldwin and Clark, 2000). Several authors have argued that the structure of a product development organization "mirrors" the architecture of the product it develops (von Hippel, 1990; Henderson and Clark, 1990; Sanchez and Mahoney, 1996; Teece, 1996; Chesbrough and Teece, 1996; Fine, 1998; Baldwin and Clark, 2000; Sturgeon, 2002; MacCormack et al., 2006; Colfer, 2007). For instance, integral products require an integral organization that develops them, while modular products require a modular organization (Sanchez & Mahoney, 1996, Langlois and Robertson, 1995: 300).

The idea that product architecture and organization architecture 'mirror' each other has been disputed, however, both on empirical and theoretical grounds. From a theoretical perspective, some dissenting voices in the literature argue that the centrality of product architecture in guiding decisions such as task allocation, might have been pushed too far, pointing to the technological determinism inherent in emphasizing product architecture as a criterion for allocating development tasks (Sako, 2003). The occasion to accumulate empirical evidence was provided by the trend towards design and engineering outsourcing in the 1990's (see for example the predictions of Sanchez and Mahoney, 1996 and Sturgeon, 2002) that often leveraged product architecture as an enabler. As it turns out, for many firms outsourcing design and engineering tasks guided by modular product architecture led to problematic consequences, such a substantial decay of architectural knowledge and a subsequent loss of control over development projects (Lincoln et al., 1998; Takeishi, 2001, 2002; Chesbrough and Kusunoki, 2001). Empirical evidence indicates a gap in our understanding of the impact of product architecture on task allocation, in particular as a response to the question of what type of competences firms developing complex products should retain in-house and what rationale they should follow in taking this decision. For example, task allocation decisions can generate extremely negative consequences on a firms' ability to understand the components of a product and to integrate them into a system, leading to decaying project performance (Fine, 1998; Brusoni *et al*., 2001; Takeishi, 2002). The question is: given the need of leveraging external sources of innovation, how can firms avoid the negative consequences of outsourcing design and engineering tasks? How can firms assure they develop internal competences on new technologies? How can firms assure they also develop the competence to integrate new with old competences, and deploy both in developing new products?

When negative consequences of outsourcing design and engineering tasks materialize, the dominant response provided by management literature is to in-source, i.e. to reduce the level of design and engineering outsourcing. The inevitable outcome of such a reaction is, however, that firms embark in a difficult, time and resource consuming process of trial and error regarding the appropriate amount of design and engineering to carry out in-house (e.g. Mac Duffie, 2008). As shown below, this answer is unsatisfactory because in-sourcing substantially *trades off* the benefits of knowledge specialization, provided by leveraging external sources of innovation, with the benefits of accumulating competences for designing and engineering new products.

In the remainder of the paper, we not only provide an in-depth analysis of the reasons for such trade-off but also propose a response. We develop our insights on the basis of a 10-year research carried out at Fiat Auto (henceforth Fiat), a major player in the world automotive industry, Fiat's two research centers and 16 of its first-tier suppliers. We document and analyze the solutions that Fiat chose to respond to the need of integrating external sources of innovation, and how it was implemented. We claim that such an in-depth and long-term empirical research is particularly suited for providing a better understanding of the issues at stake. Our empirical data consists in interviews and company documents. The deliberate goal of the empirical research was to trace the evolution of the strategy and implementation of design and engineering tasks allocation of Fiat and its impact on the competence development process and competence distribution in the industry. Our focused research strategy allowed the observation of the full circle Fiat went through, all the way from complete vertical integration in design and engineering, to extreme design and engineering outsourcing. Oscillating between these two ends of the continuum is common for many firms. Extreme design and engineering outsourcing, however, led Fiat very close to failure. In particular, a specific circumstance makes our case especially interesting: when the problems triggered by outsourcing were acknowledged, Fiat was not able to pursue in-sourcing to acquire new competences for lack of time and financial resources. This apparently hopeless situation induced a major organizational change that represents a novel response to the problem. The most important measure adopted by Fiat was that Fiat did not any more try to get the 'degree of outsourcing' right but rather, focused on designing its product development organization. Recognizing that the allocation of development tasks does not have to be constrained by the product architecture, it employed an instrument (the template process) that permitted alternating between different task allocation schemes for different project types. This instrument had a systematic impact on firm boundaries – importantly, it allowed both aligning the knowledge and task boundaries more closely and making sure that Fiat's knowledge exceeded the knowledge needed for the immediate tasks at hand (Brusoni et al., 2001), but without changing its vertical scope. Therefore, Fiat shifted the focus of its efforts from deciding about the degree of outsourcing development tasks to deciding about its organization design, which allowed it to align its knowledge and task boundaries but without a massive increase in its engineering staff. This finding sheds light on several aspects of crucial relevance to innovation management and firm boundaries design.

Concerning the link between the division of labor and competence development in complex product innovation, we show that design and engineering task allocation has a major impact on competence development as it decides on the allocation of learning opportunities. As Henderson & Clark (1990) have argued, task allocation and the following decisions concerning the organizational structure, constrain learning processes and thus the firm's ability to develop and acquire competences, including new competences. We add further empirical details on the drivers of such learning processes showing why and how system integrators benefit from *learning by doing* processes. We show that this form of learning is necessary to maintain a full grasp on project and product performance. These insights extend but also partially revisit existing literature on system integration (Brusoni et al., 2001, Takeishi, 2001, 2002).

Our work also contributes to a better understanding of the logic underlying the division of labor within and across firms' boundaries. We submit that the literature still overvalues the role of product architecture in taking decisions concerning design and engineering task allocation and question the tight link between product architecture and organization architecture. On this point, our work adds to previous literature that has criticized the emphasis on the role of modular product architectures in the decision of outsourcing development tasks (Brusoni, 2005, Fixson and Park, 2008), to the debate of modularity (Baldwin & Clark, 2000), to the literature on managing innovation of complex products (Hobday et al., 2005), and to the innovation management literature more generally.

Finally, we offer insights that can contribute to existing theories on organizational boundary design. We observe that firms can influence competence development processes without leveraging vertical scope, thus adding to a recent turn in boundary design research that has provided empirical evidence to advance the notion of firm's boundary beyond the traditional emphasis on vertical scope (Harrigan, 1984; Heide, 2003; Jacobides & Billinger, 2006; Rothaermel et al., 2006; Parmigiani, 2007; Parmigiani & Mitchell, 2009). We also add a new firm boundary design principle – alternating between different task allocation schemes over time. Moreover, we identify an organizational instrument for implementing that principle, i.e., alternating between different project types (template and derivative projects). Each project type uses a different task allocation scheme. We can thus expect a boundary change when that design principle is employed.

In the next section, we first review previous research on the issue. Section three then explains the method applied in the empirical research, while section four describes the empirical findings. Section five discusses the findings and presents the main implications of our research. Section six concludes the paper.

2. Previous research

2.1 The dominant approach to division of labor and task allocation in innovation management

The dominant stream in the innovation management literature currently turns around the concept of 'design rules' (Baldwin and Clark, 2000). Design rules are made up of the product's architecture, interfaces, integration protocols and testing standards (Baldwin and Clark, 2000: 77). They capture 'architectural knowledge', i.e., knowledge about how to decompose the products into components and how they are linked together and integrated into the final product (Henderson and Clark, 1990). Design rules play an important role in determining the division of labor of innovation tasks and their allocation to different actors, and also in explaining industry evolution. One of the most prominent features of research on design rules is that it revolves around the concept of modularity (Brusoni and Prencipe, 2006: 179; Ulrich, 1995; Sanchez, 1997; Baldwin and Clark, 2000). Modularity refers to a decomposition scheme that assumes independence between modules, with interdependences confined within modules' boundaries (Baldwin and Clark, 2000) [1]. Some parts of the literature have suggested that modular product architecture can serve as a good map for the decomposition of the development task and task allocation (Sanchez and Mahoney, 1996; Baldwin and Clark, 2000). Product architecture therefore is used as the task decomposition scheme.

[1] A somewhat different but also influential definition of modularity has been given by Ulrich: key to modular architectures is a one-to-one mapping from functional elements to the physical components of the product, which specifies de-coupled interfaces between components (Ulrich, 1995: 422). We follow Baldwin & Clark's (2000) definition here. See Campagnolo and Camuffo (2009) for an overview and a discussion on the concept and many definitions of modularity.

Modular task decomposition has powerful implications on make or buy decisions. Firstly, *modular decomposition* (with standardized interfaces) *provides new possibilities for outsourcing*. Standardized interfaces generate 'market modularity', i.e., a situation in which 'suppliers can opt to provide some portion of the system, without fear of disrupting other parts of that system' (Chesbrough, 2003: 179). Modular decomposition is supposed to have beneficial effects on coordination as it enables independent problem-solving for each module, while standardized interfaces assure that all modules will fit together without the need to bring about such a fit by organizational coordination. These features make it much easier to draw on the competences of external suppliers and other partners in the innovation network (Sturgeon, 2002). Secondly, *modular decomposition enables knowledge specialization*. As Sanchez writes, 'the standardizing of component interfaces based on the firm's current architectural knowledge largely decouples architectural knowledge-based processes from the component-level knowledge used to develop specific component design during product development' (Sanchez, 2003: 382). Modular product architecture thus enables specialization in architectural knowledge for the Original Equipment Manufacturer (OEM).

The literature on systems integration has extended this idea. As Hobday *et al*. (2005: 1128) write, what is typical of systems integrators is that 'the lead firm moves away from an in-depth control over component design and manufacture to the systems integration knowledge and skills needed to integrate the modules produced by others in the supply chain'. In other words, architectural knowledge holds the key to successful systems integration. The dominant perspective in the literature thus gives strong emphasis to product architecture, as a guide for what design tasks to outsource.

2.2 The limits of outsourcing: the role of component specific knowledge

Empirical research has identified limits to some of the key ideas of the dominant approach, however. The first limit arises from incomplete decomposability of complex products; they often are nearly, rather than fully, decomposable (Simon, 1962). This difference is important because it is impossible to decompose such products so that no interdependences at all will remain between the chunks into which the product is decomposed. Empirical research has found that in order to address the remaining interdependences, component-specific knowledge is required (Takeishi, 2002). Component-specific knowledge also matters for a second reason, i.e., because product technologies can change (including the interdependences between parts of the product). Product architectures need to be adapted over time to counter the risk of being stuck with an inadequate decomposition scheme (resulting in not addressing the remaining interdependences and thus, loss of control of product performance) (Chesbrough and Kusunoki, 2001; Brusoni *et al*., 2001). Again, in order to be able to adapt decomposition schemes according to interdependences, component-specific knowledge is required (Brusoni, *et al*., 2001; Takeishi, 2002). Thirdly, empirical studies in the Japanese automotive industry have concluded that component-specific knowledge is particularly important in the case of technological newness (Takeishi, 2002). The reason is that new technology is less well-understood and thus, an understanding of the interdependences with other components of the system can only be developed through strong knowledge of the component-specific technology of the other components. Brusoni *et al.* (2001) make a similar argument for the importance of component-specific knowledge by pointing to the uneven rates of development in the technologies on which the firm's products rely, and unpredictable product-level interdependences. Brusoni *et al.*'s (2001: 597) argument is that having component-specific knowledge 'in excess of what [firms] need for what they make enables firms to cope with imbalances caused by uneven rates of development in the technologies on which they rely, and with unpredictable product-level interdependences'. In other words, component-specific knowledge holds the key for avoiding some of the main problems in developing complex products. All these arguments highlight the role of component-specific knowledge in preventing decaying project performance due to problems in integrating systems (which involves building architectural knowledge) and designing product performance on the level of the car as a whole.[2] In order to avoid this problem, it is essential that firms nurture their component-specific knowledge (Fine, 1998; Takeishi, 2002). One of the most important means for nurturing this knowledge is to maintain a certain level of *direct* involvement in the design and engineering of components and systems by innovating firms (Takeishi, 2002). Such involvement provides occasion for learning by doing, particularly important for acquiring tacit knowledge (Polanyi, 1958; Nonaka and Takeuchi, 1995), and for accumulating competence, i.e., being able to apply knowledge (Orlikowski, 2002).

