The timing of openness in a radical innovation project, a temporal and loose coupling perspective

1. Introduction

While firms are prone to opening their innovation models in order to acquire resources and complementary assets, particularly when they operate in highly turbulent and technologically intensive environments (Katila and Mang, 2003; Gassmann and Enkel, 2004; Schweitzer et al, 2011), there are also several risks such as misappropriation of their knowledge resources by external partners (Alexy, Criscuolo and Salter, 2009), loss of control over the technological trajectory (Almirall and Casadesus-Masanell, 2010) and erosion of the uniqueness of internal competences (Ciravegna and Maielli, 2011; Manzini, Lazzarotti and Pellegrini, 2016). All of these risks constrain openness and are likely to dampen the ability of firms to profit from their innovations, and consequently may lead to a reversion to a closed model (Appleyard and Chesbrough, 2017). Building on the Profit from Innovation (henceforth, PFI) framework of Teece (1986), the purpose of this paper is to address the tension between openness/closedness at the project level by exploring project-level processes that determine the ability of an innovating firm to maximize profits and reduce the risks of misappropriation.

Previous studies have shown that a firm's openness choices go hand in hand with their appropriability strategies in order to maximize the returns from their innovation (Laursen and Salter, 2014; Teece, 1986; Zobel, Balsmeier and Chesbrough, 2016). The large majority of studies on open innovation and appropriability are at the firm level, yet firms organize innovation activities in R&D projects. There are conceptual tensions between open innovation at the firm and project levels, as the dynamics of open innovation at the project level are different from firm level dynamics due to the presence of project contextual factors (Vanhaverbeke; Chesbrough and West, 2014). R&D projects develop over time and therefore the project level of analysis rather than the firm level is most directly subject to time-dependent variables, such as innovation speed (Kessler and Chakrabarti, 1996), speed of reaching the market, or the timing of partnerships in R&D projects (Milison and Wilemon, 1992; Handfield, Ragatz, Petersen, and Monczka, 1999; Swink, Talluri and Pandejpong, 2006). There are many alternative models of openness and closedness, and a company can rely on innovation partners during one or more stages but not necessarily from the start to the end. There may be very good reasons for keeping an NPD project closed during specific stages of the project, and the timing of the shift between closed and open innovation during the project may be crucial to its success. The timing of openness to external partners is a central characteristic of NPD projects, but when, and how a project team manages the shift from a low degree of openness to a higher degree of openness are under-researched questions in the innovation management literature.

Given the limited theory and empirical evidence on how the timing of openness is managed at the project level, we have conducted an in-depth case study at Jaguar Land Rover (UK) which captures the full lifecycle of a radical NPD project. By incorporating the element of time in the theory-building process, we contribute to a process and temporal perspective of open innovation by identifying two core project processes which influenced the ability of Jaguar to maximize profits from the innovation: a) the timing of openness to external partners, and b) an external loose coupling project strategy. On the one hand, the timing of shifting from a closed to an open model of innovation was enabled by a pro-active change in the formal defense strategy (i.e. submission of a patent), and an internal loose coupling project strategy that involved autonomy of the project champion and internal engineers' weak membership of internal engineers in the project (Weick, 1976). On the other, an external loose coupling project strategy was enabled by the deployment of two informal appropriation mechanisms namely, the reduction of project scope to external partners and the development of guarded relationships with them.

The paper proceeds as follows. In Section Two, we review the open innovation and appropriability literature at both the firm and project levels, and we introduce our main research question. Next, in Section Three, we present the setting of the case study and the method, including data collection and analysis. In Section Four, we provide the results of the case study. Finally, in Section Five, we discuss the results and outline the limitations of the study, and also provide several directions for future research.

2. Theoretical approach to open innovation and appropriability

2.1 Open innovation, and appropriability at the firm level

Open innovation entails challenges in relation to the appropriation of the outcomes derived from inter-firm collaborative efforts (Belderbos et al., 2014; Di Minin and Faems, 2013). At the firm level, the drivers to open to external partners in the innovation process are related to managerial attitudes towards its appropriability strategy (Laursen and Salter, 2014). The deployment of formal (i.e. patents, registration of design patterns and copyrights) and informal defense mechanisms (i.e. secrecy, lead time, sales and service effort) can partly mitigate the risks of misappropriation by external partners, thus enabling the innovating firm to open to external partners while profiting from its innovation (Amara, Landry and Traor, 2008; Das, 2005; Katila and Mang, 2008; Hurmelinna-Laukkane, 2009; Levin et al., 1987; Teece, 1986). There is an ambiguous relationship between appropriation mechanisms and open innovation; some studies suggest that IP enables open innovation as it is a safeguard for knowledge protection and a signaling mechanism for displaying innovative capabilities to attract new collaborators (Hsu and Ziedonis, 2013; Laursen and Salter, 2014; Teece, 1988; Reitzig, 2004; Rivette and Kline, 1999, 2000; Zobel et al., 2016); others claim that formal mechanisms, specifically patents, may hinder open innovation relationships at the firm level (Katila and Mang, 2003; Katila, Rosenberger and Eisenhardt, 2008; West and Gallagher, 2006). In addition, informal appropriation mechanisms such as complexity, secrecy and lead time have a stronger link with search openness than formal appropriation mechanisms such as patents, trademarks, copyrights and design rights (Zobel, Loshina and Hagerdoon, 2017). Prior studies examining the role of appropriation mechanisms have mainly been conducted at the firm level and there is limited understanding when and how managers deploy different types of defense mechanisms, both formal and informal ones, at different stages of NPD projects to reduce the risks of misappropriation.

2.2 Open innovation, appropriability, and project strategies at the NPD project level

The aforementioned studies that have explored the drivers for open innovation have largely focused on the firm level rather than the individual NPD project level, despite the fact that NPD projects are likely to vary in their payoff from open innovation within the same firm (Salge et al., 2013; Vanhaverbeke, Du, Leten and Aalders, 2014). Recently, scholars have started to address the lack of understanding of open innovation at the project level (Bahemia and Squire, 2010; Bahemia, Squire and Cousins, 2017; Du et al., 2014; Salge et al., 2013). By moving the angle of analysis from the firm to the project level, these studies have found that the contingencies influencing the financial performance of open innovation at the project level are related to the type of innovation (incremental versus radical), the strength of formal appropriation mechanism (Bahemia and Squire, 2010; Bahemia, Squire and Cousins, 2017), the degree and nature of the formalization of the collaboration, the type of external partner (science-based versus market-based partners), and the type of governance mechanism (rigid versus flexible contract application) (Hoang and Rothaermel, 2010; Du et al., 2014; Salge et al., 2013). Although these studies have contributed to a better theoretical and empirical understanding of specific project factors and strategies that influence the financial returns from the innovation when firms adopt an open innovation strategy at the project level, there remains a lack of understanding about the relationship between the timing of open innovation in R&D projects, as for example, the timing of when innovating firms choose to rely on open or closed innovation during different stages of NPD projects, and the link between this timing decision and their ability to appropriate profits. The question related to the factors that determine the ability of firms to profit from their innovation is central to the seminal PFI model (Teece, 1986).

