

Factorial Analysis as a tool to support the measurement of Open Innovation practices in Small Business in important Brazilian industrial centers

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Abstract

Most of innovation studies and researches are not related to innovation measurement and, in general, it only addresses some innovative actions in terms of products, services or processes. This paper addresses the difficulties in researching innovation and Open Innovation (OI) performance metrics through an exploratory literature research followed by a survey conducted with small technology-based enterprises incubated at important Brazilian industrial and technological centers. It is well known that for many small business entrepreneurs and managers, the idea of OI practices are still restricted to large corporations. Against this idea, this work proposes an understanding of these OI practices, besides an analysis of its measurement. The indicators proposed by this work developed with the support of the statistical technique of factorial analysis, has been proved to be the most significant to measure OI at this kind of company and, with them, it has been possible to understand that small companies can successfully use OI and, although it is not common today, it should be encouraged. This study's conclusions can be useful for researchers and Small to Medium Enterprises (SMEs) interested in joining or increasing their OI practices.

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Abstract

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Introduction

Since the early 1970s, in the context of the economy globalization and the transition from an industrial era to an era of knowledge, innovative processes and products have stood out in business strategies and, with

these, trade rivalry is being gradually replaced by partnerships that are best established by the ability to integrate knowledge into products and services.

Although coexisting with innovation involves risks and barriers for companies, this is one of the main ways of gaining a competitive advantage (Biancolino et al. 2013). Thus, innovation and its openness are increasingly becoming a trend in management and a key part of economic growth (Lopes and de Carvalho, 2018). Following this development, Small to Medium Enterprises (SMEs) are often highlighted as possible solutions for economic progress.

Small businesses can and should use external and internal sources as well as market information to generate combinations of resources and meet the needs of that market. When developing new technologies, SMEs aspire to inexpensive alternatives to reduce the vagueness attributed to traditional innovation processes, along with the need to establish and extend relationships with partners, supporters, and others involved in the organizational issues.

Even knowing collaboration efforts among various stakeholders in innovation are important, Radziwon and Bogers (2018) warn that SMEs face an intrinsic tension for relying on external partners to complement some internal activities and, at the same time, they have limited resources to manage their own innovation processes.

Chesbrough (2006) defines Open Innovation (OI) as a model in which valuable ideas can come from inside or outside the company and can reach the market from inside or outside the company as well. Adding some knowledge and "core competencies" to the process makes easier to balance external and internal technological knowledge and opportunities.

A literature review conducted by the authors has identified that only a few papers addresses metrics for innovation and even less for open innovation. During the beginning of this work, a search for the combined terms "metrics" and "open innovation" on the topic or title of articles published in the last 15 years available in English or Portuguese was carried out at the two main academic literature collections: Web of Science (WoS) and Scopus.

The search on these databases resulted in 12 papers published in WoS (Web of Science) and 70 papers in Scopus, which can be considered little for a 15-year horizon. In these works, some authors (Dodgson et al., 2006; Böhme et al., 2014; Rangus et al., 2016) reveal how they elaborate metrics for innovation and others (Chesbrough, 2006; Steninger, 2014; Vanhaverbeke, 2017) that study mainly on small business innovation are still evolving their researches toward this topic, revealing a gap in the literature related to the metrics for small business OI. This gap is evidenced on the following evidences:

- Most publications on innovation are not related to the measurement of innovation and open innovation, but rather to the "action of innovating" in products, services and processes (Erkens et al., 2014; Curley, 2016 Erkens et al., 2014);
- Many entrepreneurs and managers of small businesses still consider OI restricted to large corporations (Vanhaverbeke, 2017; Teixeira and Santos, 2016; Chesbrough, 2006);
- Absence of an effective performance measurement system for innovation and OI for small enterprises (Vanhaverbeke, 2017; Joubert, 2013; Greenhalgh et al., 2004).

Thus, this research first started analyzing the literature about innovation and OI metrics in small companies. Based on a group of indicators identified in these works, a survey was developed and then answered by managers or Chief Executive Officers (CEOs) of small technology-based enterprises incubated at important Brazilian industrial and technological centers. Finally, using a measurement tool and a factorial analysis, this work proposes a set of indicators suitable as OI metrics for this kind of companies.

Literature Review

2.1 Open Innovation (OI)

As Chesbrough (2006) states, the OI model guides the companies to opportunities in a more interactive way, seeking the integration of knowledge between them. This approach requires some changes in the project management process, as well as a new insight into the importance of the knowledge available outside the company. Competing companies begin to cooperate with each other to generate solutions together, and one of their objectives becomes the transfer of knowledge.

