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Research Article

Open innovation integration to product development: a sector level analysis within the manufacturing industry

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Abstract

Paper aims: the purpose of this study is to analyze how Open Innovation (OI) activities occur in Product Development Processes (PDP) and in the design of new products.

Originality: the study is based on a self-developed and conducted survey, applied to engineers and managers working in departments involving product development and innovation among the Brazilian automakers.

Research method: the method adopted is that of a questionnaire-based survey. Results are analyzed through a principal component analysis, followed by ordinary least squares regressions, in order to test the hypotheses proposed.

Main findings: results suggest that 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 user-centered approach). Correlation between an organizational culture that favors OI and adoption to newer PDP methods and tools indicate that adopting newer product development methodologies and technologies could lead to a more "open" design process.

Implications for theory and practice: the research provides an overview of open innovation within the Brazilian automakers, and reports what could be opportunities for the automotive industry to head towards.

Keywords

Product development. PDP. Open innovation. Innovation management. Automotive industry.

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1. Introduction

Open innovation (OI) has been a subject of extensive research for the past fifteen years, since the coinage of the term and formal definition (Chesbrough, 2003). Even though its origins stem from high-tech industries, it has now been developed into a widely discussed and firmly implemented innovation practice (Gassmann et al., 2010).

The branch of innovation theory that deals with how products or services are developed and how this development process is structured, managed and optimized is generally put into the context of Product Development Process (PDP) (Brown & Eisenhardt, 1995). PDP is an organizational process that can be 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, p. 01). As an organizational process, it can be divided into a series of activities that can be formalized, measured, and optimized. As such, it has been evolving since its formalization, dating back to an engineering design framework in the early 60's (Evans, 1959), and then evolving into the study of the whole development process, expanding further from the design phase, into a model unifying PDP to external knowledge and technology management (Liyanage et al., 1999).

Current PDP literature is extensive, with reviews differentiating between the myriad of approaches created by adapting new technologies to traditional processes (Canuto da Silva & Kaminski, 2017).

This paper explores the following research question: what are the implications of open innovation regarding product development processes? Following upon this, does an increase in openness relate to a different actor network? And do the perceived barriers and risks found in the implementation of OI projects change as the perceived openness of the firm change?

The purpose of this paper is to analyze how different OI activities occur in the Product Development Process (PDP) of a specific industry, aiming to identify the main actors involved in OI in the sector, the main barriers that are present in the implementation of OI projects, as well as the maturity those companies have with OI and how all of this affects their new product design processes.

West et al. (2006) described five different levels of analysis in open innovation research: (1) individuals and groups, (2) firm and organization, (3) value networks inter-organizational, (4) industry or sector and (5) institutional and innovation systems. Chesbrough & Bogers (2014) have shown that there is extensive research for the first two levels, as well as a considerable interest in the value networks level. The industry or sector level, however, was considered underdeveloped at the time.

This paper tests the developed research questions by means of survey data obtained from the Brazilian automotive industry (more specifically, from Brazilian automakers), analyzing the effects of open innovation within the product development process of those firms.

The automotive industry is coming to an inflection point with regards to its R&D paradigm, with the industry as a whole about to experience a revolutionary discontinuity in generating innovations (Ili et al., 2010). For decades, the industry has engaged in what would now be called open innovation strategies, including an intricate supplier network acting in multiple stages of research and product development (Parente & Geleilate, 2016) as well as being an industry with an extensive knowledge base for product development processes (Canuto da Silva & Kaminski, 2017). This makes the automotive industry an especially interesting subject of study.

Research of open innovation has been done majorly in developed countries (Armellini et al., 2014), especially North American and European companies (Blankesteijn et al., 2019; Karlsson & Sköld, 2013; MacNeill & Bailey, 2010). Open innovation in emergent economies is also seen in the context of Asian countries (Gurcaylilar-Yenidogan, 2014; Massis et al., 2012; Wang et al., 2018). The Brazilian case is interesting not only because the country invests a higher percentage of its GDP in R&D than its neighboring countries, but also because the most important innovation strategy in Brazilian firms is technology acquisition (Jugend et al., 2018), which furthers its importance as a *locus* of research of open innovation. Other researches have also addressed the subject of open innovation in the Brazilian automotive industry (Balcet & Consoni, 2007; Gondim et al., 2017; Ibusuki et al., 2015; Martins & Kaminski, 2019).

The present study is also a continuation of other published research, both concerning case studies within the Brazilian automotive industry (Marin & Kaminski, 2018) as well as comparisons of the Brazilian case with the French case (Marin et al., 2018).

This paper is structured as follows: after this brief introduction, Section 2 provides a literature review and reference frame regarding open innovation and product development process; Section 3 then delves into the research method, the survey developed, and the analytical model employed; Section 4 presents the results obtained and its analysis. Finally, Section 5 concludes the study, offering suggestions toward future research topics.

2. Literature review

2.1. Product Development Process (PDP)

Expanding on the definition provided in Section 1 of this text, PDP (also sometimes regarded as New Product Development, or NPD) can be defined as:

> [...] 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, p.03).

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 steppingstones to modern PDP literature.

Another contribution worth mentioning is the development funnel concept (Clark & Wheelwright, 1993), with a visual representation of the PDP through 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. Similarly, the stage-gates model (Cooper, 1990) is 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 & Kaminski (2017), compiling relevant references to PDP, with a special focus on PDP in the automotive industry or, more generally, in the manufacturing industry, over the decades, and their main contributions.

Table 1. PDP approaches in the manufacturing industry.

Author	Title	PDP Approach
(Evans, 1959)	Basic design concepts	Product 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 Product Development
(Clark & Fujimoto, 1991)	Product development performance: strategy, organization, and management in the auto industry	Development Funnel Concept
(Clark & Wheelwright, 1993)	Managing new product and process development	Development Funnel Concept
(Krishnan & Ulrich, 2001)	Product development decisions: a review of the literature	PDP Perspectives
(Suh, 2001)	Axiomatic Design	Axiomatic Design
(Rozenfeld et al., 2006)	Product development process management	Product Lifecycle Management
(Dieter & Schmidt, 2009)	Engineering design	Technical and managerial gates
(Weber, 2009)	Automotive development processes	Customer Oriented
(Omar, 2011)	The automotive car body manufacturing systems and processes	Automotive manufacturing design
(Canuto da Silva & Kaminski, 2016)	Selection of virtual and physical prototypes in the product development process	Virtual and physical prototypes selection
(Wynn & Clarkson, 2018)	Process models in design and development	PDP models framework
(Blankesteijn et al., 2019)	Closed-open innovation strategy for autonomous vehicle development	Closed-open innovation strategy in R&D

Source: adapted from (Canuto da Silva & Kaminski, 2017).

2.2. Open innovation and its integration to PDP

Since its conception (and first formalization) in the early 2000's, several definitions for Open Innovation (OI) have been proposed. A report from the Organisation for Economic Co-operation and Development (2008) presents nine different definitions for OI, and still newer definitions have been made to understand what is meant by open innovation (West & Bogers, 2014; Bogers et al., 2018). 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 & Bogers, 2014, p.12).

Although Chesbrough considered the concept of OI a paradigm-shift, many of the issues and processes associated with open innovation that affect the PDP are not necessarily new to many industries. It is possible to observe many of those individual practices and activities happening, even when the company does not have a formal structure for it (Chiaroni et al., 2011). Chiaroni et al. (2011) also argued that there is a path – or a "journey", as the authors call it – by which companies willing to incorporate open innovation into their strategy follow, comprised of three aspects: dimensions of open innovation, managerial levers for open innovation and process of adoption of open innovation.

