Open within a box: an analysis of open innovation patterns within Canadian aerospace companies

Received
14th December 2015
Revised
4th May 2016
Accepted
8th November 2016

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Abstract

Purpose of the paper: *This paper investigates whether and how aerospace firms in Quebec (Canada) engage open innovation within R&D strategies.*

Originality of the paper: *Despite the increasing interest of open innovation among scholars and practitioners, very few studies tackle the topic within traditional high-tech industry sectors, such as aerospace.*

Methodology: *This paper critically analyzes data from a survey carried out through in-company questionnaire-structured interviews with R&D senior management of 31 companies in the Quebec aerospace cluster. The survey addresses a wide range of innovative and collaborative practices often associated with open innovation, including managerial, cultural and strategic aspects of the concept.*

Findings: *The research indicates on an exploratory basis that innovation in the sector is product-oriented, with low adoption of formal intellectual-property (IP) protection mechanisms (e.g., patents) compared to strategic ones (e.g., secrecy and complexity of design). We found significant evidence of collaboration in the sample, ranging from external sourcing to co-development with strong support from local government, universities and research institutes. However, these open approaches are mostly confined within the boundaries of the aerospace industry and, therefore, not part of diversification and expansion strategies, but a natural consequence of complementarities required to develop complex aerospace products.*

Practical implications: *The paper promotes a discussion of the possible consequences of engaging in such limited open-innovation strategies in a world of rapid technological changes with significant risk of substitute technologies replacing entire niche markets. Also at risk are business opportunities that these knowledge-intensive companies lose when they do not disseminate internal technologies into different markets.*

Research limits: *All analyses in this paper are exploratory. This is mainly due to the number of samples, which is small in absolute terms, although representative in terms of the universe of analysis. This factor also limited our statistical analyses to non-parametric methods.*

Key words: open innovation; aerospace industry; Canada; innovation management

1. Introduction

The emergence of the concept of open innovation in the past decade has contributed to the existing research on collaboration, networking and outsourcing within R&D management. According to the OECD (2008), one novelty of the open-innovation mindset, first suggested by Chesbrough (2003), is that this approach is not simply about external knowledge sourcing, but also comprises an outbound or inside-out core process. In this process, companies strive for diversification by finding alternate uses of internal knowledge assets in different markets. Another major contribution of open innovation to innovation theory is that it ties together a number of existing practices and impels firms to make these practices a part of their R&D strategies (OECD, 2008).

Openness is a matter of increasing importance for R&D managers in many companies. Previous studies about open innovation (e.g., Chesbrough and Crowther, 2006; Van de Vrande *et al.*, 2009) have already shown that this interest is not limited to high-tech and large firms. However, most case studies and analyses found in the literature focus on what Chesbrough and Appleyard (2007) called "open-dominated" industry sectors in which evidence of open innovation is more easily found, such as the open-source software, mobile electronics and pharmaceutical sector. Publications about open innovation in more traditional industries, the metal-mechanical segment, for instance, are sparse.

To measure the adoption of open innovation in a given industry, the straightforward way is to assess whether its companies use the tools and practices associated with open innovation. However, most of these practices existed long before the coining of the term (Freeman, 1991). In the case of aerospace, since the output is in general complex products, collaboration is required because no single player in the supply chain possesses all the knowledge to deliver the final product on its own (Anderson, 1995). Moreover, as aforementioned, there is more behind open innovation than the simple adoption of external sourcing and collaboration practices within the new product development (NPD) process. What distinguishes open innovation from earlier research on inter-organizational collaboration is the strategic adoption and the integration of such practices, so to achieve product and market diversification (OECD, 2008; West and Bogers, 2013).

What we intend to do in this paper is to understand the use of open-innovation practices within aerospace and its actual connection to open strategies, which, according to Chesbrough and Appleyard (2007, p. 73), "balances the tenets of traditional business strategy with the promise of open innovation." Our background question is to assess whether companies in the aerospace sector regard open innovation as part of their R&D strategies.

The lack of publications that address open innovation in this sector motivates the choice of aerospace in this paper. The reason for this gap in the literature may be because of the common sense opinion, which suggests that openness and aerospace are incompatible ideas due to the latter's close relationship to military and national sovereignty matters. As we will show in this research paper, though, aerospace companies in Quebec are indeed inclined to collaboration and external knowledge sourcing; the issue is to know whether this is part of open strategies.

To that effect, this paper analyzes the results of a survey-based research that took place between 2010 and 2013, whose goal is to probe open innovation patterns among Canadian aerospace companies. The research is exploratory, based on 31 interviews, which is a representative sample in terms of the size of the population, but small in absolute terms, for statistical ends.

2. Theoretical framework

While studying the concept of open innovation, one must be aware of the competing scopes and definitions of the topic that "pollute" the literature. This lack of uniformity poses difficulties to advance our knowledge in the field and compare results from our peers, a problem noticed and stressed in review papers in the past (Dahlander and Gann, 2010; Huizingh, 2011). Sometimes, the issue is not the general comprehension of the scope of open innovation, but on focusing details of the concept (e.g., the development of absorptive capacities), giving less attention to the impact to the culture and strategy, which is essential to distinguish open innovation from simple R&D collaboration and outsourcing (West and Bogers, 2013).

For the purpose of this paper, we developed a theoretical framework that divides the scope of open innovation into the widespread three core process archetypes (Enkel *et al.*, 2009), namely: outside-in (inbound), inside-out (outbound) and coupled (inbound and outbound simultaneously).