2.3 Tensions in the different approaches to task allocation

The empirical research described above evidences a trade-off. On the one hand, there are the benefits of knowledge specialization. In the case of modular product architecture, some firms (e.g. "system integrators") can specialize in architectural knowledge, while other firms (e.g. suppliers) can specialize in component-specific knowledge. Modular product architecture (with standardized interfaces) also facilitates allocating the development of modules to suppliers. Therefore, it also becomes easier to draw on outside sources of innovation. On the other hand, carrying out design tasks in-house has the benefit of providing learning opportunities (through learning by doing) regarding component-specific knowledge, which nurtures component-specific knowledge. Table 1 provides a summary.

Table 1 HERE

[2] Lack of component-specific knowledge can trigger a second, related set of problems. An inferior level of component-specific knowledge relative to suppliers' component-specific knowledge can lead to dependence on suppliers for such knowledge (Fine, 1998), giving rise to problems with governing suppliers due to increased information asymmetries, a shift in bargaining power and higher transaction costs. In this paper, we focus on the problem of loss of control of product performance, not on the implications for governance.

Apparently, these two alternatives are diametrically opposed. One can either carry out a task in-house or allocate it to a supplier. Depending on this decision (and the allocation of the learning opportunities), either the benefits of knowledge specialization (in architectural knowledge) or of nurturing component-specific knowledge will accrue. It is important to note that once we acknowledge such a tension, to attain the benefits of involving external sources of innovation seems a non-trivial challenge. In the case of products that are not decomposable in a fully modular way, the possibilities of leveraging external sources of innovation are thus constrained. In fact, in the case of products that cannot be modularized to some degree, in circumstances of technological newness, technological change, uneven rates of change of components, or unpredictable product-level interdependences, firms are advised to maintain a broader knowledge base than the one required for the actual products and thus, to keep the pertaining design tasks in-house to avoid the problems identified in the literature (Brusoni et al., 2001)[3].

It is worth noting that the circumstances identified above are common, and indeed, characteristic, for many industries. Moreover, to implement the advice, a firm would need to build up a huge staff in order to cover the increasing range of technologies incorporated in some products. Firms in the circumstances identified above are thus left with no option other than to attempt some fine-tuning of the degree of outsourcing of

[3] Of course, adapting the allocation of innovation tasks (e.g., vertically integrating) or the product architecture is not the only way to respond to the trade-off. One could also manage it by relying on organizational measures such as different forms of networked innovation and relational practices that OEMs should implement in order to maximize the operational benefits (cost, quality and lead times) linked to the involvement of suppliers in the OEM's NPD (New Product Development) process (covering such means as the use of contracts, ICT tools, joint teams, and co-location of engineers) (Helper, 1991, Lamming 1993, Smitka, 1991, Nishiguchi, 1994, Helper & Sako, 1995, Helper et al. 2000, Sako, 2004). Fine and Whitney (1996), however, show that even in the case of a partnership with suppliers, the OEM should never be 'dependent for knowledge', i.e. it should hold some component-specific knowledge. Helper et al. (2000) arrive at similar conclusions, emphasizing the importance of relying on 'learning by monitoring' to enhance 'pragmatic collaborations' as a way for integrating external sources of innovation. Learning by monitoring does not work, however, if the OEM lacks component-specific knowledge. This once again supports the argument that the OEM should retain some component-specific knowledge in-house in order to manage supplier relationships successfully. There seem to be no ways around the trade-off.

design tasks to suppliers, in order to balance the two antagonistic forces. For lack of more precise advice, this is likely to be implemented in a trial and error process. Summing up research on the issue, MacDuffie (2008: 42) argues that firms developing complex products such as cars should 'develop the capability to experiment and move activities back and forth across organizational boundaries'.

We believe this advice on how firms should manage the tension between product architecture, boundary design and competence development is reasonable but not satisfactory, both from a managerial and a theoretical perspective. Given the uncertainty that is inherent to innovation activities, accepting the necessity to rely on trial and error in defining the boundary of the firm means to accept that the fate of innovating firms is left to serendipity, at least in the short term. A firm that has decided to leverage the modularity of electronic hardware in the product architecture of a car, would, for instance, outsource electronic hardware components to suppliers and, de facto, not design and manufacture such electronic hardware in-house. This was exactly what happened to some car makers in the nineties (our interview at Fiat, 1998). This strategy seemed to work at the beginning. However, as the use of electronics was spreading in subsequent generations of cars, car makers realized that electronic hardware and software were turning the car into a more integral product. Thus, they needed to develop in-house competences on electronics, but also competences regarding the integration of electronics systems in the overall product. However, since in-sourcing takes time and money, many car makers experienced a lot of problems in integrating electronics in the mean time, with negative effects on their product performance and customer satisfaction. Product architecture, and the assumption of its modularity, turned out a bad guide for deciding how to allocate design tasks. Moreover, the consequences of the error and the resources (time, money and competences) needed for a new trial can leave firms with huge problems. We decided to direct our research to the question how firms can enable leveraging external sources of innovation while avoiding the negative consequences of relying on design and engineering outsourcing. Our particular interest is in how firms can assure they develop internal competences on new technologies, including the competence to integrate the new technologies into the product.

The next two sections describe how we gathered our data, and the main findings.

3. Method, unit of analysis and sampling

Given the exploratory nature of the research question, we chose the case study method. To describe the evolution of product development competences in the case of design and engineering outsourcing, we present *longitudinal* evidence (Eisenhardt, 1989, Pettigrew, 1990, Yin, 1994) on the New Product Development (NPD) process of a technology-intensive firm developing complex products. In particular, we focused on: (1) the decisions (and the rationale applied in making those decisions) concerning the allocation of innovation tasks along the value chain, with specific interest on the outsourcing of design and engineering tasks to suppliers; (2) the effects that task allocation produced on the firm and its suppliers' knowledge and competence base; and (3) the firm's organization for product innovation.

We chose the sampling approach following the argument that "cases are selected because they are particularly suitable for illuminating and extending relationships and logic among constructs" (Eisenhardt and Graebner, 2007: 27). The sampling process was based on two steps. First, we chose to gather our empirical observations in the context of the automotive industry. The automotive industry is one of the most complex industries in terms of technologies and players involved in innovation processes. Moreover, in the nineties, the auto industry went through a paradigmatic shift in the design and engineering of cars due to the broad introduction of electronics into the vehicle's main systems (e.g., the power train system) (Maxton and Wormald, 2004). This circumstance, as exemplified below, provided the research opportunity of investigating design and engineering outsourcing at a key turning moment for the industry. Moreover, the auto industry offers an extensive variety of situations concerning the effects of the product architecture on the division of development tasks and their coordination (Takeishi and Fujimoto, 2003).

Second, we selected the carmaker: Fiat. Headquartered in Italy, Fiat is a multi-brand company whose product range covers all market segments, from luxury to small cars, from trucks to Formula 1 racing. In 2009, Fiat acquired a significant stake in Chrysler, one of the American "big three", re-gaining the role of a major player in the industry. Fiat, a previously fully vertically integrated company (as far as design tasks are concerned), became an extreme outsourcer and subsequently decided to once more reverse its task allocation scheme. These changes were observable within a time-span of only 10-15 years.[4] The description of these changes and the in-depth analysis of their triggers were well-suited to address our research questions. Finally, both authors are bilingual and gained privileged access to a company whose managers did not generally speak English.

We also included in the sample Fiat's two research centers, as well as 16 first-tier suppliers belonging to Fiat's value chain. Suppliers were chosen on the basis of the following criteria: relevance in terms of contribution to Fiat's development activities, heterogeneity of their industry, technologies, dimension, ownership, and nationality, and their independence from Fiat.

Two main data collection methods were used. The first was the study of archival sources to define the characteristics of the sector and the history of the selected companies. The second involved extensive semi-structured interviews with managers in the selected companies and industry experts. Such data gathering enabled triangulation between the quantitative and qualitative data, and between what managers belonging to different organizations had to say on the same units of analysis. Moreover, the

[4] The case, therefore, offers at least as much insight into industry evolution as the electronics industry – the paradigmatic example of an industry where changes are observable in a relatively short time span (Fine, 1998). This point is a matter of interest in itself and makes the case intriguing for analyzing industrial and organizational change. For this reason we believe our sampling choice seizes, as good single-case research does, the "opportunities to explore a significant phenomenon under rare or extreme circumstances" (Eisenhardt and Graebner, 2007, p. 27).

sample also addressed the research question from both Fiat and supplier sides. This is a distinctive characteristic of the present study.

Between 1997 and 2008, we carried out 77 interviews with managers and engineers belonging to 18 different companies, totaling about 145 hours (see the appendix). All interviews were taped and transcribed. Particularly important for the purposes of this paper is the data gathering campaign of 2006-2008.

Our inferences from the case were drawn in a complex triangulation process that involved longitudinal and cross sectional comparisons. We observed the same unit of analysis, the development process of a new vehicle, from the angle of the car maker, its research centers and its suppliers, and we saw them evolve over a considerable period of time, during which several reorganizations occurred. The level of granularity at which we observed was that of the car model development project. This perspective fits well with the nature of the research questions.

Interviewees were chosen according to the relevance of their roles in Fiat's innovation process and its first-tier suppliers. We deliberately involved people in charge of strategic decisions as well as personnel with more operative roles. In this way, we combined the perspectives of top management with micro-level details about the execution of the NPD process provided by people involved in the execution of the NPD process. To quote just a few, at Fiat we interviewed the Chief Technology Officer, the Senior Vice President of Human Resources, the Vice President of Product Portfolio Management (all three were members of Fiat's top-level steering committee), the Director of Vehicle Concept & Integration, four of the five vehicle line executives (i.e. the engineers responsible for the development of cars in each segment), and the staff functions of the Design and Engineering division. We thus covered most of the top managers leading the product development process. This set of interviews provided us with a comprehensive picture of Fiat's perspective. Regarding the suppliers involved in the study, we interviewed 'account managers' (responsible for the commercial relationship with Fiat from the pre-offer phase until the end of the project) and 'project managers' (responsible for component or system development). In some cases we also interviewed the supplier's CEO or plant managers (for a list of the interviewees see the appendix). The people we interviewed at Fiat and at the suppliers' frequently dealt with each other on a daily or weekly basis. In these cases, there was a solid possibility for data triangulation, strengthening our interpretation. Overall, given the nature of the research questions, our investigation greatly benefited from this double perspective; much of the information concerning the real competences of Fiat and suppliers in performing design and engineering tasks, the complexity of system integration tasks, the inter-organizational routines of product development, and the overall complexity of organizing distributed innovation could not have been gathered had we relied solely on either Fiat's or the suppliers' point of view.

Our study is subject to limitations. Our sample could be biased by the fact that we only interviewed companies located in one country, and belonging to one industry. However, the vast majority of companies in the sample are local branches of multinational corporations. Moreover, technological heterogeneity counterbalances industry specificity. As shown in the appendix, the companies analyzed belong to completely different sectors (from pure mechanical engineering to electronics, engineering consultancy, and rubber). Exposure to multiple technological domains, product development priorities, communities of practice, technical complexity, and system, component and module integration characteristics during the research process provided a source of learning and contributed to conclusions that are well informed and empirically grounded (although they can, of course, be considered neither normative nor generally applicable).