For Dodgson et al. 2006 and Huizingh (2011), OI is a basic part of an attractive management strategy because it enables the flow of ideas, contributing to the intellectual capital from the initial processes to the final generation of innovation. It presents two typologies: the "inbound OI" and the "outbound OI". The first one refers to the internal use of external learning or experiences, while the second one refers to the exploitation of internal knowledge and its dissemination to the external environment (see Figure 1).

Figure 1

Internal and external ideas can and should be brought to market, as illustrated by Chesbrough (2006) in Figure 1. In the last decade, companies have shifted their focus from internal information to external sources such as customers, universities, research institutes, suppliers, business partners and innovation networks (Teixeira and Santos, 2016). Valuable ideas can arise both from inside and outside the organization with the goal of accelerating internal innovation and bringing it to the market.

The OI model is based on the search for information or resources outside the organization boundaries and on the work to manage a joint risk of connections and network relationships (Vanhaverbeke, 2017). The ideas are usually sought in favorable environments, where other companies are willing to negotiate techniques, technologies and knowledge that could contribute to generating further innovation (Steninger, 2014; Giannopoulou et al., 2010).

There is a strong similarity between companies that seek actions to encourage and increase the collaboration of other companies and/or consumers in their processes, even adopting different innovation practices to establish these innovation and knowledge networks. Those actions become excellent complements in the development of products or services (Huizingh, 2011; Lindegaard, 2010; Greenhalgh et al., 2004; Ritter and Gemünden, 2004).

Lindegaard (2010) points out that OI is becoming more and more urgent and, for innovation to happen, it is necessary to create value in services or products through internal collaborators and through practices that include the use of external sources, such as licensing or investment in patents, spin-offs, acquisitions, divestitures, etc (see Figure 2).

Figure 2

According to De Mattos et al. (2018), information technology has enabled the development of virtual environments for collaboration with external agents. However, companies are still looking for better ways to apply and create value.

In this context, some corporate practices has become potential actions for the development and promotion of corporate success, as the establishment of alliances and partnerships, creation of knowledge networks, encouragement to crowdsourcing and co-creation, investment in venture capital, capturing and disposing of intellectual property, adapting the organizational culture to the OI, among others.

2.2 Performance Metrics

For Frederiksen and Mathiassen (2005) and Silva Júnior and Costa (2014), measurement is how data are described and accessed to understand the facts and phenomena of interest. How to do it properly is an issue in all sciences and several studies are being developed in this subject. Black and Baker (1987) reported a growing number of companies and researchers, at that time, considering qualitative measures of competitiveness as the performance results. Today the scenario is no different.

When developing projects or discussing business, much is heard about metrics and indicators, these terms are used to quantify the results and guide a performance assessment. Indicators are important drivers of strategic objectives and they are useful for describing and evaluating current situations, planning future situations or comparing a current situation with a future one (Frederiksen and Mathiassen, 2005).

Usually, performance indicators can be classified as: Descriptive - performance represented by means of a description or the use of adjectives; Numerical or Quantitative - performance represented by a number or a numerical relationship between events; Qualitative - performance represented by variables or dimensions that cannot be quantified in numbers, such as initiative, attitudes, and capacities.

According to Chesbrough (2006), measurement errors are likely to occur especially from subjective and abstract judgments about the commercial potential of early-stage projects. Using different performance metrics could help a company to enhance its business model based on external sources of innovation, for example, allowing it to spare the cost of false negatives that could otherwise be lost.

2.2.1 Innovation Performance Metrics

In the literature review it was noticed that some researchers carried out different studies on innovation performance metrics. In order to measure and compare different performances, these studies typically emphasize aspects such as culture, knowledge, organizational success, strategies, collaboration and the organization itself, as shown in the following examples:

