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ANALYSING OPEN INNOVATION INTEGRATION TO PRODUCT DEVELOPMENT PROCESSES WITHIN THE BRAZILIAN AUTOMOTIVE INDUSTRY

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Abstract

The purpose of the present study is to analyze how different Open Innovation (OI) activities occur in Product Development Processes (PDP) from the Brazilian automotive industry. From conceptual frameworks unifying both OI and PDP, the study presents the main OI practices that are applicable to the PDP, as well as four constructs regarding that interrelationship. A case study approach is taken in 7 companies with 11 interviews, and a comparative and critical analysis is made, providing insight into how OI and PDP literature relate to the actual work being done in the automotive industry.

Keywords: open innovation, new product development, innovation management, automotive industry, product development processes

1. Introduction

The automotive industry has continuously proven to be a cornerstone to the development of many countries, being of great importance to economic and social growth, both in the short and long term (de Mello et al., 2016). According to the Brazilian Automotive Industry Association (ANFAVEA, 2017), the Brazilian automotive sector, hereby meaning the auto parts, automakers and their respective suppliers, represents 22% of the country's industrial GDP (4% of the national GDP). The economic and social impact that this industry represents to the country is clear, and keeping this industry competitive at the global level is a matter of the utmost importance, with governments acknowledging that an important driver for that is innovation.

The Product Development Processes (PDP) are organizational processes defined as "the collective of activities, involving almost all the departments of a company, that have the purpose of transforming market needs into economically viable products or services" (Kaminski, 2000). As an organizational process, it can be divided into a series of activities that can be formalized, measured and optimized, and as such, it has been evolving since its conception during the early 60's (Evans, 1959) into a model unifying PDP to external knowledge and technology management (Liyanage et al., 1999, p. 376). Therefore, innovation taps not only into the internal infrastructure of a company, but also into external knowledge sources, managing globalized research networks, collaborations, and strategic alliances. This shift in innovation is regarded as Open Innovation (OI). Open Innovation is defined as " the purposive use of inflows and outflows of knowledge to accelerate innovation in one’s own market, and expand the use of internal knowledge in external markets, respectively" (Chesbrough et al., 2006). This concept assumes that companies can and should use external information, knowledge, and technology into their innovation processes. Recent research has shown evidences that collaborative innovations are more probable of having more technical significance and commercialization capacity (Walsh et al., 2016).

It is evident that the level of adoption to OI is different from company to company and industry to industry, depending on variables like technology intensity of the offered products and services and their position in the value chain. Adoption to OI has also been studied, and different ways to categorize it have been discussed (Chiaroni et al., 2011). Even though most of the OI literature focus on the developed world, particularly the US and their innovation ecosystem (Armellini et al., 2014), it is still important to relevant to study the aspects of OI within an emerging economy context.
The purpose of the present study is to analyse how different OI activities occur (and if they do) in Product Development Processes (PDP) from the Brazilian automotive industry, identifying the most common OI practices, actors involved, the maturity those companies have with OI and how all this affects their new product design processes. Three research questions are posed: what are the implications of open innovation regarding product development processes, especially concerning those of the (Brazilian) automotive industry? How mature are those companies regarding open innovation concepts and tools in their innovation processes? Who are their main actors involved in open innovation and which activities are developed through collaborations?
The structure of this paper is as follow: Section 2 provides a brief literature review and reference frame regarding PDP and OI; Section 3 then details the research method and the analytical model used; Section 4 presents the results obtained from the research and its analysis. Finally, Section 5 presents the conclusions of the study, and offer suggestions toward future research topics.