2.3 Extending the Profiting from Innovation (PFI) model in the context of open innovation

The PFI model predicts that the strength of appropriability regime, ownership of complementary assets, and emergence of dominant design determine whether the innovator or imitator will get the lion's share of the rents of the innovation (Teece, 1986). In the original PFI framework, appropriability regimes are taken as a given, implying implicitly a fixed conceptualization of time. However, appropriability regimes are endogenously shaped by the behaviors and strategies of firms (Pisano, 2006). Typically, within a NPD project, technology protection will evolve from weak to strong as IP will be written, submitted, filed and granted as the project proceeds. Looking at the creation of IP as a process that develops over time helps us understand when an innovating company can decide to open up to partners. Another factor is the distribution of the complementary assets (Teece, 1986, 2006) between the innovating company and the potential innovation partners; the need for different complementary assets evolves as an NPD project progresses. Due to the inherent uncertainty of the NPD process, the demand for resources becomes more specific only as the project evolves through the different stages, and an innovating company may have to shift from closed to open innovation if the required capabilities are absent in the company.

Extending the PFI model, we focus on the project level and relax the assumption that the appropriability regime is fixed over time for the reasons mentioned above. In the case study, we combine process theory (Langley et al., 2013; Pentland, 1999) with a temporal lens (Ancona and Caldwell, 2001; Langley, 1999) to explore how events and appropriation mechanism (formal and informal) evolve during the project as processes, and hence consider how managers adjust their innovation (closed and open innovation model), appropriability, and project strategies to profit from the innovation and to minimize the risks of misappropriation. Process research is concerned with how and why things evolve over time (Van de Ven and Huber, 1990; Ancona et al. 2001), while process time is conceptualized as being dependent on events (Morgeson, Mitchell and Liu, 2015). Using this line of approach, we address the following research question: *when* and *how* do managers make a transition between closed and open innovation[1], and adjust appropriability and project strategies during the lifecycle of a New Product Development project to maximize profits from the innovation?

Setting of the Case Study and Method

3.1 The context

Jaguar is a luxury car manufacturer forming part of the Jaguar Land Rover (JLR) group, whose main operations are based in the UK. The project for the Jaguar XF started in 2001 and launched onto the market in 2006. The unit of analysis of the case study is at the project level. Our case study focused on the development of the main radical technological innovation of the Jaguar XF: the electronic rotary gear selector actuated by a multi-stable shift-by-wire system that replaces the traditional gear stick. Instead of a traditional gear stick, there is only a circular knob that the driver has to turn to select the driving mode, which is enabled by an

[1] By a closed model of innovation, we imply that there is reliance on internal R&D rather than on collaboration with external partners during the NPD project. As for the open model of innovation, we capture the degree of openness, in terms of collaboration with different types of external partner, such as suppliers, customers, universities, consultants, and open innovation intermediaries, during the project (Bahemia et al., 2017; Leiponen, 2012).

electronic multi-stable ‘shift-by-wire’ system. When the start button is pressed, the gear selector rises and comes into the palm of the driver’s hand; this motion is described by the design manager as:

“*The Jaguar handshake, this human machine interface technology creates genuine package benefits, it was seen by the public as being first to market … it was something that no one else had done before and we created a massive selling point for the car… and it was the wow factor of the XF and has increased its emotional appeal*.”

In the automotive industry, although other car manufacturers have been experimenting with new designs for shifters to replace traditional gears, the drive mode of these shifters is based on a mono-stable system, implying that it always returns to a central position not indicative of a selected drive mode. A mono-stable system was a major innovation challenge for the automotive industry as “*legislation in the UK prohibits the use of a gear selector that can be placed in a position that does not reflect the actually selected gear, as was the case with a mono-stable system*” (Director of Patent, Jaguar), and therefore the concept could not be brought to market. The inventiveness brought by Jaguar was the development of a rotary shifter based on a multi-stable system, i.e. it remains in a set position until moved. Until this development, the previous mono-stable system was constrained as the gear selector could be changed into a position that did not correspond to the actually selected gear, representing a safety risk for drivers. On these grounds, Jaguar has successfully been granted four patents for a multi-stable system for the rotary shifter, and there are additional ongoing patents which have been filed as a reaction to the responses of competitors. In the round of interviews that the authors conducted in 2015, the Advanced Technology Specialist at Jaguar highlighted the extent to which the rotary gear selector using a multi-stable shift-by-wire system was new to the automotive industry, and to the market, when it was launched:

“*Everybody else has the concept for a mono-stable, in other words the gear selector always returns to the same position. Ours doesn’t do that, it stays in the position that you started. That’s what hasn’t been done before and still hasn’t.*”

We classify the development of the electronic rotary gear selector actuated by a multi-stable shift-by-wire system by Jaguar as a radical innovation project as it was new to the automotive industry and departed from previous designs (i.e. the mono-stable system), as well as being first to market when launched. Radical innovations are perceived to be new to the industry and are characterized by a discontinuity in relation to existing technology (Garcia and Calantone 2002; Johannessen, Olsen, and Lumpkin, 2001). In terms of the sampling strategy, the rotary shifter project was an ideal candidate for the case study as it is a typical case of a radical innovation, for which a series of patents was successfully filed by Jaguar. Both a closed and open innovation strategy was implemented during different stages of the lifecycle of the project. Thus, it was a good case to explore in-depth and explain our focal concept concerning the issue of timing of openness to external partners (Corbin and Strauss, 2015).

3.2 Data collection

The data collection process spreads over twenty-six months starting in 2009, with additional interviews conducted in 2015 and 2017. There were three stages in the data collection. A total of forty-four interviews were conducted from the definition to the exploration of the problem. During the first stage of defining the problem, Jaguar’s product portfolio was studied via secondary data (brochures, car magazines, press reports, web site information, and the patent documents for the electronic gear selector). Three interviews were conducted with the Head of Research and engineers involved in open innovation at Jaguar. In parallel, a preliminary pilot-study was conducted with sixteen New Product Development managers from different industries such as scientific equipment, medical equipment, aircraft seats and telecommunication equipment in the high value manufacturing sector in the UK. The aims of the preliminary interviews were to understand the key factors that managers take into consideration when implementing an open innovation, and to formulate the research problem from both a theoretical and practitioner's perspective.