Another dominant classification of the open innovation scope is that introduced by Dahlander and Gann (2010), which combines the direction (inbound or outbound) with the presence or not of pecuniary aspects. As a result, they came up with four possible types of openness: sourcing (inbound and non-pecuniary), revealing (outbound and non-pecuniary), acquiring (inbound and pecuniary) and selling (outbound and pecuniary). To take out the issues associated with each core process, we have performed a literature review combining the three core process archetypes with the four types of openness. The result is the list of issues presented in Tab. 1.

Tab. 1: Issues within open-innovation core processes

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

Source: the authors

Within the scope of the outside-in process, one finds that issues are associated to external knowledge sourcing (Fabrizio, 2009; Veugelers *et al.*, 2010), technology scouting programs (Rohrbeck *et al.*, 2009), as well as early integration of suppliers and clients (Mankin, 2004), in-licencing (Fosfuri, 2006), mergers and acquisitions - M&A (Hagedoorn and Duysters, 2002). The inside-out process encompasses intellectual property (IP) management issues and out-licence (Lichtenthaler, 2010), provision of R&D services to third parties (Grimpe and Kaiser, 2010), spin-outs and divestments (Iturriaga and Cruz, 2008). Finally, the coupled process comprises venture capital (Van de Vrande *et al.*, 2009), crowd sourcing (Howe, 2006), peer production (Benkler, 2005; West and Gallagher, 2006) and many issues connected to collaborative agreements, namely: co-development (Nieto and Santamaría, 2010), research consortia (Fabrizio, 2006; Armellini *et al.*, 2011), licencing and R&D servicing within partnerships (Vanhaverbeke, 2006).

3. Methodology and data

3.1 Methodology

The database used for this paper's analysis was populated with the results of in-depth, quantitative, structured interviews with senior business executives and R&D managers. Since the literature exploring the adoption of open innovation practices in aerospace is rather close to non-existent, this survey performs an extensive investigation of open-innovation concepts, tools, practices, strategies and culture in order to verify which aspects of open innovation have indeed been adopted in aerospace product development.

The interviews were structured by means of a 71-question survey, split into three sections, which covers all relevant aspects related to open innovation, as we present in the appendix. In the first set of questions, we ask general information about the company in order to characterize the sample. In the second part, we measure how innovative firms are using the standards defined by the Oslo manual (OECD, 2005). Our scope within innovation management is technological innovations, that is, product and process innovations, covering the five years preceding the interview (from 2007 to 2011). Finally, in the third and more extensive set of questions, participants were inquired about open-innovation issues, according to the theoretical framework previously presented. In the end of this third section, we also asked some general questions about the corporate organization and culture towards open innovation, separated for outside-in, inside-out and coupled directions.

The data set consists of the responses to the 71 questions, along with the anecdotes and personal remarks given by respondents during the interviews, and the impressions during our visit to the plants. This rich data set provided insights on a number of research questions on how these companies manage innovation and openness within innovation. Although we were not able to find much more significant statistical correlations in the dataset, due to the limited number of samples, the descriptive analysis of the data combined with personal remarks and anecdotes helped us to better understand, from an exploratory standpoint, the implication of open innovation for product development and innovative performance in the cluster. The aim of this paper is to provide insights to answer the following research questions: (i) Do aerospace companies of the Quebec cluster practice open innovation? How? (ii) Is the practice of open innovation in these companies connected to an open strategy?

3.2 Data

To investigate the questions formulated in the previous section, we present here some of the results of a survey that took place throughout 2012, with questions relating to the five-year period from 2007 to 2011. A total of 31 companies are represented in the sample of respondents. Data collection was performed by means of personal interviews with R&D managers or directors responsible for managing the innovation process within the company. All interviews were performed in-company and took on average 75 minutes. We registered as anecdotal any additional information that was provided outside the scope of the 71 questions in the survey.

All data collected was then compiled, treated and analyzed using Stata 11 software. The design of the survey questionnaire included some redundant questions intended to check consistency. In the correlational tests applied on these redundant questions, we verified the quality of the dataset and identified and eliminated eventual outliers. Finally, data was consolidated in order to allow a descriptive and critical analysis of the population under study.

Although the official Quebec aerospace industry directory includes more than 240 aerospace companies (AéroMontréal, 2012), through an analysis of the description of firms' activities in the directory, we found that only 77 companies within the cluster actually perform R&D activities and were therefore target of this research. It is worth remarking that, throughout this text, whenever we refer to the population of the research, we mean these 77 companies. Therefore, the subset of 31 companies interviewed for this analysis represent about 40% (31/77) of the population. As previously mentioned, this sample, although representative for our universe of analysis, is small in absolute terms, for the ends of statistical analyses. However, it is worth mentioning that our discussion and conclusions are not only based on statistics, but they are also based on the impressions and anecdotes extracted from 31 face-to-face interviews and visits to companies, which enriches our sources of analyses.

The aerospace industry embraces companies from many different technological fields due to the very nature of aerospace products, which combine different technologies. To classify the companies in the cluster from this perspective, we have used a technological classification system consisting of 13 fields that we adapted from the 18-field classification system used by AéroMontréal[1], the official think-tank of the cluster. By doing so, we came up with the evenly spread distribution in our sample as shown in the middle column of Tab. 2.