Armellini et al. (2014) proposed a conceptual model (Figure 1) 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.

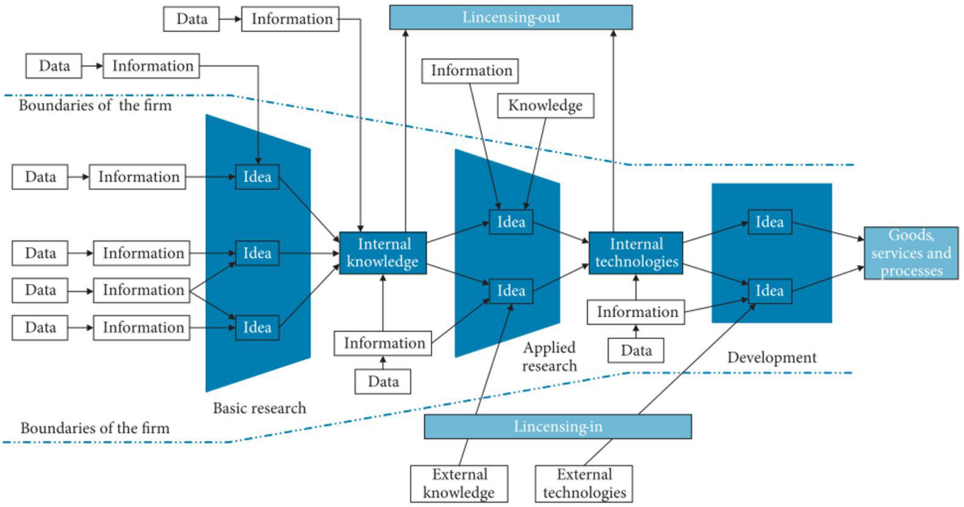

Figure 1. Open product development process framework. Source: (Armellini et al., 2014).

3. Research method

The research method adopted is that of a questionnaire-based survey, with the objective of inquiring pre-selected individuals that were, at the time of the research, working for automaker companies in positions related to product development and its management.

3.1. Survey design

The survey was designed and applied in order to extract information on three main **constructs**. Each construct was then broken up into **measures**. A measure translates directly to a group of questions in the survey. Each question was treated in the analytical model as a **variable**. Figure 2 presents the three main constructs, and their respective measures. The following text describes the subject of each measure (highlighted in italics).

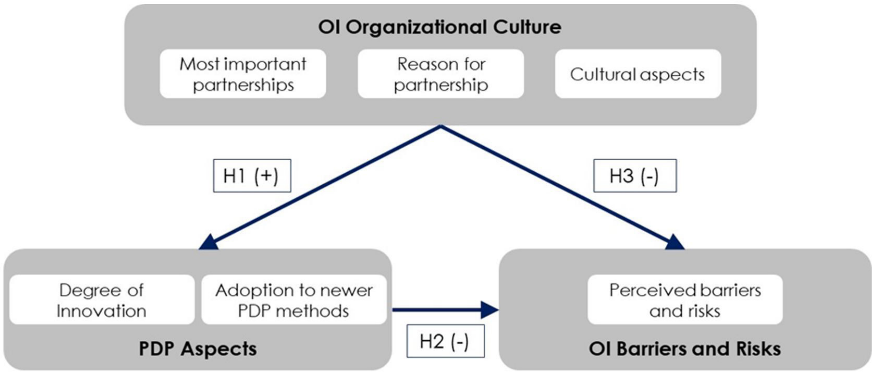

Figure 2. Conceptual model for the constructs' hypotheses.

The first construct, OI Organizational Culture contains three measures: in *most important partnerships,* the subject of study is the main actors or partners involved in the practice of OI of each company, as well as the main OI activities done through that partnership. In *reasons for partnership,* questions assert which open innovation activities (or practices) are performed and how important each one is, as well as assess what respondents believe that could be obtained from open innovation (i.e. what the value of open innovation is). The last measure, *cultural aspects,* groups questions about changes in open innovation culture that their company might have experienced in the past few years, characteristics of the company's management and employees so that it has an environment that favors open innovation practices, as well as how mature the company is in open innovation practices and how ingrained and explicit in its strategy open innovation is.

The following construct, OI Barriers and Risks, are those that hinder or block the implementation of open innovation projects, and the questions assess how important each risk is to this hinderance OI *(perceived barriers and risks)*. Common risks or barriers that are internal to an organization could be a corporate culture that does not favor open innovation, opposition or passivity by employees, or a lack of resources. Other risks, that could be called external, could be possibility of theft or misappropriation of key information or technology, a lack of trust with partners or even the loss of control of projects being conducted with partners.

PDP Aspects are the main characteristics of the PDP of each company, and the measures pertain to how much radical innovation the company has performed in the past years (*degree of innovation)*, as well as whether the organization has changed or evolved the PDP to adopt newer techniques in the past few years (*newer PDP models or methods*). The mentioned techniques include agile project methodologies, or rapid prototyping techniques.

With all the measures described, the research initial hypotheses can be stated:

H1: companies that perform more open innovation, perceive more value in OI and engage in partnerships that are considered important to the company are more likely to engage in more radical innovation, as well as to adopt newer PDP models and development methods.

H2: companies that engage in more radical innovation, as well as adopt newer PDP models and development methods are more likely to encounter fewer barriers and value less the risks of the implementation of OI engagements.

H3: companies that have perform more OI and perceive more value in OI are more likely to encounter fewer barriers and value less the risks of the implementation of OI engagements.

The relationship between the arrows' directions in Figure 2 are maintained to represent the variables - the arrow point to the independent variable from the dependent variable. For the purposes of this study, the construct OI Barriers and Risks (and its respectives variables) are taken as independent variables, and OI Organizational Culture as dependent variables. PDP Aspects acts as a mediator variable, acting as independent *vis a vis* OI Organizational Culture and dependent against OI Barriers and Risks. The new hypotheses, breaking down the constructs into the variables enunciated above, are then shown in Table 2. These hypotheses are then tested on a measure by measure basis in Section 4.

Table 2. Hypotheses for the regression model.

Hypothesis	Dependent measure	Independent measure
H1a	Most important partnerships	Degree of innovation
H1b	Most important partnerships	Adoption to newer PDP methods
H1c	Reasons for partnership	Degree of innovation
H1d	Reasons for partnership	Adoption to newer PDP methods
H1e	Cultural aspects	Degree of innovation
H1f	Cultural aspects	Adoption to newer PDP methods
H2a	Degree of innovation	Perceived barriers and risks
H2b	Adoption to newer PDP methods	Perceived barriers and risks
H3a	Most important partnerships	Perceived barriers and risks
H3b	Reasons for partnership	Perceived barriers and risks
H3c	Cultural aspects	Perceived barriers and risks

3.2. Survey application

The prepared survey was applied to engineers, managers and directors that were, at the time of the survey application, working at automaker companies in departments related to product development – those usually go by the name of one or more of the following: (New) Product Development, R&D, Systems Engineering, Product Engineering, Project Office, among a few others. Other criteria, such as having been enrolled in a post-graduate course before and/or publishing a paper in a scientific journal or event, was also used to prospect possible respondents.

1032 invitations for the survey were sent, of which 342 started the survey. Of those, 140 individual responses were completed, comprising a 13.6% response rate. This study focuses on a specific subsection of respondents: those that come directly from automaker companies (professionals from automotive parts companies or direct suppliers were also invited). The final number of complete and valid answers for the automaker companies is 65.