In the second stage of data collection, we carried out twenty semi-structured interviews composed of fifteen interviews with the Jaguar internal development team and five interviews with key external partners involved in the project. Although we acknowledge the partial risk of retrospective sense-making as the interviewees at Jaguar could rationalize the individual NPD phases by taking into account the successful outcome of the project, we have been careful to counter-balance this risk by incorporating the perspective of several external partners that have contributed to the development of the innovation. A snowball method was used to develop additional contacts with internal engineers and external partners engaged in the project. Data were collected from the internal NPD team (head of research, project champion, advanced design manager and leading engineers) and from external partners involved. As for the procedures of the interview protocols, following each round of interviews with the internal NPD team, the interview guide was continuously being improved and those new concepts that emerged were added to the subsequent interviews. For instance, a visual presentation of a time-line display of the different stages of the NPD process (Figure 2, Stages 1-5), similar to the NPD model (Handfield, Ragatz, Petersen, and Monczka, 1999), was added to the interview guide and respondents were asked to indicate the specific stages of the NPD process where external partners were involved and their level of interaction at each of these stages.

Although our 2009 data were not collected when the shift occurred, we told our informants we were interested in the timing of the shift from closed to open, and we returned several times to ask further questions about what happened and in what order and when. It was only when we had understood the process that we noticed its shift from tight to loose coupling, and the role of loose coupling in facilitating the shift to open innovation. Data related to the drivers and enablers of closed and open model of innovation were searched at each of the stages of the NPD process. The inclusion of a time-line of the NPD project to the interview guide allowed us to clearly detect variation in the degree of openness to external partners at different stages of the NPD project. By adding a visual presentation of the NPD project to the interview guide, each stage of the project was clearly defined and respondents were asked to identify the stages where external partners and the Jaguar NPD team were involved, thus ensuring a common understanding of the stages of the project among all respondents. In this way the consistency of the data collected at each stage of the NPD project was controlled. In the third stage of our data collection, we conducted three additional interviews with the Patent Director of Jaguar in 2015 on the effectiveness of the patents, and two further in-depth interviews with the Research Technology Strategist and Product Engineer in 2017. In this paper, the names of the external companies involved in the project are anonymized.

3.3 Data analysis

As the purpose of the case study was to trace and explain the processual unfolding of closed and open models of innovation during the same project, we adopted a process perspective for the data analysis for both the surface and underlying events that explain the temporal choices between a closed and open model of innovation. Process theorization goes beyond surface description to penetrate the logic behind observed temporal progressions, whether simple or complex, so as to capture the explanatory mechanisms that underlie the surface events, project processes and their enabling mechanism that change during the lifecycle of the project (Ancona, et al. 2001; Langley et al., 2013; Morgeson, Mitchell and

Liu, 2015; Pentland, 1999; Van de Ven and Huber, 1990). In line with the principle of inductive research, data collection and analysis were performed concurrently (Gioia, Corley and Hamilton 2012; Strauss and Corbin, 1998). Figures 1A and 1B provide an overview of the analysis of how we dimensionalized the aggregate closed and open model of innovation during the project from the first order categories, and its related second order themes. In the second order analysis, we used axial coding (Strauss and Corbin, 1998) to group the raw data derived from the first order analysis into theoretical categories, and the second order themes were then assembled as illustrated in Figures 1A and 1B to form the aggregate dimension of closed and open model of innovation (Gioia, Corley, and Hamilton, 2012).

The quality of the data was ensured in several ways. First, the internal validity of the data was continuously checked (Yin, 2014). After data collection and analysis, the time line-display (Figure 2) was sent to the Project Manager, two internal engineers, and the external partners. Respondents were asked to confirm whether the stages when external partners were integrated in the NPD process were accurate. The aim of this validation process was to increase the reliability of the data collected. When the data collection and analysis neared its conclusion, an open interview was conducted with the Head of Research to validate the explanatory model, which illustrated the relationships between the key categories; we also sought feedback from the project champion on the last explanatory model. Second, construct validity was tested by triangulating data across different sources (Yin, 2014). A chain of evidence was used to develop the emerging constructs from multiple perspectives and to check that the lines of inquiry were converging. For example, similar semi-structured questions were addressed to internal members of the project, as well as to key external project partners, with the aim of understanding the timing of shifting from closed to open innovation from both an internal and external perspective.

4.0 Results

Based on the five different stages of the NPD model (Handfield, Ragatz, Petersen, and Monczka, 1999), we examined *when* and *how* the project champion made the transition between closed and open innovation, and adjusted appropriability and project strategies in response to events that occurred during the lifecycle of the project. Figure 2 illustrates a dynamic representation from a closed to an open model of innovation. All the factors that determine the ability of Jaguar to profit from the innovation, as predicted by Teece (1986), are identified in Figure 2 to distinguish them from those which emerged from our case study.

