CSCanada
International Business and Management
Vol. 8, No. 2, 2014, pp. 45-64
DOI:10.3968/4799

ISSN 1923-841X [Print]
ISSN 1923-8428 [Online]
www.cscanada.net
www.cscanada.org

Analysis of the Innovation Potential of Brazillian Oil and Gas Companies

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Received 15 March 2014; accepted 5 May 2014

Abstract

This study presents a methodology designed to evaluate the innovation potential of a set of companies operating in the oil and gas segment in Brazil. This methodology was used as a tool to map these companies, with the purpose of evaluating their innovation potential for the development of pioneer technologies, products and services for offshore exploration and production activities in deep waters. The tool was applied to 33 companies and it is composed by seven macro-indicators, among which are Organizational and Technological Management, Personnel Management and Technological and Informational Infrastructure. Each macro-indicator stands for a sub-index and the weighted sum of all seven sub-indexes composes the Innovation Potential Index ($IP_{INNOVATION}$) of the company, standardized to a scale from zero to one. An analysis of the instrument used to calculate the $IP_{INNOVATION}$ as well as the application of the Principal Component Analysis (PCA) regarding the weights used for each macro-indicator consolidates this evaluation. This work emphasizes the importance of using this evaluation procedure as a tool to support the establishment of governmental policies in developing countries.

Key words: Innovation; Oil & gas industry; Brazil; Research & development

Marcus Vinicius De A. Fonseca, Maria Cristina Labuto F. P. Pinto, Paulo Sergio R. Alonso, Edival Dan Junior (2014). Analysis of the Innovation Potential of Brazillian Oil and Gas Companies. *International Business and Management, 8*(2), 45-64. Available from: http://www.cscanada.net/index.php/ibm/article/view/4799
DOI: http://dx.doi.org/10.3968/4799

INTRODUCTION

Among the business indicators used to evaluate the potential for technological innovation, the literature highlights, as input indicators, the operational expenses in R&D, technology services, acquisition of technology and non-routine engineering; the organizational configuration oriented to R&D; the human resources in R&D+E and the investment of funds in fixed and intangible assets. The number of patents and the number of completed projects have been used as output indicators, while the income generated by new products, the reduction of costs arising from improvements in manufacturing processes and the market share and revenue from technology sale to third parties have been standing out among the indicators of business outcome (Andreassi & Sbragia, 2002; Sbragia & Kruglianskas, 1996; Brown & Svenson, 1988).

However, the complexity of conceptual models and the lack of robustness of indicators to assess the innovation strength in a company are usually listed as sources of discrepancies in empirical studies of valuation of the business outcomes tied to innovation (Moweri & Rosemberg, 1979; Kupfer & Hasenclever, 2002).

Innovation in industry is recognized by Utterback (1994) as a process that involves a huge amount of uncertainty, human creativity and change. According to the author, although it is possible to identify "patterns" of success in industrial innovations, such success is not entirely predictable. Nevertheless, the study of these patterns reveals relationships between changes in products and processes and the development level of an industry. In the explanation of the model proposed by Utterback (1994), called *The Dynamics of Innovation*, three phases of development of industrial innovation are defined: *fluid*, *transitional* and *specific*. Each phase is distinguished by distinct characteristics regarding the source of innovation, the diversity of the products, the flexibility of the production processes, the focus of R & D, the need for equipment automation, the size and nature of the industrial plant, the cost of process change, competitors, the basis of competition, the organizational control and the vulnerabilities of industry leaders.

Burgelman and Sayles (1986) differentiated the activity patterns in models of induced innovation known as *Technology Push* and *Need Pull*. The relationship established between technology and market, regarding innovation management, can be perceived both by the technology perspective (technical competence, access to knowledge, cooperation with sources of external knowledge, etc.), and by the market perspective, since the transformation of an invention into innovation can happen due to a market's demand perceived by the company.

Regarding the contribution of human capital to the induction of innovation, Johansson (2004) highlights the movement of people contributing to what he calls *The Medici Effect*[1], along with two other aspects, the convergence of sciences and the increase of computing sciences. In this last aspect we point out the expanded potential of information and communication technologies (ICTs). The internet, social media and globalization have generated benefits that were unimaginable in the recent past. Therefore, when proposing to evaluate the innovation potential of a company, its infrastructure of internal and external communication should be addressed.

Kaplan and Norton (2004) and Davila, Epstein and Shelton(2006) explain the links between the innovation process and the human capital, information capital and organizational capital, relating these to the identification of opportunities for new products and services, to the management of research and development portfolio, to the project and development of the innovative product or service and its market launch.

Burgelmanand Sayles (1986) and Lundvall et al. (2002) stress the importance of relations between the organization and the National Innovation System for the generation of skills that are essential for innovation and assimilation of knowledge to local, regional and global economies today.

> One of Schumpeter's major contributions to the understanding of innovation processes is the interpretation of innovation as a new combination. This concept is important because it brings together two contradictory but important aspects of innovation: its continuity (existing elements) and radical change (the new combination). (Lundvall et al., 2002, p.216)

On the other hand, and not less relevant, are the issues related to environmental and social responsibilities as emphasized by Senge et al. (2008) in The Necessary Revolution.

> With nature and not machines as their inspiration, today's innovators are showing how to create a different future by learning how to see the larger systems of which they are a part and to foster collaboration across every imaginable boundary (Senge et al., 2008, p.11).

The association between culture of innovation, performance improvement and competitive advantage is pursued by all types of organizations, a fact that is somehow corroborated by several researches. The existence of a complexity of factors involving innovation culture or aspects of organizational culture related to innovation, as well as commonalities and divergences, show how challenging it is to reach consensus on the issue.

The culture of innovation is undoubtedly part of a larger culture of an organization. Among the aspects that favor the construction of a culture of innovation or an organizational culture associated with innovation, include: the role of leadership (Zien& Buckler, 1997; Martins & Martins, 2002; Mclean, 2005; Zairi& Al-Mashari, 2005; Jaskyte & Dressler, 2005; Twati & Gammack, 2006;-Bravo Ibarra & Herrera, 2009; Peçanha & Godoy, 2009; Cakar & Ertürk, 2010; Lauzikas & Le Bas, 2010; Janiunaite & Petraite, 2010; Lin Mcdonough & Iii, 2011); communication and sharing of information (Das, 2003; Martins & Terblanche, 2003; & Ismail; Abdmajid, 2007; Dombrowski et al., 2007; Godoy & Peçanha, 2009; Janiunaite & Petraite, 2010; Johannessen & Olsen, 2011); risks (Das, 2003; Serra, Fiates & Alperstedt, 2007; Abdmajid & Ismail, 2007; Valencia, Valle & Jiménez, 2010; Apekey et al., 2011; Brettel & Cleven, 2011). The intention to innovate or innovation strategy is also an aspect mentioned by some authors, such as Zien and Buckler (1997), Martins and Martins (2002) Das (2003); Dobni (2008); Peçanha and Godoy (2009), among others.

The intention of inducing a culture that is conducive to innovation is not enough; a set of strategies should be drawn – and translated into indicators – in order to facilitate the sharing of values and assumptions associated with innovation.

That being said, this work approaches a subject whose production is still new, pointing to the need for a deeper analysis of the numerous propositions of different authors derived from qualitative studies of typical exploratory research.

Ahmed (1998, p. 30) reinforces this claim by stating that "virtually all companies talk about innovation and the importance of 'doing' innovation, many actually try to do it, and only a few actually succeed in doing it".

Regarding theoretical models, Martins and Terblanche (2003, p.73) emphasize that models based on an open systems approach are the most suitable because they offer "a holistic approach that allows the investigation of the interdependence, interaction and interrelationship of the different sub-systems and elements of organizational culture in an organization". These models consider "patterns of interaction between people, roles, technology and the external environment" denoting a very complex environment. A holistic approach to innovation is also emphasized by Ahmed (1998), as well as the fact that culture can act as a facilitator or inhibitor of innovation.

The proposal of evaluation of the innovation potential

[1] Alluding to the Medici family, one of those responsible for sponsoring artists and inventors in the fifteenth century, in Florence, when there was an amazing explosion of creativity.

of companies presented herein is actually one more stage in the pursuit of understanding the complex relationship between organizational management – which includes strategy, people, communication – and the results, the market positioning - the competitiveness – of the company.

This paper presents a mapping study of the innovation potential of companies that develop goods and services for the oil and gas segment in Brazil, by defining an empirical indicator called the Innovation Potential Index - $IP_{INNOVATION}$.

The structure of the formula for calculating the $IP_{INNOVATION}$ is based on seven macro-indicators, called sub-indexes. They are:

a. Organizational and Technological Management;
b. Personnel Management;
c. Technological and Informational Infrastructure;
d. Engineering and Manufacturing Qualification Infrastructure;
e. Market positioning;
f. Results;
g. Social Responsibility

The evaluation model presented herein intends to combine, coordinate, qualify and quantify strategic, tactical and operational characteristics of the companies from the perspective of innovation, improving the set of indicators suggested in the literature and aligning it with the mission of the appraiser company.

Thus, the infrastructure indicators of this tool were contextualized in the development of goods and services of sectors that interest PROMINP[2] (Program for Mobilization of the National Industry of Petroleum and Natural Gas).

The definition of weights, for each portion of the sub-indexes, as well as for the sub-indexes themselves, used in the generation of $IP_{INNOVATION}$, considered three aspects:

I. The relationship between management, innovation and competitiveness as well as their intrinsic future bearing factors – human, structural, relationship and environmental capital;
II. The identification of strengths, weaknesses, opportunities and threats in the scope of the participation of companies in the national innovation system, according to the Board/Management's own opinion; and
III. A comprehensive and rigorous analysis of the "quality" of answers from a representative universe of answered questionnaires.

Associated with the weights for each portion, the $IP_{INNOVATION}$ is calculated as a factor ranging between 0 and 1 according to the following formula:

$$IP_{INNOVATION} = \frac{\sum \text{of points obtained in the 7 sub-indexes}}{\text{Maximum number of valid points}}$$

1. APPLICATION OF THE TOOL

The tool, containing 784 questions, was distributed to companies as an electronic spread sheet. Thirty-three companies answered and returned the tool in an encrypted file, through the Internet.

Most companies were concentrated in the southeast region of Brazil (82%), especially in São Paulo and Rio de Janeiro, which together comprise 73% of all replying companies. In contrast, none of the companies is situated in the north, in the center-west and in great part of the northeast regions. Figure1 shows the geographic distribution of the companies that participated in the study.

Thirty-three companies were evaluated: two in Bahia, three in Minas Gerais, fourteen in São Paulo, ten in Rio de Janeiro, one in Santa Catarina and three in Rio Grande do Sul.

Figure 1
Distribution of Companies in Brazil by State

As to the areas of activity, most assessed companies operate in the area of Machinery and Equipment Manufacture, which along with the Metal Products Manufacture totalize 39% of the companies operating areas. If we include the Machinery Manufacture, Electronic Devices and Materials, Rubber Products and Plastic Materials for Industrial Automation and Extraction of Petroleum and related services, we reach 66% of the areas of activity declared by the companies.