1 Available on the company search engine at http://www.aeromontreal.ca/

Tab. 2: Comparison of technology distribution of the sample vs. cluster firms that perform R&D activities

Technology field	Sample # (%)	Population# (%)
ICT / software	5 (16%)	9 (11.5%)
Electronic systems / avionics	5 (16%)	11 (14.5%)
Aircraft parts	5 (16%)	8 (10.5%)
Maintenance, repair and overhaul (MRO)	4 (13%)	4 (5%)
Simulation equipment	3 (9.5%)	4 (5%)
Technical consulting	2 (6.5%)	17 (22%)
Mechanical manufacturing / machining	2 (6.5%)	8 (10.5%)
Materials	2 (6.5%)	7 (9%)
Aircraft	2 (6.5%)	3 (4%)
Instrumentation / automation	1 (3.5%)	2 (2.5%)
Defence equipment	0 (0%)	2 (2.5%)
Satellites and components	0 (0%)	1 (1.5%)
Speciality chemicals and lubricants	0 (0%)	1 (1.5%)
Total of firms:	31 (100%)	77 (100%)

Source: the authors

When compared to the distribution within the population (right column) of 77 companies that perform R&D activities, we realize that technical-consulting firms and mechanical manufacturing and machining firms are the two fields that are misrepresented in our sample. Additionally, we realize that three of the fields are not represented at all in our sample, but they are fields of limited relevance in the cluster (accounting for only 4% of the object of analysis). What is more, we also notice a slight predominance of information and communication technology (ICT) and electronic systems companies, which together stand for almost 1/3 of the sample. Nevertheless, we do not believe that these differences between the sample and the population distribution should bias the results towards one specific niche of the industry. With respect to firms' value-chain positions, we realize that roughly 61% of the sample are subcontractors, 26% are equipment manufacturers and 13% are prime contractors. As Tab. 3 shows, this distribution is similar to that of the population of the research.

These numbers show that we were able to raise a representative sample of the population under study. Even though the small sample size prevented us from the use of more sophisticated parametric statistical tools, we were still able to extract from the data some interesting insights for the research questions previously formulated as we intend to show in the following sections.

Tab. 3: Comparison of value-chain–position distribution of the sample vs. cluster firms that perform R&D

Value-chain position	Sample # (%)	Population # (%)
Prime contractors	4 (13%)	4 (5%)
Equipment manufacturers	8 (26%)	15 (19.5%)
Subcontractors	19 (61%)	58 (75.5%)
Total of firms:	31 (100%)	77 (100%)

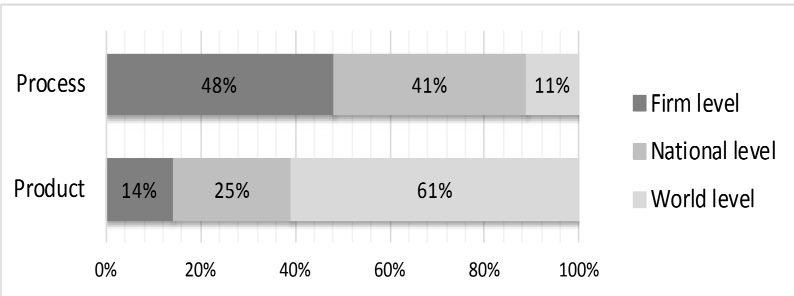
Source: the authors

4. Results

4.1 Technological innovation metrics

During the interviews, we asked companies about the innovations they had performed in the 5-year timespan from 2007 to 2011, using traditional innovation metrics as defined in the Oslo manual (OECD, 2005). All interviewed companies have performed at least one process or product innovation in that period. What is more, the vast majority of firms interviewed (about 74%) claimed to have performed both types of innovations. However, when asked about the global impact of such innovations, their responses are biased towards product innovation as Fig. 1 shows. Anecdotally, a couple of companies added that, according to their innovation strategy, they are intentionally follower-innovators in terms of process development, but leader-innovators or fast-followers in terms of product development. That seems to be the tendency in the industry as corroborated by the results shown in Fig. 1. With respect to intellectual-property (IP) protection, in our 31 interviews we have found that formal methods of protection (patents, trademarks and industrial design registration) are less used than strategic methods (secrecy, complexity of design and lead-time advantage), as shown in Tab. 4.

Fig. 1: Highest impact of product and process innovations



Source: the authors

The data indicate that less than half of the firms interviewed had submitted a patent demand in the five-year span. For those that did apply for a patent, the average number of demands is around 76, with a standard deviation of around 163. In other words, the findings indicate that very few companies in the sample patent their technologies with great intensity. For most companies in the sample, patenting is not a very common practice or not practised at all. This result follows the low-patent tendency observed in the aerospace industry globally and was somewhat expected, given the proximity of the sector to the military and matters of national sovereignty that demand secrecy.

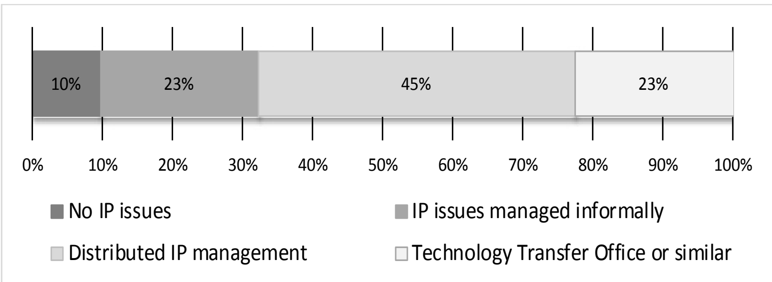
Tab. 4: Adoption of IP protection methods in the sample

Type of protection	IP protection method	Sample
Formal methods	Patents	48%
	Trademarks	48%
	Registration of industrial designs	23%
Strategic methods	Secrecy	61%
	Complexity of design	68%
	Lead-time advantage	58%

Source: the authors

In spite of that, IP protection is an issue in the cluster, and the companies are, therefore, well structured to manage it (see Fig. 2). Only 10% of the companies in the sample claimed not to have IP issues and almost 70% claimed to have a formal structure to deal with IP. Therefore, it is not a matter of organization; Canadian aerospace companies seem to allot low importance to patenting and other formal IP protection methods within their innovation strategies. This cultural attitude towards IP protection affects these companies' perceptions of open innovation as we will argue in the discussion section.