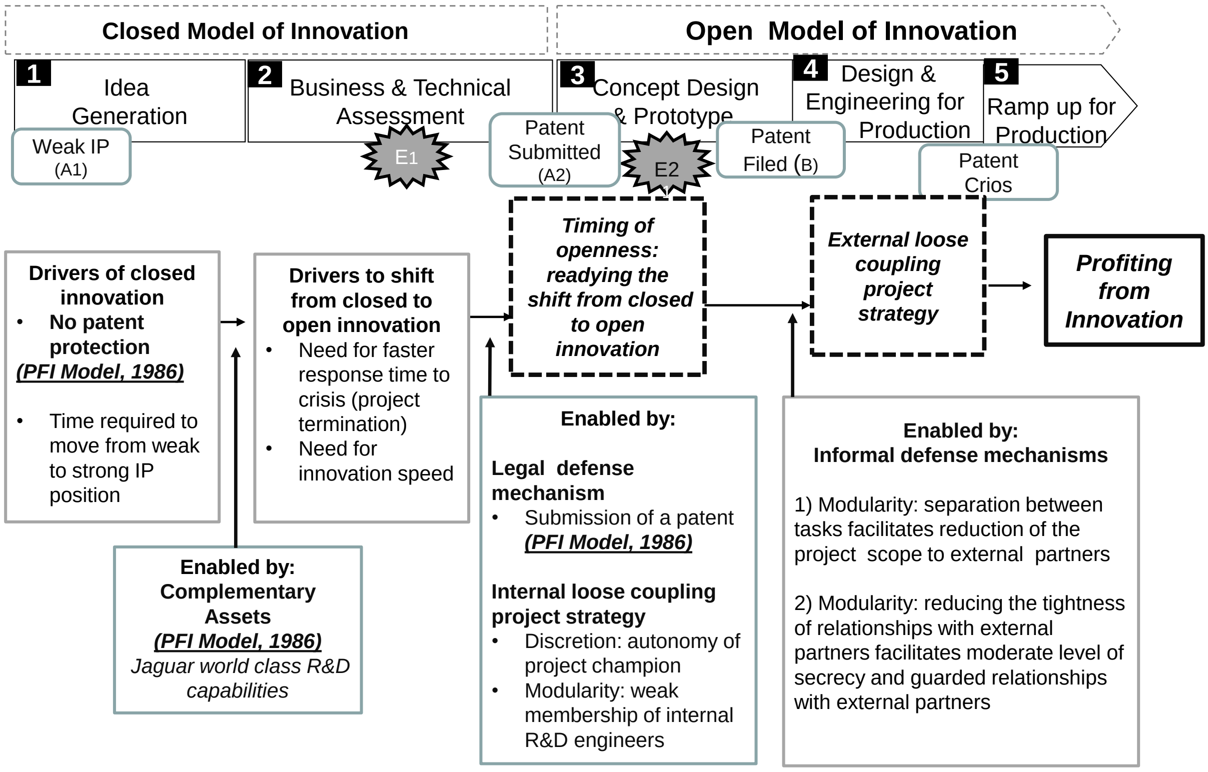

Figure 2. From top to bottom: The project has 5 phases from idea generation to Ramp up for production. Jaguar kept the project closed in phases 1 and 2 and opened it in the three other ones. IPR regime goes from weak (A1) to strong as Jaguar submitted a patent (A2) and later filed it (B). E1 indicates the start of the internal crisis and E2 indicates the end of the internal crisis . Drivers for closed innovation and for shifting from closed to open innovation are represented in the bottom grey boxes on left hand side. The closed model innovation was enabled by Jaguar world class R&D capabilities as shown in the bottom grey box on the left hand side. For readying the shift and implementation from closed to open innovation in the middle stage of the project, two core project processes were deployed: the timing of openness and the implementation of an external loose coupling project strategy(dotted black boxes). These two core project processes combined with their respective enablers (bottom grey boxes, right hand side) drove the success of profiting from the the innovation (black box, far right hand side). The supplier, Crios also filed a patent during the project.

4.1 A closed model of innovation in the early stages of the project

The idea of the rotary shifter was generated and initiated by the Research Technology Strategist and Product Engineer, who was the project champion. In the upstream stages of the project, research and development was done in-house to develop the concept of the rotary shifter and the enabling concept of shift-by-wire. The project champion, designers and engineers were secretive and preferred not to form collaborative relationships with any external partners, as the concept of a multi-stable shift-by-wire rotary gear selector was too fuzzy and unprotected by any patents. As the design manager pointed out:

> "*The rotary shifter enabled by the multi-stable shift-by-wire was a pure Jaguar innovation …. We find a problem, work it through and solve it… the rotary shifter came from the research department very early on during the project… we did it on our own and then we worked very closely with suppliers to get what we wanted in the later stages of the project.*"

The duration of the closed model of innovation during the early stages of the project was about one year and this period was important for internally building and developing the maturity of the concept prior to the filing of a patent:

> "*I didn't want to open it earlier because we hadn't got adequate protection for the idea, nor had I got adequate maturity in the concept. So, going earlier I would have had an immature concept and the risk of losing the intellectual property would have been higher*" (Project Champion, Research Technology Strategist and Product Engineer)

Several key drivers influenced Jaguar's decision not to open up the first two stages of the project to any external partners. They include a weak patent position, high risk of knowledge misappropriation, and the time required to increase the technological maturity of the rotary shifter prior to the application of a patent. A closed model of innovation was enabled by Jaguar’s world class internal R&D capabilities.

As the project was progressing, there was a high level of concern among the Senior Engineering Team about both the risk of failure and the readiness of the market to accept a change from the predominant stereotypical control of a stick shifter to a rotary one:

> “*At this point, I knew that the business itself was very divided on the concept. There were some people who thought it might have been a good idea. There were an awful lot of concerns.*” (Project Champion)

The emergence of the Senior Engineering Team’s concerns can be interpreted as a crisis because an escalation of this state of tension would have led to an early termination of the project, thus jeopardizing the opportunity for Jaguar to profit from the opportunity of a potentially promising radical innovation. The emergence of this crisis (Figure 2: E1) was the key temporal marker at the end of stage two of the project, which triggered the need for a faster response time, and innovation speed so as to address these concerns swiftly and to restore trust in and support for the project:

> “*So, some of the concerns were ‘Customers won’t like this when they’re driving’ or ‘Customers won’t be able to use this’ or ‘Customers might have to look down more than they would if it was a stick shifter and therefore look away from the road’… The best way to alleviate all of these concerns was to know every concern that everybody had and then conduct experiments to generate data that would either show that their concern was in fact valid or would demonstrate that their concern was not valid.’*
> (Project Champion)

To do so, the project champion required a working prototype vehicle to conduct experiments to compare and contrast the manoeuvres of participants driving vehicles with a rotary shifter and with a traditional stick shifter. Although there was the capability to develop the working prototype in-house, the project champion allocated this engineering task to Venus, an engineering service company, to accelerate the response time and innovation speed:

> "*It would have taken me longer to get all the people in the workshops together, all the people that knew about shift-by-wire together, all the people in the rapid prototyping team to generate the prototype parts. Whereas an engineering services company has got everything there and I can tell them, 'This is what I want and I want it by this time. It was definitely in my interest to get the concerns addressed as fast as possible.'*" (Project Champion).

4.2 Timing of shifting <u>between</u> a closed to an open model in the middle stages of the project

The shift from a closed to an open model of innovation in stage three was marked by the submission of a patent for the concept of the rotary shifter on Anaqua, an invention disclosure submission software package (Refer to Figure 2, A2: Patent Submitted). It was the first legal defensive mechanism deployed against opportunistic behavior prior to opening up to any external partners and, at that point, the idea is legally considered as being patent pending until the final filing and submission of the patent (Figure 2: B Patent Filed). In line with process theory (Langley et al., 2013; Pentland, 1999), we have also explored the underlying and generative mechanisms specific to the project structure which further facilitated the readiness to open to external partners , as a response to the two surface events described above (emergence of a crisis that led to an early submission of a patent).

Our analysis shows that the structure of the project displays the characteristics of a loosely coupled system, in which elements are responsive, but retain evidence of separateness (Orton and Weick, 1990). The direct positive effects of a loosely coupled system are modularity, requisite variety, and discretion (Weick 1976). Modularity is achieved from the elimination of unnecessary relationships and reduction of the number of necessary relationships; it is facilitated by loose couplings instead of tight couplings (Page-Jones, 1980). Requisite variety is observed in a loose coupling system by the extent to which its elements serve as a medium that can register numerous inputs with accuracy, while discretion is defined as the capacity for autonomous action by the agents (Orton and Weick, 1990).