In the following sections, the main features observed in the analysis of each sub-index that composed the assessment of companies will be discussed.

[2] The PROMINP is coordinated by the Ministry of Mines and Energy in order to increase the participation of the national industry of goods and services, with sustainable and competitive conditions, in the implementation of projects for oil and natural gas in Brazil and abroad.

2. ORGANIZATIONAL AND TECHNOLOGICAL MANAGEMENT

Considering the different features of the Organizational and Technological Management, the behavior of companies was assessed according to several factors, in which the respondents would have to choose if a specific measure was never adopted, if it was occasionally adopted, or if it was widely adopted. Figures 2 and 3 show the results obtained for some of these specific features.

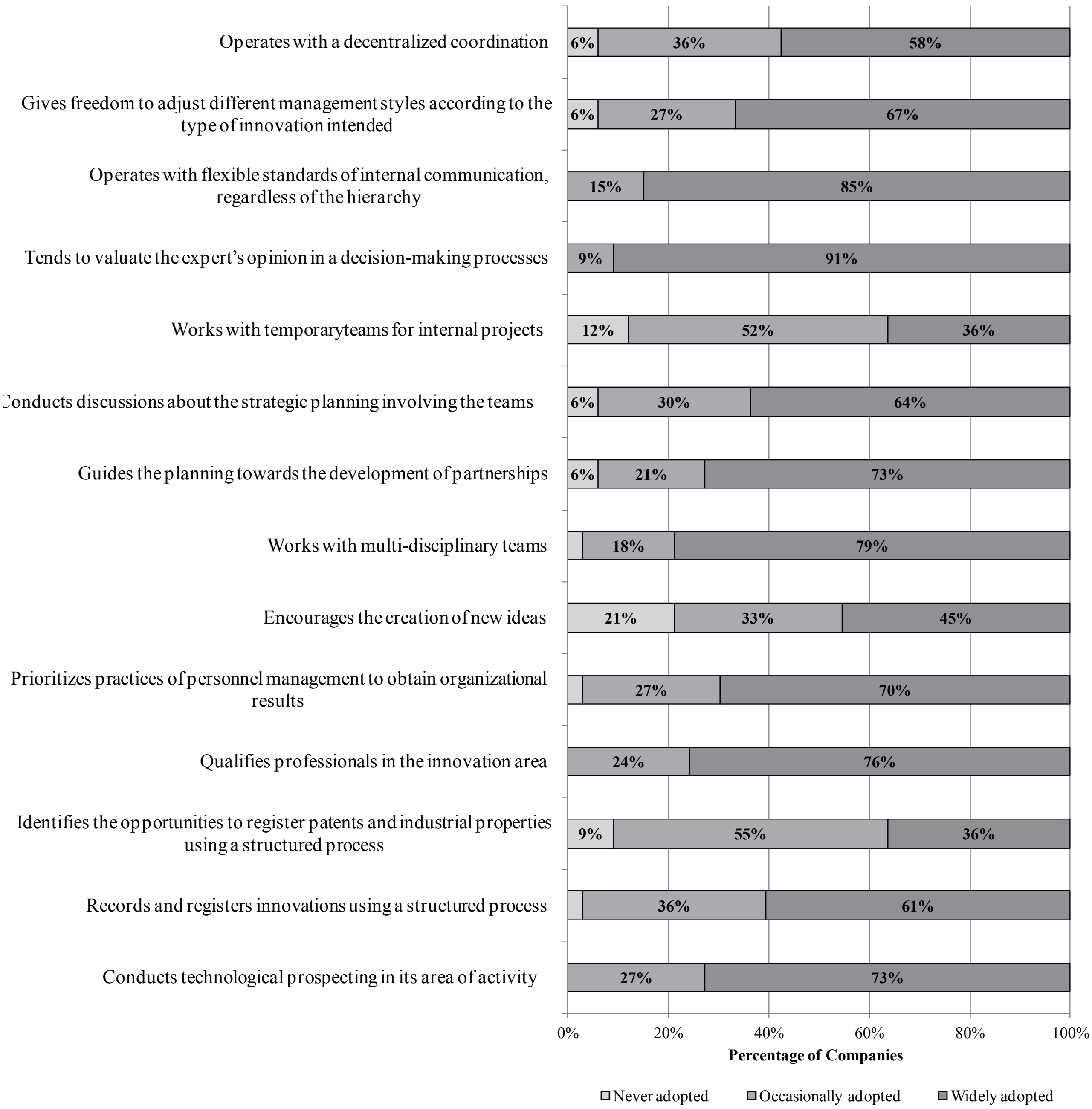

Figure 2
Features Related to Organizational and Technological Management

As to the decision-making decentralization and the hierarchic structure flexibility, most companies declared that they operate with flexible internal communication standards and tend to value the experts' opinions for decision-making processes. As to the freedom for adjusting different managing styles and the decentralized coordination, there was a higher percentage of companies answering that these behaviors were only occasionally adopted, and a small percentage declaring that they were never adopted.

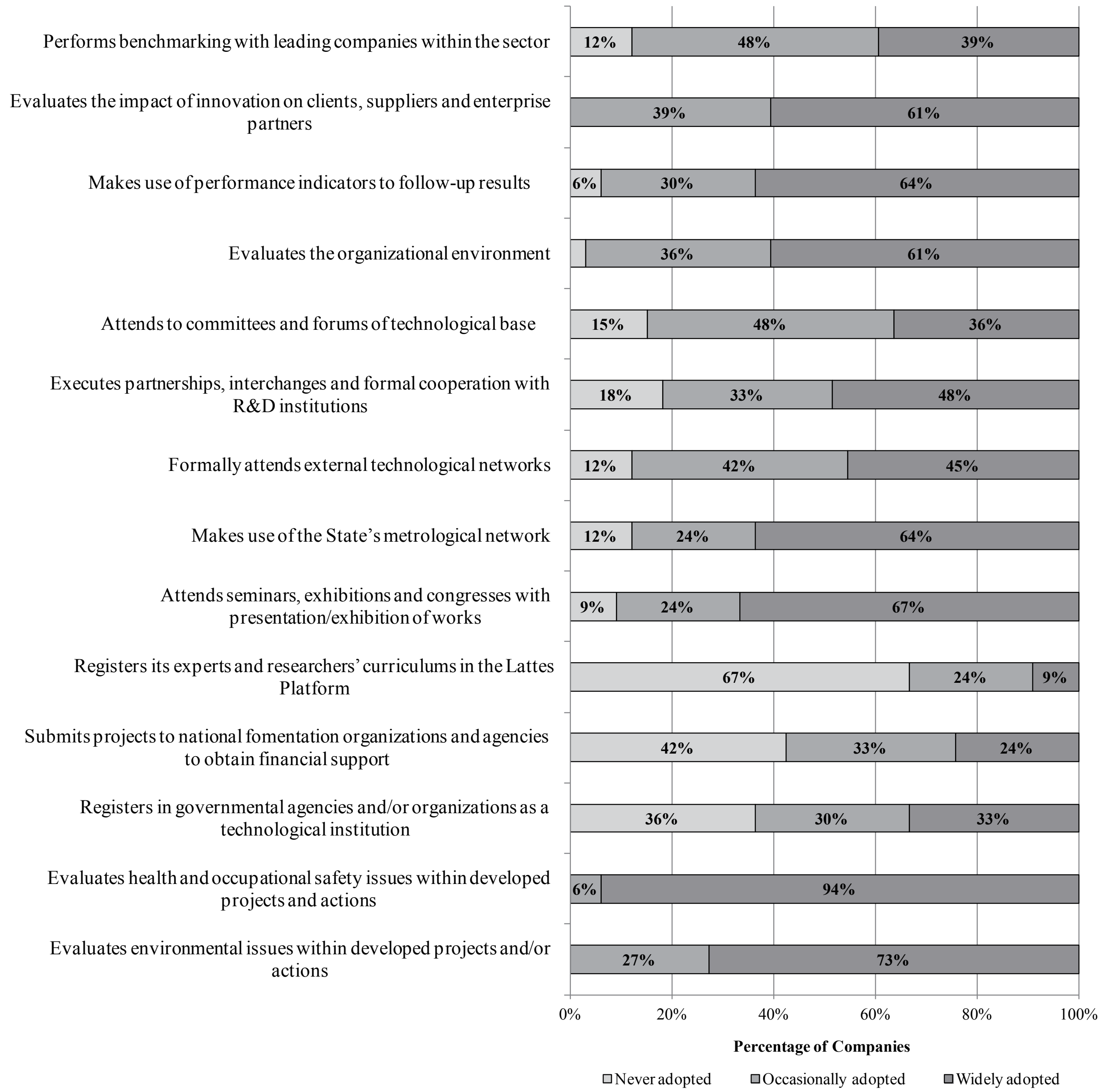

Figure 3
Behavior Regarding the Organizational and Technological Management

As to the horizontalization of companies and the processes-focused strategy, it was observed that even though most companies work with multi-disciplinary teams, directing the planning towards the development of partnerships and involving teams in the construction of the strategic planning, they have only operated with temporary internal project teams occasionally, demonstrating a vertical organizational matrix.

As to the appreciation of human capital, most companies declared they prioritize the management of personnel to obtain organizational results, investing on the qualification of professionals in the innovation area. However, a representative part of the companies did not offer incentives for the creation of new ideas or only did that occasionally.

As to the business knowledge management, all companies perform on a regular basis a technological prospecting in their areas of activity, a behavior adopted by the majority of the respondents. They had a structured process for documentation and registration of innovations, but they occasionally identified opportunities for registration of patents and industrial properties through a structured process.

Most companies assessed the organizational environment and used performance indicators to follow-up results, and approximately a third of these only did that occasionally. As to the external assessment, they analyzed the impact of innovation on clients, suppliers and third parties, but most of them only performed the benchmarking occasionally, and some of them have never adopted such behavior.

As to the interaction with the external environment, most companies declared that they participate in seminars, exhibitions and congresses, and also use the metrological network in their states. However, the formal participation in external technological networks, in committees and technology-based forums and the implementation of partnerships with R&D institutions was either occasional or not adopted by most companies.

Most companies declared they do not present projects to agencies and national fomentation organizations to obtain funding; little over a third of the companies declared that they have never applied to governmental agencies or organizations to be registered as a technological institution and two-thirds do not register its experts and researchers in the Lattes Platform[3]administrated and regulated by CNPq[4] (National Council of Technological and Scientific Development).

As to responsible performance, the vast majority of companies declared that they assess health and occupational safety issues, in developed projects and actions; however, 27% of them state that they only evaluate environmental issues occasionally.

The companies that declared themselves as being service-rendering companies indicate "Project Engineering Services" as the service category that most stimulates the development of innovations, followed by "Operational Services", "Experimental Development" and "Applied Research". None of the companies have indicated the categories "Assistance and advice on health and safety", nor "Assistance and advice on business management", as shown in Figure 4.