- Zizlavsky (2014) and De Felice and Petrillo (2015) developed their innovation measurement systems dedicated to management control. They both emphasized the "strategies" and used Balanced Score Card (BSC). Although there are numerous papers discussing and recommending BSC's implementation, there are limitations such as time, organization and costs.
- Böhme et al. (2014) organized their metrics emphasizing "culture" when they quoted the human capital (training, turnover, length of service, values), the customer capital (sales, profitability and satisfaction), the structural capital (investment in information processing systems) and the intellectual capital (innovation and experience, time in activity).
- Bonazzi and Zilber (2014) emphasized "organization" and "strategies" pointing out that the amount of innovations at any organization is built by several strategic drivers, such as the percentage of revenues applied in R&D and other metrics.
- Lobosco et al. (2011) emphasized "collaboration" and "knowledge", discussing the importance of universities for innovation policies in a knowledge-driven society, and that such policies are not only in teaching and research but also extend to the legal protection of results and their transposition to economic values.
- Brito et al. (2009) concluded there is a positive and significant relationship related to the company's net revenue growth: the innovative effort, emphasizing "success". However, they warn that a single metric cannot be considered relevant, but rather a set of them.
- Alegre et al. (2006) developed a measurement scale for innovative business performance based on two complementary dimensions: effectiveness and efficiency. This study contributes to innovation management researches by providing a set of valid and reliable operational measures which emphasizes organizational "knowledge" and / or "culture".
- Chesbrough (2006) reported as innovation indicators the dissemination of practices or technologies and human resources development related to all activities whose system is integrated with the partnership activities and other actors or activities such as acceptance and cooperation of contracts, co-publication and commercialization of intellectual property, emphasizing "knowledge" and "collaboration".
- Tidd et al. (2005) reinforce that when measuring innovation some approaches should be considered, for example, the use of available public domain indicators collected through survey instruments to capture large numbers of indicators such as: proportion of technicians or professionals involved, proportion of sales or profits, products launched and investments in patents, i.e. they emphasized "strategy" and "collaboration".

2.2.2 Open Innovation (OI) Performance Metrics

Erkens et al., 2014 consider OI to be an excellent tool, but it does require appropriate metrics in order to allow the company to change its strategy before errors become costly or great ideas are rejected. They also emphasize that OI measurement cannot be made by a single indicator, but a set of them. Rangus et al. (2016) developed a quantitative research using innovative approaches to measure OI. As in this work, they focused on small companies and assessed their organizational and behavioral perspectives using dimensions such as internal IP licensing, outsourcing R&D, external networks and involvement of clients and employees.

Joubert (2013) stated that the CEO of small companies may be the central actor of local innovation once strategic decisions are affected by their actions and interpretations. This author conducted a study to identify the relationship between the CEO and the practice of OI in small companies, suggesting that the development of human capital, represented by employees and CEOs, can be an important indicator.

According to Rajapathirana and Hui (2017), OI introduces new forms of organization for the internal process of innovation, but these practices and processes need time to mature and work effectively, i.e. the constant improvement of management capabilities and measurement results is in fact necessary.

Most researchers do not direct their works to investigating OI metrics or indicators, neither at least specify them in the context of their research. The few that does, focus on indicators such as Research and Development (R&D) expenditures, number of patents, launch of new products, proportion of technicians, design or personal research, proportion of sales and profits using research tools (Curley, 2016). However, they do admit those are not accurate. This lack of consensus corroborates to the main objective of this work.

Materials & Methods

Initially, a deep literature review was carried out to identify the main practices and metrics used for innovation management and OI. A lack in the literature related to OI metrics or indicators was identified and a survey was developed to be applied with managers of small technology-based enterprises incubated at important Brazilian industrial and technological centers located at the states of São Paulo (SP) and Minas Gerais (MG).

The survey was developed in order to identify innovation and OI practices, indicators or metrics used by these companies to manage actions and features that influence and contribute to their performance improvement. This research was built based on the idea that when it comes to metrics for SMEs applying OI, the most innovative business could be studied, measured and then used to explain it, as an example to be followed. Technology-based enterprises incubated at industrial and technological centers are usually known for their innovative features. The chosen respondent companies are in cities, centers and environments that have won regional, national and even international awards because of their innovative development and superior performance. Their incubators are located at the cities of Itajubá (MG), Santa Rita do Sapucaí (MG) and São José dos Campos (SP). All respondents interviewed at the companies gave their consent to participate in this research. In Brazil, an ethics committee is only necessary in health-related research cases, so this procedure was not necessary for this present research.

Cardoso et al. (2015) and Quintal et al. (2015) characterize the technological center of Itajubá (MG) as a location with a technology park and an award-winning incubator from the partnership between municipal government, state and university. This incubator promotes the industrial development mainly by integrating the private companies to the local university. The infrastructure and the access to cutting-edge technologies is provided, as well as the contact to researchers and their academic knowledge, which support the development of innovative products and new patents.