2. Literature review

2.1. Product Development Processes (PDP)

Expanding on the definition provided in the introduction of this text, a useful definition for PDP (also sometimes regarded as New Product Development, or NPD) is: "a set of activities through which one seeks, from the market needs and technological possibilities and constraints, and considering the competitive and product strategies of the company, to reach technical specifications for the design of a product and its production process, so that manufacturing is able to produce it" (Rozenfeld et al., 2006). Other definitions (Krishnan and Ulrich, 2001) give PDP a more strict meaning, not involving the process of research and development of the technology itself into the product development process. For those authors, PDP can be divided into two categories: one dealing with decisions concerning an individual project, and another focusing on decisions concerning the entire organization and its planning towards new products and services development. That latter category is also sometimes regarded as portfolio management (Cooper et al., 2001).
Two very important concepts of recent PDP literature are based around the concept of the design spiral (Evans, 1959) and in Asimow's design process, also known as the production and consumption cycle (Asimow, 1962). The former regards the iterative nature of design as one of its main points, while the latter is more linear in nature, going from the identification of need to the design phases and then the production and consumption (not unlike a lifecycle analysis) cycles. Those two authors set the stepping stones to modern PDP literature. A final contribution worth mentioning is the development funnel concept, proposed by Clark and Wheelwright (1993), and illustrated in Figure 1. A linear process characterized by the geometric shape of a funnel, with the number of inputs being larger than outputs, giving the idea that the process of product development should filter the good ideas and recombining them until a final product is ready for the market. The implication here is that there should be steps in the development process to review past activities and, if deemed necessary, stop development, or discard the project altogether. Similarly, Cooper (1990) developed the stage-gates model, another linear model grouping activities into two kinds: stages, and gates. Gates serve as points for systematic and structured decision making so that the project can advance to the next development step according to a company's strategic planning.
Several different approaches and reference models have been proposed to PDP, and numerous literature reviews have been made on the subject. It is not the purpose of this paper to present an extensive review on PDP, and therefore it is useful to rely on past reviews. Table 1 presents an adaptation of Canuto da Silva and Kaminski (2017), compiling relevant references to PDP over the decades, and their main contributions.

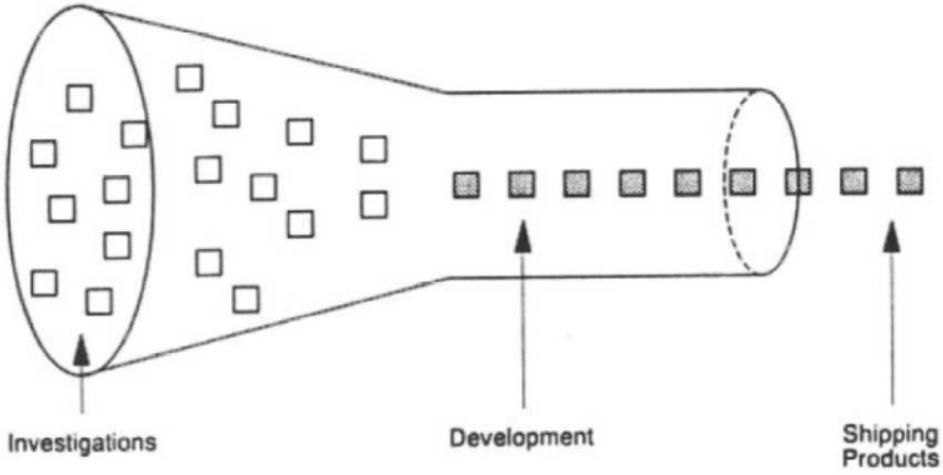

Figure 1. Product development funnel (source: Clark and Wheelwright, 1993)

Table 1. Overview of PDP approaches (source: adapted from Canuto da Silva and Kaminski, 2017)

Reference	Title	PDP approach
(Evans, 1959)	Basic design concepts	Design spiral
(Asimow, 1962)	Introduction to design	Production and consumption cycle
(Cooper, 1990)	Stage-gate systems: a new tool for managing new products	Stage-gates concept
(Womack et al., 1990)	The machine that changed the world: the story of lean production	Lean production concepts
(Fujimoto and Clark, 1991)	Product development performance: strategy, organization and management in the world auto industry	Development of funnel concept
(Clark and Wheelwright, 1993)	Managing new product and process development	Development of funnel concept
(Krishnan and Ulrich, 2001)	Product development decisions: a review of the literature	Perspectives (marketing, organizations, engineering design and operations management)
(Suh, 2001)	Axiomatic design	Axiomatic design concept. Domains and subdomains
(Rozenfeld et al., 2006)	Product Development Process Management	General reference model and product life cycle management (PLM)
(Dieter and Schmidt, 2009)	Engineering design	Stage gate concept
(Weber, 2009)	Automotive development processes	Customer oriented
(Omar, 2011)	The automotive car body manufacturing systems and processes	Automotive manufacturing design. Detailed phases and activities
(Canuto da Silva and Kaminski, 2016)	Selection of virtual and physical prototypes in the product development process	Guidelines to select virtual and physical prototypes in PDP
(Wynn and Clarkson, 2018)	Process models in design and development	In-depth review of current PDP works

2.2. Open Innovation and integration to product development

Since its conception (and first formalization) in the early 2000's, several definitions for Open Innovation (OI) have been proposed. A report from the Organization for Economic Co-creation and Development (OECD, 2008) presents nine different definitions for OI, and still newer definitions have been made to understand what actually is open innovation (West and Bogers, 2014). For the scope of this study, the following definition for OI, a refinement from the one previously mentioned in the introduction of this text, is considered: "following the original and more recent conceptualizations […], we define open innovation as a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organization's business model. These flows of knowledge may involve knowledge inflows to the focal organization (leveraging external knowledge sources through internal processes), knowledge outflows from a focal organization (leveraging internal knowledge through external commercialization processes) or both (coupling external knowledge sources and commercialization activities) […]" (Chesbrough and Bogers, 2014).