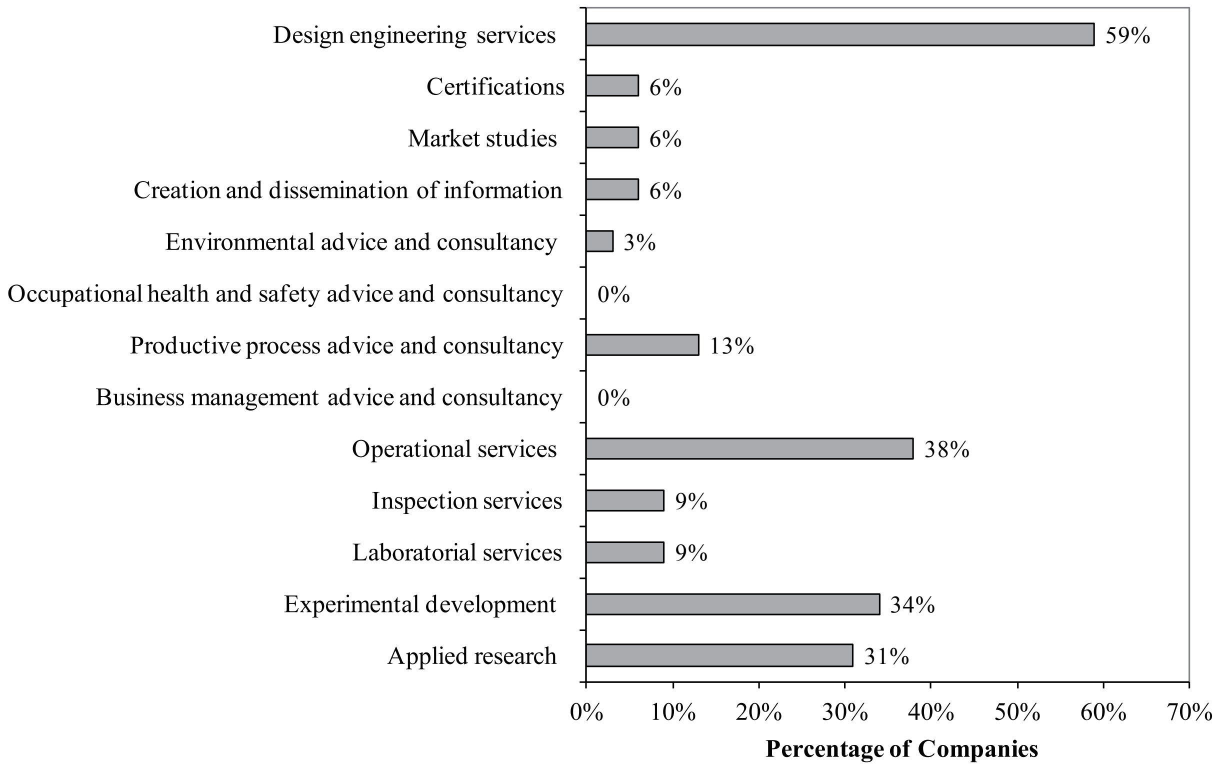

Figure 4
Services that Promote the Development of Innovations in the Companies

All assessed companies had pricing methods and the vast majority (67%) had a pro-active conduct in the search for clients to offer services for innovation development (data not shown).

The vast majority of companies (91%) valued the gatekeeper professional, but a third of them did not have an Intelligence System to collect and analyze significant technical information (data not shown).

Figure 5 shows the companies' relationship with the external sector regarding imports. It was observed that about half of the companies imported inputs, products and capital goods, but only a quarter of them imported services, either for technical and scientific assistance, or for contracting R&D+E (Research, Development and Engineering).

3 Information system integrated with a database of resumes and institutions in the areas of science and technology in Brazil.
4 Agency of the Ministry of Science, Technology and Innovation for the promotion of scientific and technological research and training of human resources for research in the country.

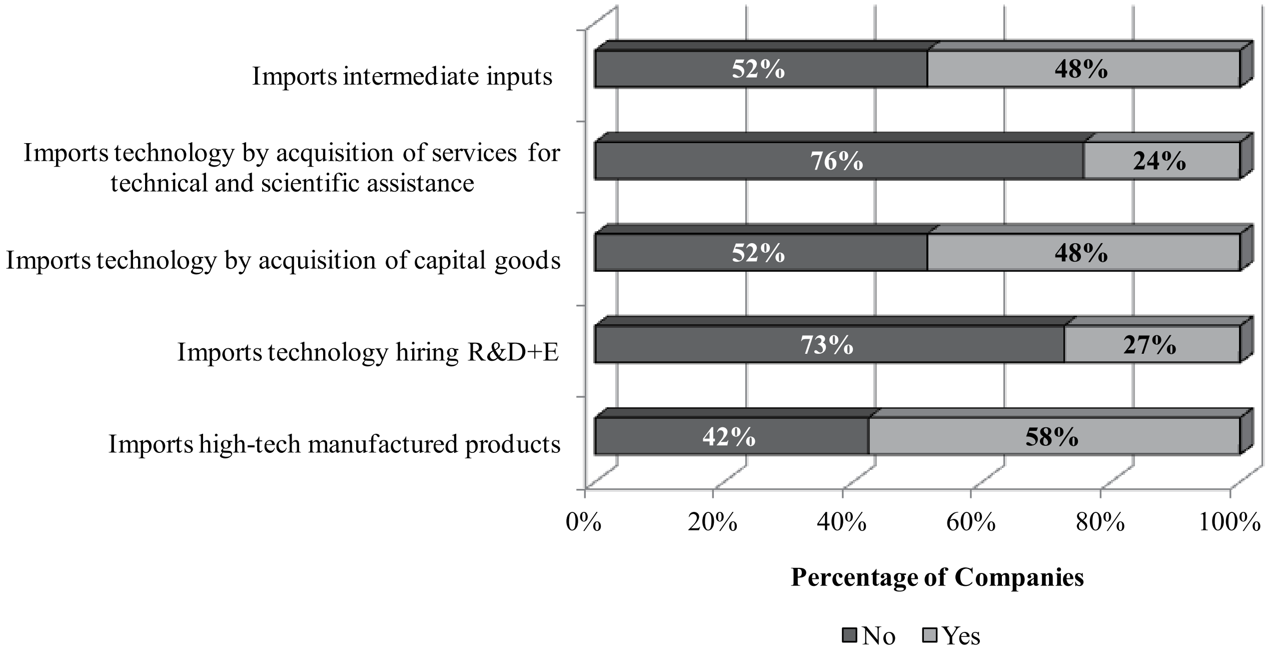

Figure 5
Levels of Importation of Inputs, Products and Technology

Figure 6 displays the companies positioning with respect to five challenges to an innovating company. It was noticed that companies have positioned themselves very well when responding, in the vast majority, that these challenges are constantly confronted.

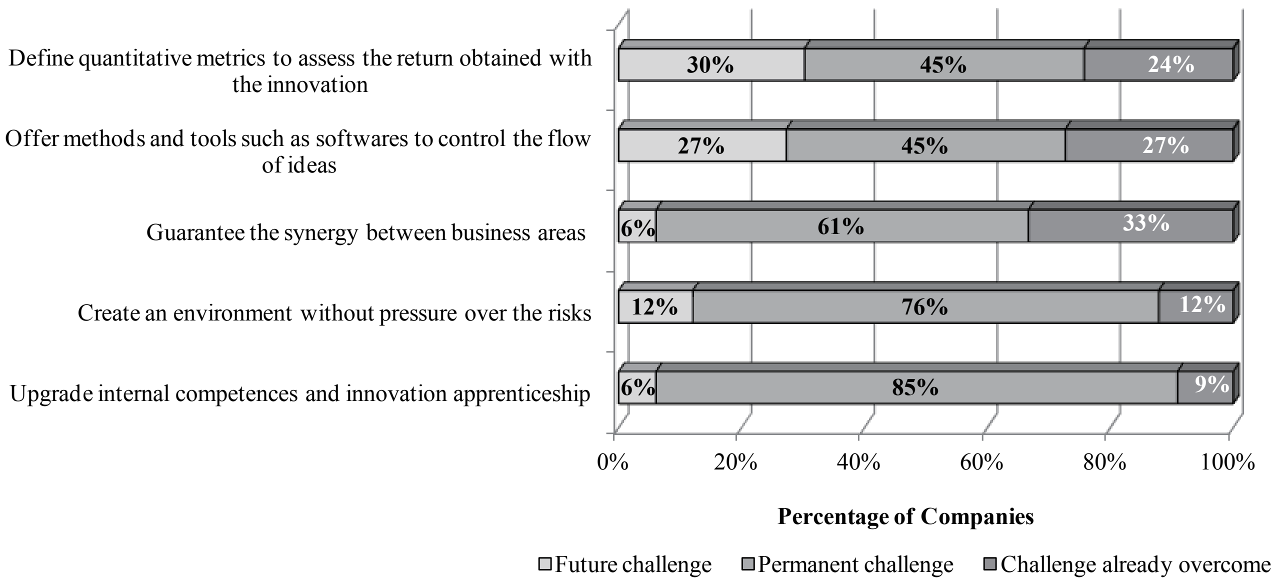

Figure 6
Position of Companies Facing the Challenges of an Innovating Company

Among the actions practiced by companies to promote the development of innovations, the most indicated one was the "Human capital qualification", followed by "Improvement of processes", "Marketing focusing on the client" and "Acquisition of machines and equipment". On the other hand, it must be stressed that the strategy "Absorption of researchers" was usually practiced by less than a third of the companies. Figure 7 presents these results.