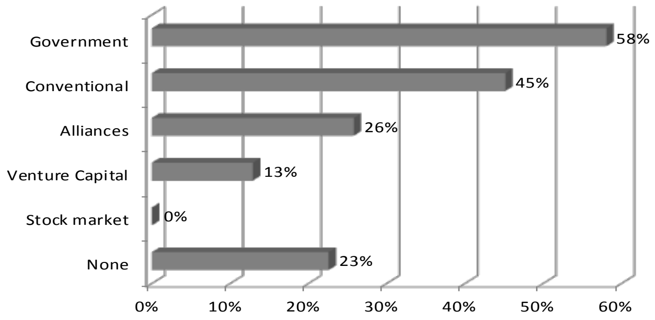
Fig. 2: IP management patterns



Source: the authors

Another important innovation metric is that of funding and public support. About 3/4 of the sample receive external funding for RD&I (research, development and innovation) activities. Fig. 3 summarizes the findings regarding the use of funding sources. One piece of information that stands out is that the government funds more than half of the companies in the sample. This result shows the importance of public support for local innovation. The results shown in Fig. 3 also reflect the lack of a well-developed venture capital (VC) market for the industry: only 13% of the sample makes use of this type of funding.

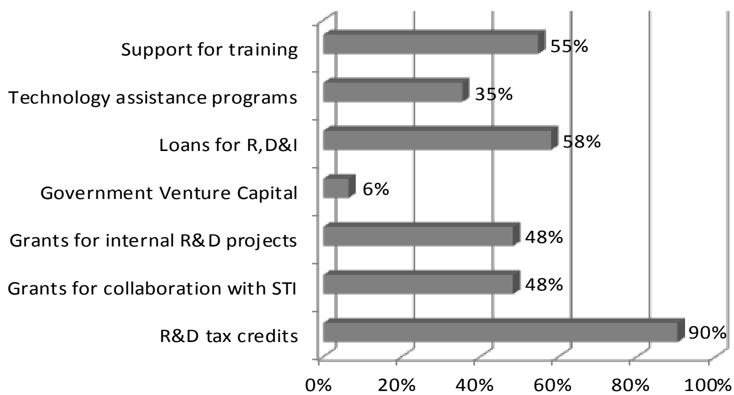
Fig. 3: External funding sources



Source: the authors

With respect to government support outside of funding, Fig. 4 summarizes the sample's use of innovation public policies. Excepting public VC, all policy types found a reasonable ratio of users within the sample. R&D tax credits were of particular importance to users with 90% of the sample benefiting from them. This remarkable result is due to the Canadian RD&I policy strategy, which, according to Bibbee (2012), does not privilege a few strategic technology sectors, but supports market-oriented innovation. This strategy is accomplished through horizontal incentive programs, such as the Scientific Research and Experimental Development (SR&ED) tax credit program, which costs the federal government approximately CAD$3.53 billion annually. It represented roughly 55% of the total expenditure of the government in support of business R&D in 2010-2011 (Industry Canada, 2011).

Fig. 4: Use of public policies in the sample



Source: the authors

To close this first section of the survey, we asked the companies to indicate where they operate across the R&D spectrum. All companies in the sample but one, which has a particular situation, described themselves as committing to development activities. About 2/3 of the sample claimed to perform applied research internally, and about 1/3 affirmed to perform basic research.

In the case of multinational companies (MNC) hosted in Quebec, a series of questions regarding R&D intensity of the local plant in comparison to the company's other plants revealed a very interesting piece of information: 86% of the plants in the sample have a level of R&D intensity that is equal to or greater than other plants owned by their global firm. This result demonstrates the importance of the Quebec cluster for aerospace R&D at global level. MNC establish subsidiaries in Quebec not exclusively to exploit local market advantages, but also to make use of the scientific and innovative skills in the cluster.

4.2 R&D management and openness

While engaging R&D activities, companies often make use of external sources of knowledge. Aware of this reality, the survey inquired about their importance throughout the R&D process: basic research, applied research and development. The importance was scored according to a seven-point Likert scale with no central point. Fig. 5 shows in a radar-like diagram the average importance allotted by the sample to a list of external and internal sources for each one of these stages. Since the number of sample respondents that claimed to be engaged to basic research was low (only 11 respondents), we attribute a lower reliability to the resulting graph for this specific phase.

Among the possible knowledge sources, we have included in the survey the CRIAQ (Consortium for Aerospace Research and Innovation in Quebec, in the French acronym), which is a partner in our research. CRIAQ is a government initiative created in 2000 to stimulate the establishment of government-funded collaborative pre-competitive research between local universities and aerospace companies (Armellini *et al.*, 2011) in a clear application of the triple-helix concept (Etzkowitz, 2008).

Post-hoc analyses using Wilcoxon signed-rank tests on the survey data revealed that, for the sample, internal R&D is significantly more important than all the other sources both for the applied research and the development stages. The same test also revealed that universities, research laboratories (public and private ones), industry associations and CRIAQ play a secondary but important role for applied research. In the case of development, this "second place" ranking goes to internal sources other than R&D, clients, suppliers and, again, to industry associations. Two players that ranked as least important in all R&D stages are companies from other industries and aerospace firms that are neither clients nor suppliers.