The project champion had the discretion needed to choose a faster innovation speed to acquire complementary resources. The decision to shift from a closed to an open model belonged entirely to the project champion; the high level of autonomy and discretion in the decision-making process enabled a smooth and swift transition from a closed to an open model of innovation as illustrated by the following excerpt from the interview:

> "*I made the decision to go to the University of Eos and to Venus for a quotation for the scope of the work. Based on their quotation, I raised a purchase order. And at that point, that's the only point at which I needed approval from the Head of Research.*" (Project Champion)

In addition, instead of having a traditional team with permanent members and strong team membership during the duration of the project, internal engineers and designers were brought in for specific project tasks in a loose way, when needed, as suggested in the evidence below.

> "*It wasn't a team. They were people that I could call upon for help for different aspects of the work. So, for example I had help from Design in terms of they would input what it would look like. So, would it be a chrome-type surface finish or would it be a leather-type finish? So, I had input from Design. I had support from the Human Factors team, they helped me with the experiments.*" (Project Champion)

The weak membership of the engineers is a form of modularity as unnecessary strong relationships with internal engineers were avoided and it ensured a smooth integration of variety (inputs from external partners) and avoidance of a defensive Not Invented Here syndrome (Katz and Allen, 1982).

4.3 Benefits of shifting to an open model of innovation

At the beginning of stage three, when the project champion shifted to an open model of innovation, different types of external partners such as suppliers and universities were allocated specific tasks related to the rotary shifter and its enabling shift-by-wire. In this way, the required complementary capabilities were acquired in a timely way to accelerate the NPD process, and to respond swiftly to the internal crisis. For example, the University of Eos conducted user trials and generated data about the preferences of users in terms of the optimal design of the rotary shifter:

> "*I didn't want to get a prototype made when at first I didn't know if mono-stable would be better or multi-stable. I didn't know what diameter to make the shift, I didn't know what height to make it. So, having got that data I could then progress to a working prototype.*" (Project Champion)

The outcomes of the task allocated to the University of Eos were the design specifications and parameters for the rotary shifter in relation to its height and diameter. Based on these design parameters, Venus, an engineering service company, was brought into the project to build the prototype "*because, again, it was quicker for me to do that rather than try to get a large cross functional team within JLR to develop the prototype in-house.*" In parallel, the project champion and engineers from Jaguar Land Rover were heavily involved in the project and were conducting internal engineering activities for the development of the concept of the rotary shifter.

From Table 1, we can also observe that the temporal map is densely populated with multiple activities that are fast paced, short term, and short cycle as they were compressed into stage three of the project, and innovation speed was gained during stage three. By managing a broad range of activities concurrently with both internal and external partners, the project champion stimulated a sense of urgency by increasing pace (Ancona et al., 2001) during this stage to address the concerns of internal stakeholders swiftly.

Project Lifecycle	**Actors**	**Level of Interaction**	**Sequence of Activities**
Stage 3:Concept Design and Prototype	Internal: Project Champion, designors and engineers	High	Focus on engineering work on the concept of the rotary shifter and shift-by-wire
	External: University Of Eos	Moderate	Conduct user trials to generate data and understanding about their preferences when using a rotary shifter
		Moderate	Work on the best design parameters of the rotary shifter to fit the preferences of users
		Moderate	Develop the design specifications for the rotary shifter (diameter and height)
	External: Engineering Service Company: Venus	High	Build prototype of the rotary shifter based on the above design specifications
	Internal: Project Champion and different functions of JLR	High	Use the prototype of the rotary shifter to conduct experiments with users to record how they manoeuvre the rotary shifter when driving
			Communicate the data of the internal and external expriments to Senior Engineering Team
	External: University of Asteria	Moderate	Conduct market research with customers to evaluate how to improve the ergonomics and ease of use of the rotary shifter
	External: Customers	Low	Conduct first clinic test with customers to collect feedback on the rotary shifter
Stage 4: Design and Engineering for Production	Internal: Engineering Programme Team	High	Decide whether to take forward the rotary shifter into production
		High	Nominate the suppliers for the design, development of a production prototype
	External: Engineering Service Company: Venus	High	Support the transfer of the prototype of the rotary shifter to Tier 1 suppliers
		High	Develop the software for the rotary shifter to be compatible with the overall system of the XF
		High	Conduct extensive Failure Mode Effect Analysis to test that the rotary shifter was robust against any failure
Stage 5: Ramp Up to Production	External Strategic Suppliers: Crios and Jupiter	High	Design and development of a fully functioning prototype of the electronic transmitter selector
		High	Test the components for the shift-by-wire components

Table 1. Low level of interaction: Customers were consulted only to provide feedback
Moderate level of interaction: External partners were directly consulted for the development of the new products and to conduct trial experiments,
High level of interaction: External partners were directly involved in the design and development of the innovation

The working prototype developed by Venus was used to conduct a series of experiments with users to address the concerns raised by the Internal Engineering Team and to generate both objective and subjective data to address every point of concern raised:

> "*Without data to specifically address the concerns, it's very difficult to argue whether the concerns are valid or not…these concerns were very understandable and if this was ever going to go to production I knew that I would have to generate some data to address every point of concern that was raised. …..*" (Project Champion)

For example, one of the experiments was designed to collect video evidences in order to address the concerns of the Senior Engineering team that was related to the rotary shifter being potentially distracting to drivers as they would have to look down and away from the road more than they would with a traditional stick shift:

> "*The results of the experiment actually showed that people looked down less with the rotary shifter than they did with the stick shifter. So, that point was addressed very specifically head on that in fact the rotary shifter, in a controlled experiment, people looked down less.*" (Engineer, Jaguar)

After conducting a series of controlled experiments with 30 different participants, additional subjective data were collected and the participants were asked to report their preference between the stick shifter and the rotary shifter:

> "*And the ultimate, the last question was, 'If you had a choice of driving a vehicle with either the stick shifter or the rotary shifter which vehicle would you pick?' and the*

results for that were very clear. People would pick the rotary shifter vehicle."

(Engineer, Jaguar)

The resulting change that occurred on the strength of the objective and subjective data and video-recorded evidence generated from the series of experiments was a shift from a state of concern (Figure 2: E1) to one of restored confidence in the potential of the rotary shifter (Figure 2: E2). The Senior Engineering team approved the progress of the project to the next stage. By shifting to an open model of innovation to accelerate innovation speed as a means to respond swiftly to the crisis, the internal threat of project termination that could likely destroy the opportunity of future profits for Jaguar from this promising radical innovation was overcome.