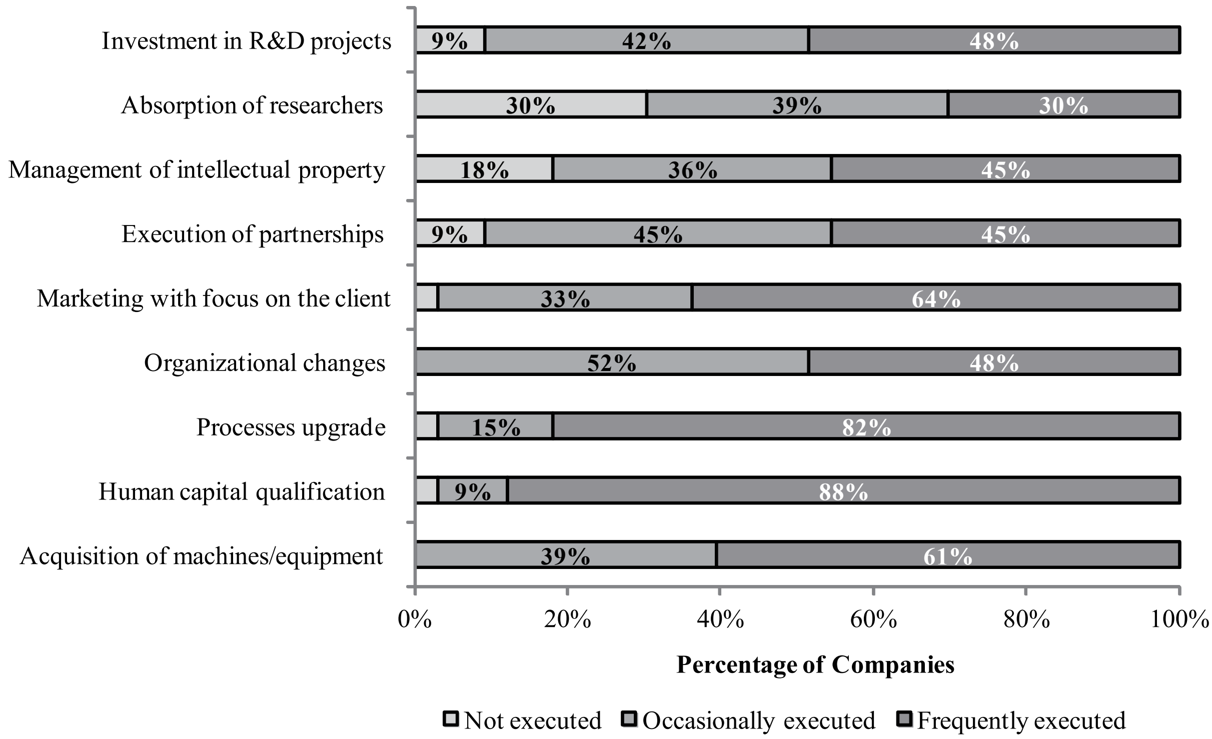

Figure 7
Actions Practiced by Companies in order to Promote Innovations

This macro-indicator demonstrated that the group of companies is well-structured with regards to their organizational and technological management. The basis of a good management exists; the investment in actions and activities that could induce a culture of innovation would be significantly beneficial.

3. MANAGEMENT OF PERSONNEL

Figure 8 shows the distribution of the companies' own employees that work on R&D+I+E (Research, Development, Innovation and Engineering) according to the level of education and experience time. Most employees have *lato-sensu* post-graduate education, from 5 to 10 years of experience, and only 3% have a PhD.

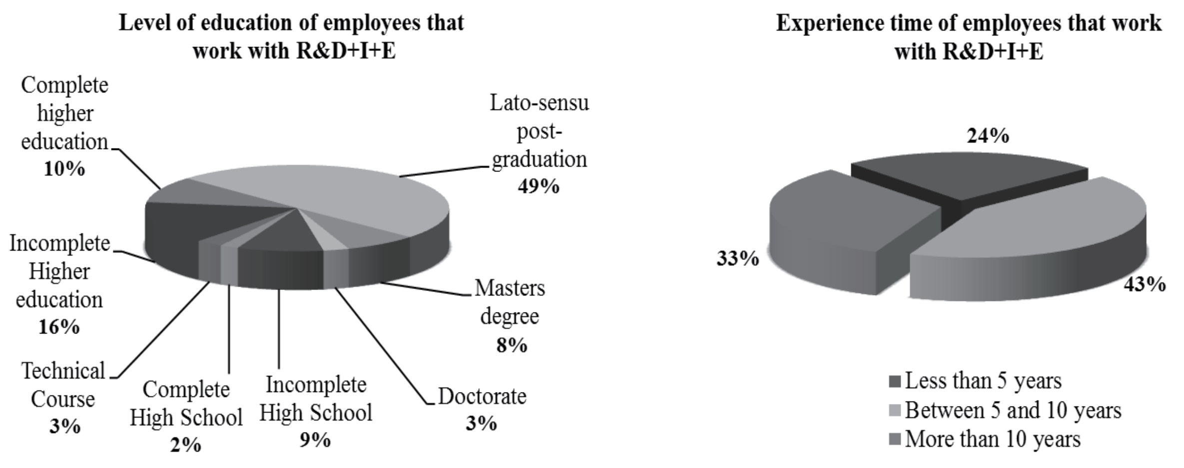

Figure 8
Distribution of Employees That Work on R & D+I+E

Sixty-six percent of the companies declared that their employees who work on the development of innovations pass through a qualification process according to specific needs, and not according to the annual planning. They also mentioned that qualification is mainly performed at Universities and similar Institutions or by internal courses given by the companies' own employees (see Figure 9).

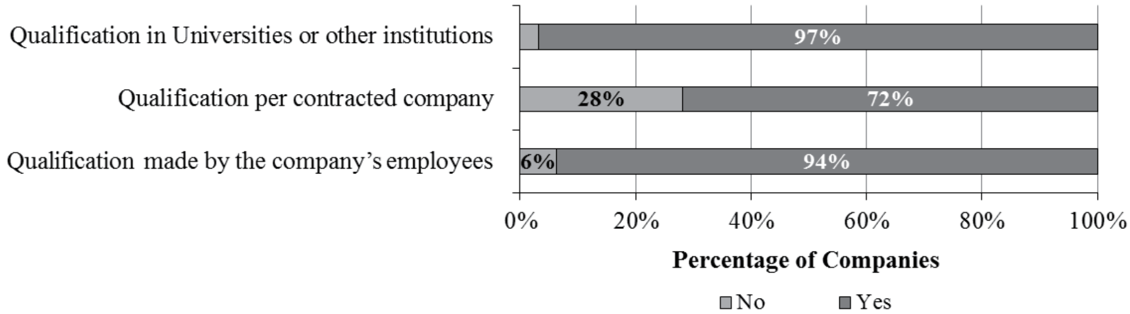

Figure 9
Types of Qualification Offered by Companies to Employees Who Work With R&D+I

When the companies were inquired on possible incentives for increasing the employees' level of education, most companies declared that they allow flexible working hours, announce better payments and offer scholarships, as shown in Figure 10.

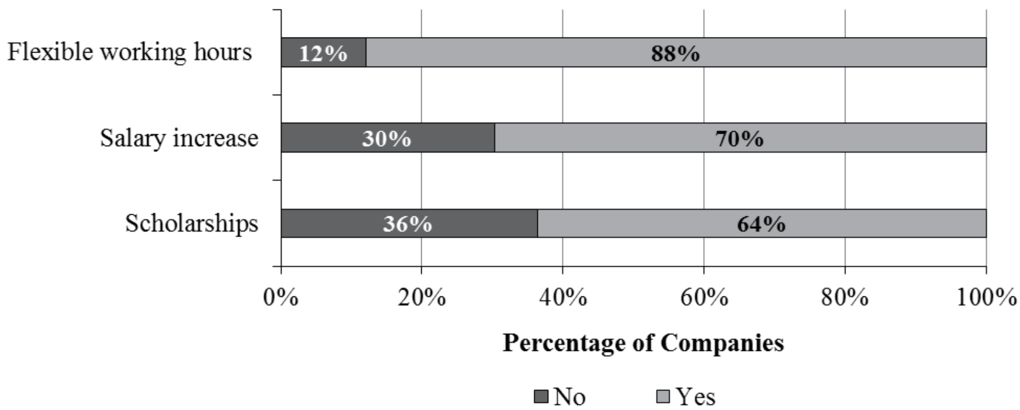

Figure 10
The Companies' Incentive to Increase the Employees' Level of Education

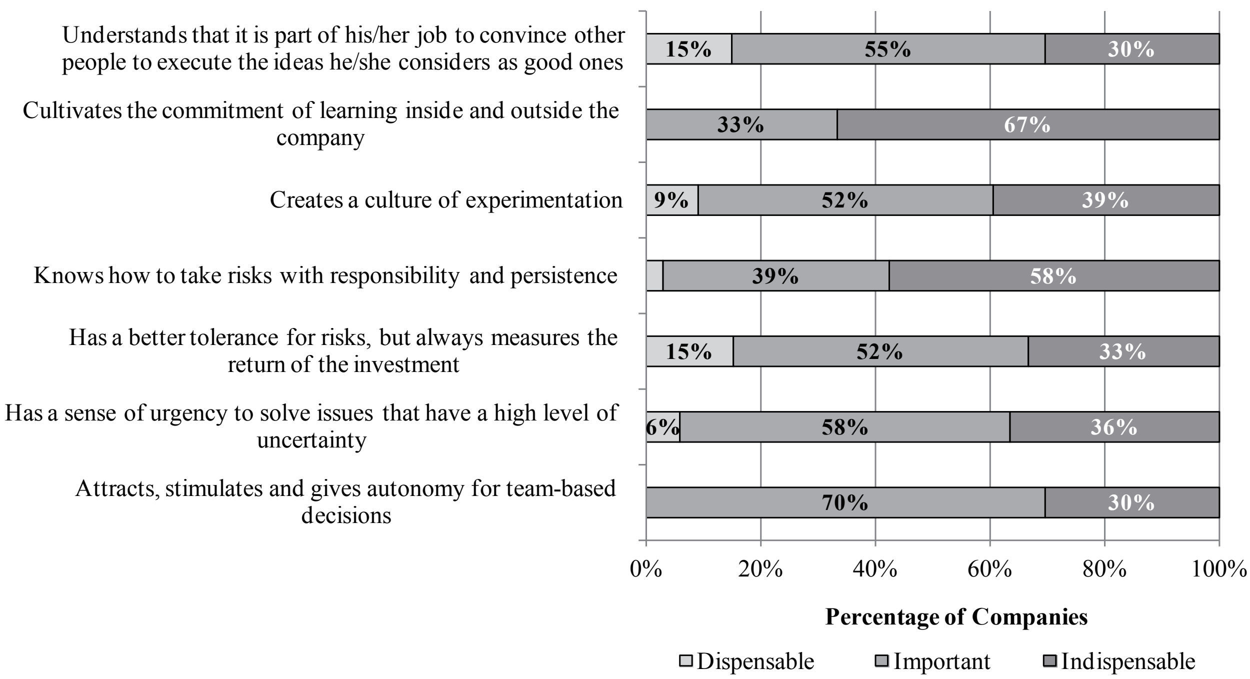

Figure 11
The Companies' Opinions About the Profile of an Innovative Professional

As to the profile of the innovative professional, companies have declared that the main indispensable characteristics for this professional are to develop a commitment tolearning, inside and outside the company and to know how to take risks with responsibility and persistence. The capability to attract, stimulate and give autonomy to team-based decisions stood out among the most important features. Management-oriented characteristics, such as understanding that part of his/her work is to convince people to execute the ideas that he/she considers as good ones, and provide greater tolerance to risk, but always measure the return on the investment, had the highest percentage of response as being "dispensable" (see Figure 11).

With regard to the companies' opinion in relation to the innovative executive's mission, the main attributions considered as being indispensable consisted in "disseminate learning: provide methods, tools and technology to lead teams and maintain the board's support" and "lead: create multi-disciplinary innovation teams and redefine working rules". The Figure 12 has detailed results.