4. Empirical findings

4.1 Outsourcing and competence development

In the nineties Fiat decided to pursue a strategy based on the allocation of a growing responsibility for the design and engineering of sub-systems to global suppliers. The main motivation that led Fiat to an outsourcing strategy was to reduce the assets invested in R&D facilities and, at the same time, to leverage the suppliers' state of the art knowledge, especially on new technologies such as electronics. Following a standard product decomposition scheme, the allocation of design tasks along the value chain (outsourcing) mirrored the distribution of competences in the industry. For example, the development of the occupant safety system (seat belts, airbags, steering wheel, etc.) was completely outsourced to specialized suppliers and so were the brake system, the suspension system, the sealing system, the air conditioning system, the dashboard system, etc. The logic that guided Fiat in the outsourcing of design and engineering tasks to suppliers was substantially determined by the competences that suppliers could offer. In turn, supplier specialization and the overall industry structure mirrored the evolution of the product architecture, i.e. the scheme according to which the product was decomposed in sub-systems.

The outsourcing strategy had some important consequences for the organization of Fiat's new product development process (on this point see [self-citation]). At the central level (i.e. Fiat's two major research centers) Fiat's engineers maintained a certain level of involvement in some design activities related to the systems that had been outsourced in order to monitor their long term developments. At the project level, however, suppliers' engineers replaced Fiat's engineers in the design and engineering of these sub-systems. New product development teams became permanently staffed with both Fiat's and suppliers' engineers. For every development project Fiat applied the same task allocation scheme and staffing procedure, just fine-tuning the level of involvement of each component and system supplier according to the type of product under development (car segment, car novelty, etc.) (on this point see [self-citation]). More specifically, the only variables Fiat acted on when starting a new development project were the numbers of suppliers bidding for a given system development, the degree of design carry over that was permitted, the level of system performance, etc. Fiat's engineers' role in the NPD process was de-facto confined to the management of vehicle development projects. In fact, Fiat carried out the design and engineering of only very few components and systems[5]. Fiat gave up most of component and system development, retaining the responsibility for the definition of the product architecture, most assembling activities, engine development and little more. The average percentage of engineering design carried out by suppliers reached a peak of 85% of the value of a vehicle.

The Director of Vehicle Concept & Integration reported to us in 2006 that Fiat pretended it could be substantially detached from certain component and systems technologies and focus primarily on 'architectural' know-how. The idea of systems integrator that Fiat applied was coupled with the idea of modularity, and sometimes interpreted in the sense that the system integrator should have the competence of integrating systems as its core competence. Accordingly, Fiat tried to build and maintain architectural competence, privileging it over other competences such as knowledge about component technologies (as exemplified by the high level of outsourcing). To summarize, Fiat focused on system integration as its core competence and, at the same time, used product architecture as a guide for outsourcing.

This strategy, however, turned out to be problematic in practice. The roots of Fiat's problems are complex and, in many respects, their detailed description falls outside the scope of this paper (on this point see [self-citation]). What is important to note here, is that Fiat's decision to massively outsource design and engineering to suppliers came in a moment in which the engineering of some key systems was beginning to involve new technologies, often exogenous to the automotive industry. Among these technologies, electronics (hardware and software) was by far the most relevant in the nineties: its introduction contributed to re-shape most of engineering principles in the industry (Maxton and Wormald, 2004).

Our interviews confirm that the increasing recourse to electronics produced huge consequences both on the nature of design activities and

[5] Fiat had retained its competences and responsibilities in setting the vehicle marketing concept and the related technological choice. This phase of the NPD process, however, is antecedent to the phase we are describing here.

their partitioning. The nature of design activities changed as by introducing the software component into systems, systems could now adjust to feedback. The example of the changes brought by electronics in the design and engineering of the engine and the exhaust system can help clarify this key point. Before "electronics" and in the early stages of the engine electronic control era, the fuel and air intake system, the engine and exhaust system were usually designed sequentially. This significantly impacted the design and engineering of these systems, in that each component was developed by one group of engineers in a sequential fashion. Upon introduction of electronic control units (ECUs) and new injection systems, oxygen sensors were also introduced to enable feedback-based fuel metering. Such sensors collect information about injectors and the functioning of the catalytic converter, to be forwarded as feedback to a control system that enables the proper fuel metering action after having interpreted the information through a software. By introducing both oxygen sensors and a software capable of changing the working conditions of the hardware, the whole system became more tightly coupled.

The diffusion of electronics also generated important consequences in terms of task partitioning, a byproduct of the design and engineering skills that engineers need to have to develop electronic systems. The carmakers' engineers were forced by the new design logic to dominate the knowledge of the whole system and of its components and develop a higher level knowledge of how the system works. As seen in the previous example, before electronics applications in cars reached a maturity stage, the design and engineering of the three-way-catalytic converter could be decoupled and easily outsourced to suppliers. The relative component specific knowledge necessary to develop the catalytic converter was not particularly relevant for the carmaker as the optimization of the system was realized "locally", i.e. for each specific component. After the introduction of electronics in the car, this approach was not feasible anymore (interview with an industry expert, 2009).

The main consequence of the increasing use of electronics in cars thus was to make the car a more integral product. As explained above, in the product itself technical interdependences between systems and components increased, as did the organizational interdependences between the people who designed those systems and components. That circumstance reinforced the consequences of Fiat's decision to step up design and engineering outsourcing. The main problems Fiat experienced are reflected well in the following quote:

> "It is naïve to believe you can integrate a system without holding an in-depth and detailed knowledge of the components that are going to affect the performance of the whole car. Managing each system performance does not, in fact, automatically result in effective system integration. The performance is the ultimate objective, not systems. ... We realized you cannot integrate the performance of components you know very little about ... if you have never designed a component or a system it will be very difficult to understand the subtle interactions with the rest of the vehicle. (Director of Vehicle Concept and Integration, 2006)".

One of the crucial insights by the Director of Vehicle Concept and Integration was that understanding interactions between systems in the car was the key problem. As argued above, such interactions had become more important because of the increased integrality (and thus, the increased interdependences) of the product. The quote by the Director of Vehicle Concept and Integration identifies a specific source of the problem, i.e., a substantial lack of knowledge about the components and systems at the project level[6].

Why was that? The Director's quote puts it to the point by diagnosing that it is *actually designing* a component or system that matters. It indicates that it is one thing to have the abstract, underlying knowledge about the functioning of a component (for instance, a board computer). It is a different thing to provide guidance to the supplier of the board computer in integrating it with the other systems in the car during a development project.

The difference comes to the fore quite clearly when considering the new product development project as the unit of analysis and gathering data at this level of granularity, as we did. A large part of the task of developing a car model consists in carrying out design and engineering of systems and components, or if that is outsourced, guiding the suppliers that do it. Fiat engineers that were staffed in new product development projects (consider that overall there were 3200 people working in parallel on the NPD projects in Fiat) had a very vague idea of how to design and engineer the components they had to integrate into the vehicle under development (including many components designed by suppliers). In the daily interaction with suppliers in the development projects, this resulted in a substantial hand over of control to suppliers' engineers. Describing the disadvantage of Fiat's engineers, an engineer at a supplier told us "if you have never designed a complex component you will never understand how we do it and really control what we do".

As the quote by the Fiat Director of Vehicle Concept and Integration shows, he seemed to endorse this vision. Moreover, he underlined that the introduction of electronics was among the major reasons for a change of the

[6] It is important to note that this quote contrasts with the picture we gathered from interviews with staff in the R&D centers. In those centers, there were indeed people with in depth knowledge about components and systems. Thus, considering Fiat as a whole, it would have been correct to say that Fiat had in-house component-specific knowledge, and that some form of knowledge overlap between Fiat and its suppliers exited even during the period of radical outsourcing. There were indeed skilled engineers with sufficient competences to master the whole range of technologies employed in cars and, hence, potentially able to guide first tier suppliers. Yet again, we know that the problem persisted nonetheless.

vehicle's architecture towards a more integral form. This, in turn, contributed to make the knowledge related to each component even more relevant for designing the whole system. Fiat's managers, hence, realized that acting as a system integrator without underlying component-specific knowledge was just not possible anymore; without such underlying component-specific knowledge, systems integration competence was difficult to achieve. The problems first materialized as difficulties in achieving the desired product performance. These technical problems eventually resulted in costly re-design. The re-design process was further complicated by the need to coordinate design and engineering efforts with suppliers and negotiating the cost implications of re-design. This also resulted in longer NPD lead times.

Most of the *product* performance problems were usually fixed by the time the product was launched on the market. However, the substantial lack of system integration competences resulted in poor *project* performance: the cost of re-design and re-engineering products and delays of product launches were major reasons why these products had difficulties in breaking even.

4.2 Outsourcing and performance

Fiat's experience and its interpretation of that experience allowed us to better understand what precisely is at stake when design and engineering outsourcing decisions are taken. Fiat was pushing outsourcing far, and in order to do so was relying on modularity. Figure 1 plots this relationship. The diagonal expresses the 'constrained' link, as hypothesized in the literature, between product architecture and task allocation: in-sourcing would be 'unnatural' with a highly modular product architecture, while outsourcing would be more difficult in the case of highly integral architecture. Interestingly, Fiat's approach was completely consistent with the prescriptions in the literature.

Figure 1 HERE

What were the consequences of this approach? As described, in Fiat's case outsourcing of design tasks did not necessarily lead to poor system integration. Fiat, in fact, managed to achieve the desired *product* performance in most cases. The products it launched on the market were, in fact, eventually successful. However, Fiat's outsourcing strategy was the main cause of poor *project* performance. While product performance refers to the technical performance achieved by the new product, project performance refers to the costs and the time required to develop a product with certain technical performance characteristics (product performance). Our interviewees helped us clarify that technical product performance and project performance are very much intertwined in practice. Given that Fiat mainly based its NPD process on supplier involvement, most energies were devoted to managing the development work of external suppliers. However, Fiat's lack of technical skills on component technologies resulted in fuzzy and incomplete specifications to suppliers in early stages of the development process. Insufficient specifications often led to costly re-design that, in turn, resulted in longer lead times and overall poor project performance. A very high degree of design outsourcing thus did not alter system integration capabilities *per se*. However, extreme outsourcing led to difficulties in obtaining the desired product performance at the expected cost, lead times and quality levels, resulting in project performance that did not meet expectations. Figure 2 plots the relation of outsourcing and performance.

Figure 2 HERE

Figure 2 also helps make a further step ahead in our understanding of the Fiat case. Fiat realized that the product architecture was more integral than initially thought. As a consequence Fiat resisted attempts to modularize it further and eventually reverted its approach. Pursuing a modular strategy coupled with a high degree of design outsourcing would, in fact, have required Fiat to make compromises regarding the levels of product and project performance.

Fiat realized it had a performance problem caused – at least to some degree – by its extreme outsourcing strategy and its attempt to pursue a modular design strategy for a product whose architecture is substantially integral[7]. It had to react.

4.3 Fiat's reactions to competence erosion

4.3.1 The limits of in-sourcing

Once Fiat recognized and acknowledged it did not have all the competences required, in order to remedy this situation, it started hiring staff knowledgeable in the areas where it had lost competences, and began to emphasize internal development and learning on the new technologies. It also intensified personnel rotation between its research centers (CRF and Elasis), the Engineering and Design department internal to Fiat and Magneti Marelli, a Fiat owned supplier with some expertise in electric and electronic systems. It now outsources about 50% of the design and engineering of new systems (down from 85%). However, there were some important limitations to this reaction to the problem. Fiat's manager in charge of Systems and Vehicle Integration put it succinctly:

> "We should have reversed our strategy by integrating back competences that we had lost. We had two problems, however, no money and no time" (Manager in charge of Systems and Vehicle Integration, 2006).