Following the change when the concerns were resolved, we observed further openness to external partners to continue improving the ergonomics of the rotary shifter before the first clinical test with customers. The University of Asteria conducted further market research to examine user acceptance in terms of the ergonomics and ease of use of the rotary shifter, and to improve the ergonomics of the rotary shifter. During stages four and five, there was a further change in the innovation model marked by a gradual progression to open the project further to other external partners for the design and engineering of the rotary shifter and its enabling shift-by-wire and to facilitate its readiness. At stage four, Design and Engineering for Production, as is typically the case, there was a shift in the ownership of the project from the project champion to the Chief Programme Engineer with a Programme Engineering Team, who had a budget to deliver the XF to market. As the development of the rotary shifter was moving towards production, the Programme Engineering Team was responsible for the development of a production unit of the rotary shifter and its enabling shift-by-wire that would be fit for mass production.

At that point, patents for the rotary shifter and enabling shift-by-wire had already been filed and the Programme Engineering Team collaborated with traditional Tier-1 suppliers for the detailed engineering design, development and production costs of the two items for mass production. Jupiter and Crios were the strategic suppliers nominated for the development of the shift-by-wire gearshift system. The duration of the collaboration between Crios and Jaguar for the rotary shifter project was two years. Table 1 shows that Crios was also integrated in the middle and downstream stages (4 and 5) of the project, and their role was coded as highly important. During the middle stages of the rotary shifter project, Crios provided a fully functioning prototype of the electronic transmitter selector. As a result, Crios was nominated as a strategic Tier-1 production supplier in stage five. Jaguar relied heavily on Crios for the design, development and testing of the components for the shift-by-wire system, as the supplier "*has resources worldwide and strong capabilities from a mechanical point of view*" (Internal Jaguar Engineer). That observation is further supported by the engineer from Crios: "*Jaguar had the idea of what they wanted, but they relied heavily on us to turn this idea into a working product.*" Crios evaluated the safety specifications of the rotary shifter by checking whether it met safety and functional considerations. In summary, the shift to an open model of innovation after a patent was submitted at the end of Stage Two, and the progression to further openness in Stage Four provided Jaguar with key benefits, such as faster response time to resolve the internal crisis, and access to valuable complementary capabilities from different types of external partners (engineering services companies, suppliers, customers and universities). These benefits were all critical in maximizing the ability of Jaguar to preserve and nurture the opportunity during its NPD process to profit from the innovation of the rotary shifter at a later stage.

4.4 The implementation of an external loose project strategy

We can observe from Table 1 that the project champion partitioned the NPD activities in a modular way to the external partners. As mentioned earlier, one of the direct effects of a loose coupling strategy is modularity, defined as the elimination of unnecessary relationships (Orton and Weick, 1990: 210). Modularity can also be used to protect IP by dispersing information (Baldwin and Henkel, 2015), by dividing the task at hand and providing only the information that an agent would need to fulfill the task (Ronde, 2001). As modularity enabled tasks to be partitioned and worked in parallel, division of labor between firms and loose coupling are thus facilitated (Von Hippel, 1990, Sanchez and Mahony, 1996). In our case study, we observed a similar strategy where Jaguar implemented an external loose coupling project strategy was implemented the risk of knowledge expropriation. As illustrated in Table 1, the scope of the development activities allocated to the external partners was reduced as each external partner was responsible for specific activities The reduction of the scope of R&D activities to external partners forms part of the deployment of an informal defense mechanism to minimize the risk of knowledge misappropriation, as the external parties had knowledge of some modules and not others.

In addition, the project champion and engineers deployed a moderate level of secrecy towards the strategic external partners, as an informal relational defense mechanism against knowledge misappropriation. Despite the fact that Venus was heavily involved in the development of the multi-stable, shift-by-wire rotary gear selector, the Jaguar NPD team maintained a secretive, distant and circumspect approach, as one engineer at Jaguar commented: "*Although the relationship with Venus was good, trust was not high… there is always an element of risk that they will seek patents too.*" Jaguar only selectively disclosed the minimum level of information necessary for Venus to develop the prototype for the rotary shifter. Similar to Venus, the project champion and the engineers exercised a moderate level of control and secrecy with Crios during the project by regularly requesting reports on the status of work in progress. The relationship was governed with contractual mechanisms such as non-disclosure agreements (NDAs), and fixed price contracts. The fixed price contract was in fact an effective mechanism for Jaguar to keep full control over the project and in Venus's view: '*an open ended contract with a drawback budget would have been more appropriate*'. The distance of the relationship between Jaguar and Venus is further exemplified by the fact that the key engineer at Venus was not yet aware that Jaguar had successfully registered a patent for the rotary shifter in our round of interviews in 2009.

As illustrated in Figure 2, despite the use of an external loose coupling project strategy during different stages of the project, one of the external partners, Crios, independently filed and successfully registered a patent for a technological innovation of a component within the rotary shifter at stage four (design and engineering) of the project. The relationship with both universities was less guarded and secretive than the relationships with Venus and Crios as the risks of misappropriation of knowledge were lower. For example, the collaboration with the University of Asteria lasted for three months and the level of cooperation was '*constructive and informal'*. As the task was less critical and uncertain, the Jaguar team exercised less pressure and control during the project as the Project Engineer at the University reported: *'they trusted us to do the work with minimum supervision and auditing*'.

4.5 Who profited from the innovation?

Jaguar largely profited from the innovation of the rotary shifter that contributed to the success of XF sales as "*it was the most prominent technological innovation of the XF*" (Head of Research). There are three indicators of the success of the rotary shifter. First, Jaguar was granted four patents for different aspects of the multi-stable shift-by-wire rotary gear selector in the US and a number of other jurisdictions, indicating that the multi-stable system of the rotary shifter developed by Jaguar had a unique product competitive advantage, which was legally protected. Second, the rotary shifter was rolled out in other subsequent models of Land Rover and Jaguar vehicles as a result of its strong endorsement by customers. The quality of the shifter and the multi-stable system developed by Jaguar was good in relation to the safety standards of drivers; in contrast to competitors, there have been no quality issues leading to product recall and impairment of the ability of Jaguar to generate long term profits. Third, the sales performance of the XF indirectly reflects the success of the multi-stable shift-by-wire rotary gear selector, which was regarded as its key technological innovation. As reported by the Finance team of Jaguar, there was a sharp growth in sales of the XF in the UK, with an increase of 36% between the first half of 2008 (launch of the XF) and the first half of 2010. Despite the financial crisis and recession, the XF gained market share in the UK with an appreciation of seven per cent in the premium car market between the first half of 2008 (12.6%) and the first half of 2010 (19.6%). However, despite the pro-active deployment of a range of formal and informal appropriation mechanisms combined with project strategy (i.e. loosely coupled project), we also observe the risk of an open innovation strategy in terms of inadvertent knowledge spill-over and potential threat to the profit of the innovating firm. Although Jaguar appropriated the lion's share of the innovation, Crios also appropriated a small share by independently filing a patent.