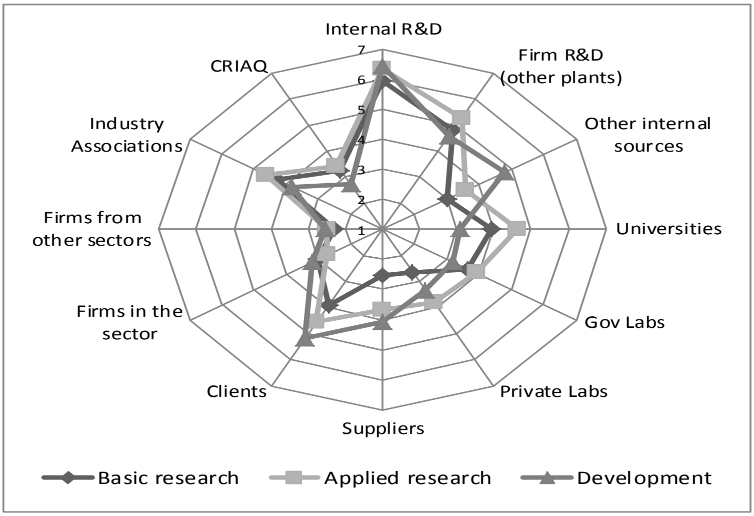
The previous information leads us to the finding that inspired the title of this paper - "Open within a box." The portrait that our survey database has revealed is that of an industry that is closed to other industries. Its members do perceive the importance of sourcing and collaborating with external actors, but these activities are mostly confined within the borders of the industry. What is more, they are normally limited to the supply-chain relationship (from the raw-material suppliers to the direct suppliers and clients up to the final customers, at the most).

It is expected that the importance of certain sources vary according to the R&D stage. Although we were not able to demonstrate the variance for all players from the statistical standpoint, due to the small sample size, we did confirm, using Wilcoxon signed-rank tests that universities ($p \approx 0.003$) and government laboratories ($p \approx 0.019$) are significantly more important during applied research phase. Another significant statistical finding is that internal sources (other than R&D) ($p \approx 0.070$) and clients ($p \approx 0.036$) are more important during the development stage.

In the survey questionnaire, we ask respondents to indicate the two most valuable players from the list of players presented in Fig. 5. Just one single company pointed to "firms from the sector" as a top-of-mind source of knowledge, and even this respondent clarified that he was referring to a couple of SMEs (small and medium enterprises) that attend for this company's specific affairs. Not a single company identified "firms from other sectors" as the most valuable source of knowledge for their RD&I activities. Then again, the three players that stand out in this analysis are clients (58%), suppliers (32%) and universities (26%).

In its turn, Fig. 6 reveals the types of partnerships and collaborations entered into by the companies in the sample. As one can see, participation in research consortia, such as the CRIAQ, and the within co-development projects overshadows other types of collaborations.

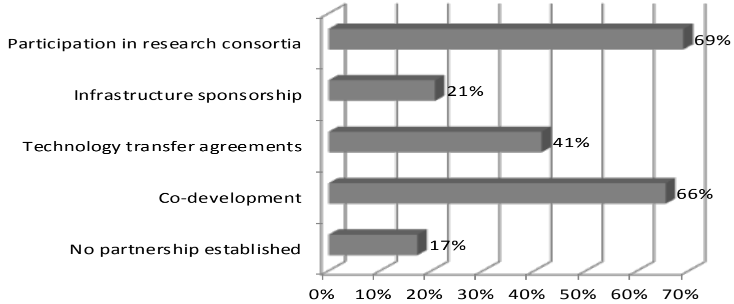
Fig. 5: Importance of sources of knowledge for R&D activities



Source: the authors

All these results show that collaboration for the aerospace companies in the sample, although existent, is limited to collaboration with close links in the value chain and with the science and technology infrastructure around the cluster (universities and research institutes). Their innovation is then open but within a box, limited to a well-defined and limited network of players that somehow complement each other. We shall get back to this open-within-a-box issue and its consequences later on in this article.

Fig. 6: Types of collaborative arrangements



Source: the authors

4.3 Open innovation and strategy

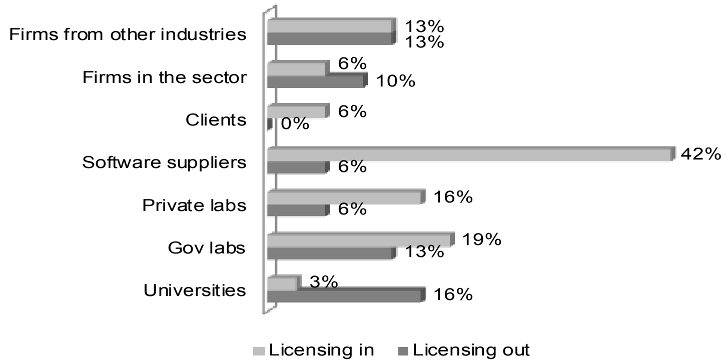
Recalling the types of openness defined by Dahlander and Gann (2010), there are two types of strategy for open innovation: pecuniary and non-pecuniary. Pecuniary strategies consist of external practices directly related to acquiring or selling companies. On the other hand, non-pecuniary practices refer to other knowledge sourcing and revealing processes, which may also involve monetary transactions, in spite of the name attributed to them.

Regarding pecuniary practices, the survey asked aerospace companies if they engaged in this the acquisition or selling of companies between 2007 and 2011. In the outbound direction, only 35% of the companies in the sample claimed to have performed any spin-offs or divestments; as for inbound spin-in and acquisitions, the ratio is even smaller at 23%. Regarding licencing, we found that only 26% of the interviewed firms have out licenced at least one technology or solution in the 5-year period, while 70% claimed to have acquired at least one licence in the same period.

As one can see, the rates for licencing out are quite modest, which is evidently due to the fact that the cluster does not patent very often. In the inward direction there is a higher share of positive responses, but when inquiring about the origin of such licences, we realize that most of them are for the acquisition of specific software tools needed either for product development or for software embedding in the company's own products. One finds evidence of this in Fig. 7, which shows that a high percentage (42%) of licence sources is software development firms. It is worth mentioning that percentages in Fig. 7 are absolute values, that is, calculated over the whole sample (31) and not only over those who claimed to perform licensing (in or out). That is to say that more than half of the 70% of companies that did licence-in, purchased software licences. In some cases, this was the only kind of licence they purchased.