According to the definition, there are three main cores of OI activities, divided with respect to the direction of knowledge inflow: from the outside-in, from the inside-out, and one combining both. Another classification of OI activities (Dahlander and Gann, 2010) groups them into four types of openness: sourcing, acquiring, revealing, selling. Armellini et al. (2016) presented a useful combination of those two different classifications, as well as issues associated with each combination (of core process and type of openness), as shown in Table 2.

Table 2. Issues within open innovation activities (source: Armellini et al., 2016)

Core process	Type of openness	Associated issues
Outside-in	Sourcing	External knowledge sourcing and technology scouting
		Early integration of clients in PDP
		Early integration of suppliers in PDP
	Acquiring	Licensing-in
		Spin-in and M&A
Inside-out	Revealing	IP portfolio activity
	Selling	Licensing-out
		R&D services
		Spin-outs and divestment
Coupled	Sourcing/Revealing	Co-development and participation in research consortia
		Crowd sourcing and peer production
	Acquiring	Venture capital
		Licensing-in (with collaboration agreements)
	Selling	Licensing-out (with collaboration agreements)
		R&D services (with collaboration agreements)

Armellini et al. (2014) also proposed a conceptual model identifying the internal "products" within an R&D framework, effectively mapping OI activities within the PDP framework of a development funnel (in his case, dividing the funnel into three R&D core activities: basic research, applied research and development). For those authors, the products obtained throughout PDP are intellectual assets, and as such, may also be exchanged within other companies. It is within this conceptual framework that this study is structured.

Although the concept of OI may sound like something new, it has also been observed that many of the activities listed are common among many industries, including the automotive industry. The challenge is, therefore, in a company move from the occasional use to the institutionalized formalization of open innovation processes in its innovation management structure (Chiaroni et al., 2011).

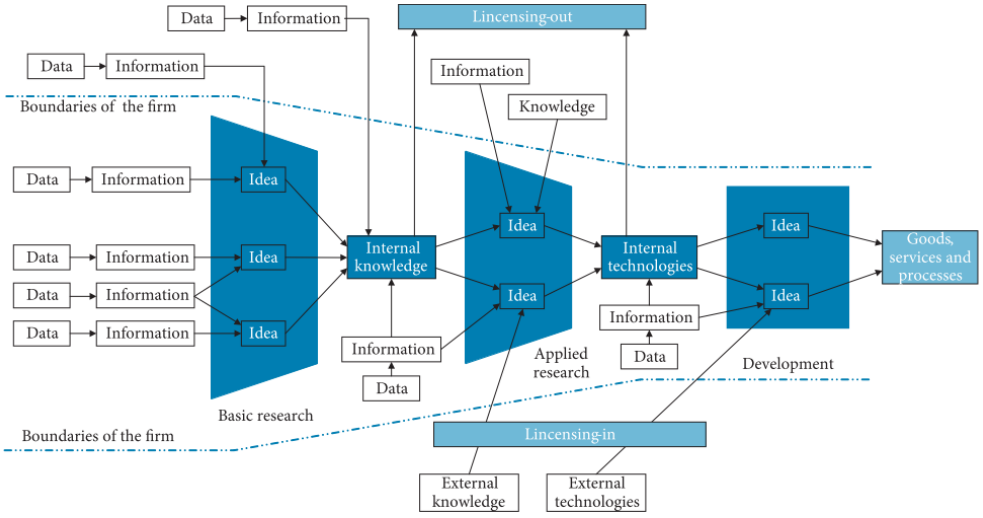

Figure 2. Open product development process conceptual model (source: Armellini et al., 2014)

3. Research method

Since the purpose of this paper is to analyse how different OI activities occur (and if they do) in PDP from the Brazilian automotive industry, the research method chosen for this study is a multiple case studies approach. Data was collected through the means of face-to-face interviews, performed by the research team on managers and product engineers directly related to design and new product development. To formalize the term "Brazilian automotive industry", the study was restricted to companies directly involved in the manufacturing of vehicles (i.e. automakers), all of them transnational companies headquartered in the "triad" of North America, Europe and Asia. The reason for that is that, by restricting the focus of the study to automakers, a limited number of case studies is enough to a considerable portion of the relevant (in terms of production and revenue) companies of the industry. The sample size chosen of different 7 automakers amounts to more than 66% of the country's production of auto vehicles (based on data from ANFAVEA for 2017), covering a wide enough amplitude to be considered representative of the automotive industry in Brazil.