Sousa et al. (2015) and Ribeiro et al. (2005) contextualize that, in the past, Santa Rita do Sapucaí (MG) was a city known as a major coffee and milk producer, but currently it is nationally and internationally known as the "Brazilian Electronic Valley". The city became one of the main technology developers at the national territory, producing and exporting electronics to more than 41 countries. The city also has an incubator nationally recognized.

Medeiros and Perilo (1990) and Coimbra and Hopfer (2017) assign the distinguished development of São José dos Campos (SP) technological center to the public policies planned for the short, medium and long term. According to Jimenez-Zarco et al. (2013), this technological center operates in important sectors such as automotive, aerospace, defense, communication and information technology (IT). Special dedication is given to the SMES focused on technology and there is also strong incentive to entrepreneurship. For many years local incubators have been receiving positive ratings on government assessments. For this research, two of them were chosen and identified as São José dos Campos I and II.

The steps for sample size calculation derive from the definition of the data collection techniques, determined according to the nature of the research (Marconi and Lakatos, 2010). The ideal survey sample size was calculated using Equation (1) so that the results were representative and enabled the application of estimation techniques, as suggested by Marconi and Lakatos (2010).

Equation 1

The values assigned to the parameters for the ideal survey sample size calculation, the calculated sample size and the number of surveyed companies at this research, are shown in Table 1.

Table 1

In short, the population of small technology-based companies was different in each incubator, a sample error of 10% was considered in all cases. When it comes to innovation, this specific population distribution is homogeneous, so the variable p was given a value of 80%. Also, a confidence level of 95% leads to a z -score of 1.96. A data collection was carried out and the survey had a sample of 77 companies. As also shown in Table 1, the number of surveyed companies reached the target calculated for the ideal sample size for all industrial centers, therefore it can be considered significant for the research development.

The responses given by specialists is commonly used to validate the data. When the survey questionnaires were sent to the companies, they were asked to be answered by one of the main company managers. This means the responses represent their vision and ideas. Likewise, when the industrial centers were selected for the survey to be performed at, it was verified and certified that those managers took courses, training or had information on the subject addressed.

3.1 Developing and conducting of the survey and the data production

Survey questionnaires were developed to identify innovation and OI practices commonly used to evaluate the performance of the surveyed companies from the industrial centers in order to propose OI indicators or metrics. This research started from features mentioned in the literature that were adapted as indicators of innovative models that works for SMEs.

These indicators are:

- Organization: understanding the basic information on how the company and their employees are situated in the community and lied to the universities and other partners has a direct impact on innovation activities management;
- Collaboration: effective cooperation of stakeholders;
- Culture: promoting an environment where the culture of innovation can multiply;
- Strategies: effective planning of activities focused on innovation;
- Knowledge: enables the perception of new possibilities. Knowledge management and innovation are intrinsically connected;
- Success: positive results related to innovation, OI and related practices.

To use these indicators as OI metrics, a numerical association was assigned to each one of them. This stage was an adaptation of the questionnaire models proposed by Enkel et al. (2011) and later Vanhaverbeke (2017). As detailed in Table 2, the instrument used to produce the numerical data consists of 32 questions divided into seven sections representing, in this case, the six OI indicators.

Table 2

Following the methodology proposed by Olivares and Dalcol (2010), the instrument requires the respondents to indicate their degree of agreement or disagreement in each question based on a Likert scale. In this work, each answer received a score of 1 or 2 for minimum agreement, 3 for neutral and 4 or 5 for maximum agreement.

The traditional number of Likert alternatives is centered on seven points. However, in some cases, to use only five points may cause greater data reliability, broaden the respondent understanding and even increase response rate (Jenkins and Taber, 1977; Cox III, 1980; Bouranta et al. 2009).

Besides assigning scores to the question's alternatives, it was provided a value for each similar attitude or event (same indicator) assigning weights according to each section contribution degree to OI: 1 to low contribution, 2 to moderate and 3 to significant. As instructed in the literature, the section weights were attributed by the researchers themselves, supported by the theoretical reference (see Table 2).

Then, a mathematical systematization of the managers' responses was conducted using sums and averages. The sum of the scores from all questions (1-5) at the same section was multiplied by its weight (1-3) and then divided by the total of questions, i.e. a weighted average of the scores was calculated. The result generated an *Average General Score* (AGS) that represents the use of OI by the companies.

Despite of some common evidences in innovative business models, in the literature review there were some authors who disregard the possibility of an universal model to measure innovation (and then OI), arguing that when an innovation measurement is performed, some adaptations must be specially made for each situation or approach (Enkel et al., 2011; Vanhaverbeke, 2017).