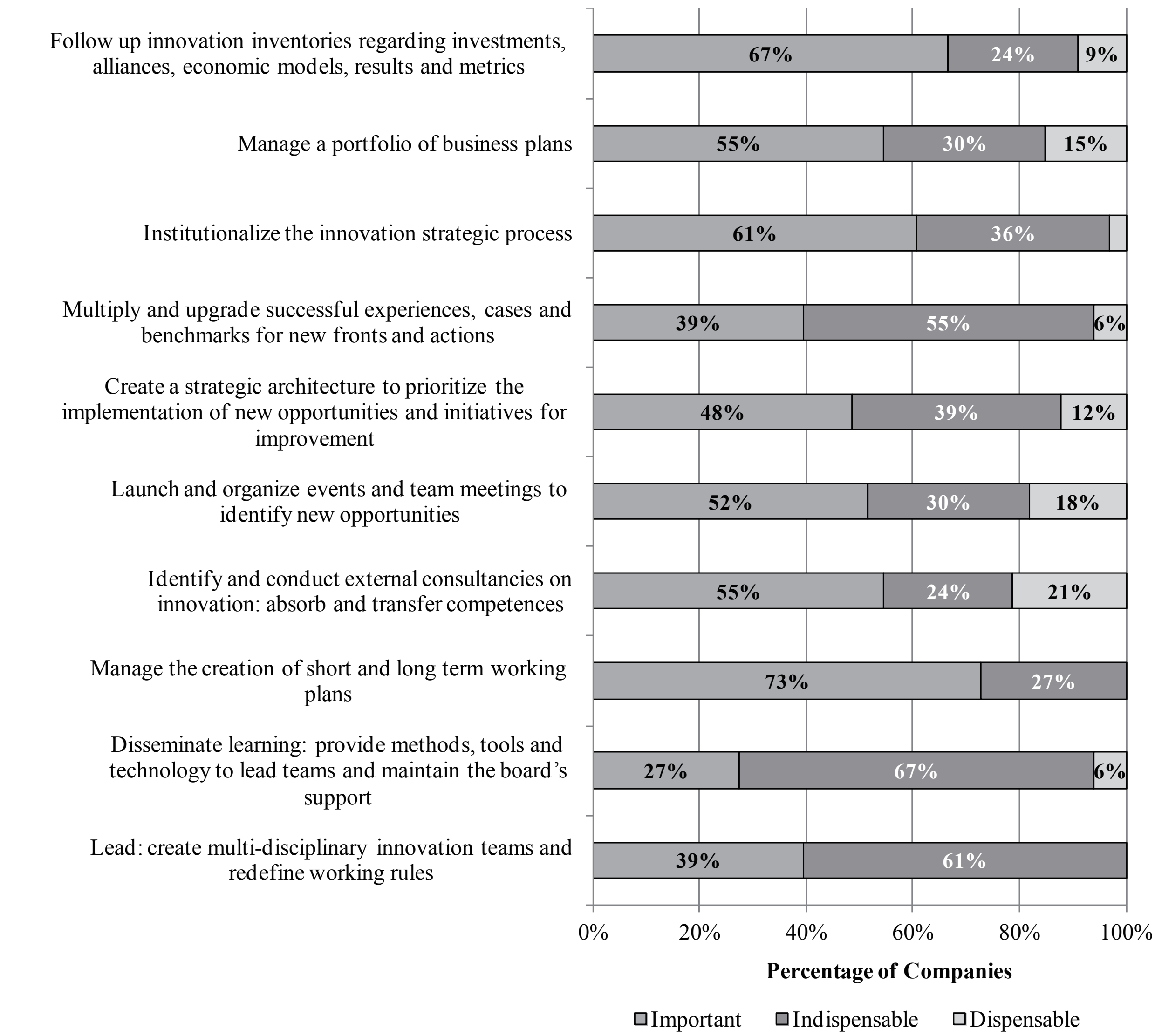

Figure 12
The Companies' Opinions About the Liabilities of an Innovation Executive

This is a macro-indicator that demands attention by the companies. The discrepancy between the higher and lower scores obtained is quite substantial. The incorporation of more people with master's and doctoral degrees on their human resources would favor the companies' innovation potential.

4. TECHNOLOGICAL AND INFORMATIONAL INFRASTRUCTURE

As to the Intranet and the Internet access availability, most companies have declared that there is no limitation to access those networks, the internet (75%) being more widespread than the Intranet (69%)(data not shown).

Among the investments made by companies to develop innovations, the "Qualification" appears as the greatest agent of change, followed by "Introduction of technological innovations in the market" and "Acquisition of machines and equipment". Companies indicated the "Acquisition of research and development outside the company" as the less implemented strategy, although only 24% of them had a Research Center in Brazil (Figure 13).

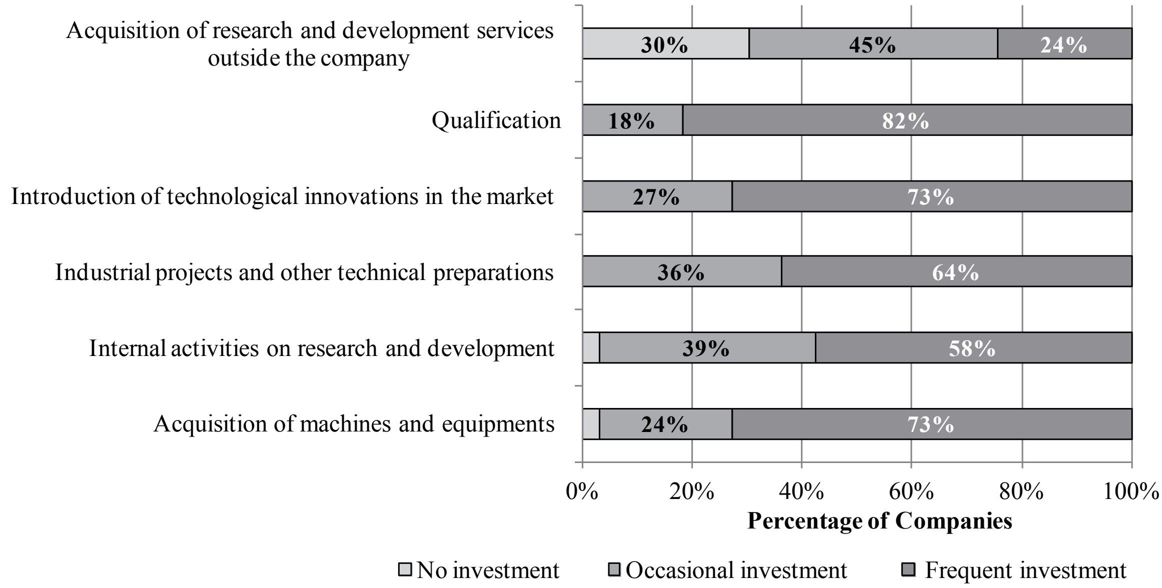

Figure 13
Investment Made by the Companies for the Development of Innovations

Most companies (79-88%) have declared they have permanent access to databases that provide national and international technical documentation, and to libraries with specialized and updated collections for their field of operation (data not shown).

Information is the basis of knowledge, which supports competitiveness. The maximum and minimum scores obtained in this macro-indicator show that the association of knowledge sources that are external to the companies would significantly broaden their ability to innovate.

5. ENGINEERING AND MANUFACTURE QUALIFICATION INFRASTRUCTURE

Figure 14 displays the percentage distribution of companies according to their number of labs and/or workshops for tests, simulations and manufacture and to the number of pilot plants within companies that have declared their intent to develop Engineering products and services.

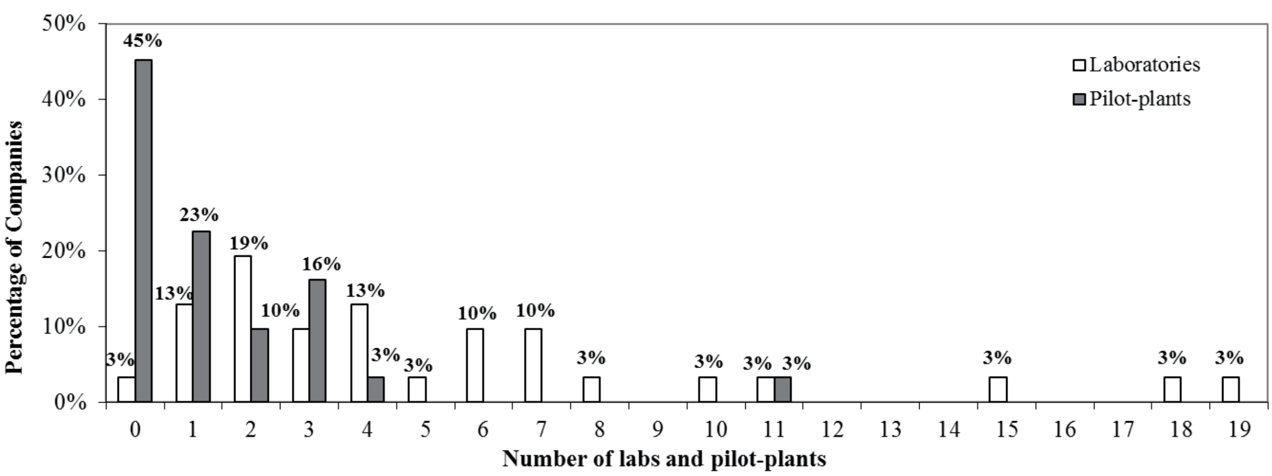

Figure 14
Percentage Distribution of Companies According to the Number of Labs and Pilot-Plants