With respect to the open innovation aspects studied, the research is concerned with three core constructs (as shown in Figure 3): (1) the open innovation practices, their state of maturity and structure within the organization, (2) the barriers and risks associated with the implementation of open innovation projects, and (3) the main actors or partners involved in the practice of open innovation in related to those companies. The fourth construct compares each of those to the main characteristics of the PDP from each company.

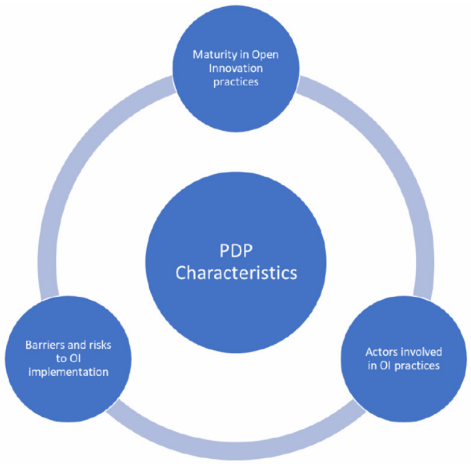

Figure 3. Open Innovation aspects, to be related with PDP

4. Case studies and analysis

As discussed in Section 3, the case studies were restricted to interviews with managers and engineers, working for automakers and directly related to design and new product development. A useful classification for the companies interviewed is that of the Brazilian car makers first comer and newcomer dichotomy (Ibusuki et al., 2012). Those terms are related to the period when each company (none of them Brazilian in origin) installed their first manufacturing plants in Brazil. The first comers (namely Volkswagen, Fiat, Ford and General Motors) are those that began their operations after the so called First Automotive Regime, in 1956, while the newcomers are those that came after the trade liberalisation, in 1990 (among them: Peugeot Citroen, Honda, Renault, Toyota, Hyundai, Daimler, Mitsubishi and Nissan). This distinction is important to the Brazilian automotive industry because there is a considerable difference between the two groups, especially in their R&D and product development capabilities. For many years, most of the newcomers were characterized by having little or no R&D capabilites locally (Ibusuki et al., 2015; de Mello et al., 2016). With that said, Table 3 presents the interviewed companies, categorized by their classification and region of origin. In total, 11 interviews were performed among seven automakers. There is also information relating to interviewees' positions and expertise in the automotive sector (quantified by years of experience).

Table 3. Case study interviews, by automaker classification and region of origin

Case #	Automaker classification	Region of origin	Number of interviews	Interviewee Background	Years of experience in automotive sector
1	First comer	European	2	Engineering Coordinator, PD Engineer	20, 20
2	First comer	European	1	PD Engineer	10
3	First comer	North American	2	PD Engineer, PD Engineer	20, 10
4	Newcomer	European	2	Senior Manager, PD Engineer	18, 16
5	Newcomer	Asian	1	PD Analyst	6
6	Newcomer	Asian	1	PD Engineer	4
7	Newcomer	Asian	2	PD Engineer, PD Engineer	4, 7
			Total interviewed: 11		

The analytical model presented in Figure 3 is a useful way to organize the data obtained throughout the interviews in a more practical form. As such, Table 4, organizes the data related to open innovation partners for those companies. The next two Sections, 4.1 and 4.2, present a brief case description (grouped between the first comer/newcomer dichotomy as well), and in Section 4.3 a comparative analysis is made.