At the same time, for Enkel et al. (2011) and Vanhaverbeke (2017), some of the innovation management or OI features are major contributors that could increase different SMEs performances. The development of metrics to measure innovative activities has become a necessity because it could improve the actions to understand, differentiate and prioritize them at the companies.

3.2 Pilot test

The first visits to the incubators were only to check the possibility of conducting the research at those industrial and technological centers. These cities were chosen because of its relevance in the national scenario in terms of innovation in incubated technology-based companies. A pilot test for the research tool was previously carried out with four companies belonging to incubator located in the city of Itajubá (MG), in order to better understand the difficulties in conducting the survey and to test the accuracy of the instrument.

Results

Based on Table 2, and with the support of Factorial Analysis (supplementary material) a score was extracted from the survey responses, enabling to calculate an AGS for each surveyed company (Tables 3 – 6), each industrial center (Table 7) and each indicator (Table 8). This means that the measurement results for each indicator in the surveyed companies are disposed individually and in details in Tables 3 – 6. Then, all this data is summarized with different approaches in Tables 7 and 8. Some of the highest AGS were perceived at the companies located in Itajubá (MG), that obtained minimum AGS of 3.92 and maximum of 4.11. This information is confirmed by Cardoso et al. (2015) and Quintal et al. (2015). This was a location that scored very high on several OI indicators such as success and innovation strategy (see Table 3).

Table 3

As predicted by Ribeiro et al. (2005) and Sousa et al. (2015), the companies of Santa Rita do Sapucaí (MG) showed a lot of concerns related to innovation and OI, despite their commitment and success. The AGS of these companies were smaller comparing to the others, revealing that the location is not considered the best place at the current OI scenario. The cumulative AGS per company shows a minimum of 3.75 and maximum of 4.16 (see Table 4).

Table 4

Two incubators of technology-based companies were analyzed in the city of São José dos Campos (SP), a well-known Brazilian industrial center. In this work, these two incubators were identified as São José dos Campos I and São José dos Campos II. According to Medeiros and Perilo (1990) and Coimbra and Hopfer (2017), São José dos Campos I is very productive in terms of innovation and OI. This statement was confirmed by the data, since the score was high. In general, it was measured a minimum AGS of 3.83 and maximum of 4.23 (see Table 5 for more details). São José dos Campos II confirmed the expectation for showing innovation and OI features, since it received high scores in several indicators comparing to the other centers. A minimum AGS of 3.88 and maximum of 4.32 were calculated for the respondents (see Table 6).

Table 5

Table 6

After the data collection through a survey and the treatment using descriptive statistics they received, companies, segments, actions and locations surveyed could be compared. Judging by the specific literature about the industrial centers and by the high score they received at the survey, all of them can be considered as propitious environments for OI. Also, the companies in Itajubá were the ones that most adhered to this business development model until now. Table 7 shows a data compilation organized by industrial center.

Table 7

Finally, Table 8 presents the same results organized by location (industrial center) and indicator. The indicators “success” and “strategy” were the ones that received the highest scores at the surveyed industrial centers, “organization” and “knowledge” the lowest. The low AGS in organization (basic information) and knowledge (in-depth information) from the first diagnosis, may reveal a need for studies and dissemination of learning about OI at all four surveyed industrial centers in order to increase those values.

Table 8

For a better understanding of the metric and the survey results, all data were arranged as bar graphs in Figures 3 to 6, showing the AGS each industrial center received for different OI indicators.

Figure 3

Figure 4

Figure 5

Figure 6

These bar graphs show that all surveyed industrial centers had very similar results (and then actions) related to how they approach and feel OI in a daily basis. From the general numbers, some of the most significant and expressive results detected in the empirical research are discussed in detail in the following sections named as each one of the proposed indicators.

4.1 Knowledge

According to Chesbrough (2006), the most remembered words or expressions to define OI are “multiplying the knowledge”, “conversion of ideas into joint actions” and “knowledge dissemination”.

Answering to the question “why did the company adopt OI?”, most respondents chose the alternative that said the OI practice provides opportunities for new technologies. The second most chosen was the alternative that considers OI a way to explore new capabilities and business opportunities, which are related to the work of Lopes and De Carvalho (2018). The statistics of the answers to this question can be seen in Table 9.