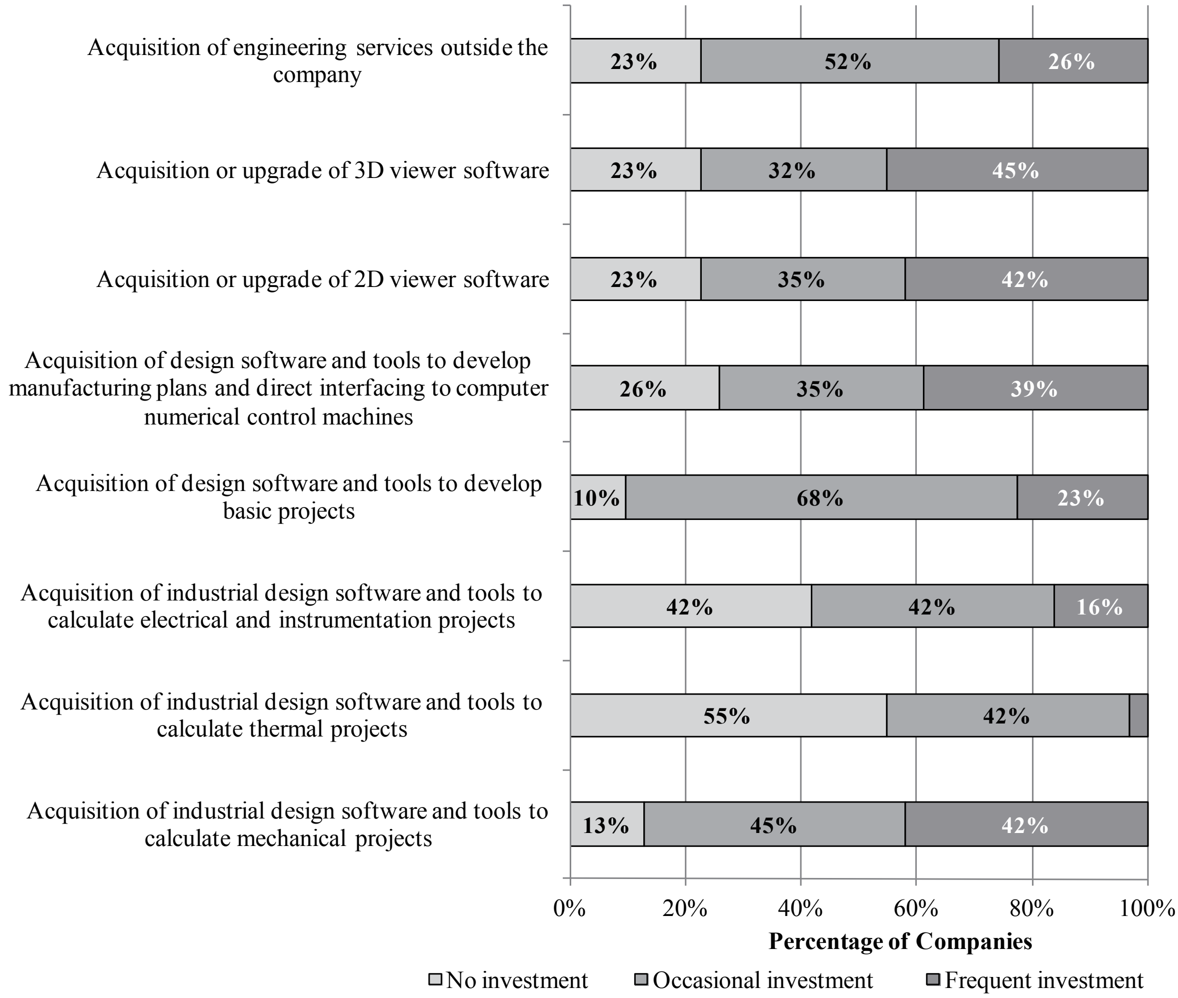

Figure 15
Companies Investments on Design Engineering and Industrial Engineering Areas

Figure 15 presents the assessment of the investments flow made by companies that work on Engineering Design and Industrial Engineering.

An elevated score in this macro-indicator demonstrates that the company understands the importance of laboratories and pilot plants in the research, development and innovation initiatives. While some companies have this understanding, others revealed an incipient vision regarding the indispensability of this infrastructure.

6. MARKET POSITIONING

As to the market leadership, regarding the activity of developing innovations for the PROMINP sectors, most companies stated that they had a consolidated position and competed towards leadership, as shown in Figure 16.

Among the possible sources of information and knowledge used by companies in the innovation development process, the clients, research on the Internet and trade shows and exhibitions were the most indicated by companies. Figure 17 has detailed results.

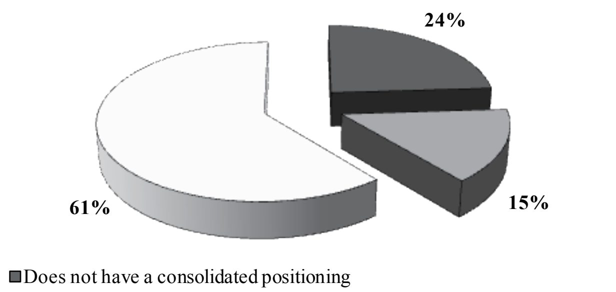

Figure 16
The Companies' Market Positioning, According to the Development of Innovations for PROMINP Sectors

Considering the adoption of partnerships regarding innovations, most companies indicated that the most adopted partnerships occurs with clients, suppliers and Universities or Research Centers, whereas the less adopted occurs with SENAI[5] (Brazilian National

5 Largest complex of professional education in Latin America provides appropriate care for the different needs of industry,

Service of Industrial Learning), SEBRAE[6] (Brazilian Micro and Small Business Support Service) and similar, and companies from the same sector, as shown in Figure 18.

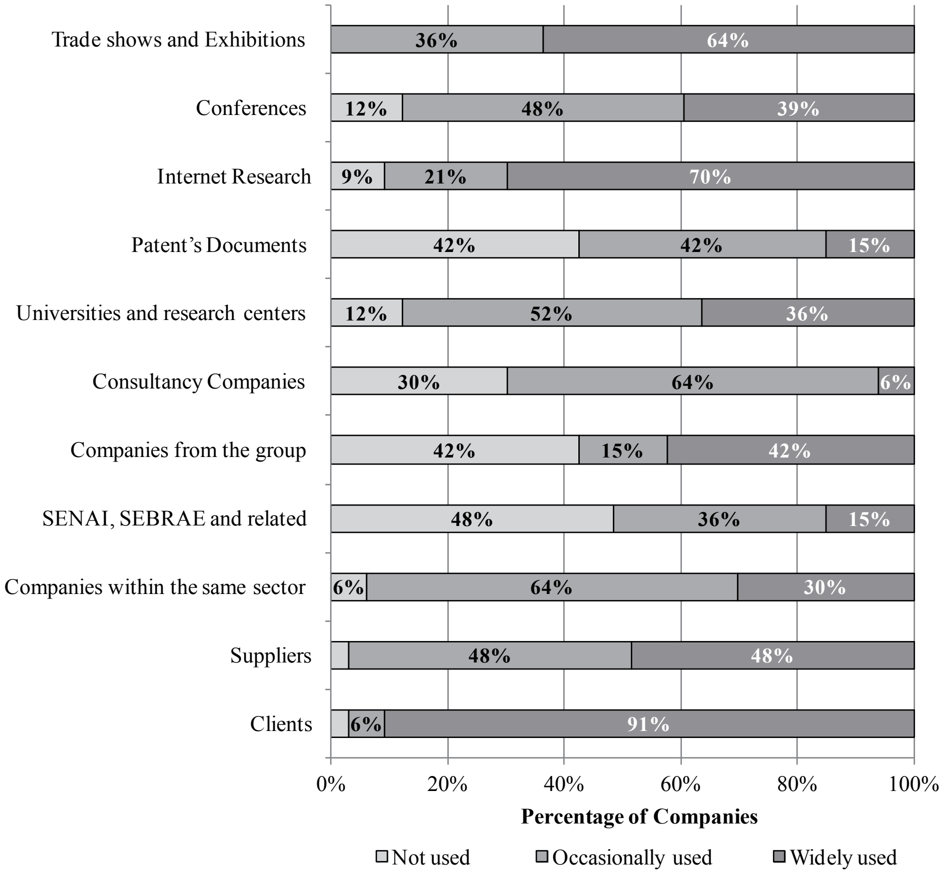

Figure 17
Sources of Information and Knowledge Used by the Companies to Develop Innovations

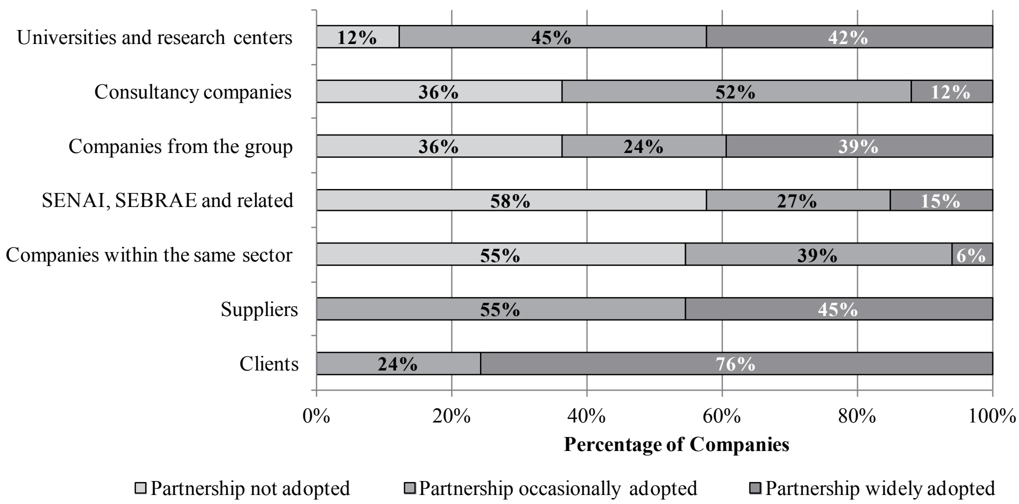

Figure 18
Relationship Between Companies and Possible Partners for the Development of Innovations

Market positioning is a presupposition of competitiveness. The low score obtained by some companies in this macro-indicator is partially due to the incipient use of the Universities and Research Centers as information sources for innovation.

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contributing to the full and sustainable development of Brazil.

6 Private entity of public interest that supports the opening and expansion of small businesses and encourages the development of Brazil by generating income and employment through entrepreneurship.

7. RESULTS

Most companies have developed innovations for up to five companies, working with more than 250 employees during the analyzed period, and 61% of them declared that they have already participated in the development of radical innovations. The percentage distribution of companies according to the number of innovations developed can be seen in the Figure19.