Table 4. Most important open innovation partners involved in open innovation activities, for each case

Case #	Most important	2nd most important	3rd most important
1	An R&D plant/unit within their company	A key supplier	A private research institute, an R&D company, or a technical consulting firm
2	An R&D plant/unit within their company	A key supplier	A university or higher education research centre
3	An R&D plant/unit within their company	Another plant/unit (not R&D) within their company	A key supplier
4	An R&D plant/unit within their company	A key supplier	A private research institute, an R&D company, or a technical consulting firm
5	An R&D plant/unit within their company	A key supplier	A private research institute, an R&D company, or a technical consulting firm
6	An R&D plant/unit within their company	Another plant/unit (not R&D) within their company	A key supplier
7	Another plant/unit (not R&D) within their company	A private research institute, an R&D company, or a technical consulting firm	A key customer

4.1. Case #1 through #3: The first comers

Regarding the maturity in Open Innovation shown by these companies, all the interviewees considered that their respective companies have been practicing open innovation for longer than ten years, and they considered open innovation vital to the strategy of their design unit. However, for cases #1 and #2, they considered the structure of the organization toward open innovation rather informal and working on a case-by-case basis, while for case #3 the structure was considered more "developed" - meaning that open innovation is better formalized and not restricted to the few usual partners. Reasons for practicing open innovation varied among interviewees, however, for all cases, reducing costs with design and product development was the main reason, and having access to government incentives was cited as a close second. Another similarity between cases was in the open innovation practices listed as most important. For all cases, inbound practices were more important and more structured than outbound practices, with the main practices cited being: for case #1, the acquisition of R&D services, collective intelligence application and co-creation with partners. For case #2, cited practices were collective intelligence application, patents and licenses acquisition and participation in standardization committees (the only outbound practice listed). And finally, for case #3 the main practices cited were intelligence surveillance and co-creation with partners.

With respect to the risks and barriers found in the development and implementation of open innovation projects, the main reasons cited among the interviewees were the lack of clarity in open innovation strategy and differences between explicit intentions and resources allocated to that approach. Other important issue cited in all three cases was the loss of control in projects conducted with partners. Case #3 also cited possible theft or misappropriation of intellectual property or key knowledge to be important risks.

Finally, concerning characteristics of the PDP for each case, all cases considered their product development to be more incremental than radical in its nature, with current projects relying heavily on information from past projects. However, there was a strong trend for all cases citing a concern with products being developed for new markets and needing the development of new business models - traits that define radical innovation. Case #1 and #3 cited new design tools and techniques being used since 2014, and the same cases also mentioned that open innovation has influenced the way that design and new product development is done in their companies. Among the cited tools and techniques, the use of rapid prototyping in partnership with a supplier, of methodologies such as Design Thinking, and co-creation with partners were all considered important parts of their design processes that have been influenced by open innovation practices, according to the interviewees. Other evolution in the design process cited was the adoption of rapid prototyping, and the open innovation aspect is in the integration with the supplier during prototyping.

4.2. Cases #4 through #7: The newcomers

Newcomers are characterized in the literature (Ibusuki et al., 2012) by being more centralized in their design and product development departments - that is, most significant design activities are not done in subsidiaries like the ones studied, but rather in their headquarters. With that said, in all cases the interviewees believed that open innovation was adopted in their units somewhat recently (from 5 to 10 years), and the perceived importance of open innovation to product development varied from of little importance for case #5 to extremely important for case #4 (case #6 and #7 considered it moderately important). For all cases, and similarly to the first comer cases, the perceived organizational structure towards open innovation was considered still in development or in its introduction. Reducing design and R&D costs, and sharing risks and uncertainties in product development were the two most cited reasons for practicing open innovation in those cases.

With respect to the important open innovation practices cited by the interviewees, cases #4, #6 and #7 cited the acquisition of R&D services and collective intelligence application during design as the most important practices, while case #6 considered co-creation with partners to be the most relevant. Again, all the most important practices cited were categorized as inbound innovation practices, with outbound practices being considered less important for all cases interviewed. The most important risks and barriers found in the development and implementation of open innovation projects were found to be theft or misappropriation of key knowledge or intellectual property and a lack of clarity in the open innovation

strategy, which does seem to agree with the complaint about lack of organizational structure for open innovation. Another factor common to all cases was that open innovation practices were too distant from the corporate culture, with inappropriate tools and resources for open innovation being considered relevant to all cases.
Finally, concerning the characteristics of PDP in these cases, and similarly to the first comer cases, innovation was considered more incremental than radical, and projects rely heavily on information from past projects. With the exception of case #5, all the other cases also considered that projects were being developed towards new markets, and necessitating new market platforms or business models. However, unlike the first comer cases, all interviewees from newcomers considered that PDP has evolved dramatically since 2014, adopting new tools and techniques in product design, with a lesser factor of updating existing techniques also being mentioned. Among the cited tools and techniques used in product design, the use of rapid prototyping in partnership with a supplier, and the use of methodologies such as Agile and Design Thinking were mentioned. A relevant remark to be made is that Agile methodology was not mentioned during Section 2 of this text, and such methodologies are usually more traditional to a software development environment, and their mention here is rather surprising.