[7] The diagonal in this case represents the optimal frontier given the product architecture characteristics. Fiat could not increase its performance without in-sourcing some component specific knowledge. MacDuffie's study (2008) on the limit of modularization in the auto industry shows the close relationship between task allocation and performance. In particular, MacDuffie observes that 'persistent integrality' represents a major constraint for the choices automotive firms take on boundaries, which is confirmed in our case.

Due to insufficient financial and human resources, Fiat's managers did not have the option to completely in-source all the competences that were now considered necessary (competences it previously had but that eroded, and new ones, such as competencies in electronics). Fiat thus could not move up the curve of figure 2 by in-sourcing design and engineering activities. Fiat's management realized they could overcome this constraint if they reconsidered the current way of allocating resources to development projects, and how tasks were allocated. The next section describes the changes that Fiat implemented.

4.3.2 A new outsourcing logic: the template process

Why was Fiat induced to adopt a new task allocation scheme? And what are the distinctive characteristics of its new system? In the previous new product development process, Fiat outsourced the same development tasks for all its new product development projects. For instance, dashboards were always outsourced and Fiat did not design dashboards in-house for any of its car models. When Fiat realized it had to in-source competences on key components such as suspensions, dashboards, electronics, etc., it did not have sufficient engineering resources (people) to staff on each single project. In addition, market trends called for a higher number of new product introductions. It is at this point that the idea of developing a novel NPD process started taking shape.

With the new process, in fact, Fiat deliberately decided to assume the responsibility for designing all key systems in *selected* projects. In what follows we refer to these projects as *template projects*, to the vehicles developed in these projects as *template models*, and to the novel organization of Fiat's NPD process as *template process*.

In the process of developing a template model, Fiat continues to involve system suppliers, but is now fully responsible for the engineering and the application of all of the most relevant systems in the vehicle. Figure 3 shows the new outsourcing logic for each development project (the number of projects is illustrative). On the left panel, the figure describes how Fiat used to carry out the design and engineering of a limited number of components and systems before. This resulted in a situation in which Fiat led the development projects of all products under development, but designed and engineered only selected types of components and systems, the same for each product under development. On the right panel, the figure shows that Fiat now fully develops, i.e. designs and engineers, all the most important systems of a template model. Derivative product development projects can then either be led by Fiat or by engineering suppliers, and the detailed design and engineering of components and systems of the derivative models can be allocated both to suppliers and to Fiat itself.

Figure 3 HERE

Please note that in Figure 3 we present the extreme case. For derivative projects, not just the engineering and design of systems but also the complete integration of these systems in the vehicle is outsourced to engineering suppliers. The engineering suppliers, rather than component and system suppliers, are responsible for integrating functions within the vehicle[8]. Having formulated templates, Fiat realized it was possible to outsource the complete development of entire vehicles for derivative projects. Our interviews and data indicate that the move towards the new logic held the key to economize on the overall amount of resources invested in the NPD process and, at the same time, achieve unprecedented performance in *all* NPD projects (see details below).

Given such a possibility, a set of practical questions arises though. What precisely is a template model, and what is the difference between a

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[8] Engineering suppliers provide engineering services to OEMs according to the car makers' contingent needs. Their contribution ranges from simple CAD calculations to the development of turnkey projects, even comprising the design and engineering of entire vehicles. The template process leverages the services of engineering suppliers much more than in the past, as the typology of vehicles they develop is completely different: no longer just niche products with small volumes but rather, mass production models with high expected production volumes that have a key position in OEMs' product portfolio. This makes a huge difference in terms of the importance of the project for Fiat's overall success, and the engineering complexity intrinsic to the project.

template and a derivative project? What is the difference between a template model and a "platform"? How does the role of first-tier suppliers change? How does Fiat manage to develop components in-house without major in-sourcing? How does Fiat decide which component technology is key? What is the impact of the template process, i.e. the novel NPD process, on NPD performance?

When compared to the old task allocation scheme, the main difference is that for template models, the integration of components and systems that affect the product performance Fiat considers key is managed completely by Fiat. More specifically, in a template project Fiat develops a new car model that, when launched on the market, usually embodies state of the art technological solutions (template models, hence, are anything but abstract exercises or a form of shadow engineering). Template projects, moreover, have the additional goal to develop a bundle of archetypical solutions to be leveraged on derivative models. This creates the possibility of outsourcing 'derivative models'. Some examples of design archetypes are the architecture of the suspension for small cars, the layout of the panel instruments for sports cars, or the design of the sealing system for luxury cars. In the occupant safety system, for example, an engineering archetype would be the layout and its implications for the interactions between the chassis, the bonnet size, the engine, the seats, the airbags, the seat belts, etc. for a specific car architecture, e.g. a small car. A template model thus consists of a set of archetypical solutions regarding the most important components and systems and the way they interact. Such archetypical solutions then become standards that characterize products in a given market segment[9]. In other words, during the development of a template model, engineers develop engineering solutions that are supposed to be reapplied to other models for some time, as long as technology does not call for a new archetype. In a metaphorical sense, this set of design archetypes defines a model that becomes the 'ancestor' which then gives rise to a family of variant models (henceforth 'derivative models'). Following a

[9] Of course, these standards are closed standards, i.e., they are specific to Fiat.

template means that every time a derivative project is started within a segment, engineers will have to apply the template solution from the template model (the segment's 'ancestor'). This is done either by carrying over the same components or, in the case of a physical misfit, by designing the new components by scaling the archetypical solution up or down. Please note that scalability is a feature that distinguishes templates (archetypical solutions) from platforms understood as, for instance, standardized underbodies for cars. Nobeoka and Cusumano (1997: 172), for instance, describe a car platform as consisting of the floor panels, suspension system, firewall, and rocker panels. Of course, by using the template process Fiat also pursues the goal of increasing component and system standardization. The main systems and components of a template model (what the literature would describe as a product platform) are indeed designed to be carried over to derivative models. (At the moment of the interviews Fiat was planning to go from 19 product platforms in 2006 to 6 in 2012, and from 1.7 models on each platform to 3.7. Today, Fiat has a similar plan for Chrysler, to go from 11 product architectures in 2010 to 7 in 2014 and from 1.9 models per platform to 3.0. Overall, the Fiat-Chrysler group plans to have 6-7 platforms selling 1 million cars each by 2014). However, the point here is that the carry over and carry across of components and systems is not the only or the primary objective Fiat is pursuing by adopting the template approach.

As the next section will outline, templates, as opposed to platforms as we know them, serve the scope of providing learning and competence development and not just leveraging economies of scale through standardization.[10]

It is important to note that, for template projects, component and system suppliers are still involved in the NPD project. However, Fiat is fully responsible for the integration of the components and systems within the

[10] In selecting the car model that will become a template models, factors such as profit margins per unit do, of course, also matter. As we describe, the predominant criteria in the choice of template models that we observed were the characteristics of the model with regard to what are the key systems for the performance dimensions that customers value in that market segment, and whether new competences needed to be acquired in order to design models with high performance in these dimensions.

vehicle and has indeed hired engineers that are capable of learning from suppliers. In practice, despite the major involvement of Fiat in the development of the components and systems, it is here that the relationship between Fiat and its first-tier suppliers is close and cooperative. The crucial point is that Fiat differentiates between two types of projects. In template projects Fiat and its first-tier suppliers work on state of the art solutions for long term applications in a truly cooperative fashion. In these projects, suppliers are asked to offer innovative design solutions. Some of these solutions are developed by the suppliers independently from their relationship with Fiat and used as plug-ins for the new generation of Fiat's vehicles, some are co-developed with Fiat's engineers. In derivative projects, on the other hand, Fiat gives more design and engineering specifications to its suppliers that, as a consequence, are asked to use Fiat's technical norms and procedures (based on archetypical solutions developed in template projects). The level of responsibility of the supplier is high in both cases but profoundly different. In template projects, the supplier is not fully responsible for its application into the vehicle under development. In derivative projects, the supplier is totally responsible for the integration of the system into the vehicle during the project but is not asked to offer innovative solutions.

Overall Fiat's and suppliers' design and engineering responsibilities *and* division of labor during projects, hence, are substantially different from before. In the old outsourcing logic, for each single new project under development, the supplier was the only player in the relationship to hold specific know-how on the systems, also guided the integration of the system into the rest of the vehicle and was responsible for the success of the performance of the system in the vehicle (often, beyond the perimeter of the components it had designed). With the new outsourcing scheme, for template projects Fiat is responsible for achieving the overall product performance of the vehicle, including the performance of the specific system and its technological contents. Consequently, it is Fiat who deals with integrating the system with the rest of the vehicle.

Notably, Fiat has set up two completely different relationships with suppliers. For templates Fiat develops cooperative innovation plans with selected suppliers. The goal is to develop state of the art engineering and design solutions to be launched on template models. For derivative projects Fiat pushes on the exploitation of existing solutions and has a more arm's length relationship with suppliers[11]. This approach is consistent with the need of having some *direct* exposure to component development but not always or for all projects (due to resource constraints). Fiat's top management decided to focus its efforts on acquiring some knowledge of *key* systems technology. The distinction between template models and derivative models is, hence, essential for the new product development system based on the template process.[12].

As for the question about what is to be considered a *key* component or system technology, the Chief Technology Officer (CTO) underlined that Fiat chose to develop in-house competences for the systems and components that directly affected performance in given market segments. For example, for the template models designed for the sports cars segment, Fiat always develops the suspension system in house as this impacts the driving experience of the customer, a key performance for customers in the purchasing decisions of sports cars. Fiat does not develop suspensions for templates in the small-fuel efficient car segment. This is why Fiat develops one template for each market segment.

Finally, the template process contributed to the increase in NPD project performance. A key enabling factor for the viability of the new system was the use of virtual simulation techniques (the overall number of

[11] Please, note that the same supplier can work on template and derivative projects. From interviews with suppliers it emerges that they are well aware of the relational implications of being involved in projects that have different purposes. Fiat's suppliers are used to work with Fiat's organizational systems and procedures that change according to the type of involvement.

[12] This distinction should not be mistaken for the usual distinction between research and development functions that carry out long term development plans and organizational units in charge for new product development projects. This distinction is still valid for Fiat but applies to basic R&D, while we focus on applied design and engineering. This is why we underlined that both template projects and derivative projects lead to an actual product (not a prototype).

prototypes for a single new vehicle has dropped from 215 to 24 in the last ten years). Once the behavior of a certain system is well known due to extensive testing on template products, virtual simulation can be employed for derivative projects to enable front loading problem solving and realize substantial savings. As far as project performance is concerned, *without investing additional resources*, Fiat managed to speed up its NPD projects cutting the lead time of some projects from 26 months to 18 and even 15 months (these measures consider vehicles of the same segment and are calculated on the same NPD projects milestones) (Figure 4).

Figure 4 HERE

4.3.3 The impact of the template process on competence development

The most noteworthy aspect of the template process, beyond its impact on NPD performance, is that Fiat does not just assume the responsibility for designing all key systems of a template model, but also does it. Fiat engineers carry out the design and engineering tasks pertaining to the integration of all of the important systems of the whole car model themselves. This is a key difference from before the adoption of the template process. Now, Fiat is aware of the importance that component-specific knowledge has for systems integration competence. The Chief Technology Officer described it in these words:

> "Engineers we staff on template projects hold an above-average component-specific know-how [The CTO referred to the average in the firm, not the industry.] This know-how derives from the fact that they themselves develop the key systems. Our engineering teams continue to work with suppliers, but delegation is not according to black box sourcing as before. Learning by doing plays a key role to understand the systems we are integrating" (Chief Technology Officer, 2007).