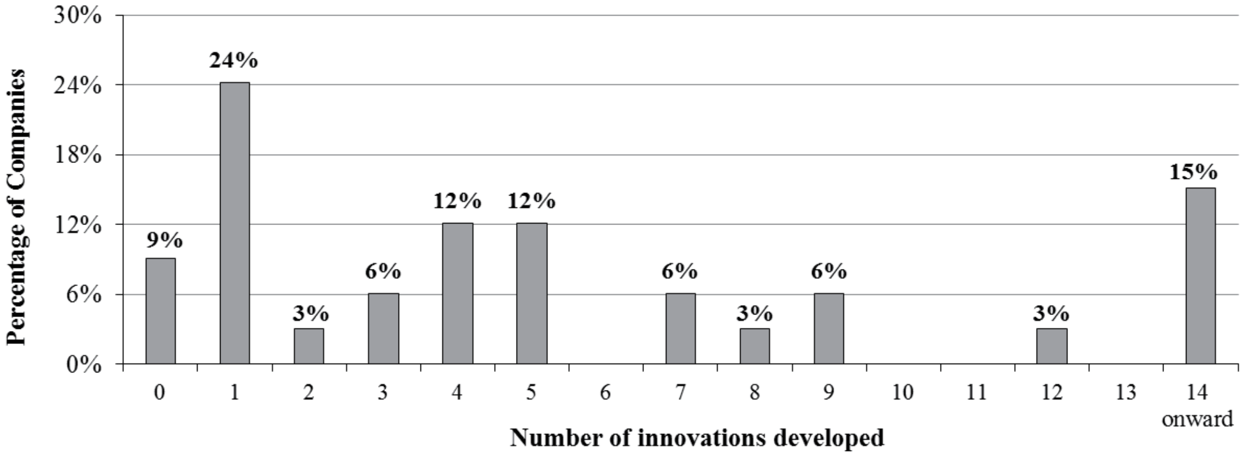

Figure 19
Percentage Distribution of Companies According to the Number of Innovations Developed

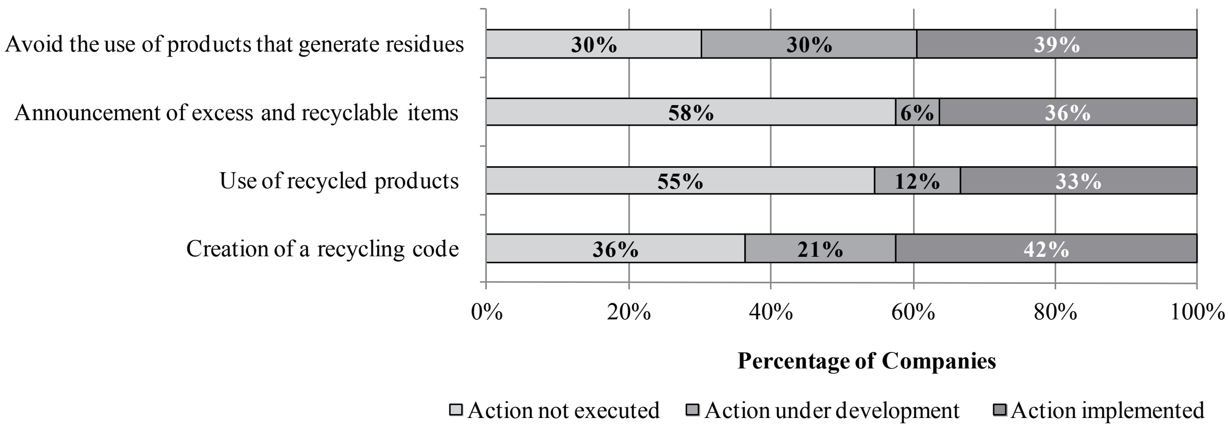

Figure 20
Actions Developed by the Companies Targeting the Reduction of Wastes

The average nationalization rate mentioned was 73%. Most companies did not register the innovation at INPI, stating the strategy for preservation of industrial secrets as the main reason for doing so.

Of 33 assessed companies, 15 declared they have published articles on periodicals during the analyzed period. Of the 157 articles mentioned, 60 were made by a single company, which corresponds to 38% of the total.

The assessed companies have reported 324 participations in Congresses and Seminars, 237 exhibitions in fairs and 345registrations in INPI. Among the assessed companies, 72% had the ISO 9000 certificate, 25%had the ISO 14000 certificate, and 50% had other accreditations. There were also reported 36 state awards, 68 national awards and 25 international awards.

The discrepant score registered in this macro-indicator reveals that the culture of non-protecting patents, as well as the non-recognition of the value of the ISO certifications is still present in a good portion of the responding companies.

8. SOCIAL RESPONSIBILITY

To assess the companies' performance in relation to social responsibility, they were questioned about:

- appreciation of ethics;
- execution of audits and accountability;
- environmental policy;
- waste minimization;
- pollution prevention;
- encouraging the effective use of energy and water;
- development of ecological projects;
- promoting the diversity;
- remuneration and incentives policy;
- dismissal policy;
- quest for the balance between work and family;

- employees' health, safety and welfare;
- concern with the community in which they are inserted;
- incentive to volunteer work;
- incentive to philanthropy;
- incentive to education;
- promotion of human rights;
- enrollment in responsible care programs;
- procurement of goods and services to meet their requirements in the environmental area.

Figures 20and 21 exemplify the results obtained in the assessment of actions and behaviors pertaining to social responsibility.

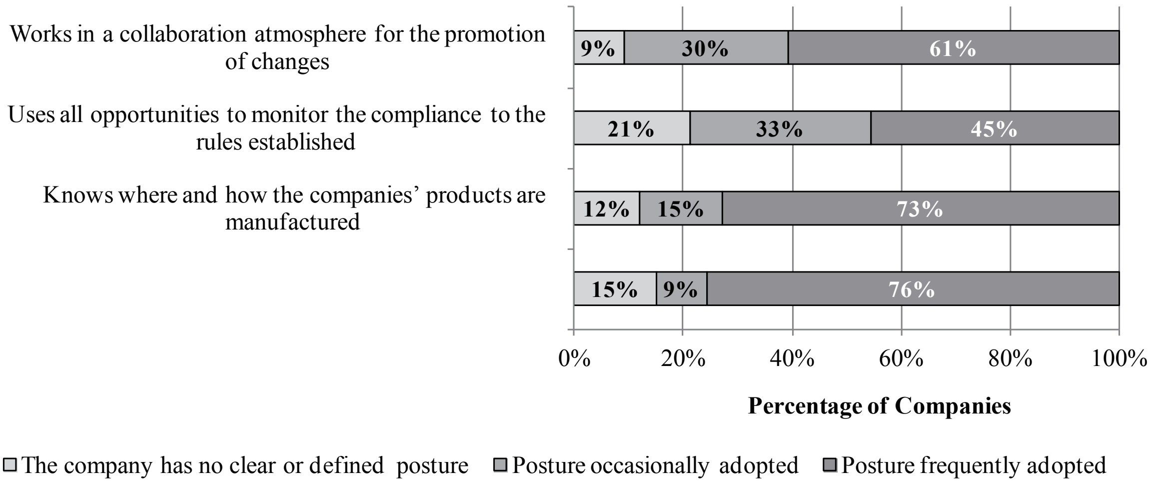

Figure 21
The Companies' Positioning as to the Promotion of Human Rights

The search for the consolidation of the social responsibility vision as an attribute of the innovation potential of a company was the reason why this macro-indicator was included in the research. As mentioned previously, one of the objectives of the research was to strengthen the basis of innovation-inducing policies in Brazil. Here, the research shows companies with extremely high scores, followed by others that still have not realized the relationship between innovation potential and social responsibility.

9. RESULTS ANALYSIS

9.1 Statistical Analysis of the Results Obtained With the Original Weights

The calculation of the $IP_{INNOVATION}$ was done using the weighted average of seven sub-indexes: Organizational and Technological Management (OTM), Personnel Management (PM), Technological and Informational Infrastructure (TII), Engineering and Manufacturing Qualification Infrastructure (EMQI), Market Positioning (MP), Results (RE) and Social Responsibility (SR). Initially, based on a strategic vision of the sector, the weights applied to the scores obtained on each worksheet were fixed.

The calculation of each sub-index was also made using the weighted average of the scores on the various questions of the questionnaire. Not all questions answered by the companies generated a score. Many of them were used to map the market performance of the companies. The score of each sub-index was always normalized to 10 points, before the weights were applied. With all the sub-indexes accounted for, the $IP_{INNOVATION}$ was calculated by dividing the sum of the sub-indexes ($\Sigma_{(i\ a\ vii)}$) by the sum of the maximum score allowed for each sub-index (250 points for the companies that were candidates to develop products or services in Engineering that were relevant to the sectors of PROMINP and that consequently answered the EMQI worksheet, and 220 for the other companies), ranging, thus, from zero to one.

The technical analysis of the evaluation instrument was based on the 31 companies (named here as Company 1 trough Company 33) that answered the seven worksheets. Company 2 and Company 11 were excluded because they were not considered as candidates to develop products or services in Engineering that were relevant to the PROMINP sectors of interest and, for that reason, did not answer to the EMQI worksheet.

To facilitate the comparative analysis of the results obtained by the companies, each sub-index score was normalized to a scale of 0 (zero) to 100 (one hundred) points.

The averages obtained by the companies in the sub-indexes TII, EMQI, MP and SR had values close to the overall average, which stands at 60.75. The PM and OTM sub-indexes showed averages above the total average, while the sub-index RE contributed to lowering that average.

To learn how the scores ranged from the average, we adopted the standard deviation, which, in the case of the total score, was 11.05, indicating that the group is fairly heterogeneous. The largest standard deviations observed corresponded to EMQI, TII and RE sub-indexes, while the lowest value was on account of the OTM sub-index.

The minimum scores obtained in the various sub-indexes ranged from 9.38 to 54.06. The lower value corresponds to the RE sub-index and the higher value corresponds to the OTM sub-index. The lowest value obtained for the higher scores was also related to the RE sub-index (81.25), while the highest value observed was 98.81 for the sub-index TII.

The sub-indexes EMQI, TII and RE showed the highest amplitude values, while the lowest values were related to the OTM sub-index.

Considering that the average score can be influenced by scores that are too high or too low, the median was also calculated in order to have a more precise notion of the distribution. That analysis confirmed that the two values were very close, and that the median (61.19) was slightly higher than the average (60.75), regarding the total score. This means that the number of companies with scores above the average was slightly higher than the number of companies with scores below the average, or that at least 50% of the group had scores that were equal or higher than 61.19. This trend was also observed for the individual sub-indexes, except for the EMQI, TII and RE.

The 10th and 90th percentiles (P10 and P90) corresponded to the scores of 46.09 and 72.61, respectively. This means that 10% of the companies presented scores below 46.09 and 90%, scores below 72.61. Analyzing the sub-indexes separately, we observe that the RE, EMQI and TII sub-indexes had the lowest values of P10, which once again demonstrates that these sub-indexes contributed most significantly to the lowering of the scores.

9.2 Evaluation of the Score Range of Open-Ended Questions

Looking at the universe of responses obtained in the open-ended questions that were used to calculate the $IP_{INNOVATION}$, it was observed that some specific score ranges could be modified to better differentiate the companies. Therefore, the upper limits of the score ranges of the 12 open-ended questions of the questionnaire containing 784 questions were reassessed.

To determine the threshold of the score ranges of these questions, we proceeded as follows:

a – To check if it was more appropriate to use the average and standard deviation or percentiles to establish the limits of the score ranges of open-ended questions, we used the Shapiro-Wilk test to verify the hypothesis of a normal distribution of the values for each question (Shapiro & Wilk, 1965).

After following this procedure for all sets of answers, the hypothesis of normality was rejected for all of them.

b – In the case of a normal distribution, the value corresponding to the average plus the standard deviation (0 + s) was intended to be used as the upper limit of the score range. As the series of data did not behave as a normal distribution, the outliers were excluded with the intention of simulating this condition. Thus, we applied the Grubbs test to all sets of answers to each open-ended question, to assess the presence of outliers (Grubbs, 1950; Grubbs, 1969; Miller & Miller, 2010).

In two of the evaluated questions, the outliers could not be removed by Grubbs test, as they presented such an asymmetric distribution that no conversion values applied could be considered valid.