We also inquired about another avenue of sharing internal knowledge, with equally modest results: only 16% of the sample claimed to provide R&D specialized services to third parties on a regular basis; 42% claimed to do it occasionally and the remaining 42% of the sample claimed they never do it.

Fig. 7: Licencing sources and destinations



Source: the authors

Finally, with regard to sourcing, we also asked companies about the importance of technology scouting as a form of external sourcing of knowledge and technologies. Here the sample is quite divided: 15 companies (about 48% of the sample) attributed a high importance to such practices, while the rest claimed not to find it important.

All these results show that, strategically speaking, the cluster is far from adopting open business models. Open innovation for the interviewed firms is equivalent to co-development with clients, suppliers, universities and other science and technology (S&T) institutes. As we have discussed in this paper's introduction, that is not exactly what open innovation is about.

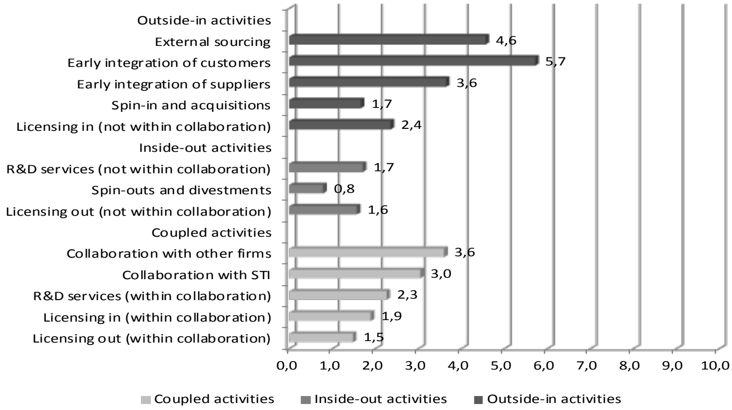
4.4 Open innovation and culture

Even though open innovation may not be a reality in the behaviour or in the strategies of Canadian aerospace, its principles may yet be present in companies' internal culture. That is why the interviews also assessed the cultural inclination of the sample towards open innovation. By means of a series of questions about the importance of a number of aspects of open innovation, we are able to determine which open innovation practices are part of the daily routine of the companies in the sample.

In Fig. 8, we show the level of importance attributed to each practice in a 0-to-10 scale and grouped by the three core processes identified by Enkel *et al.* (2009). As one can see, there is a higher predominance of outside-in practices, coupled activities are next and inside-out practices scored the lowest.

Using these numbers along with data gathered about the internal structure for managing outside-in, inside-out and coupled activities, indexes were created to score how well the core process related to the companies' culture. For the sample under analysis, the indexes found were 5.13 for outside-in, 2.79 for inside-out and 3.89 for coupled on a 0 to 10 scale. Once again, outside-in scored highest, followed by coupled, and inside-out had the lowest score. This result is consistent the finding from Enkel *et al.* (2009) finding that the outside-in core process prevails over the other two.

Fig. 8: Importance of open innovation practices as part of the day-by-day of Canadian aerospace firms in the sample



Source: the authors

Also with respect to openness culture, Chesbrough (2003) presents two potential barriers to the adoption of open innovation, the so-called closed-innovation syndromes: "not invented here" (NIH) and "not sold here" (NSH). The latter is related to the prevention of companies from revealing internal technologies for use by third parties, while the first is connected to a lack of trust in knowledge or technologies originating outside the company.

The following analysis on open innovation culture in the questionnaire focus on these syndromes.Through a set of questions designed to that effect, we found that about 81% of the interviewed companies were diagnosed with the NSH syndrome, and 83% with the NIH in the sample. Presenting with the syndrome does not mean that the company is not capable of performing open innovation, just that the company culture presents barriers to its implementation. The conclusion from this analysis is very clear: the companies in the subset adopt a closed mindset not only in their strategies but also culturally.

5. Discussion and conclusions

In this paper, we have discussed how the body of knowledge about open innovation formed over the past decade applies to high-complex product industries, such as the aerospace. Through the analysis of the dataset from an interview-based survey conducted in 2012 with 31 aerospace companies in the Montreal area, we investigated whether these companies adopt open-innovation practices and employ an open strategy as defined by Chesbrough and Appleyard (2007). The findings are summarized in Tab. 5. Within the open-innovation mindset, firms become increasingly aware of external knowledge that may be used in internal technologies and markets as well as external opportunities for the application of internal knowledge in different markets.

Tab. 5: Summary of findings for open innovation issues

Core process	Associated issues	Summary of findings
Outside-in	External knowledge sourcing and technology scouting	There is evidence of external sourcing, mostly through informal channels rather than formal programs (such as tech scouts). The most important sources are those within the cluster and in the firm's value chain.
	Early integration of clients in NPD	Client early integration was found to be the most relevant extra-muro practice in the sample.
	Early integration of suppliers in NPD	Some evidence was found in the sample, but much less relevant than client early integration.
	Licencing in	Barely used and in general restrained to specific engineering software suppliers.
	Spin-in and M&A	Very little evidence found in the sample, which was expected due to the small sample and short period covered by the survey.
Inside-out	IP portfolio activity	Very low activity, mostly concentrated on the use of strategic methods instead of formal ones (e.g. patents).
	Licencing out	Almost no evidence of out-licencing was found, except for companies engaged in ITC and software development.
	R&D services	The provision of R&D services was found to be an uncommon practice in the sample, mostly confined within subcontractor SMEs.
	Spin-outs and divestments	Very little evidence found in the sample, which was expected due to the small sample and short period of time covered by the survey.
Coupled	Co-development and participation at research consortia	This activity is the most important coupled practice in the sample, in great part due to CRIAQ. It is worth noticing that the nature of this collaboration is normally within the cluster (other aerospace companies and S&T institutes specialized in aerospace technologies).
	Crowdsourcing and peer production	Evidence of this kind of practice is close to inexistent in the sample.
	Venture Capital (VC)	Less important, as only 13% of the companies in the sample make use of this kind of funding.
	Licencing in (within collaboration agreements)	Even less evidence of in-licencing within the coupled mode than within outside-in.
	Licencing out (within collaboration agreements)	Even less evidence of out-licencing within the coupled mode than within inside-out.
	R&D services (within collaboration agreements)	Even less evidence of provision of R&D services within the coupled mode than within inside-out.