The template process translates into a product development team that develops a new car while managing the integration of all the key systems and components design and engineering in-house. This is achieved thanks to a renewed ability to work with and learn from suppliers. As the quote above shows, Fiat's engineers are skilled enough to ensure that Fiat maintains its absorptive capacity when key systems and components applications are first engineered. The template process, hence, provides an instrument for developing system integration competences, i.e. a new organizational solution for enhancing competence development on product architecture and its evolution. This observation links back to the CTO's quote reported above, which emphasizes the central role of the integration of overall product performance in system integration. Adding further evidence on this point, the CTO described template projects in this way:

> "Template projects are a means to learn about key technological interdependences and on how to manage key performance trade-offs" (Chief Technology Officer, 2007).

From a strategic perspective, the fact that the template process allows Fiat to dramatically improve its development of system integration competence is of paramount importance. What is noteworthy is that the template process provides for such competence development *without in-sourcing* and thus, without additional investment of financial and engineering resources. The key to such competence development is learning about interdependences and performance tradeoffs, provided by carrying out in-house design and engineering tasks only in template projects.

Moreover, for Fiat's derivative projects, the competences accumulated by learning about interdependences and performance tradeoffs have an important function in improving not just product performance, but also increased control over the suppliers responsible for developing systems, components, and derivative models. For example, Fiat has the competence of defining better and more detailed specifications of the components and systems it purchases, for both template and derivative projects. This translates into better chances for mutual learning but also into improved cost control during purchasing processes.

Table 2 provides a synthesis of the overall logic underlying the template process. It shows that Fiat's decisions concerning the allocation of innovation tasks have an impact on the following variables: (1) project management, i.e. who leads the development projects (in the previous section we have seen that the new solution gives a new role to engineering suppliers in this respect); (2) task allocation, i.e. who does what in the value chain; and (3) the competences of the actors involved, i.e. who knows what (and will nurture such knowledge through learning by doing).

Table 2 HERE

4.4 A crucial trade-off and Fiat's lesson

Fiat realized it had to in-source some competences, some it previously had but that eroded, and some new ones, such as competences in electronics. This move is represented in Figure 5 that reports how Fiat's organizational choices impacted on the frontier described in Figure 2. Due to some in-sourcing Fiat moved along the diagonal – step 1 represented in Figure 5. Given the limited amount of resources it could employ, however, Fiat could not achieve the desired performance, not for all projects. Due to severe resource constraints, hence, Fiat could only try to change variables other than the level of in-sourcing and, in so doing, move the optimal frontier. The performance increase we have documented shows that Fiat indeed managed to move the optimal frontier (from X to Y - Step 2 - in Figure 5).

Figure 5 HERE

Moving the frontier meant doing more with less. But how could this happen? What are the fundamental changes underlying the new approach? Fiat acknowledged that in order to improve the performance of its product development without insourcing design activities, it had to adapt its NPD organization. Fiat radically changed its interpretation of make or buy choices. Before the adoption of the template process, Fiat focused only on the scope of design activities, i.e. it decided which competence to maintain in house and which to outsource and then replicated the scheme for every project. Now, Fiat intervenes on different variables. Product architecture is still the scheme by which design and engineering tasks are *partitioned*. However, as seen above, Fiat now *allocates* tasks according to the *type of development project*, distinguishing between template projects and derivative projects. Introducing such a distinction allows applying a different task allocation scheme to each project. It also allows alternating the task allocation scheme over time, as Fiat alternates template projects with derivative projects.

Why is the segmentation of NPD projects in template and derivative projects so important? As seen above, the most important criterion for taking boundary decisions is where Fiat needs to engage in learning by doing to develop the system integration capabilities important for achieving the performance that customers consider essential in a given market segment. Because Fiat has got few skilled engineers and limited financial resources, it cannot engage in direct involvement of its engineers in actual development work to activate this learning process for every model it develops. In other words, Fiat cannot expand the segments of the value chain it is active in on a permanent basis for all its projects. Fiat's solution for extending the benefits of learning by doing to every project is to introduce different task allocation schemes for template and derivative projects, and then alternating over time between these different task allocation schemes. Fiat's engineers first engage in all the key design and engineering activities on a *template* project with the explicit goal of learning about the key product interdependencies of a given product family working closely with first tier suppliers (e.g. for a template model of an A-segment car). Subsequently, they leverage such knowledge by fully outsourcing the application of derivative components and systems in one or more *derivative* projects (e.g. all the models belonging to the A-segment developed afterwards). In designing its boundary, Fiat therefore now also considers an additional design parameter, i.e., the possibility of alternating over time between different project responsibilities and task allocation schemes for different kinds of development projects. As shown above, Fiat managed to deal with the same suppliers according to at least two different rationales: (1) learning from (and with) system suppliers for template projects; (2) leveraging engineering suppliers for derivative projects (for these projects system suppliers deal with engineering suppliers and provide standard-off-the shelf solutions directly drawing from template projects). Figure 6 synthesizes the variables that are central for the new organization of Fiat's product development process.

Figure 6 HERE

Figure 6 captures (1) how Fiat distinguishes between two types of development projects, (2) how each type of development project is linked to a different task allocation scheme, and (3) how Fiat alternates between two types of projects over time, thus translating into an alternation of task allocation schemes over time. Because each of the two task allocation schemes yields a different benefit, either competence development from learning by doing or economies of scale, such alternation of the two task allocation schemes allows Fiat to move the frontier of the trade-off between outsourcing and project performance. The template process is thus an instrument for improving product and project performance without vertical integration (i.e. in-sourcing design tasks) or changing product architecture (i.e. pushing towards a more modular approach). As our empirical evidence highlights the template process allows Fiat to realize benefits regarding absorptive capacity (acquiring component-specific knowledge), building up architectural knowledge (in part by acquiring component-specific knowledge), and supplier governance - but *without* losing the benefits of knowledge specialization and drawing on external sources of innovation as in the old system where developing certain parts of the product architecture were always allocated to suppliers. Moreover, as figure 6 shows, the template also fulfils another purpose, one that Fiat did not manage to attain under the old system: to shape competence development paths by being in full control of what the company's engineers learn in development projects. As seen, this control was exercised selectively and dynamically. For instance, Fiat can now decide to direct its competence development path to the field of electronics and how electronics competences need to be integrated with the old mechanical competences in development projects. For the next generation of templates, Fiat is in the position of focussing on integrating hybrid power train technologies, for instance.

These examples show that the template system approach can also provide Fiat with a way to achieve a balance between exploration (learning about new solutions, upper part of the figure) and exploitation (leveraging economies of scale, lower part of the figure). The template system provides a way of enabling organizational ambidexterity (Tushman and O'Reilly, 1996) that is different from the forms in which either 'contextual' or 'structural' ambidexterity (Birkinshaw and Gibson, 2004) have been implemented. It is based on alternating between different project types that are linked to different task allocation schemes.

4.5 Difficulties, drawbacks, and limits of implementing the template process

Of course, as with any organizational solution the template process has drawbacks, difficulties and limits. As the Chief Technology Officer observed, the *availability of engineering suppliers* with sufficient competences to fully develop derivative projects represents a limit to the feasibility of this approach. The strength of this limit will depend on issues such as the reaction of suppliers to opportunities of offering larger bundles of design and engineering services, the speed with which they can build up additional competences required in order to do so successfully, the incentives and pressure OEMs can build for suppliers to offer such services, the industry structure, etc. A second practical difficulty pertains to problems with *protecting intellectual property* when the template, i.e., the set of engineering archetypes, is handed over to a supplier. One of the key motivations for creating templates is to convey the archetypical engineering solutions to those who develop derivative models in a concise and precise way. This also fuels the risk of imitation. The power of the template process approach will be limited by how the problem of allowing replication (by parties that are supposed to develop derivative models) can be dealt while avoiding imitation (by parties that are not supposed to) can be dealt with (Szulanski, 1999; Winter and Szulanski, 2001; Szulanski and Winter, 2002). A third practical problem is that having mastered the generation of templates, *replicating* them reliably is not trivial either (Rivkin, 2001; Szulanski and Jensen, 2006). Amongst others, it poses the challenge of developing new competences for replicating the template and of adapting the organization for this purpose.[13] Such competences go beyond competences relating to creating and replicating templates. Because the new system is quite radically different, these differences also apply to supplier relations. We have highlighted how the turnkey engineering supplier has much larger responsibility and is required to adapt its competences. In addition, there are new problems that both Fiat and suppliers have to deal with (such as protecting the intellectual property of Fiat). Finally, a potential practical problem might arise from the fact that by shifting to a template process system, one 'freezes' technical solutions for a particular period. The time steps in which technical solutions are adapted are thus longer. In

[13] Remember that in the previous organization, product architecture and task allocation were considered tightly linked. Because of the predominantly technical nature of decisions on product architecture, the people and organization units that made task allocation decisions therefore were very much focused on technical matters.

principle, this could lead to making the template process approach unfeasible for technologies that change very fast (faster than the time steps for which an archetypical solution will be held in place). The learning advantages of the template process can potentially generate a new trade-off with the pace of introduction of new archetypical solutions[14].

5. Discussion

We started our paper by pointing to a fundamental trade-off between the benefits of leveraging external sources of specialized knowledge vs. the benefits of developing new internal competences in component design and engineering. Our findings do not only confirm the existence of the trade-off and identify its roots; they also highlight a solution for seizing learning opportunities on new technologies despite outsourcing and for maintaining state of the art system-integration competences over time.

The case shows that before adopting the template process, Fiat followed the scheme determined by the product architecture in allocating design tasks. This allocation was based on choices previously taken in the centralized R&D functions which decided the most appropriate product architectures. The resulting decomposition scheme was subsequently held constant for as many development projects as possible and so was the choice concerning the systems that had to be outsourced. The staffing of NPD projects with internal engineers or suppliers' engineers followed as a direct consequence of these choices. Note that the root of the problems Fiat encountered was not the underlying logic of project staffing itself but rather the fact that it was coupled with the outsourcing of a vast amount of design and engineering activities to suppliers for *all* of Fiat's projects. This produced the consequence that Fiat's engineers systematically missed learning opportunities about a great number of key systems of the cars. This

[14] Please note that this *trade-off* is a consequence of the need of amortizing the investments in developing systems and components for template models by carrying them over to derivative models. With the template process, Fiat is coping with a learning trap (Henderson and Clark, 1990). Still, there is 'no free lunch'. In fact, in order to be able to seize the scale advantages of the template system, Fiat has to accept the use of a high percentage of carry-over components in most of its products.

resulted in a substantial hollowing out of the company's competences related not only to the systems that were outsourced but also to the competence of integrating these systems with the rest of the vehicle. The problem was further aggravated by the fact that the outsourcing strategy was pursued in a period of technological change (in the nineties, the introduction of electronics was changing the way most systems were designed and integrated into cars).

As Fiat lost the competences to design the systems it outsourced, the boundaries of its knowledge soon had shrunk to the boundaries of the activities it carried out. Only after having experienced the partial failures of knowledge integration mechanisms (such as joint teams with suppliers and their physical co-location at its NPD locations), Fiat realized the negative consequences of its task allocation logic on competence development and the importance of having its own engineers directly involved in design and engineering activities[15]. When Fiat decided to re-gain control of its projects by integrating back in some engineering and design activities, it also realized it had to forego some of the benefits of leveraging the know-how of suppliers' engineers and suppliers' R&D investments which had played such a key role for lowering Fiat's own investments in R&D. Thus, Fiat was up against the trade-off.