After following this procedure for all sets of answers, the Shapiro-Wilk test was applied one more time and the result showed that, once again, none of the questions presented a normal distribution.

c – It was decided, then, to work with percentiles in order to fix the upper limit of the score range. The following criteria were tested as limits: (i) the median plus the interquartile range [median + (Percentil75 - Percentil25)], (ii) Top quartile (75th percentile), (iii) Percentile 80; (iv) Percentile 85, and (v) Percentile 90.

d – From the analysis of these results, the 75th percentile was chosen as a reference to be used as the upper limit of the score range. This value was chosen because it presented a more appropriate number of companies with maximum scores in the open-ended quations(between 24 - 32%), once the scale of intermediate scores had to be broadened and the upper and lower ranges were reasonably separated.

Changes made within the limits of the score ranges generated a slight change in the $IP_{INNOVATION}$values. There were few changes in the ordering of companies, especially in the central score range, i.e., between 0.5 and 0.7.

9.3 Evaluation of the Worksheets Weights

To evaluate the influence of the initial worksheets weights, the sums of each sub-index obtained by the 31 companies were taken before the application of weights, and the values of the $IP_{INNOVATION}$ were recalculated to this new condition.

The Principal Components Analysis (PCA) was made using these sums, without applying the weights, by the Unscrambler software, version 8.0.

The analysis by a principal component (PC1), which corresponded to a linear combination of seven variables, accounted for 51% of the system variation, while adding PC2 increased this percentage to 66%, and adding PC3 to 81%.

As an example of the results of this set of combinations among the seven variables, the loadings for PC1 X PC2 indicated that the variables OTM and PM were the ones that influence the system variance the least, followed by MP and SR. The most important variables are TII, EMQI and RE.

The PCA of the sums obtained by the 31 companies that answered to all worksheets, in each sub-index, after the application of the original weights, shows that for a principal component (PC1) the variation of the system is 57%, while the addition of PC2 increased this percentage to 75%, and PC3 to 87%.

Just as before, the PC1 X PC2 loadings indicate now that the variables OTM, PM, MP and TII influence system variance the least, while the variables RE, SR and EMQI are the most important. Therefore, the weights given to the worksheets made the SR variable more important than it was, and withdrew the importance of variable TII. The variable RE had increased its importance, and the variable EMQI, comparatively, had its importance diminished. Regarding the OTM worksheet, the weight assigned to it, was not able to make it important. The variables PM and MP were also not significantly changed.

After an exhaustive analysis involving the seven variables, it was concluded that there is an important variable (TII), which can increase the differentiation of companies, and that is being devalued with the low weight that was assigned to it. The variable EMQI, which also has a high discrimination power, had its relative importance diminished due to the weight given to it. The SR variable was valued with the weight that was assigned to it. The variables OTM, PM and MP have little discrimination power for the group of companies assessed.

As a result of this extensive analysis, the weight of the OTM worksheet was equaled to the PM and MP worksheets; the weights of TII and EMQI worksheets were elevated and the weights were the RE and SR worksheets were kept.

9.4 Evaluation of Results After the Implementation of the Recommended Modifications

The changes suggested in the score ranges and weights of the worksheets were implemented. A new PCA was made in order to assess the importance of the new weights and new score ranges, using the Unscrambler software, version 8.0.

It was concluded that the new weights adopted were appropriate and allowed better exploitation of the system variances.

The main statistical parameters of the scores of each sub-index obtained by the 31 companies that answered to all worksheets were recalculated, based on the normalization of the scores to a scale of 0 (zero) to 100 (one hundred) points.

The averages obtained by the companies in the TII, SR and MP sub-indexes had values close to the total average, which stood at 58.77. The PM and OTM sub-indexes showed averages above the overall average, while the sub-indexes EMQI and RE contributed to lowering the average.

The standard deviation of the total score was 12.68, higher than the one previously found, indicating that now the system variance was better explored. The largest standard deviations observed corresponded to the EMQI, TII and RE sub-indexes, while the lowest value was related to the OTM sub-index.

The minimum scores obtained in the various sub-indexes ranged from 11.81 to 54.06, the lowest value corresponding to the RE sub-index and the highest value corresponding to the OTM sub-index. The lowest value obtained for the higher scores was also found among the RE sub-index (83.85), while the highest value observed was 98.81 for the TII sub-index.

The EMQI, TII and RE sub-indexes showed the highest amplitude values, while the OTM sub-index presented the lowest values.

The median (55.20) presented a value that was lower than the average (58.77), with regards to the total score. This means that the number of companies with scores above the average was slightly lower than the number of companies scoring below the average, or that at least 50% of the group had scores equal to or above 55.20. This trend was also observed for the sub-indexes EMQI and TII. The other sub-indexes presented a median value that was superior to the average value.

The 10th and 90th percentiles (P10 and P90) of total scores corresponded to 44.59 and 76.32, respectively. Analyzing the sub-indexes separately, it was observed that the EMQI and RE sub-indexes showed the lowest values of P10, while the highest value was found in the OTM sub-index. Regarding the 90th percentile, the TII sub-index showed the highest value and the MP sub-index presented the lowest value.

Table 1 presents the companies $IP_{INNOVATION}$, recalculated with the recommended modifications, as well as the original values for comparison. It is observed that the changes made within the limits of the score ranges of the open-ended questions and the worksheets weights did not alter the $IP_{INNOVATION}$ significantly, which indicates that the evaluation method developed is robust.

Table 1
$IP_{INNOVATION}$ of the Companies Recalculated With New Score Ranges and New Weights

Company	$IP_{INNOVATION}$ recalculated	$IP_{INNOVATION}$ original
Company 25	0,89	0,88
Company 26	0,79	0,77
Company 29	0,77	0,73
Company 30	0,76	0,74
Company 33	0,71	0,70
Company 13	0,71	0,71
Company 3	0,68	0,65
Company 32	0,68	0,71
Company 27	0,68	0,65
Company 14	0,67	0,70
Company 11	0,66	0,67

To be continued

Continued

Company	$IP_{INNOVATION}$ recalculated	$IP_{INNOVATION}$ original
Company 21	0,65	0,69
Company 12	0,65	0,71
Company 4	0,62	0,64
Company 5	0,59	0,61
Company 31	0,58	0,62
Company 18	0,55	0,63
Company 6	0,55	0,60
Company 28	0,54	0,53
Company 1	0,53	0,53
Company 19	0,52	0,55
Company 16	0,52	0,58
Company 7	0,51	0,55
Company 9	0,51	0,56
Company 15	0,49	0,54
Company 20	0,48	0,51
Company 23	0,47	0,51
Company 22	0,45	0,46
Company 10	0,45	0,49
Company 24	0,43	0,46
Company 8	0,39	0,43
Company 2	0,38	0,42
Company 17	0,36	0,40

10. INNOVATION POTENTIAL ($IP_{INNOVATION}$)

In this item we will show the final results obtained after the evaluation of the $IP_{INNOVATION}$ of 33 companies that responded to the questionnaire.

The graph, shown in Figure 22, comprises three parts. The upper part of the graph represents companies that have already achieved high level innovation capacity. Companies set on this level have a big chance of success on a cooperative development. They have almost all the characteristics needed to carry out a pioneering development and they also have a historical activity on projects including innovation.

The intermediate part of the graph is the medium level. Companies set on this level have a good chance of success on pioneering developments. These companies have either a historical of development activities or have good initial attributes regarding engineering, personnel and infrastructure to carry out the development of new products or services. They probably will need to improve some characteristics, but already have the potential to develop innovations.

The lower part of the graph represents companies with low level innovation capacity. The companies set on this part are not prepared to develop innovation products or services. Normally, a big effort will be required from the managers to develop or to change some internal processes, the business management, the production capacity, the infrastructure, the engineering and some routine procedures to develop an innovation mentality. It is important to point out that developing the necessary skills on the companies` personnel is the utmost attribute in order to achieve the knowledge needed to work on innovation projects.

In Figure 22, 12 companies (34%) were assigned on the graph's upper level, reflecting the high level of innovation capacity of these companies. Because of their high $IP_{INNOVATION}$, these companies were selected by the appraiser company to sign cooperative contracts involving the development of new products or services needed to support the company's activities either in routine operations or in new projects.

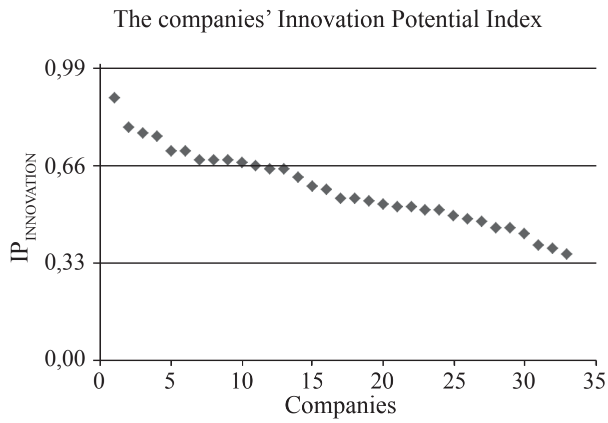

Figure 22
Dispersion of the Innovation Potential Indexes of Each Company Evaluated

In the same way, the other 21 companies (64%) were assigned on the graph's medium level. The innovations built with those companies have a reasonable chance of success but they incorporate some calculated risk. The risks involved have to be carefully evaluated and some countermeasures have to be established in order to mitigate the chances of non success in a particular project.

None of the companies were assigned on the graph's lower level. This fact shows the effectiveness of the selection process for cooperative companies that have the development of innovation projects as their primary goal.

CONCLUSIONS

One of the most important byproducts of this work is the knowledge obtained about the weaknesses and strengths of the companies that were elected to participate in the evaluation of the $IP_{INNOVATION}$. It became clear what the key factors are to work in order to achieve a good background of intellectual capital to participate in innovation projects and what the virtues are that must be kept or improved even more to foster the competitiveness and effectiveness of the company. After the evaluation process a report shall be given freely to the companies' CEO emphasizing those capital points.

The demonstrated innovative range of the questionnaire, combining aspects of management - organizational and people - infrastructure, communications, marketing and social responsibility, has made it possible to further address the idea that innovation is limited solely to new product, process or service.

The robustness of the survey instrument developed herein, characterized by the set of means and methods used in its evaluation and consolidation, contributes significantly to a new perspective for assessing the innovation potential of companies in various sectors and industries - the organizational culture of innovation is much beyond technology.

We believe that the methodology presented in this work can be further developed in order to encompass other industry segments that demand high level of innovation in their businesses. Examples are the electronics area, the defense industry, the medical services, information technology, fine chemicals and others. It is important to point out that measuring the innovation potential of a particular set of companies can be a worthwhile effort especially in the case of developing countries taking into account that the above mentioned report regarding the strengths and the weaknesses of the evaluated segment can subsidize Government offices in the establishment of policies and directives for development of their countries.

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