4.3. Results discussion

The most immediate discussion regarding open innovation practices should be made on the type of open innovation that was most relevant: for all cases, inbound practices were considerably more present in their companies than outbound practices. This is consistent with other findings from the literature. Chiaroni et al. (2011) calls that the open innovation journey, and other scholar have found similar structure (Armellini et al., 2016).
The use of the first comer/newcomer dichotomy is useful to separate Brazilian automakers between two distinct groups, and does allow the comparison between them. Newcomers are less mature in the Brazilian market, and until recent government policies, had their R&D investment centralized on their headquarters (Ibusuki et al., 2015; de Mello et al., 2016). This does agree with the data found - newcomers presented less maturity toward open innovation and stronger signs of evolution in their PDP in recent years. It is also possible to infer that the newcomers, especially those that had little or no R&D capabilities locally - are spending more resources on open innovation to "catch up" with the first comers and adequate themselves to new government policies - at least to the perspective of localised product development. A common barrier for open innovation projects that was mentioned by the newcomer cases and not by the first comers was a corporate culture that does not favour it.
The most important innovation partners cited were R&D units from the same companies and key suppliers. Interaction with clients during the design and product development processes was not mentioned by the interviewees, which could present some dilemmas when thinking of newer methodologies like Design Thinking, since it strongly reinforces the importance of integrating customers during the early design stages. Notwithstanding, many of the interviewees regarded open innovation as a not-so-new concept, since most of the practices were already done before the conception of the term in the early 2000's.
The mention of Agile and Scrum methodologies to product design in the automotive industry was a surprise to the research team, especially since those are usually more typical to the software development industry. Rapid prototyping also was cited to be a recent addition to cases from both groups, and its integration to suppliers seems to be a useful application of open innovation in the more traditional sense.
It is important to remark, however, that the sample size considered in the research might affect results in two ways: firstly, there are discrepancies in the expertise of the interviewees, with the entire range going from four to twenty years of experience. Secondly, sample size is not homogenous among each case, with some cases having one interview while others have two. With that said, the researchers involved in the study, through their experience in the industry, are confident that the data obtained is representative and that the results presented do reflect their impressions of the current state of the Brazilian automotive industry.
For further research, it would be interesting to increase the sample size and, more importantly and as much as possible, try to assess an even sample size in terms of the interviewees' expertise. It would also be interesting to extrapolate the study to an in-depth survey, facilitating the increase of sample size and

enabling a quantitative analysis. Even further, extending the research to other countries should develop an even more interesting comparative study and render new insights towards understanding the OI phenomena across one of the most relevant industries of the modern society.

5. Conclusion

This research proposed to analyse and compare if and how open innovations happen in the Brazilian automotive industry. The scope was limited to Brazilian automakers, and seven different cases with eleven interviews were gathered. Data was gathered and grouped into four different constructs: open innovation practices and maturity, barriers and risks to implementation of open innovation, open innovation partners (or actors), and the characteristics of PDP. Results indicate that open innovation does happen in the industry, even with the limitation that comes with all the cases being transnational companies with subsidiaries in Brazil.

An important limitation to the method in this study is that, by analysing multiple cases in a qualitative assessment, it is difficult to draw out the comparisons between companies. As such, a quantitative study (with a greater sample size) should probably provide more results and discussion. There is also the limitation of assuming that the interviewee does represent his company, even though each interviewee was picked based on his position on the company. The cases that had two interviews provided a better analysis, and increasing the sample size should improve the research.

In accordance to the literature, inbound practices were more present than outbound practices, with a strong presence of the supplier in the design process (and not so much of a client presence). Likewise, first comers seemed more advanced on their open innovation "journey", which also goes in accordance to literature on the subject. However, the newcomers seemed to have had a more pronounced evolution in the recent years, pointing to the fact that recent government policies have influenced in the innovation structure of the automotive industry.

Among the barriers and risks considered to hinder open innovation projects, corporate culture surfaced as a relevant topic in the discussion, indicating that corporate culture seems to influence open innovation practices and the enterprise maturity in it, and future research could be made on the subject.

Finally, the results from this research could be affected soon by future government policies - the current R&D policy affecting the automotive industry is about to end in 2017, and a new one should begin in the near future (still to be announced by the government). These policies have been shown to influence and shape the automotive industry, and the possible demand (through tax incentives) of a bigger R&D infrastructure could leverage open innovation in the subsidiaries studied.

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