With sufficient resources, Fiat would most likely have internalized engineering and design activities as the negative consequences of extreme outsourcing became evident. We thus would not have had the empirical occasion to observe a new way of managing the trade-off. There is no doubt, in fact, that Fiat came up with the organizational innovation we documented as a typical instance of what Bolton (1993) would define a case in which "necessity is the mother of innovation": for reaping the benefits of

[15] This finding contributes to the literature on buyer-supplier relationships in NPD showing that knowledge integration mechanisms such as co-location and inter-firm joint teams (see on the role of these solutions Helper, 1991, Lamming 1993, Smitka, 1991, Nishiguchi, 1994, Helper & Sako, 1995, Helper et al. 2000, Sako, 2004) need to be complemented by knowledge building mechanism such as learning by doing. In this respect, our findings point to the importance of learning by doing for benefitting from external knowledge, confirming Cohen and Levinthal's (1990) conclusion.

learning by doing in a situation in which it could not increase its internal staff, Fiat had to find another solution. It adopted a new organizational solution. At the heart of this organizational solution lies a new logic of project staffing and resource allocation, i.e., the principle of alternating over time between different task allocation schemes, which are linked to different projects (template and derivative projects). This move provided Fiat with a means to systematically utilize the insight that in order to learn one has to do, but not always. The empirical evidence shows that this solution contributed to boost Fiat's NPD performance while still maintaining a high level of engineering outsourcing. Overall, the adoption of the template process strongly mitigated the trade-off.

It is noteworthy that in the solution that Fiat found, the allocation of design and engineering tasks does not mirror the scheme by which the product is decomposed (i.e. the product architecture) anymore (and not for all projects). This finding is striking in many respects, especially if one considers the central role that product architecture has played in the innovation management literature (Baldwin and Clark, 2000). In what follows, we discuss this empirical evidence in the light of current literature focusing respectively on the drivers of competence development in NPD projects, the role of product architecture in organizing NPD activities and the implications of our findings for designing firms' boundaries.

5.1 The role of learning by doing in competence development processes

Two main insights of our study concern the main drivers of competence development in NPD projects and *how* firms can build new internal competences. In our interviews at Fiat and its suppliers, interviewees that were actively involved in development projects were unanimous in pointing to the key role played by learning by doing in accumulating component specific knowledge. Figure 6 has captured how the template process is an instrument for leveraging both the advantages of learning by doing and of economies of scale. In the context of the innovation literature, focused on the questions how firms can design a setting (comprising product and organization architecture) that is conducive to successful product innovation, our findings also support the idea that component-specific knowledge is a prerequisite for accumulating and maintaining architectural knowledge, and thus for being able to draw on external sources of innovation without losing control of product and project performance (Takeishi, 2001, 2002). Our findings therefore suggest that system integrators must be seriously involved in some form of "doing" in order to "learn". Firms, thus, do not always manage to "know more than they make". At least in circumstances such as those described here, there is no learning without doing. These points cast light on why firms often experience so many problems in integrating external sources of innovation.

Our data further underlines that the competences held by Fiat at the firm level (e.g. in its centralized R&D structures), did not necessarily turn into actual product development competences at the project level. The reason we were explicitly given (see section 4.1) was that much of the knowledge needed at the project level is tacit and very specific (this reflects prior research, such as Kogut & Zander, 1992). NPD performance, in fact, is generated at the project level and it is here that the system integrator must be able to mobilize its integration competences. When Fiat's engineers were asked to coordinate suppliers' design and engineering activities, they lacked this kind of tacit knowledge, with negative performance consequences. On the other hand, after adopting the template process, Fiat's engineers deal with suppliers in a novel way although Fiat still relies on outsourcing and still uses co-location and inter-firm product development teams with suppliers. The key is that thanks to the activation of *learning by doing* Fiat's engineers hold enough technical know-how, including competences with an important tacit component, to fully benefit from, and evaluate and control suppliers' technical contributions – and thus to leverage the advantages of outsourcing.

5.2 The role of product architecture in organizing NPD activities

The case has shown that problems in integrating external sources of innovation are not primarily related to reaching a particular *product* performance. The hardest problem in complex product development, in fact, is to deal with *both* product and project performance at the same time. The reason is that they are reciprocally interdependent – sub-optimal product performance has negative consequences on project performance (for instance, inducing the need of design changes), and sub-optimal project management and performance also have negative consequences on product performance (for instance, lower overall vehicle performance due to problems of coordinating the systems integration process). This is precisely the process that led Fiat to lose control of project performance in its development projects.

Our empirical findings show that the template process contributed to boosting Fiat's NPD performance, including increasing project performance. De-coupling decisions about product architecture and task allocation decisions was crucial for being able to do that. The first reason is that it allowed taking the task allocation decision by criteria other than technical criteria. The second reason, however, is that task allocation rather than product architecture becomes the main focus of design efforts. The template process is an instrument for alternating between different task allocation schemes. This bears important implications for the role of product architecture in the product development process and for innovation management. In order to fully elucidate the benefits of such decoupling it is necessary to recall that while the optimal product architecture is normally chosen to maximize *product* performance according to the current dominating technological paradigm, one important impact of task allocation decisions is on the development of component specific and architectural knowledge. *Choices concerning product architecture and task allocation are profoundly different, even though they are often taken in a strictly intertwined way.* Even in the presence of an optimal product architecture design, hence, firms can still experience poor system integration performance, especially in the long run, if the effects of task allocation on competence development are not taken into account.

Building on and expanding previous literature (Brusoni *et al.*, 2001; Takeishi, 2001, 2002; Hoetker, 2006), our empirical evidence thus contradicts the so called 'mirroring hypothesis', i.e., that the structure of a product development organization must necessarily 'mirror' the architecture of the product it develops (Colfer, 2007). This is because Fiat changed its task allocation scheme considerably even with an unchanged product architecture. Not only does the example show that doing so is possible. When Fiat's organization stopped mirroring the product architecture and was designed according to the impact of learning by doing on competence development processes (after adopting the template process), Fiat also experienced substantial performance benefits[16].

5.3 Consequences for organizational boundary choices

The findings we presented in the previous two sections bear important implications for organizational boundary design. Extant literature provides the following advice for organizational boundaries choices: outsource where the production plus transaction cost of the outsourced solution is lower than organizing the transaction inside the firm (Williamson, 1985) and when leveraging external sources of innovation provides significant gains in new product development efficiency (Clark, 1989). This efficiency based rationale is reinforced by the assumption that the scope of knowledge has some degree of independence with regard to what firms make (i.e. the design and engineering tasks a firm actually carries out) (Brusoni *et al.*, 2001). This view is further supported by studies that point to the possibility of learning before doing (Pisano, 1996) or of embarking in collaborations

[16] This finding also adds to existing literature that confronts modular organizations (Sturgeon, 2002) with integrated or re-integrated organizations (Cacciatori & Jacobides, 2005; Fixson & Park, 2008) showing that some of the trade-off that this literature highlights might need to be revisited. Take, for example, the idea that integral organizational forms provide richer communication opportunities (including coordination by mutual adjustment), while more modular ones allow parallel development and diminish the need for coordination. Usually, those two forms are juxtaposed. The process we document was designed to leverage the benefits from both organizational forms.

with suppliers instead of investing in component specific knowledge directly (Helper *et al.,* 2000). Firms, in fact, usually outsource design and engineering activities under the assumption that there are alternative forms of learning to *learning by doing*. Fiat also made that assumption before it realized that the efficiency criterion decoupled from an explicit focus on competence development processes was putting its own survival at risk. An important assumption did not hold, at least not under the conditions present in the case: that the learning processes of Fiat's engineers and their ability to interact with suppliers' could be fostered by *off-line* learning (as the one carried out in R&D centers) or by interacting with suppliers' knowledgeable engineers. The reason is that *what you do* and *what you know* are quite closely related.

It is worth noting that the variables that subsequently drove Fiat's new choices concerning its boundaries in development projects were neither the core variables of TCE (i.e., asset specificity, frequency and uncertainty), nor other related efficiency considerations. At least, these latter did not appear to be the most important. Rather, competence development through learning by doing, and the variables that decided on that, had a huge effect on task allocation between Fiat and its suppliers. This is not to say that the TCE logic would not matter for understanding task allocation between Fiat and its suppliers. Rather the data supports the idea that the TCE considerations need to be complemented and combined with competence considerations, an idea raised in prior literature (Langlois, 1992; Teece and Pisano, 1994). Pointing to learning and competence development as variables that matter for determining firm boundaries is also consistent with Brusoni and Prencipe's (2006: 179) finding that 'knowledge evolution mediates organizational and technological change' and with Jacobides and Winter's (2005) observation of a dynamic link between transaction costs and competence development processes: changes in vertical scope affect competence development processes and transaction costs, with the latter two in turn influencing vertical scope decisions. Indeed, in our case, competence development patterns were so important that they alone forced Fiat to embark in re-organizing its new product development activities, leading to a new boundary design. This lends support to the idea of Brusoni and Prencipe (2006), Jacobides and Winter (2005) and earlier authors that competences have an effect on vertical scope.

Our evidence also provides a stepping-stone for complementing this idea. While Jacobides and Winter (2005) point out that changes in scope affect the capability development process, we specify additional organizational design measures that can affect the capability development process. Such organizational design measures can be a key determinant of competence development processes and transaction costs differentials, *even for a given degree of vertical scope*. The Fiat case thus shows how firms can systematically seize learning opportunities and nurture competence development processes also through changes in organization design (and without changing vertical integration), rather than by shifting the boundary of the firm by vertical integration or disintegration. We therefore contend that firms can make use of alternating task allocation schemes over time as an alternative to adapting vertical scope, at least to a certain extent. It is an interesting question for further research under which circumstances the effects of adapting organizational design with unchanged vertical scope will be more important than those of changing vertical scope without using the possibilities from alternative task allocation schemes over time.

In this respect, our findings join a recent turn in boundary design research that contributes to a notion of firm boundaries which complements that of vertical scope. According to this perspective, firms have further options for boundary design than just adjusting vertical scope, such as ‘make and buy’, ‘taper integration’ (Harrigan, 1984), ‘plural governance’ (Bradach and Eccles, 1989; Heide, 2003), the ‘simultaneous pursuit of vertical integration and strategic outsourcing’ (Rothaermel et al., 2006), ‘concurrent sourcing’ (Parmigiani, 2007; Parmigiani & Mitchell, 2009), and ‘permeable vertical architectures’ (Jacobides & Billinger, 2006).

Our data identify an option for boundary design that goes beyond the options of boundary design identified in those articles, however. First, it is situated in a more complex setting. While Parmigiani (2007: 287), for instance, focuses on concurrent sourcing as a 'simple and clean hybrid sourcing mode, involving a single firm and a single good', product development in the automotive industry is characterized by the involvement of multiple (tiers of) suppliers in a development task. Second and most importantly, the mechanism behind the template process is very different from the mechanisms identified previously. For instance, permeable boundaries allow to sell and acquire intermediate goods (Jacobides & Billinger, 2006). The principle underlying concurrent sourcing is to make a proportion of the overall volume in-house and outsource a proportion (Parmigiani & Mitchell, 2009). The mechanism the template process draws on is to alternate over time between different task allocation schemes for different types of projects. As we documented, unlike in the case of concurrent sourcing in manufacturing documented by Parmigiani and Mitchell (2009), in the case of new product development, partial outsourcing can be implemented in the sense of *always* outsourcing the design and engineering of *some* systems – rather than *sometimes* outsourcing systems design and engineering. As it turns out, in the product development context, this difference matters because in the case the development of complex products (as opposed to the case of manufacturing) the integration of components and systems is a crucial challenge. But for integrating, one needs to span all important systems – the exact opposite of the principle of 'partial integration'. Learning by doing regarding integration is essential, and such learning takes place when in template projects, Fiat integrates all these systems itself. The point is precisely that alternating between different task allocation schemes provides a way of carrying out some development tasks in-house and outsourcing in a way that, however, preserves possibilities for learning by doing about integrating the whole system. (This is also why one would actually overlook the central mechanism of the template process if one simply calculated an average degree of outsourcing for a particular period of time.)