3.3. Analysis methodology

Following from the hypotheses and the analytical model enunciated in Section 3.1, results gathered from the survey are analyzed through the following steps: first, a rotated principal component factor (PCF) analysis groups variables from the same measure into consistent and representative factors (obtained through a series of criteria). These factors are then subjected to ordinary least squares (OLS) regressions, and the statistically significant (i.e. the ones with p-values that reject the null hypothesis) are then used to establish a newer analytical model and the test of hypotheses mentioned in Section 3.1.

4. Results and discussion

This chapter is structed as follows: Section 4.1 addresses the descriptive statistics of the collected answers, as well as presents some demographic data on the respondents. Section 4.2 brings the authors' interpretation of the descriptive data. Sections 4.3 and 4.4 present, for one of the measures structured in Section 3, the approach used in the PCF analysis and its results. For each other measure, the same approach was taken, and results are summarized in the Appendix A.

4.1. Descriptive statistics

As one of the measures of respondents' expertise, it was assessed how experienced respondents were, with respect to their jobs in the automotive industry. Respondents' had an average of 17.4 years of experience in the sector, and the distribution is shown in Figure 3. Overall, this is considered a rather senior sample size, even for the industry standards.

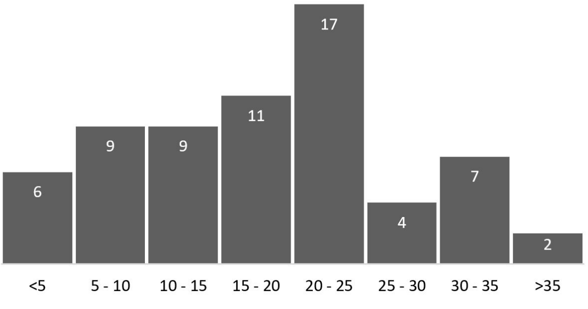

Figure 3. Histogram of respondents' year of experience in the automotive industry.

A useful classification for the Brazilian industry is to group automaker companies into two categories: the firstcomers, which were the automakers that began their operations in Brazil during the "first wave" of automakers, in the early 60's; and the new or late comers, which arrived at the country with Brazil's economic liberalization in the early 90's (Ibusuki et al., 2015). Those two groups have a very distinctive industrial and engineering structure (in Brazil) from each other, and as such it could be used as another control variable in the study. Out of the 65 respondents, 51 come from firstcomer companies, while the remaining 14 come from new or late comer companies. As expected, the firstcomer companies, that employ more professionals and have a stronger history in Brazil, also represent the majority of respondents.

With respect to open innovation and product development itself, the first aspect analyzed is which OI activities respondents claimed that their companies were employing, and how important they were. Based on a 5-point Likert scale, from Not important to Extremely important, respondents assessed the impact of a series of open innovation practices, grouped into inbound (Figure 4) and outbound (Figure 5) activities (as outlined in Section 2.2). The following question (Figure 6) asked respondents to assess how important each item from a list of potential benefits is to the implementation of open innovation projects. In other words, what is the potential value that could be obtained through open innovation.

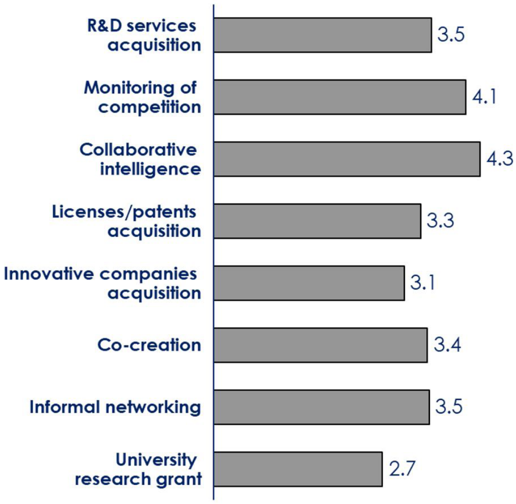

Figure 4. Open innovation inbound activities (global mean values).

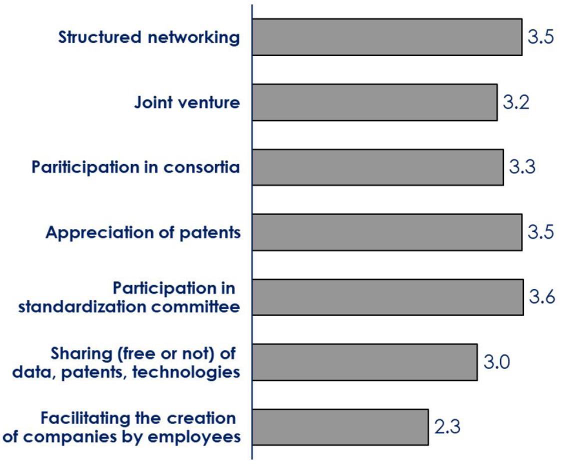

Figure 5. Open innovation outbound activities (global mean values).

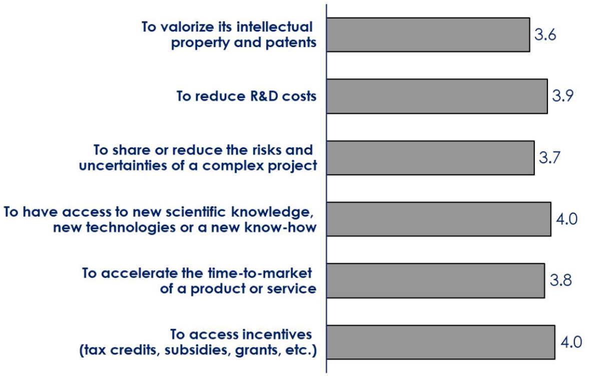

Figure 6. Perceived value of open innovation.

Next, respondents were asked to rank their three most important partnerships in open innovation, from a list of ten possible answers. Figure 7 presents the results, as a percentage of the total from the three partners listed from each candidate (so, if a candidate chose the same option for the three most important partners, it counts the answer three times).

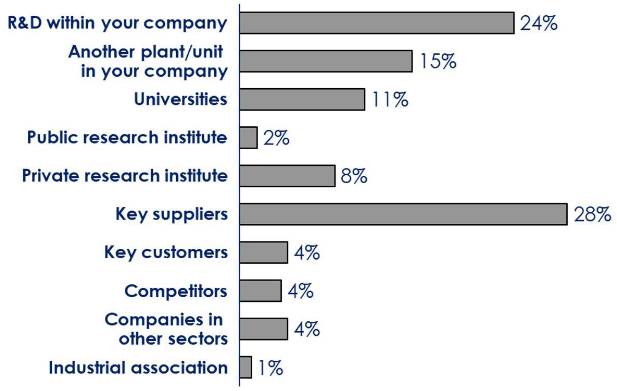

Figure 7. Most important partnerships in open innovation (as a % of total).

Finally, on the main risks and barriers that can hinder or impede the implementation of OI projects or engagements, respondents were asked to, again on a 5-point Likert scale, the importance given (and perceived) to each of the following barriers or risks in the implementation of OI engagements (Figure 8).

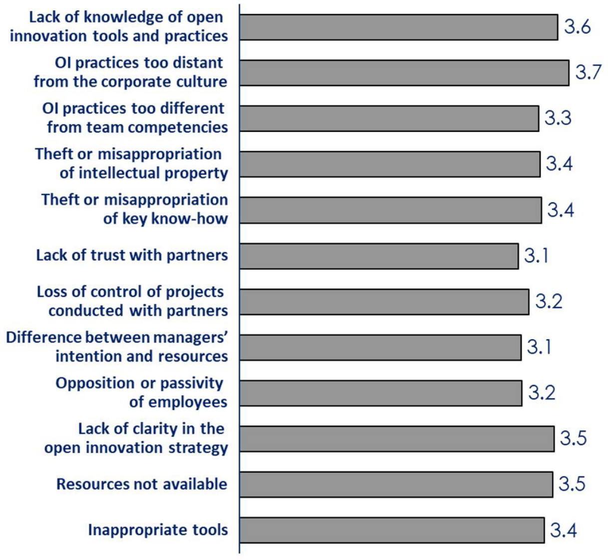

Figure 8. Barriers and risks in OI engagements (global mean values).