5. Discussion and Conclusions

Our paper examines the decision NPD project managers face about whether and when to open their innovation projects. Previous studies that have examined the tension between openness and closedness are primarily at the firm and business models levels (Appleyard and Chesbrough, 2017; Ciravegna and Maielli, 2011; Katila and Mang, 2003; Alexy et al, 2009; Manzini, Lazzarotti and Pellegrini, 2016), and therefore there is little understanding of how the choice between closed and open innovation is managed at the project level. Building on the PFI framework, we provide several contributions to the innovation management literature. First, our theoretical framework contributes to a process and temporal perspective of open innovation by providing empirical evidence that the choice between openness and closedness is not static but a dynamic strategy. Second, we extend the PFI model by considering appropriability regimes not as fixed but as variable over time. Third, we contribute to the open innovation literature by identifying two core project processes and their enabling mechanisms, which influenced the ability of Jaguar to maximize profits from the innovation of the project. These two core processes are: a) the timing of openness to external partners and b) an external loose project strategy after the shift to open innovation. Interestingly, by taking a temporal perspective our secondary contribution relates to the extension of the PFI model: we carve out an important distinction between *factors* and *processes*. We were in a position to go beyond the *factors* as represented in the PFI model at a specific point of time, and instead observe project *processes* and their *enabling mechanisms* which unfold during the different stages of the project.

5.1 Timing of shifting from a closed to an open model of innovation

The first core project process that influenced the ability of Jaguar to maximize profits from the innovation was the timing of openness to external partners. Previous research has emphasized the benefits of early supplier integration in the NPD process in terms of a reduction of modification costs and improved time to market (Milison and Wilemon, 1992; Swink, Talluri and Pandejpong, 2006; Wynstra and Pierick, 2000). However, the benefits of supplier integration into NPD are not universal, as supported in our case study (Eisenhardt and Tabrizi, 1995; Najafi et al., 2013; Trygg, 1993). Our findings show that Jaguar avoided the trap of early openness by judiciously closing the innovation model to any external partners in the early stages of the project. The drivers of a closed innovation model were a weak patent position and the time required to increase the technological maturity of the innovation, prior to the application of a patent. The closed model of innovation was enabled by Jaguar's world class R&D capabilities. In line with the PFI model, the absence of any IP protection makes imitation easy in stages one and two of the project; hence markets do not work well and the profits from the innovation may accrue to others rather than the innovator. However, in the PFI framework, appropriability regimes are fixed in time, although this misses the critical element that firms can also endogenously shape it by their behaviors and strategies, either by strengthening or weakening it over time (Pisano, 2006). By shifting from a static to a dynamic representation of the PFI framework at the project level, we extend the PFI model by providing a fine-grained view of how NPD managers proactively change the IP position from a weak to a strong one and deploy several informal defense mechanisms at different stages of the project to minimize the risks of misappropriation

As the project was progressing, higher innovation speed combined with the need for complementary capabilities motivated the shift from a closed to an open model of innovation. Our findings also suggest that it is not just a question of either closing or opening the model of innovation, but there was an intermediate process in readying the transition from closed to open innovation enabled by two mechanisms. First, the pro-active change in the IP position from a weak to a strong position, as marked by submission of a patent prior to shifting to an open model of innovation, was the first early defensive mechanism that conferred on Jaguar an effective protection against opportunistic behavior, which strengthened its potential to profit from the innovation before engaging with any external partners. Our findings support the view that IP enables open innovation as it is a safeguard for knowledge protection (Bahemia et al., 2017; Laursen and Salter, 2014; Zobel et al., 2016), rather than the view that patents may hinder open innovation relationships

(Katila and Mang, 2003; Katila, Rosenberger and Eisenhardt, 2008; West and Gallagher, 2006).

Second, an internal loose coupling project strategy that involved discretion, and modularity (Orton and Weick, 1990) was deployed as another mechanism to facilitate the intermediate process of readying the transition from closed to open innovation. For example, the project champion had the discretion and the autonomy to accelerate the innovation project. From this perspective, the project became more loosely coupled as the project champion was able to free it temporarily from the constraints of the firm (i.e. project termination) by uncoupling it from the internal R&D of Jaguar and opening the innovation model to external partners as a way of accelerating the innovation speed, and increasing variety (inputs from external partners). Furthermore, in keeping with the theory of loose coupling, modularity was present as unnecessary strong relationships with internal engineers were eliminated. In our case study, coupling provided access to internal resources, whereas modularity produced looseness and flexibility because internal R&D engineers were temporarily brought to the project only when needed.

5.2 The implementation of an external loose project strategy after the shift to open innovation

The second core project process that determined the ability of Jaguar to maximize the lion's share of the profits was the implementation of an external loose project strategy that was enabled by two forms of modularity that we observe in our case study (Orton and Weick, 1990). First, the innovation activities that were allocated to the external partners in the middle stages of the project were partitioned and modularized such that the external partners had knowledge of some modules and not of others. This form of modularity was an effective mechanism to hide information, protect IP and mitigate the risks of expropriation (Baldwin and Henkel, 2015; Ronde, 2001). Reduction of the scope of an alliance is an effective alternative response to hazards in R&D cooperation, and control of the risks of leakage (Oxley and Sampson, 2004). Second, the project manager kept strategic suppliers at a distance by developing secretive and guarded behavior as an informal relational defense mechanism against the risk of the misappropriation of resources by external partners. Embedded ties between firms and external partners may also have a negative effect on knowledge sharing for innovation, as there are increased opportunities for using exchanged knowledge, to the detriment of partners (Anderson and Jap, 2005; Grayson and Ambler, 1999; Selnes and Sallis, 2003). Taken together, the development of guarded and distant relationships as well as the reduction of the scope of the tasks assigned to external partners, can be considered as complementary informal defense mechanisms to the formal one that were deployed to nurture causal ambiguity in order to protect the radical innovation against imitation and the risks of misappropriation. According to the resource-based view of the firm, causal ambiguity "*acts as a powerful block on both imitation and factor mobility*" (Lippman and Rumelt, 1982, pp. 420).