Our finding also means that if you add an organizational mechanism that permits alternating between different task allocation schemes, the boundaries of the firm's knowledge and competences change in a way that avoid drifting apart of the knowledge and task boundaries (mainly by avoiding that internal competences on new technologies are not developed). Note that this result is achieved without adapting vertical scope, i.e., by hiring a huge engineering staff, in order to have the competences of the new technologies. Because that problem is documented also in other complex products such as airplanes (Argyres, 1999) and aircraft engines (Brusoni *et al,* 2001), our findings appear to go beyond the automobile industry and extend to complex products more generally.

A corollary of our findings is the indication that conceiving of firm boundaries mainly in terms of vertical scope, i.e. as a continuum between 'market' and 'hierarchy', has limited traction in accommodating all design variables and dimensions of firm boundaries that matter and that firms employ today. The boundary phenomena documented by some of the authors cited above, for instance, do not seem to be captured well if described as a mix of market and hierarchy. Extending the notion of 'hybrids' does not seem to be able to do that either. No 'mixture' of the two elements of market and hierarchy will be able to fully capture phenomena such as the template process we have described. There is no doubt, in fact, that such a focus and its epistemological implications would have made it impossible to detect the important change in Fiat's boundary design and the role played by organizational levers – and thus, to identify the organizational arrangement that led to considerable benefits.

Finally, we also add to MacDuffie's (2008: 41) insight that firms developing complex products such as cars should 'develop the capability to experiment and move activities back and forth across organizational boundaries'. We show that firms cannot only experiment by outsourcing activities and acquiring them back to carry out in-house. They can also try and experiment with alternative solutions, mostly based on organizational settings that leave vertical scope unchanged. These latter settings, as the case of Fiat shows, belong to a rather different set of viable solutions and in this sense, open new possibilities. And the 'capability to experiment' related to those is of a totally different nature.

5.4 Limitations

Our conclusions are subject to limitations and boundary conditions. The domains to which our conclusions apply are limited to the domain of complex products, especially when they embody heterogeneous technologies. In such products, the tension between having to draw on outside sources of innovation and the drawbacks of doing so is much more pronounced. Understanding the limitations of the applicability of our findings, however, also allows the potential of the insights to emerge; within the limitations identified, there seem to be many domains where the system we have described has not yet been applied but could potentially be, with powerful positive consequences. In the next and concluding section we summarize our main arguments and point to new possibilities, both for firms that develop complex products and for scholars of innovation management, organization and strategy.

6. Conclusion

In this paper we have addressed the question how firms that develop complex products can benefit from drawing on external sources of innovation without losing key learning opportunities, system integration capabilities and, together with them, control of product and project performance. The firm we analyzed confronted that question in a moment where it also had to acquire new competences in electronics, which changed the product architecture and the interdependences of development tasks. The case study presented here provided the occasion to contrast two ways of approaching the key choice concerning how to decide on the division of labor of innovation tasks within and across firms' boundaries, i.e., task allocation. Our empirical evidence adds further support to the literature that has pointed out the dangers of design outsourcing (Lincoln et al., 1998; Fine, 1998), and the centrality of performance integration as a criterion for *which* component-specific knowledge should be maintained in-house (Takeishi, 2001, 2002). In this respect, in organizing NPD, we highlight that managers should focus on task allocation and its consequences on the competences of the firm. When thinking about the boundary of the firm and how to manage it, what sticks out as very important is the allocation of *who* really is involved in doing *what* at the project level, division of labor in a basic and straightforward sense. This division of labor becomes problematic when task allocation is carried out according to the product architecture scheme despite the fact that the product under development is not fully modular. In this circumstance, specific efforts of *organizing* development can make the difference for developing complex products so that high product performance is achieved without major drawbacks. Changing vertical scope is not necessarily required.

The Fiat case supports the idea that vertical scope is an important determinant of competence development processes (Argyres, 1999; Teece, Pisano & Shuen, 1997; Jacobides & Winter, 2005; Teece, 2007), but it goes beyond this insight by showing that vertical scope itself is not the only or most prevalent determinant of competence development. We show that at least two additional variables matter: (1) the *rationale* for involving suppliers in the NPD process and (2) *how* firms organize what they make. The first point is exemplified by the difference between buying a component or a system vs. buying an *opportunity to learn* from (and with) suppliers about that component or system. The second is exemplified by the possibility enhanced by a purely organizational measure – the template process – to seize learning opportunities despite major outsourcing. Both variables generate effects independently of vertical scope.

This evidence contributes to reflecting on the available strategies that firms can pursue in order to benefit from innovation in the case of design and engineering outsourcing. On a more general level, our findings show that in order to conceptually capture the solutions that contribute to mitigate the tradeoff between the benefits of leveraging on external sources of innovation and the risk related to this strategy, theories on the link between vertical scope and competence development benefit from bringing the role of *organizing* back into the picture. For instance, discussing knowledge and knowledge differentials between OEMs and suppliers yields more insight when also considering the organization structures (such as projects) in which such knowledge is actually applied.

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TABLES, FIGURES & APPENDIX

Table 1 – Benefits of allocating design tasks within or beyond the firm's boundaries

	Organizational option	
	Allocate design tasks to suppliers	Carry out design tasks in-house
Related benefits	Benefits of knowledge specialization: • OEM specialization in architectural knowledge and integrating components and modules • Supplier specialization in component-specific knowledge Benefits of modular design: • facilitates allocating the development of modules to suppliers • facilitates drawing on outside sources of innovation	Benefits of learning opportunities: • learning by doing regarding component-specific knowledge, thus nurturing component-specific knowledge: o increases firms' absorptive capacity regarding new technological developments o fosters development of architectural knowledge o decreases differences to component-specific knowledge of suppliers o diminishes risks of problems in supplier governance • prevents loss of control of product and project performance by enabling o taking decisions on interdependencies o adapting decomposition schemes o adapting to technological newness o dealing with uneven rates of technological development and unpredictable interdependencies

Table 2 – A synthesis of the new approach

		Before	Now
Key variables	Project scope	Same for all products	Different for 'template models' and 'derivative models'
	Allocation of design and engineering tasks	OEM for 25%-30% of components/systems Suppliers for the rest	Mainly OEM for 'template projects' Mainly suppliers for derivative projects
	Technological competences	OEM holds competences on selected technologies and outsources the remaining	OEM controls the competences to manage performance trade offs Suppliers hold component specific technologies
	Project management / control through hierarchy	OEM	OEM for 'template projects' OEM, Fiat's off-shore development and engineering centres, Engineering Suppliers for 'template projects'