4.2. Interpretation of descriptive statistics

4.2.1. OI practices in the automotive industry

Though section 4.3 goes into detail on the statistical analysis of the data obtained through the survey, some observation of the descriptive statistics provided in section 4.1 could assist in providing some insight on open innovation in the automotive industry.

The first array of questions in the survey relate to open innovation activities that respondents consider most important for their companies, both inbound and outbound. The main inbound activities were the acquisition of R&D services, corporate intelligence surveillance and "collective intelligence" (defined as benchmarking with other companies). Those are mostly management techniques and tools used with product development, but they do not change the essence of its process. On the other hand, more costly activities, both financial and risk-wise, such as the purchase of patents and licenses, as well as the acquisition of startup companies, were considered the least important for the respondents.

Outbound activities were rated less important than the inbound ones, in accordance with the current literature. Specifically, the activity of sharing data, technology and patents was considered the least important among all (inbound and outbound activities).

When asked what reasons are the most important in performing open innovation, respondents consider that valorizing their patents and IP is the least important reason, while gaining access to tax incentives is the most important.

Though the focus of this study is not on the effect of public policies in open innovation, it is important to comment about the Brazilian case. On the subject of tax incentive policies, the Brazilian automotive industry has benefited from a few different programs that rewarded investments in research and development. Since 1995, and still active as of the time of this writing, Lei do bem ("*Law of good"*) is a federal policy aimed to encourage companies in dedicating their resources to R&D, maintaining tax reductions with such effort. Exclusive to the automotive industry, Inovar Auto was another federal policy, active from 2012 to 2017, structured to accelerate the development of more energy efficient vehicles, by means of incentivizing investment in R&D, engineering and process improvements (Ibusuki et al., 2015). Since 2018, program Rota 2030 ("*Route 2030*") aims to further improve and incentivize development in the automotive industry, with basically the same strategic direction as Inovar Auto, but with a greater focus on job creation and patent development (Brasil, 2018).

4.2.2. The effects of OI in PDP

On PDP, 91% of the respondents considered the products developed in their companies more incremental than radical with respects to its innovation. It has already been stated that all the auto makers present in Brazil are subsidiaries with headquarters overseas, and most of the R&D is performed outside (Ibusuki et al., 2012). However, 68% of the respondents agree that the way product development is done has changed in the last two years, and 65% of them agree that open innovation was part of this change.

4.2.3. Risks and hindrances in engaging in OI

Implementing new OI projects seem to carry considerable risks. 64% of the respondents consider that newer OI projects could be hindered by setting themselves too far apart from current corporate culture.

On the subject of organizational culture and its influence on open innovation, 71% of the respondents agree that external sources are one of the main ways of introducing new technologies and techniques to their business. However, only 38% of them believe that their company encourages them to find and use outside technology, and 45% of them think that developing the technology themselves is preferable to sourcing it from an outsider.

Respondents seem to set their own business unit/plant apart from the corporate headquarters. 62% of the respondents believe that there is a lack of clarity in their company's open innovation strategy, and over half of the respondents believe that there is both a lack of resources, tools and knowledge hindering the implementation of new OI projects. The fear of theft or misappropriation of intellectual property also concerns over 66% of the respondents.

4.2.4. Partners in OI

The most important partners in open innovation are, according to the respondents, mainly R&D units within the same parent company and key suppliers. Those partners are considered most important when sharing privileged information on the industry (82% of respondents consider this important), reducing development lead time and costs (78% of respondents agree) and on granting access to key R&D capabilities (77% of respondents). These points do make sense with the idea that the subsidiaries installed in Brazil are heavily dependent on the headquarters and with their key suppliers in order to develop new products faster and cheaper. Key suppliers should give access to niche technologies and work together with the local development teams to develop new solutions specific to the local industry and market.

4.3. Measures for the regression model

Measures presented in Section 3 were subjected to rotated principal-component factor (PCF) analyses in order to reduce and identify relevant factors for each measure. Orthogonal rotations (varimax) were performed using Stata/IC13 software. The criteria chosen for adopting or discarding factors was based on a minimum eigenvalue of 1.0, with a minimum Cronbach's alpha of 0.6. Variables with a factor loading of less than 0.5 were purged and the analysis was iteratively rerun. A Kaiser-Meyer-Olkin (KMO) test was also used to assess the sampling adequacy for each measure in the model, with a minimum threshold of 0.5.

The next sections describe, for the first measure (partnerships in open innovation), the approach used in the PCF analysis and its results. For each other measure, the same approach was taken, and results are summarized in the Appendix A.

4.3.1. Most important partnerships in open innovation

For the measure of most important partnerships in open innovation and the activities performed in those relationships, participants had to first list the three most important partners for their company. Then, for each one, a five-point Likert scale (from not important to extremely important) was used to assess how important certain activities were in establishing that partnership.

For the PCF analysis of this measure, there is an assumption that the three most important partners are equal and, therefore, the results for the three can be averaged to a single variable. Then, the rotated PCF analysis can proceed as usual. Two factors with eigenvalue greater than 1.0 were found, *Partners_F1* ($\lambda = 4.7$) and *Partners_F2* ($\lambda = 4.43$), explaining 70% of the variance found. Both presented a sufficient value of Cronbach-alpha (0.91, for both). The KMO for the measure was also greater than 0.5 (0.84) and, therefore, both factors were kept in the analysis. Table 3 presents the factorization for each of this construct's questions.

Table 3. Importance of partnerships in OI factor analysis.

Importance of partnerships in OI	Factor 1 (Partners_F1)	Factor 2 (Partners_F2)
Access to new markets	0.86	-
Sharing privileged information on the market/industry	0.84	-
Scaling up production processes	0.85	-
Access to new distribution networks	0.88	-
Sharing information for production and procurement	0.83	-
Access to critical R&D competencies	-	0.92
Access to R&D infrastructure (e.g. laboratory equipment)	-	0.91
Long-term research on prospective technologies (exploratory research)	-	0.83
Development of prototypes	-	0.67
Reduction of costs or lead time for product development	-	0.59
Sharing technical information for R&D and/or product development	-	0.80
Access to incentives or government funds	0.62	-
Facilitate the networking and/or intermediation in the business ecosystem	-	0.60
% prop.	0.36	0.34
% cumul.	0.36	0.70
Eigenvalue	4.70	4.43
Cronbach-alpha	0.91	0.91
KMO	0.84	

4.3.2. Summary of variables

For each of the factors, new variables were defined. The PCF analyses resulted in the creation of thirteen variables, to be used in the regression models. Table 4 presents a summary of all the variables used in the models.

Finally, two control variables are used in the regression model. The first, *Type_Maker,* which categorizes the respondents' companies binarily as First or Newcomers (as defined by Ibusuki et al., 2015), an important characterization of the Brazilian industry that could have influence on the results. The second variable is *Total_Exp*, and corresponds to the amount, in years, that each respondent has of experience working in the automotive industry.

Table 4. Summary of variables.