Table 9

4.2 Organization

Agreeing that the OI is a growing practice within the organization (Zizlavsky, 2014; De Felice and Petrillo, 2015), most surveyed companies claim that they used, practiced and implemented OI in periods between 1 and 3 years, not reducing their practices until the moment of the research (see Figure 7).

Figure 7

In Dodgson et al. (2006)'s research, the respondents considered innovation management and their process of planning, approving, budgeting, revisions and targets were well met. Now, the surveyed companies agreed that in their company this management is well done and that the impact of this for innovation is very significant (see Table 10).

Table 10

4.3 Collaboration (Inbound OI and Outbound OI)

Recognizing the importance of OI collaborative practices, as in Radziwon and Bogers (2018), when responding to the question "are alliances used in acquiring new knowledge?", most respondents agreed that their company makes use of it and, likewise, understands that this has a lot of impact on innovation (see Table 11).

Table 11

In this survey, companies answered that they use intermediaries to search for ideas, organize sections and perform brainstorm trainings (see Table 12), usually inviting internal and external collaborators to participate.

Table 12

Most of the respondents agreed that their company cooperates or has partnerships with universities, and most of them believe that the impact of this relationship is relevant for innovation (see Table 13). Especially for this feature, the importance of public policies to encourage the development should be highlighted.

Table 13

Considering in particular the companies surveyed for this research, the universities that have this good relationship with the initiatives are public (state and federal) and also private (Namely: Instituto Nacional de Telecomunicações - INATEL in Santa Rita do Sapucaí, Universidade Federal de Itajubá - UNIFEI in Itajubá and Universidade Estadual Paulista - UNESP, Universidade do Vale do Paraíba - UNIVAP and Faculdade de Teologia e Ciências - FATEC in São José dos Campos. Also, it is important to consider that alliances are well managed and that there is a dedicated OI (Rajapathirana and Hui, 2017) or innovation team that ensures this. In the conducted survey, most respondents agreed that in their company alliances are well managed (see Table 14).

Table 14

4.4 Strategy

Recognizing that the manager support is a feature that impacts innovation (Huizingh, 2011; Dodgson et al. 2006) and influence its results, the surveyed companies agreed that, in their companies, managers and the Human Resource department support OI use (see Table 15).

Table 15

4.5 Culture

Emphasizing the company culture, most respondents stated they systematically share the knowledge (see Table 16). The company culture as an OI performance metric is also approached by Böhme et al. (2014) and

Alegre et al. (2006).

Table 16

Most respondents agreed that their company rewards OI activities, and they also believe that the impact of this is great for innovation (Table 17).

Table 17

Success

Meeting expectations described by Chesbrough (2006), most participants stated that using OI and their practices they succeeded in 3 years (Table 18).

Table 18

Finally, it was found that the internal processes of searching for innovative ideas through OI were usually based on the easiness of meeting internal and external information, for example, when the knowledge is in an accessible database. The advantages of monitoring process locally in a flexible way and the idea that OI practices result in collaborative gains were common to all employees and all surveyed companies.

Conclusions

This work was based on a systematized study of the literature for learning the conceptual evolution of the approaches regarding innovation and OI. Since only a few papers addresses metrics for innovation and even less for OI, a survey was conducted in four Brazilian industrial centers to propose a new system of indicators to measure OI in small companies. For this research, a number of 77 small technology-based enterprises incubated at important Brazilian industrial and technological centers were surveyed. The questionnaires were answered by the managers or CEOs of these companies.

As indicated in the literature review, many OI practices were clearly identified in the respondent companies, such as alliances and partnerships for technological development, crowdsourcing and co-creation, intense collaboration from clients in projects, good relationship with universities (in this work: INATEL in Santa Rita do Sapucaí, UNIFEI in Itajubá and UNESP, UNIVAP and FATEC in São José dos Campos), as well as several investment in R&D and venture capital.

When it comes to the success of small companies applying OI, the most innovative business could be measured and explained as an example to be followed. Technology-based enterprises incubated at industrial and technological centers are usually known for their innovative features. Then, several OI and innovation management features were detected in their responses to the questionnaires. Based on this diagnosis and the previously knowledge, it was possible to understand that the surveyed companies know and apply the OI in their daily actions, providing an adequate basis for identifying indicators.