FIGURES

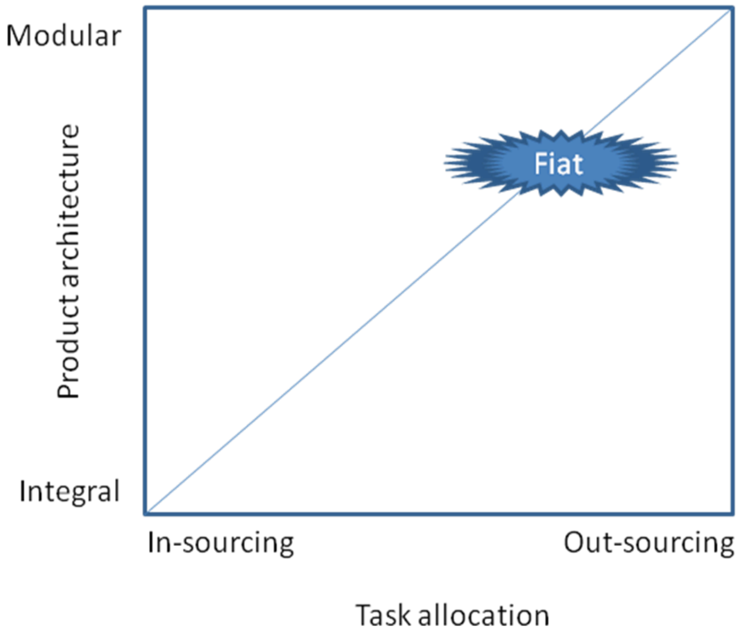

Figure 1 – Product architecture and task allocation

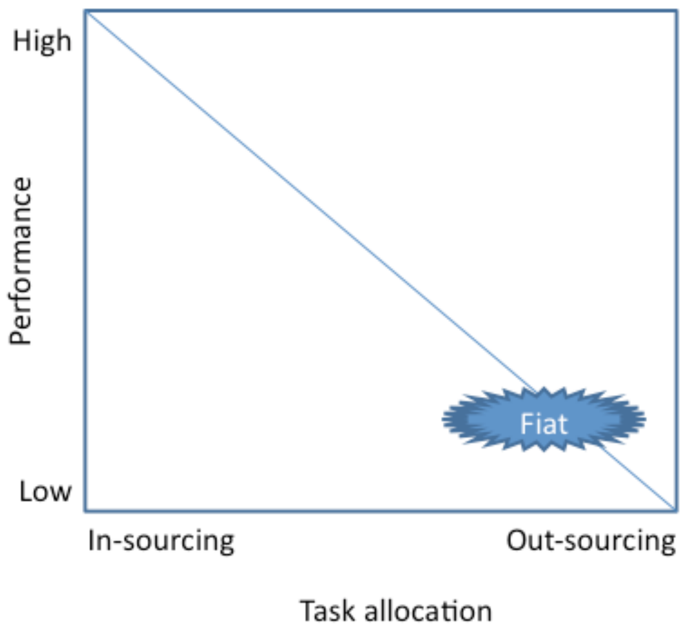

Figure 2 – Task allocation and performance

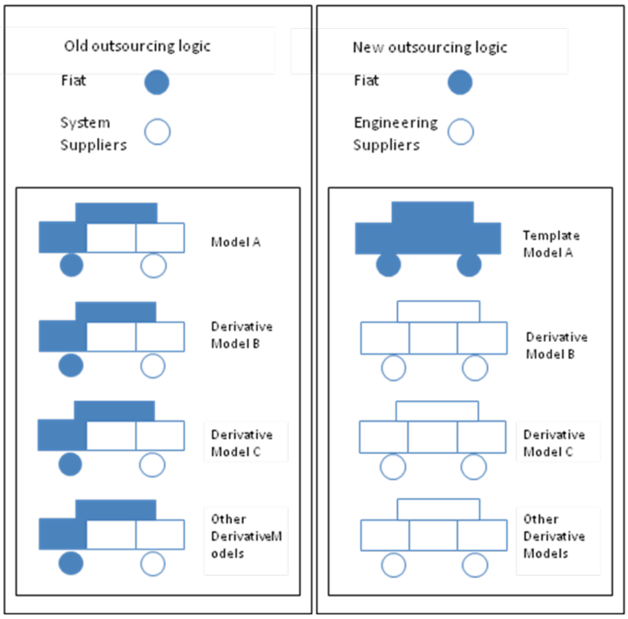

Figure 3 - Old and new outsourcing logic

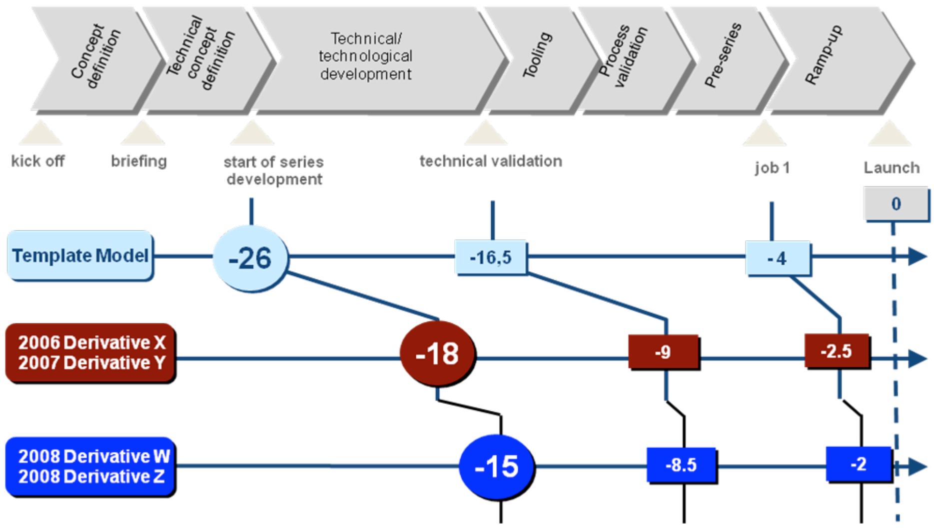

Figure 4 – The impact of the template process on lead times

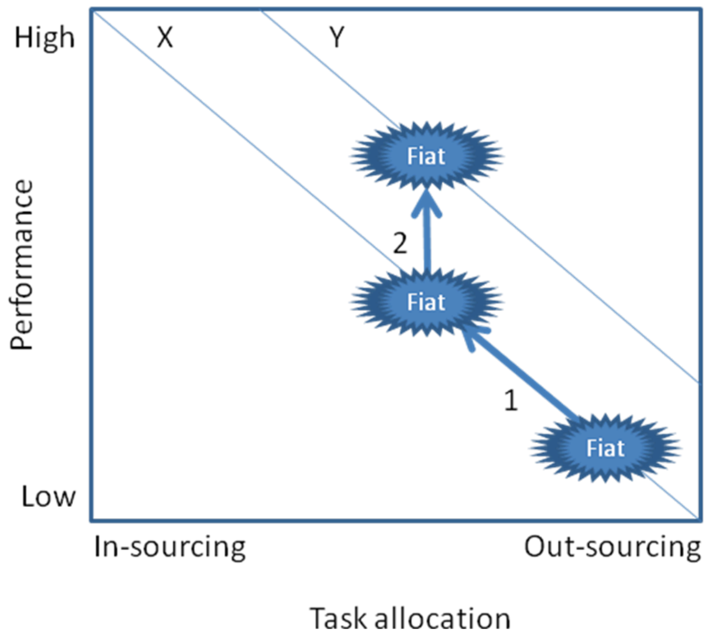

Figure 5 – A new viable frontier

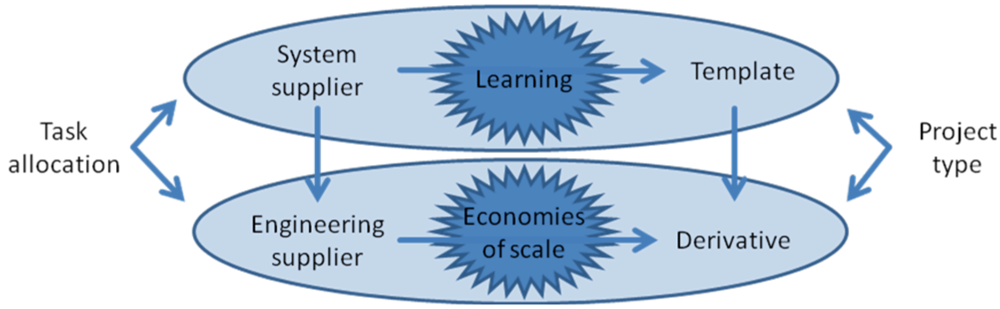

Figure 6 – A synthesis of the implications of the template process

Appendix A: companies involved in the study and interviews

Company	Product	Date	Interview length in hours	Role of person interviewed
Fiat	Auto	25/05/1998	2	Purchasing director Segment C
Fiat	Auto	27/04/1998	3	New Product Development Methodologies Manager
Fiat	Auto	28/07/1999	1	Global Sourcing Director
Fiat	Auto	28/07/1999	2	Component Development Platform Manager
Fiat	Auto	28/07/1999	1	Global Sourcing and Purchasing Policy Manager
Fiat	Auto	15/09/2001	2	Purchasing responsible for new product development
Fiat	Auto	1/03/2001	2	Purchasing Director
Fiat	Auto	1/03/2001	2	New product development Director
Fiat	Auto	2/03/2001	1	Global sourcing director
Fiat	Auto	2/03/2001	1	Product Planning Manager
Fiat	Auto	06/2001	1	Racing division Manager
Fiat	Auto	07/2002	2	Vehicle line executive segment A-B
Fiat Research Centre (1)	R&D Auto	22/3/2006	1	CEO of Fiat's research center
Fiat Research Centre (1)	R&D Auto	8/02/2006	2	Business Development Director Technologies Division of Fiat's research center
Fiat	Auto	8/02/2006	1	VP Investor relations
Fiat	Auto	23/06/2006	2	VP Product Portfolio Management
Fiat	Auto	23/06/2006	1	VP Human Resources
Fiat	Auto	23/06/2006	1	Business Development Manager
Fiat	Auto	23/06/2006	1	Manufacturing Director
Fiat	Auto	14/07/2006	1	Director of Vehicle Concept and Integration
Fiat	Auto	14/07/2006	1	Director Design Center
Fiat	Auto	14/07/2006	1	VP Design & Engineering (CTO)
Fiat	Auto	14/07/2006	1	Vehicle line executive segment A-B
Fiat	Auto	14/07/2006	1	Vehicle line executive segment C,
Fiat	Auto	09/05/2006	1	Vehicle line executive segment C,
Fiat	Auto	14/07/2006	1	Vehicle line executive segment D-E
Fiat	Auto	14/07/2006	1	Vehicle line executive segment Commercial Vehicles
Fiat	Auto	14/07/2006	1	HR Director for Design & Engineering + Controller for Design & Engineering
Fiat	Auto	11/07/2007	2	Chief Innovation and Methodologies
Fiat	Auto	11/07/2007	2	VP Design & Engineering (CTO),
Fiat	Auto	13/12/2007	2	Chief Innovation and Methodologies
Fiat	Auto	13/12/2007	2	Innovation and Methodologies Manager
Company A	Sealing systems	01/06/1999	2	Plant Director
Company A	Sealing systems	01/06/1999	2	Program Manager

Company B	Air bag, steering wheel, seat belt	23/06/1999	3	Plant Director
Fiat Research Centre (2)	Fiat Research Centre	25/06/1999	5	New Product Development Methodologies Manager
Fiat Research Centre (2)	Fiat Research Centre	1/04/2003	3	New Product Development Methodologies Manager + Assistant to the New Product Development Methodologies Director
Fiat Research Centre (2)	Fiat Research Centre	2/04/2003	3	Vehicle development division Manager
Company R	Plastic components (e.g., fuel tanks, brake clutches)	29/06/99	3	CEO + Plant Director
Company B	Air bag, steering wheel, seat belt	26/07/1999	5	Program Manager
Company C	Car design development, turnkey development projects/supplier	27/07/1999	4	Program Manager
Company C	Car design development, turnkey development projects/supplier	27/06/1999	1	Program Manager
Company D	Cables, switchers	28/07/99	2	Program Manager
Company E	Safety systems (airbags, seat belts, brakes, chassis control (ABS – traction control systems, etc.) /supplier	29/09/99	3	Plant Director
Company F	Power train, exhaust systems, electronics, thermal systems, lighting systems, suspensions, etc.	21/04/1998	2	Program Manager (Electronics Division)
Company F	Power train, exhaust systems, electronics, thermal systems, lighting systems, suspensions, etc.	21/04/1998	2	Program Manager (Power train Division)
Company F	Power train, exhaust systems, electronics, thermal systems, lighting systems, suspensions, etc.	27/04/1998	1	Product Planning Manager
Company G	Stamped parts in metal/supplier	17/04/1998	4	Plant director
Company H	Sealing systems	21/02/2006	2	Plant General Manager
Company H	Sealing systems	21/02/2006	3	Assistant to Technical Director Engineering & Design
Company H	Sealing systems	21/02/2006	3	Quality Manager
Company H	Sealing systems	07/06/2006	1	Assistant to Technical Director Engineering & Design
Company I	Brakes	28/03/2006	1	Product Engineering R&D Manager Brake Systems
Company I	Brakes	28/03/2006	1	Business Development Director
Company L	Car design development, turnkey development projects/supplier	23/03/2006	1	Business Strategy Development Manager
Company L	Car design development, turnkey development projects/supplier	23/03/2006	2	Project Manager
Company L	Car design development, turnkey development projects/supplier	23/03/2006	2	Numerical simulation director
Company L	Car design development, turnkey development projects/supplier	15/05/2006	2	Customer Manager
Company L	Car design development, turnkey development projects/supplier	15/05/2006	3	Body and trim engineering department
Company M	Car electronic systems, power train, lighting systems, car entertainment systems, etc.	29/03/2006	4	Manager Automotive Technology Product Planning and Marketing + Cross Functional Project Manager

Company N	Car interiors, seats/supplier	9/02/2006	2	CEO
Company N	Car interiors, seats/supplier	9/02/2006	1	Fiat Account Manager
Company N	Car interiors, seats/supplier	23/03/2006	2	Fiat Account Manager
Company O	Safety systems (airbags, seat belts, brakes, chassis control (ABS – traction control systems, etc.) /supplier	9/02/2006	3	Fiat Account Director
Company O	Safety systems (airbags, seat belts, brakes, chassis control (ABS – traction control systems, etc.) /supplier	9/02/2006	3	Manager Programs & Application Engineering Inflatable Restraint Systems
Company O	Safety systems (airbags, seat belts, brakes, chassis control (ABS – traction control systems, etc.) /supplier	23/03/2006	2	Fiat Account Director
Company O	Safety systems (airbags, seat belts, brakes, chassis control (ABS – traction control systems, etc.) /supplier	23/03/2006	1	Manager Programs & Application Engineering Inflatable Restraint Systems
Company P	Stamped parts in metal/supplier	3/02/2006	5	Plant manager
Company Q	Thermal systems	3/04/2006	2	Sales & Marketing General Manager
Company Q	Thermal systems	3/04/2006	2	Fiat /GM/ sales manager
Company Q	Thermal systems	3/04/2006	2	R&D Thermal Systems Division Manager
Company Q	Thermal systems	15/11/2007	2	R&D A/C systems – Systems Eng & Concept Manager
Company Q	Thermal systems	15/11/2007	1	Fiat Account Manager
Company Q	Thermal systems	10/01/2008	2	PSA Account Manager
Company Q	Thermal systems	10/01/2008	2	Responsable Application PSA
Company Q	Thermal systems	10/01/2008	2	Renault Account Manager
Company Q	Thermal systems	12/02/2008	2	Responsable Application Renault
Company R	Car design development, turnkey development projects/supplier	21/05/2008	5	Director Innovation, Manager Innovation and Technology,
Total of 19 companies			Total of 145 hours	