Description of variable	Method	Variable
Partnerships in OI	PCF	Partners_F1
Partnerships in OI	PCF	Partners_F2
Open innovation inbound practices	PCF	OI_Inbound
Open innovation outbound practices	PCF	OI_Outbound
Perceived importance of OI	PCF	OI_Reasons
Organizational culture	PCF	Cult_Aspects_F1
Perceived importance of OI	PCF	Cult_Aspects_F2
Maturity of company in OI	Single var	OI_Maturity
How important OI is to the company's strategy	Single var	OI_Strategy
Evolution of OI culture in company	PCF	Cult_Change
Degree of innovation	PCF	PDP_Degree_F1
Adoption to newer PDP methods	PCF	PDP_Adoption
Barriers and risks	PCF	Barriers_F1
Barriers and risks	PCF	Barriers_F2
Barriers and risks	PCF	Barriers_F3
First or late comer in Brazil	Category	Type_Maker
Respondent's years of experience in auto industry	Single var	Exp_Total

4.4. Regression model and discussion of results

First, a correlation matrix performed on the variables to assess whether a regression analysis is suited for the data (shown in the Appendix B, Section B.1), shows that there are no significant correlations among the same group of measures. This allows the analysis to move on to the regressions.

Ordinary Least Squares (OLS) regressions were performed using Stata/IC13 software. For each analysis, three regressions were performed: one without control variables (**Model 1**), one controlling for years of experience (**Model 2**). The final model, (**Model 3**), restricts the sample size to only the sample for First comers, which comprises most of the sample size (51 of 65 respondents). This is important because first comer companies might have a very different stance on innovation in Brazil than the late comers.

The full results of the regressions are available in the Appendix B, Section B.2. Variables which regression resulted in a significant p-value (taken to be less than 0.1 in this exploratory analysis), are highlighted in bold. Table 5, Table 6 and Table 7 present summaries of the regressions, grouped by the constructs outlined in Section 3.1, directly translating the three hypotheses enunciated (also in Section 3.1).

Table 5. OLS regressions correlations summary for hypothesis 1: OI Organizational Culture versus PDP Aspects (model 3).

Measure	Dependent Variable	Independent Variable	
		PDP_Degree	PDP_Adoption
Most important partnerships	Partners_F1	0.17	**0.36****
	Partners_F2	-0.23	-0.10
Reasons for partnership	OI_Inbound	-0.08	**0.67*****
	OI_Outbound	0.04	**0.65*****
	OI_Reasons	0.11	**0.64*****
Cultural aspects	Cult_Aspects_F1	-0.08	**0.37****
	Cult_Aspects_F2	0.01	**0.27+**
	OI_Strategy	0.16	**0.84*****
	OI_Maturity	**0.19+**	**0.33****

p- values: + p<.1; **p<.01; ***p<.001 (highlighted in bold).

Table 6. OLS regressions correlations summary for hypothesis 2: PDP Aspects versus Barriers and risks (model 3).

Measure	Dependent Variable	Independent Variable		
		Barriers_F1	Barriers_F2	Barriers_F3
PDP Aspects	PDP_Adoption	0.17	-0.10	-0.18
	PDP_Degree_F1	0.00	**-0.36****	0.12

p- values: **p<.01; (highlighted in bold).

Table 7. OLS regressions correlations summary for hypothesis 3: OI Organizational Culture versus Barriers and risks (model 3).

Measure	Dependent Variable	Independent Variable		
		Barriers_F1	Barriers_F2	Barriers_F3
Most important partnerships	Partners_F1	**0.36****	-0.08	**-0.25***
	Partners_F2	-0.19	**0.37***	0.07
Reasons for partnership	OI_Inbound	**0.26**+	0.12	**-0.34***
	OI_Outbound	0.13	-0.09	**-0.36****
	OI_Reasons	0.21	0.08	-0.17
Cultural aspects	Cult_Aspects_F1	-0.01	0.01	-0.16
	Cult_Aspects_F2	**0.30***	-0.16	0.10
	OI_Strategy	0.24	-0.00	-0.16
	OI_Maturity	0.12	**-0.42****	0.15

p- values: + p<.1; *p<.05; **p<.01; (highlighted in bold).

From the regressions summaries, very few hypotheses can be accepted through the regressions since most of them presented a p-value that do not reject the null hypothesis. The results of all hypotheses test are presented in Table 8.

Table 8. Hypotheses test.

Hypothesis	Decision	Observation
H1a	Rejected	No statistically significant correlations were found
H1b	Partially accepted	A significant positive correlation was found between Partners_F1 and PDP_Adoption, but not with Partners_F2
H1c	Rejected	No statistically significant correlations were found
H1d	Accepted	A significant positive correlation was found between all the three variables in the measure and PDP_Adoption
H1e	Partially accepted	There is a positive correlation between the variables OI_Maturity and PDP_Degree, which is one out of five variables from this measure
H1f	Accepted	A significant positive correlation was found between all the five variables in the measure and PDP_Adoption
H2a	Partially accepted	A significant negative correlation was found between PDP_Degree and Barriers_F2, but not in Barriers_F1, F3
H2b	Rejected	No statistically significant correlations were found
H3a	Contradictory results	Partners_F1 showed a positive correlation with Barriers_F1, but a negative correlation with Barriers_F3
H3b	Contradictory results	OI_Inbound showed a positive correlation with Barriers_F1, but a negative correlation with Barriers_F3
H3c	Contradictory results	Cult_Aspects_F2 showed a positive correlation with Barriers_F1, while OI_Maturity showed a negative correlation with Barriers_F2

Both hypotheses relating the Cultural Aspects and PDP Aspects measures (H1e and H1f) were accepted in the model, which do suggest a positive relationship between having a corporate culture that favors open innovation practices and evolving their PDP to adopt newer methodologies, as well as having a bigger focus on radical innovation.

All of the measures from the construct OI Organizational Culture presented a positive correlation with the measure PDP Adoption (hypothesis H1b, H1d and H1f). This could be evidence that adoption to newer product development methodologies and technologies is related to a more "open" design process, which also includes a stronger innovation network and higher value perception in open innovation itself. However, the causation clause is far from proven: it is not clear whether "more open" companies tend to approach newer design methodologies, or whether companies that tend to adopt newer design methodologies, by approaching newer concepts more frequently, tend to be more open and favor open innovation.

Hypotheses relating Cultural Aspects and the Perceived Barriers and Risks constructs (H3a, H3b and H3c) were not accepted, yielding contradictory results.

The remaining contradicted hypotheses, that is, those that presented results with both a positive and negative correlation, could be further studied to be broken up into more measures.

It is important to acknowledge the limitation of the sample size gathered (n=65). Even with considerable effort to track and obtain 65 valid answers, most of the hypothesis could not be confirmed. This number of answers can be explained partially because of the survey length, which takes around thirty minutes to answer fully.

The principal components approach taken, though useful in handling a large number of variables, does make the interpretation of results much harder by grouping variables in an intangible manner. For instance, the questions for the barriers and risks measure were divided into three variables, and though in some regressions the significance of one or two of the three were confirmed, the abstraction of this calculated variable does make interpretation of the results much harder.

5. Conclusions

This research proposed to analyze and compare how open innovations happen in the product development processes. With a survey, data was gathered from 65 professionals working in the Brazilian automotive industry, specifically to Brazilian automakers. Three different constructs were analyzed: the organizational culture surrounding open innovation, barriers and risks to implementation of open innovation, and the characteristics of PDP. Results obtained were discussed both in terms of the descriptive data and statistics, as well as in terms of the PCF analysis and hypothesis tests.

Descriptive data suggests that 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). This suggestion corroborates the open innovation “journey”, as mentioned in the literature review from Chiaroni et al. (2011). The most important practices mentioned were, besides the acquisition of R&D services, mostly management techniques and tools used with product development, that do not change the product development process in a substantial way. More costly activities, such as the purchase of patents and licenses, as well as the acquisition of startup companies, were considered the least important for the respondents.