Although the timing of the shift from a closed to an open innovation model and the implementation of an external loose coupling project strategy were key project processes that determined the ability of Jaguar to capture most of the value generated from the innovation, there were still risks of misappropriation of IP, as was demonstrated by Crios who independently patented technology from the foreground knowledge of the project (Granstrand, 2001). This shows that despite the development of guarded relationships, there was a collateral risk of losing intellectual capital as external partners engaged in the project can find ways to circumvent patents (Arundel, 2001; Cohen, Goto, Nagata, Nelson, and Walsh, 2002; Granstrand and Holgersson, 2014; Levin, et al., 1987). Although Crios filed a patent, the benefits that Jaguar has gained from their open innovation strategy in terms of speed of innovation and access to complementary capabilities substantially outweighed the small share of profits appropriated by Crios as it was ultimately reflected by the project champion, '*there are risks to open innovation, these risks can be managed….the biggest risk is not to open the innovation process.'*

5.4 Limitations and future research

Whilst this research has provided a fine-grained view of the dynamics between closed and open innovation at the project level, the findings of the case study remain limited to a single case study of a luxury car manufacturer, and its external validity therefore remains limited. We need additional case studies from the automotive industry, as well as from industries that are less conservative in their innovation strategy than car manufacturers (Dodourava and Bevis, 2014). Our findings are also restricted to a radical innovation, and it is uncertain if the conclusions can be extended to other types of innovation, such as incremental and process innovations. There are several suggestions for future research. First, by moving from cross-sectional studies to longitudinal or panel studies that incorporate a temporal perspective, researchers can develop better theoretical frameworks of open innovation, as opening or closing of a project proves to be an essential dimension in the conceptualization of open innovation. We encourage researchers to do quantitative research about the dynamics of openness across different stages of NPD projects as our case study has clearly demonstrated there is a high degree of variation in terms of the type of innovation models (open versus closed), and in terms of the appropriation strategies (formal and informal) during the lifecycle of the project. Second, the current study describes a relatively successful project with respect to the timing of the transition between closed and open innovation. It would be interesting to examine failure cases and analyze how the poor timing of the transition between closed and open innovation during a project leads – among other factors – to a poor outcome. Finally, our case study has focused on factors that influence the movement from closed to open innovation, but the dynamics can also go in the other direction. Multiple case studies will allow an in-depth understanding of the wide array of other possible causal conditions that would potentially influence a different sequencing between closed and open models of innovation than the one charted in our case study.

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Appendices.

Figure 1A: Aggregate dimension: Closed model of innovation during the project

First Order Categories	Second Order Themes
	Stages 1, 2 and beginning of stage 3 **Drivers of a closed model of innovation**
We created and sketched it in our studio to create something that is very Jaguar The rotary shifter was a pure Jaguar innovation Design was managed internally, we very much have control over design of the rotary shifter	Need to generate a unique and novel automotive industry concept
I didn't want to open it earlier because we hadn't got adequate protection for the idea nor had I got adequate maturity in the concept'. *(Project Champion)*	Need time to mature the concept internally
We worked heavily in the research department with the patent department in stages 1 and 2 of the project (Jaguar) before applying for the patent There was no patent for the rotary shifter in stage 1 and 2 of the project, the idea was quite fuzzy	Weak patent regime
We find a problem, work it through and solve it'. *(Design Manager)* The rotary shifter came from the research department very early on during the project' *(Research Director)* The initial work was done remotely from any suppliers and collaborators in stage 1 and 2 We did it all internally in stage 1 and 2 of the project We did it on our own and then we worked very closely with suppliers to get what we wanted in the later stages (stages 3,4,5)' *(Engineer, Jaguar)* The idea of the rotary shifter was born internally in the company and the concept was created internally	**Enabler of a closed model of innovation** Internal research and development during the project: high research capability

Figure 1B: Aggregate dimension: Open model of innovation during the project

First Order Categories	**Second Order Themes** **Middle and late stages of the project (3,4,5)**
At this point, I knew that the business itself was divided on the concept… there were an awful lot of concerns… so some of the concerns were: 'customers won't like this when they're driving' (*Project Champion)*	**Surface Trigger to switch from a closed to open innovation** Critical Event: High level of concerns by Senior Engineering Team
'It would have taken me longer to get all the people in the workshops together, all the people that knew about shift-by-wire together, all the people in the rapid prototyping team to generate the prototype parts. Whereas an engineering services company has got everything there and I can tell them, "This is what I want and I want it by this time. It was definitely in my interest to get the concerns addressed as fast as possible' *(Project Champion)*	Need for a faster response time to the risks of project termination and need for innovation speed
So, when I submit into Anaqua from that point on I can legally declare the idea as being patent pending, which we do. So, we say we have an idea under NDA, under the non-disclosure agreement, we say we have an idea and we say it is patent pending. *(Engineer, Jaguar)* The rotary shifter was heavily patented by us and we work closely in stage 3 with the patent department before we start any collaboration' (*Engineer, Jaguar)*	**Enablers to open innovation** Readiness to submit a patent before opening up to external partners
'I made the decision to go to the University of Eos and to Venus for a quotation for the scope of work. Based on their quotation, I raised a purchase order. And at that point, that's the only point at which I need approval from the Head of Research…..And at that point he approves it and the purchase order goes' *(Project Champion)*	**Internal loose coupling strategy** High level of autonomy of the project champion
It wasn't a team. They were people that I could call upon for help for different aspects of the work. So, for example I had help from design in terms of they would input what it would look like... I had support from the Human Factors team, they helped me with the experiments. *(Project Champion)*	Structure of the Team: weak membership of internal engineers to the project

Figure 1B (continued): Aggregate dimension: Open model of innovation during the project

First Order Categories

Refer to Table 1 for the narrow scope of the innovation tasks to each external partners

'The contract was not open ended…. an open ended with a drawback budget would have been more appropriate' *(Engineering Service Company, Venus)*

Although the relationship with Venus was good, trust was not high there is always an element of risk that they will seek patents too' *(Engineer, Jaguar)*

Non-disclosure agreements and contracts were used with external partners: 'we would secure a non-disclosure agreement with whoever we were speaking to, but the second thing is we prefer to have applied for a patent so that the prior art is, if you like, recognised and stated that we had lodged rights to IP prior to any discussion with any third party. *(Engineer, Jaguar)*

Sometimes it (sharing of information) was not always reciprocated: you put a question, it floats as no-one answers it' *(Supplier, Crios)*

Second Order Themes

External Loose Coupling Project Strategy

Modularity
Reducing the scope of innovation tasks assigned to external partners

Informal Defense Mechanisms

Modularity
Reducing the tightness of the relationships with external partners
Moderate level of secrecy
Guarded relationships with external partners