Source: the authors

As we showed in the previous sessions, innovation in the Quebec aerospace cluster is product-oriented, with lower adoption of formal IP protection mechanisms (e.g., patents) compared to the use of strategic ones (e.g., secrecy and complexity of design). We found much evidence of collaboration, external sourcing and co-development in the sample, with strong support from local government, universities and research institutes. However, this collaboration is mostly confined within the boundaries of the aerospace industry and, therefore, not part of diversification and expansion strategies. The evidence of open innovation found in the cluster is related to co-development with clients and suppliers or, at the most, within research consortia (e.g., CRIAQ), with universities and with other S&T institutes. This is a natural consequence of complementarities, rooted in the complexity of aerospace product development. Since aerospace products involve the integration of so many different and complex technologies that hardly a single company could dominate alone, it is natural that aerospace companies seek to work in collaboration with companies with complementary skills and technologies. Therefore, they are indeed open, but within a limited and known network of collaborators or, as the title of this paper suggests, they are open within a box.

This is not what open innovation scholars advocate, though. In a world of rapid technological changes and the risk of substitute technologies replacing entire niche markets, companies should be aware of the risk of having their business suddenly vanish due to the emergence of a disruptive and unexpected innovation. For example, what would happen to the space-rocket industry as a whole if one of the so-called non-rocket space-launch (NRS) technologies discussed by and experimented on by physicists and astronomers (e.g., Bolonkin, 2003; Birkan, 2008; Siceloff, 2010) proves to be able to change the current technological paradigm?

Open innovation advocates that companies acting in one specific market under its current technology paradigm should look for external ideas that might be useful in their current markets. With a systematic outside-in approach (technology scouting, technology intelligence methods and so on), a given company should be able to identify and absorb a technology that might change the current business before it becomes an actual risk for the company. Additionally, the inside-out approach would be able to identify opportunities for the internal knowledge and technologies in new markets and business models that are currently unexploited.

However, it requires a strategic and cultural shift in order to benefit from this new mindset. In the strategic field, a major issue is to rethink the use of formal methods to protect IP. The only way to viably commercialize knowledge is through its clear definition through a patent, trademark or registered industrial design. The formalization of internal knowledge is also a means of making known to the rest of the world where the expertise of the company lies. However, secrecy and sovereign issues will not vanish from the industry; therefore, managing open innovation will continue to be more challenging in aerospace than in the so-called open-dominated sectors. In addition, we have found, in general, little interest from the aerospace companies we interviewed to overcome these difficulties because they do not think about open innovation strategically.

Policy makers engaged in promoting the aerospace industry, not only in Quebec but worldwide, should also be wondering how to stimulate the sector to think "outside the box." Changing an industry culture is not the goal of a public policy, but there are ways to make companies aware of the benefits of open innovation and of adopting formal methods of IP protection to allow internal technologies to be commercialized outside the company's current business model.

For the industry to truly engage open innovation, more evidence is needed to convince industry and government to adopt open models, by showing successful models and cases. Therefore, additional research on innovation management to explain if and how open innovation can be translated into competitive advantage is needed, for aerospace and to other mature highly complex industries where open innovation suffers from this same lack of credibility.

For practitioners and innovation managers in aerospace, the implication of this paper is to raise awareness of the lack of formal IP protection in the cluster. Its benefits go beyond the prevention of the use of internal IP from third parties, as it also increases a company's capacity to share and commercialize internal technologies on business models that differ from the current channels the company use. That should also enable aerospace companies to go beyond the "box" determined by their cluster.

Limitations and future perspectives

The dataset used in this research paper is limited to aerospace companies located in the Montreal cluster, and therefore additional research is required to confirm our findings under different contexts. Looking specifically to the aerospace industry, since it is characterized by global marketing and competition (Emerson, 2012), one should expect to find many similarities of other relevant aerospace clusters worldwide in the USA, France, Germany, Italy and Brazil, for instance. However, additional research within these locations is required to generalize our findings.

One such example is the survey that took place in Brazil (Armellini *et al.*, 2014), which can now be compared with the Canadian sample presented in this paper, in order to allow comparative analysis of different innovation ecosystems. This component of the research shall contribute to the understanding of current issues derived from the globalization trend of the last decades.

Another limitation of this research lies on its extensive and unfocused nature of inquiring. As we could not find previous research whose focus was to investigate open innovation within aerospace, our goal was to look for patterns as to know which practises and challenges, found in the body of knowledge of open innovation, make sense for this specific context. This paper enables future research on the topic to establish higher goals grounded over our findings, which provides managers and scholars an insight of what open innovation means for aerospace.