Partners in open innovation partners seem to be considered most important when enabling key capabilities or knowledge to the local subsidiaries, giving the impression of their dependency on the headquarters and with their key suppliers in order to develop new products faster and cheaper.

Respondents also seem to believe there is a disconnection in corporate culture and the local culture in respect to open innovation, with a lack of clarity in their company’s open innovation strategy, culminating in a lack of resources, tools and knowledge hindering the implementation of new OI projects.

Quantitative analysis using principal components factors and statistical regressions abled the test of hypotheses. Due (and in spite of) the exploratory nature of the research, most of the hypotheses could not be fully verified. However, a correlation between all the measures from the construct OI Organizational Culture and the measure Adoption to newer PDP methods and tools could be evidence that adoption of newer product development methodologies and technologies is related to a more “open” design process. This, in turn, also includes a stronger innovation network and higher value perception in open innovation itself. Unfortunately, nothing could be said of the degree of innovation performed by those companies, i.e. if more open innovation leads to more radical innovations. However, the automotive industry is currently on a pivotal point and, perhaps, open innovation is the key to gain the much-needed competitive advantage to keep those companies alive.

The methods chosen in this study carry with themselves plenty of limitations. For one, there is the limitation of, even though each interviewee was picked based on his position on the company, assuming that the interviewee does in fact represent his company. Still, the sample size presented a significant experience in the industry (over 17 years on average).

Another limitation was the sample size chosen. With considerable effort to track and obtain valid answers, the resulting sample size amounted to 65 answers. This number can be explained partially because of the questionnaire length, which takes around thirty minutes to answer fully. A quantitative study like the one performed could definitely benefit from more answers. Not only that, but the survey was initially only applied to Brazilian automakers. There are still the additional 75 answers from respondents that come Brazilian auto parts manufacturers, extracted from the same survey. Future work could be done comparing results between countries or between industries.

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Appendix A. Measures for the regression model.

1. Open innovation perceived value and practices (reasons for partnership)

Open innovation practices were measured separately in relation to inbound and outbound practices. Both were assessed by asking respondents to indicate the level of importance (in a Likert scale, from Not important to Extremely important) for each practice in their company. The perceived value found in open innovation was assessed by the same parameters, but instead listing benefits that could be obtained through the practice of open innovation.

For the inbound practices, all variables resulted in a factor loading greater than 0.5 and were, therefore, kept in the factor analysis. The first factor was the only one with an eigenvalue greater than 1 ($\lambda = 4.1$) , and explained 51% of the variance. With a Cronbach's alpha of 0.87 and KMO also equal to 0.87 (greater than 0.6 and 0.5, respectively), the variables can be reduced to the single factor OI_inbound.

Table A1. Open innovation inbound practices factor analysis.

Open innovation inbound activities	Factor 1 (OI_inbound)
Purchase of R&D services	0.58
"Active" monitoring/surveillance of technologies with advanced tools	0.61
Collective intelligence tools to gather or test ideas, products, concepts, etc.	0.70
Purchase of licenses/patents	0.81
Acquisition of innovative companies	0.75
Co-creation projects with third parties	0.79
Informal networking	0.70
University research grant	0.74
% prop.	51%
% cumul.	51%
Eigenvalue	4.10
Cronbach-alpha	0.87
KMO	0.87

For the outbound practices, the results are similar. All variables obtained a factor loading greater than 0.5 for the first factor, which was also the only one with an eigenvalue greater than 1 ($\lambda = 4.23$). The factor *OI_outbound* explains 60% of the variance. With satisfactory values of Cronbach-alpha (0.88) and KMO (0.84), it is therefore sufficient to reduce the variables to a single factor.

Table A2. Open innovation outbound practices factor analysis.

Open innovation outbound activities	Factor 1 (OI_outbound)
Structured networking (publication, social media, congresses, conferences, associations, etc.)	0.59
Joint Venture	0.79
Participation in a consortium	0.89
Appreciation of your patents	0.78
Participation in standardization committees	0.72
Sharing (free or not) data, patents, technologies, etc.	0.88
Facilitating the creation of companies by collaborators	0.76
% prop.	60%
% cumul.	60%
Eigenvalue	4.23
Cronbach-alpha	0.88
KMO	0.84

Finally, for the perceived importance of OI engagements, results are also similar to the other two measures. Only one factor presented eigenvalue greater than 1.0, *OI_reasons*, and its metrics are satisfactory (alpha of 0.89 and KMO of 0.81). The factor explains 64% of the variance of all variables, since none had a factor loading of less than 0.5.

Table A3. Perceived importance of OI engagements factor analysis.

Perceived importance of OI engagements	Factor 1 (OI_reasons)
To valorize its intellectual property and patents	0.71
To reduce R&D costs	0.83
To share or reduce the risks and uncertainties of a complex project	0.85
To have access to new scientific knowledge, new technologies or a new know-how	0.88
To accelerate the time-to-market of a product or service	0.85
To access incentives (tax credits, subsidies, grants, etc.)	0.64
% prop.	0.64
% cumul.	0.64
Eigenvalue	3.82
Cronbach-alpha	0.89
KMO	0.81

2. Organizational culture of open innovation (cultural aspects)

Organizational culture was assessed by two groups of questions. The first asked the respondent to assess their agreement on a five-point Likert scale on changes in open innovation culture that their company might have experienced in the past few years (since 2014). The second asked respondents', on the same scale, to assess characteristics of management and employees that can improve the adoption of open innovation engagements (i.e. the company has an environment that favors open innovation practices).

For the first group, evolution in open innovation adoption, the rotated PCF resulted in one factor, Cult_change, with eigenvalue greater than 1.0 ($\lambda = 4.78$). All variables were retained (factor loading greater than 1.0), and the factor explains 78% of the variance found, with a Cronbach-alpha of 0.94 and KMO of 0.87, both good metrics.

Table A4. Evolution in open innovation adoption factor analysis.

Evolution in open innovation adoption (since 2014)	Factor 1 (Cult_change)
The open innovation culture has developed	0.89
The number of open innovation project has increased	0.94
Employees have progressed in their abilities to absorb external information, knowledge, or technology	0.81
The open innovation strategy has become clearer, better understood and has been clarified	0.84
The open innovation processes have grown in maturity	0.93
This plant/unit dedicates resources to open innovation	0.90
% prop.	0.78
% cumul.	0.78
Eigenvalue	4.70
Cronbach-alpha	0.94
KMO	0.87

For the second group, organizational culture in OI, two factors with eigenvalue greater than 1 were found. The first factor, *Cult_org_F1* ($\lambda = 3.55$), explains 39% of the variance with a Cronbach-alpha of 0.87. The second factor, *Cult_org_F2* $(\lambda = 2.58)$ explains 29% of the variance with an alpha of 0.80. Both factors are kept in the analysis.

Table A5. Organizational culture in OI factor analysis.

Organizational culture in OI	Factor 1 (Cult_Org_F1)	Factor 2 (Cult_Org_F2)
Management encourages teamwork	0.89	-
Management encourages everyone's participation in the search for solution	0.87	-
Leaders or managers in your plant/unit have the flexibility required to implement changes	0.57	-
Employees' suggestions for improvement are encouraged	0.73	-
Employees that propose improvements are recognized by their solutions	0.61	-
The company offers training to its employees	0.68	-
The company uses techniques to stimulate creativity among its employees	-	0.69
A team (dedicated or not) is in charge of promoting a culture of open innovation in the corporate culture	-	0.81
Indicators specific to open innovation are used	-	0.88
% prop.	0.39	0.29
% cumul.	0.39	0.68
Eigenvalue	3.55	2.58
Cronbach-alpha	0.87	0.80
KMO	0.81	

Two additional variables, *OI_Maturity* and *OI_Strategy*, assessed the respondents' perception on how mature the company is in open innovation practices and how integrated to its strategy open innovation is, respectively. Since each of these variables correspond to a single question in the survey, they are kept as distinct variables.