The surveyed companies are very open-minded and, by the trust and spirit of collaboration, they are used to sharing information about their products, services, and processes, mainly those related to strategy, culture and knowledge. In this way, they can help other companies and, at the same time, be helped by them to grow together. The indicators proposed by this work (organization, success, strategy, inbound and outbound collaboration, culture and knowledge) has been proved to be the most significant to measure OI at small companies and, with them, it has been possible to understand that SMEs can successfully use OI and, although it is not common today, it should be encouraged. This study's conclusions can be useful for researchers and managers from SMEs interested in starting or increasing their own OI practices.

Although being SMEs, the surveyed companies have a large structure behind them which facilitates the launch of new technological products or services to the market, also the access to and use of OI. This paper then ends by stating that it is urgent for Brazilian SMEs to invest in OI to grow their potential and chance of being successful, specially by approaching and establishing better relationship with other SMEs.

This set of indicators were also successfully tested in a group of consolidated small companies from the United States, showing a possible use of the indicators pointed out in this work in companies from other countries with the same characteristics as those studied here, i.e. being a SME. This opens possibilities for future works continuing and expanding this research.

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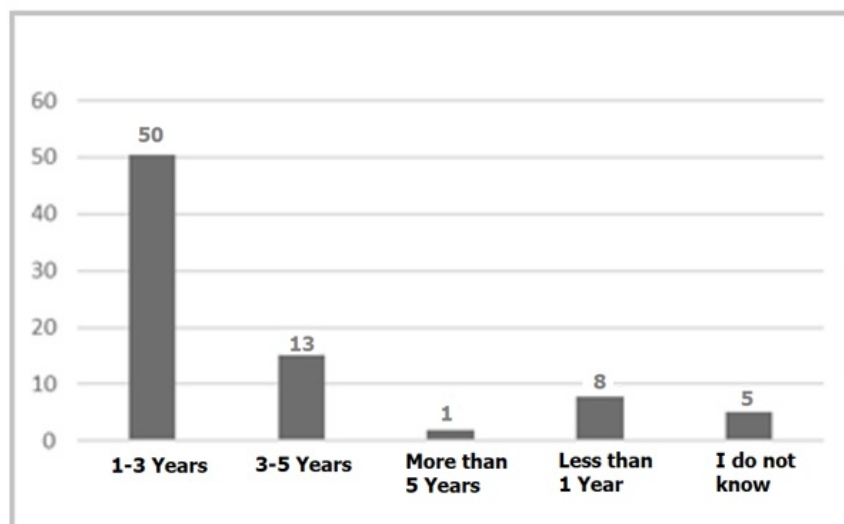


Figure 7: Time to implement OI

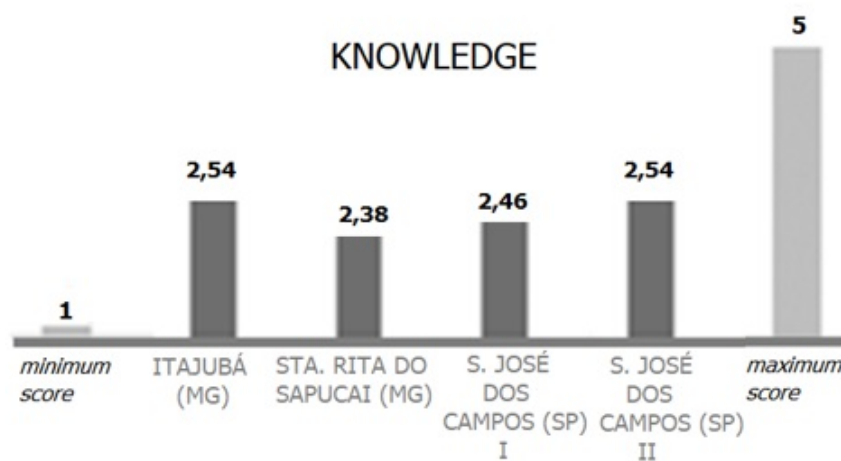


Figure 6: AGS per location for Knowledge

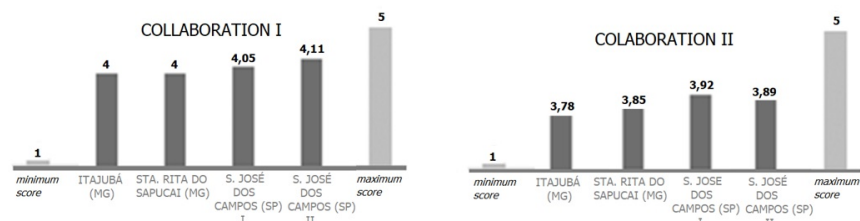


Figure 5: AGS per location for Outbound OI or Collaboration I (a) and Inbound OI or Collaboration II (b)