Still with respect of limitations of this research, one must also bear in mind that all analyses presented in this paper were performed under an exploratory basis. This is mainly due to the number of samples, which was too small in absolute terms, although representative in terms of the universe of analysis. This factor also limited our statistical analyses to non-parametric methods. Another limitation of our research is, because our data focus on a fixed five-year period (from 2007 to 2011), therefore we cannot anticipate the changing tendencies for the future. To cover for that, longitudinal analyses are required to evaluate the evolution of the adoption of the concept.

In spite of all these limitations, the results and analyses presented in this paper enabled us to understand how open innovation is apprehended in the Quebec aerospace industry. It might contribute as well to identify open innovation patterns from companies that are part of aerospace companies in other clusters around the world and even for companies from other mature high-tech industry sectors characterized by complex products.

With respect to future perspectives of research within the domain, besides those already mentioned when discussing the limitation of this present work, another possible path for future research is to incorporate the notion of open business models (Chesbrough and Appleyard, 2007) when inquiring companies about their relationship with open innovation. For those undertaking this path, we strongly suggest the use constructs from other studies aimed at evaluation open business models, such as Chesbrough and Brunswicker (2013), as to standardize the analyses and allow for cross-industry comparisons in the future.

The most recent publications show that the current agenda of open-innovation research lies in the challenge of adopting effective inside-out models (Chesbrough and Winter, 2014), pursuing IP management decisions (Chesbrough and Ghafele, 2014; Henkel *et al.*, 2014) and overcoming cultural barriers for open innovation (West and Bogers, 2013). The perspectives for future research here presented are perfectly aligned with these tendencies.

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Appendix - Survey questions

Section	Ref. #	Question
1 – General information	1	Information about the interviewee
	2	Year of establishment of the firm
	3	Placement of the company in the value chain within the sectors of the Aerospace Industry
	4	Total annual revenue OF THE PLANT in 2011
	5	Number of employees
	6	Is the firm on the stock market?
	7	Has the firm merged with another firm?
	8	Firm ownership and subsidiaries
	9	Level of education of plant's full-time employees in 2011
	10	Types of business activities performed in the plant
	11	How many clients does your plant have?
	12	How many suppliers does your plant have?
2 – Innovation in the plant	13	Product innovations introduced by the plant from 2007 to 2011
	14	Who developed these product innovations?
	15	Ratio of new-to-the-market innovations within these product innovations
	16	Ratio of already-in-the-market innovations within these product innovations
	17	Plant's average innovation lead time
	18	Level of impact of product innovations
	19	Process innovations introduced by the plant from 2007 to 2011
	20	Who developed these process innovations?
	21	Level of impact of process innovations
	22	Information about ongoing innovations
	23	Information about abandoned innovations
	24	Reason why the company did not innovate (in the case the respondent said no in questions 13 and 19)
	25	Innovation activities performed by the plant during the five years 2007 to 2011
	26	Percentage of the plant's total revenues reinvested in R&D in 2011
	27	Intellectual property (IP) protection methods used by the plant during the five years 2007 to 2011
	28	Estimation of the percentage of IP protected products in terms of their contribution to total revenue in 2011
	29	IP management structures
	30	External sources of RD&I funding
	31	Type of VC used (if applicable)
	32	The reason to engage in VC funding (if applicable)
	33	Use of public-sponsored programs during the five years 2007 to 2011?

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Section	Ref. #	Question
3- Open innovation patterns	34	R&D activities (basic research, applied research and development) performed in the plant?
	35	Importance of knowledge sources for basic research (if applicable)
	36	Importance of knowledge sources for applied research (if applicable)
	37	Importance of knowledge sources for development (if applicable)
	38	Geographical location of external sources of knowledge and technology of the plant
	39	Frequency of innovations provided by clients and/or users
	40	Use of mechanisms to early integration of clients and/or users
	41	Frequency of innovations provided by suppliers
	42	Use of mechanisms to early integration of suppliers
	43	Use of tools to integrate suppliers to the NDP process
	44	In-licencing during the five years 2007 to 2011
	45	Out-licencing during the five years 2007 to 2011
	46	Importance of peer production practices for the plant
	47	Frequency that the plant provides R&D contracted services to third parties
	48	Location of firms and organizations to which the plant provides R&D contracted services (if applicable)
	49	Establishment of collaborative alliances during the five years 2007 to 2011
	50	Types of partners and their geographical locations
	51	Name the two most valuable partners from the list provided in the previous question
	52	Reasons for partnering with universities and other S&T institutions (if applicable)
	53	Reasons for partnering with organisms other than universities and other S&T institutions (if applicable)
	54	IP protection culture
	55	Frequency of use of external sourcing practices
	56	Importance of acquiring or spinning-in companies for the firm's strategy
	57	Creation of spin-offs in the five-year period from 2007 to 2011
	58	Divestments and selling of business units by the firm in the five-year period from 2007 to 2011
	59	Importance of OUTSIDE-IN activities in the firm's daily routine
	60	Existence of a department formally responsible for implementing OUTSIDE-IN processes
	61	Existence of formal procedures for OUTSIDE-IN activities in the firm
	62	Relevance of the NIH (not-invented-here) syndrome to the firm's corporate culture
	63	Importance of INSIDE-OUT activities in the firm's daily routine
	64	Existence of a department formally responsible for implementing INSIDE-OUT processes
	65	Existence of formal procedures for INSIDE_OUT activities in the firm
	66	External visibility of firm's internal technologies
	67	Relevance of the NSH (not-sold-here) syndrome to the firm's corporate culture
	68	Importance of COUPLED activities in the firm's daily routine
	69	Existence of a department formally responsible for implementing COUPLED processes
	70	Existence of formal procedures for COUPLED activities in the firm
	71	Conclusion and self-evaluation: Is the firm is engaged on several collaborative fronts?

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italian journal of management

ISSN 0393-5108
DOI 10.7433/s101.2016.02
pp. 15-36

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