3. Perceived barriers and risks in OI engagements

The measure of perceived barriers and risks in OI engagements were assessed by means of a five-point Likert scale (from not important to extremely important) on how much each risk (from a list of 13) hindered the implementation of new OI projects or engagements in the respondents' company.

Results from the PCF reduced the thirteen variables to three factors, Barriers_F1 ($\lambda = 3.28$), Barriers_F2 ($\lambda = 2.27$) and Barriers_F3 ($\lambda = 2.59$). All presented a greater than 0.6 Cronbach-alpha, and the KMO found for the variables was greater than 0.5. Therefore, the three factors were kept in the analysis.

Table A6. Perceived barriers and risks in OI engagements.

Perceived barriers and risks in OI engagements	Factor 1 (Barriers_F1)	Factor 2 (Barriers_F2)	Factor 3 (Barriers_F3)
Lack of knowledge of the open innovation tools and practices	-	-	0.75
Practices too distant from the corporate culture	-	-	0.89
Practices too different from team competencies	-	-	0.84
Theft or misappropriation of intellectual property	-	0.94	-
Theft or misappropriation of key know-how	-	0.92	-
Lack of trust with partners	-	0.79	-
Loss of control of projects conducted with partners	-	0.84	-
Difference between the intentions displayed by the managers and the resources allocated to the approach	0.67	-	-
Opposition or passivity of employees	0.65	-	-
Lack of clarity in the open innovation strategy	0.78	-	-
Resources not available	0.85	-	-
Inappropriate tools	0.90	-	-
% prop.	0.27	0.27	0.22
% cumul.	0.27	0.55	0.76
Eigenvalue	3.28	2.27	2.59
Cronbach-alpha	0.88	0.92	0.84
KMO	0.78		

4. PDP aspects

The last two measures are more related to new product development. Both use a five-point Likert scale (from completely disagree to completely agree). The first asks of respondents to assess how incremental or radical the innovations performed by their company are, the second measure assess, and the second measure assess whether the processes related to product development have changed in the last few years (since 2014) and whether new methods and tools have been adopted.

For the degree of innovation measure, two factors with eigenvalue greater than 1.0 were found. PDP_Degree_F1 ($\lambda = 1.51$) presented a Cronbach-alpha of 0.67 and remained in the analysis. Even though the other factor presented sufficient eigenvalue, its Cronbach-alpha was of 0.58, and was discarded in the analysis.

Table A7. Degree of innovation performed in their company factor analysis.

Degree of innovation performed in their company	Factor 1 (PDP_Degree)	Factor 2 (discarded)
The products developed are more incremental than radical in their innovations	0.86	-
The products are developed based on information from prior projects/products	0.87	-
Products are being developed to new target markets	-	0.84
The products developed necessitated the development of a new platform and/or new business models	-	0.83
% prop.	0.38	0.36
% cumul.	0.38	0.73
Eigenvalue	1.51	1.42
Cronbach-alpha	0.67	**0.58**
KMO	0.50	

Finally, for the measure of adoption to newer PDP methods and tools, only one factor remained, *PDP_adoption* ($\lambda = 3.12$), explaining 78% of the variance found. With a Cronbach-alpha of 0.9 and KMO of 0.8, was kept in the analysis.

Table A8. Adoption to newer PDP methods and tools factor analysis.

Adoption to newer PDP methods and tools	Factor 1 (PDP_adoption)
The way PDP is done has changed since 2014	0.70
Open innovation has influenced the way PDP is done	0.94
Open innovation is responsible for the improvement of existing and implemented PDP methods or tools in your plant/unit	0.96
Open innovation is responsible for the adoption of new PDP methods or tools (scrum, agile, etc.) in your plant/unit	0.91
% prop.	0.78
% cumul.	0.78
Eigenvalue	3.12
Cronbach-alpha	0.90
KMO	0.80

Appendix B. Complete results from OLS regression.

1. Correlation Matrix

Table B1. Correlation matrix for variables used in regression model.

Description of variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
OI_Inbound (1)	1.00	-	-	-	-	-	-	-	-	-	-	-	-
OI_Outbound (2)	.83	1.00	-	-	-	-	-	-	-	-	-	-	-
OI_Reasons (3)	.61	.60	1.00	-	-	-	-	-	-	-	-	-	-
OI_Maturity (4)	.47	.50	.33	1.00	-	-	-	-	-	-	-	-	-
OI_Strategy (5)	.53	.59	.62	.60	1.00	-	-	-	-	-	-	-	-
Cult_Change (6)	.50	.58	.32	.50	.48	1.00	-	-	-	-	-	-	-
Cult_Aspects1 (7)	.57	.62	.45	.49	.51	.72	1.00	-	-	-	-	-	-
Cult_Aspects2 (8)	.26	.29	.04	.09	-.06	.36	.15	1.00	-	-	-	-	-
Barriers_F1 (9)	.35	.27	.28	.04	.17	.14	-.02	.10	1.00	-	-	-	-
Barriers_F2 (10)	-.19	-.31	-.14	-.42	-.34	-.22	-.05	-.10	.06	1.00	-	-	-
Barriers_F3 (11)	-.09	-.14	.03	-.18	-.06	-.04	-.21	.07	-.02	.31	1.00	-	-
PDP_Degree (12)	-.08	.09	.06	.09	.22	.08	-.17	-.15	.24	-.33	.11	1.00	-
PDP_Adoption (13)	.74	.75	.49	0.53	.61	.67	.64	.29	.10	-.22	-.25	.01	1.00

2. Regression tables.

Table B2. OLS regressions for Reasons for partnership measure versus PDP aspects measure (statistically significant p values in bold).

Variable	OI_Inbound			OI_Outbound			OI_Reasons		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
PDP_Degree_F1	-0.07	-0.10	-0.08	0.05	0.02	0.04	0.14	0.12	0.11
	(0.10)	(0.12)	(0.12)	(0.11)	(0.12)	(0.13)	(0.11)	(0.12)	(0.13)
PDP_Adoption	**0.72*** **	**0.74*** **	**0.67*** **	**0.72*** **	**0.74*** **	**0.65*** **	**0.62*** **	**0.63*** **	**0.64*** **
	(0.12)	(0.13)	(0.14)	(0.13)	(0.13)	(0.15)	(0.11)	(0.11)	(0.12)
Exp_Total		-0.01	-0.01		-0.01	0.00		-0.01	-0.01
		(0.01)	(0.01)		(0.01)	(0.02)		(0.01)	(0.02)
N	49	49	41	47	47	38	53	53	46
adj. R^2	0.42	0.41	0.34	0.40	0.39	0.35	0.38	0.37	0.36

Standard errors in parentheses, statistically significant p values in bold. Only non-null answers for all relevant constructs were considered. ***$p < 0.001$.

Table B3. OLS regressions for Reasons for partnership measure versus Barriers and risks (statistically significant p values in bold).