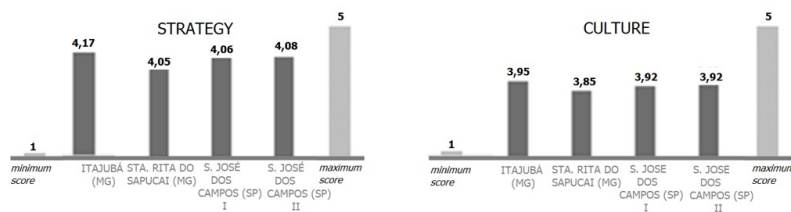


Figure 4: AGS per location for Strategy (a) and Culture (b)

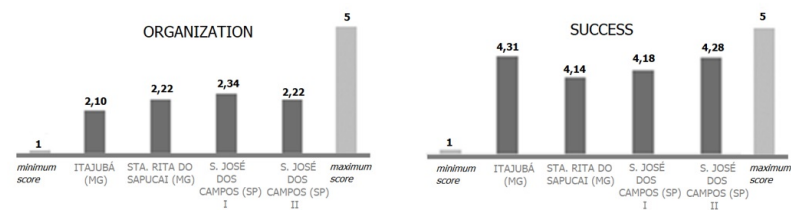


Figure 3: AGS per location for Organization (a) and Success (b)

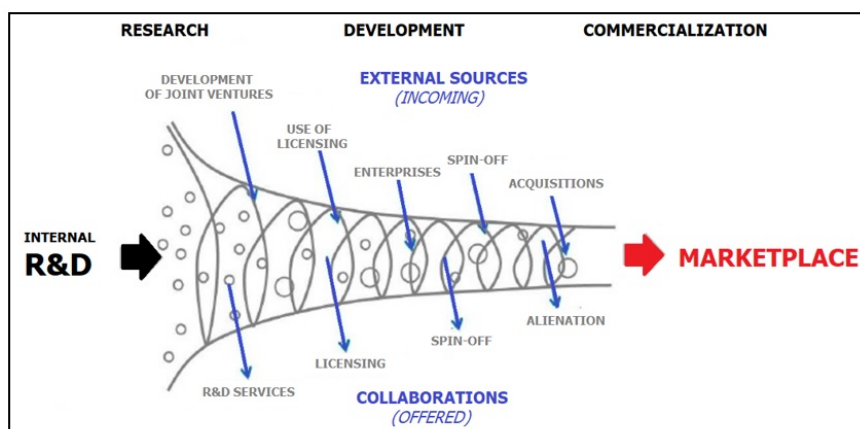


Figure 2: Inbound and Outbound Open Innovation (OI)
Source: Adapted from Chesbrough (2006)

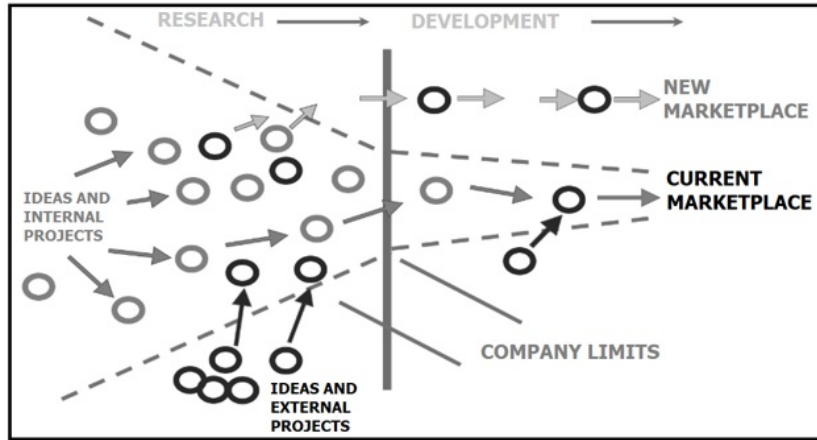


Figure 1: Flow of ideas in an Open Innovation (OI) process
Source: Adapted from Chesbrough (2006)

$$n = \frac{N \cdot z^2 \cdot p \cdot (1 - p)}{z^2 \cdot p \cdot (1 - p) + e^2 \cdot (N - 1)} \quad (1)$$

In which:

- n: Ideal sample size;
- N: Population size;
- e: Sample error;
- z: Z-score, variable associated with the confidence level;
- p: Population distribution, true probability of the event.