Variable	OI_inbound			OI_outbound			OI_Reasons		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Barriers_F1	0.19	0.22	**0.26+**	0.09	0.11	0.13	0.20	0.20	0.21
	(0.14)	(0.13)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.16)
Barriers_F2	0.07	0.07	0.12	-0.11	-0.10	-0.09	0.07	0.07	0.08
	(0.13)	(0.13)	(0.14)	(0.14)	(0.14)	(0.15)	(0.13)	(0.13)	(0.15)
Barriers_F3	**-0.22+**	**-0.24+**	**-0.34***	**-0.25+**	**-0.26+**	**-0.36****	-0.13	-0.13	-0.17
	(0.13)	(0.13)	(0.13)	(0.13)	(0.13)	(0.13)	(0.13)	(0.13)	(0.14)
Exp_Total		0.03+	0.03+		0.01	0.02		0.00	0.01
		(0.01)	(0.02)		(0.01)	(0.02)		(0.01)	(0.02)
N	53	53	43	51	51	40	56	56	47
adj. R^2	0.03	0.08	0.15	0.03	0.02	0.15	0.01	-0.01	-0.02

Standard errors in parentheses, statistically significant p values in bold. Only non-null answers for all relevant constructs were considered. + $p < .1$; *$p < .05$; **$p < .01$.

Table B4. OLS regressions for PDP aspects measure versus Barriers and risks (statistically significant p values in bold).

Variable	PDP_Adoption			PDP_Degree_F1		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Barriers_F1	0.15	0.17	0.17	0.03	-0.00	0.00
	(0.13)	(0.12)	(0.14)	(0.12)	(0.12)	(0.12)
Barriers_F2	-0.10	-0.11	-0.10	**-0.23+**	**-0.22+**	**-0.36****
	(0.12)	(0.12)	(0.14)	(0.12)	(0.12)	(0.13)
Barriers_F3	-0.14	-0.15	-0.18	0.03	0.04	0.12
	(0.13)	(0.13)	(0.14)	(0.12)	(0.12)	(0.12)
Exp_Total		0.03+	0.02		-0.03*	-0.04**
		(0.01)	(0.02)		(0.01)	(0.01)
N	61	61	49	65	65	51
adj. R^2	0.01	0.05	0.01	0.01	0.08	0.21

Standard errors in parentheses, statistically significant p values in bold. Only non-null answers for all relevant constructs were considered. + $p < .1$; *$p < .05$; **$p < .01$.

Table B5. OLS regressions for Partners measure versus Barriers and risks (statistically significant p values in bold).

Variable	Partners_F1			Partners_F2		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Barriers_F1	**0.36^{**}**	**0.37^{**}**	**0.36^{**}**	-0.16	-0.16	-0.19
	(0.12)	(0.12)	(0.13)	(0.12)	(0.12)	(0.14)
Barriers_F2	-0.04	-0.05	-0.08	**0.40^{**}**	**0.40^{**}**	**0.37^{*}**
	(0.12)	(0.12)	(0.13)	(0.12)	(0.12)	(0.14)
Barriers_F3	**-0.23^{*}**	**-0.23^{*}**	**-0.25^{*}**	0.03	0.04	0.07
	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)	(0.13)
Exp_Total		0.01	0.01		-0.00	-0.01
		(0.01)	(0.02)		(0.01)	(0.02)
N	65	65	51	65	65	51
adj. R^2	0.14	0.14	0.14	0.15	0.13	0.10

Standard errors in parentheses, statistically significant p values in bold. Only non-null answers for all relevant constructs were considered. $^{*}p < .05$; $^{**}p < .01$.

Table B6. OLS regressions for Partners measure versus PDP Aspects (statistically significant p values in bold).

Variable	Partners_F1			Partners_F2		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
PDP_Degree_F1	0.16	0.18	0.17	-0.09	-0.10	-0.23
	(0.12)	(0.13)	(0.14)	(0.14)	(0.15)	(0.16)
PDP_Adoption	**0.45^{***}**	**0.44^{***}**	**0.36^{**}**	-0.13	-0.12	-0.10
	(0.12)	(0.12)	(0.13)	(0.13)	(0.14)	(0.15)
Exp_Total		0.01	-0.00		-0.00	-0.01
		(0.01)	(0.02)		(0.02)	(0.02)
N	61	61	49	61	61	49
adj. R^2	0.20	0.18	0.12	-0.01	-0.03	-0.01

Standard errors in parentheses, statistically significant p values in bold. Only non-null answers for all relevant constructs were considered. $^{**}p < .01$; $^{***}p < .001$.

Table B7. OLS regressions for Cultural aspects measure versus Barriers and risks measure (statistically significant p values in bold).

Variable	Cult_Aspects_F1			Cult_Aspects_F2			OI_Strategy			OI_Maturity		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Barriers_F1	0.06	0.09	-0.01	**0.25^{*}**	**0.26^{*}**	**0.30^{*}**	0.22	0.25	0.24	0.01	0.10	0.12
	(0.13)	(0.12)	(0.14)	(0.12)	(0.12)	(0.13)	(0.16)	(0.16)	(0.18)	(0.13)	(0.10)	(0.11)
Barriers_F2	0.05	0.04	0.01	-0.20	-0.20	-0.16	-0.03	-0.03	-0.00	**-0.30^{*}**	**-0.31^{**}**	**-0.42^{***}**
	(0.13)	(0.12)	(0.14)	(0.12)	(0.12)	(0.13)	(0.16)	(0.16)	(0.19)	(0.12)	(0.10)	(0.11)
Barriers_F3	-0.18	-0.18	-0.16	0.11	0.10	0.10	-0.09	-0.09	-0.16	0.00	0.09	0.15
	(0.13)	(0.12)	(0.13)	(0.12)	(0.12)	(0.12)	(0.16)	(0.16)	(0.18)	(0.13)	(0.11)	(0.12)
Exp_Total		0.03^{*}	0.02		0.01	0.01		0.04^{*}	0.04		0.05^{***}	0.05^{***}
		(0.01)	(0.02)		(0.01)	(0.01)		(0.02)	(0.02)		(0.01)	(0.01)
N	65	65	51	65	65	51	65	65	51	50	50	41
adj. R^2	-0.01	0.07	-0.01	0.07	0.06	0.08	-0.02	0.05	0.01	0.06	0.40	0.47

Standard errors in parentheses, statistically significant p values in bold. Only non-null answers for all relevant constructs were considered. $^{*}p < .05$; $^{***}p < .001$.

Table B8. OLS regressions for Cultural aspects measure versus PDP Aspects.

Variable	Cult_Aspects_F1			Cult_Aspects_F2			OI_Strategy			OI_Maturity		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
PDP_Degree_F1	-0.16	-0.07	-0.08	-0.02	-0.01	0.01	0.08	0.16	0.16	-0.01	**0.18^{+}**	**0.19^{+}**
	(0.12)	(0.13)	(0.14)	(0.13)	(0.14)	(0.15)	(0.13)	(0.14)	(0.15)	(0.12)	(0.10)	(0.11)
PDP_Adoption	**0.43^{***}**	**0.38^{**}**	**0.37^{**}**	**0.30^{*}**	**0.29^{*}**	**0.27^{+}**	**0.89^{***}**	**0.85^{***}**	**0.84^{***}**	**0.46^{***}**	**0.32^{**}**	**0.33^{**}**
	(0.12)	(0.12)	(0.13)	(0.13)	(0.13)	(0.14)	(0.13)	(0.13)	(0.14)	(0.11)	(0.10)	(0.11)
Exp_Total		0.03^{+}	0.02		0.00	0.00		0.02	0.02		0.05^{***}	0.05^{***}
		(0.01)	(0.02)		(0.02)	(0.02)		(0.01)	(0.02)		(0.01)	(0.01)
N	61	61	49	61	61	49	61	61	49	49	49	40
adj. R^2	0.19	0.22	0.15	0.06	0.04	0.02	0.44	0.46	0.45	0.23	0.49	0.50

Standard errors in parentheses, statistically significant p values in bold. Only non-null answers for all relevant constructs were considered. $^{+}p < .1$; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.