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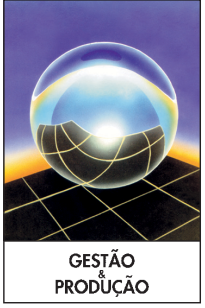

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Association between innovation competences and competitiveness in the Brazilian electromedical device industry

A relação entre competências para inovar e competitividade na indústria de eletromédicos no Brasil

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Abstract: The aim of this article is to investigate the existence of a causal relationship between innovation competences and competitiveness in electromedical device manufacturers operating in Brazil. A survey was conducted in 2015 with 34 companies, and the data gathered were analyzed qualitatively and quantitatively. Innovation competences were addressed from two perspectives. In the first, the capacity to follow, predict, and act on market developments was the best developed capability, while the capacity to sell new products was the least developed. In the second, technical competences were found to be better developed than relational and organizational ones. Concerning competitiveness, fewer than half the respondents reported improved performance in at least one of the seven indicators evaluated. Considering the two variables together, no statistical correlation was found between innovation competences and competitiveness using Spearman's Rank-Order Correlation Test. As such, the competitiveness of the companies from the sample under study was understood as being more strongly associated to their commercial performance, itself affected by their capacity to fulfill regulatory requirements.

Keywords: Innovation; Innovation competences; Competitiveness; Electromedical device; Spearman's Rank-Order Correlation Test.

Resumo: *Este artigo objetiva investigar a existência de relação causal entre as competências para inovar e a competitividade dos fabricantes de equipamentos eletromédicos instalados no Brasil. Foi realizada uma survey em 2015 junto a 34 empresas, cujos dados foram analisados quantitativa e qualitativamente. As competências para inovar foram abordadas segundo duas perspectivas. Na primeira, a capacidade de seguir, prever e agir sobre a evolução dos mercados foi a mais desenvolvida, enquanto a capacidade de vender os novos produtos, a menos desenvolvida. Na segunda, as competências técnicas mostraram-se mais desenvolvidas que as relacionais e organizacionais. Em relação à competitividade isoladamente, menos da metade dos respondentes apresentou melhoria em pelo menos um dos sete indicadores avaliados. Aplicando-se o Teste de Correlação Posto-Ordem de Spearman, não foi encontrada correlação estatística entre as duas variáveis. Ficou entendido que, na amostra estudada, a competitividade das empresas é mais associada ao desempenho comercial, por sua vez afetado pela capacidade de atender aos requisitos regulatórios.*

Palavras-chave: *Inovação; Competências para inovar; Competitividade; Equipamentos eletromédicos; Teste de Correlação Posto-Ordem de Spearman.*

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1 Introduction

The concept of innovation competences, originally devised by François et al. (1999), has received considerable attention on the part of Brazilian researchers in recent years. Alves et al. (2005) have investigated them in the context of the petrochemicals industry; Alves (2005) has researched innovation competences in the plastic packaging industry; and Moraes et al. (2011) have studied these competences in the aeronautical, automobile, and chemicals industries in the Vale do Paraíba industrial hub, São Paulo state.

A common goal of these studies has been to trace out the profile of corporate innovation competences. Although innovation is recognized as an important criterion for companies' survival, the question of whether innovation competences contribute to their competitiveness is not addressed in these studies.

The aim of this study is to investigate whether such a relationship exists. To this end, a survey was conducted in 2015 with a non-random sample of 34 of the estimated 89 manufacturers of electromedical device based in Brazil. The findings shed new light on this industry and implications for public policymakers and managers, indicating areas where their strategies would benefit from being reviewed.

The rest of the article is organized into five sections. The first presents the industry in question; the second reviews the literature on the main constructs: innovation competences and competitiveness; the third section presents the methodology employed in the research; the fourth section sets forth the analysis and discussion of the results; and the last section offers some concluding remarks and recommendations.

2 The electromedical device industry

The electromedical device industry is understood here as encompassing all the companies that manufacture electromedical device, such as incubators for newborns, anesthesia apparatus, multi-parameter monitors, and medical imaging equipment (MRI scanners, CT scanners, x-ray machines, etc.).

The industry is dynamic from an innovation, technology, and economic point of view (Gadelha et al., 2012), and the companies that form it can be divided into two strata with different levels of resources, rationales, and strategies.

The upper stratum is competitively dynamic. These are the equipment manufacturers that use complex, advanced, or cutting-edge technologies. They are mostly subsidiaries of major transnational corporations (e.g., General Electric, Siemens, Toshiba) and their decision-making processes are guided by the rationale of global market leaders. They invest heavily in R&D and marketing and have strong brand names and substantial complementary resources, such as global technical support and distribution networks (Sturgeon et al., 2013). Their competitive and innovation strategies are geared towards maintaining their market and technological leadership. Although they are smaller in number, they account for the lion's share of global sales.

The lower stratum of the electromedical device industry occupies the competitive periphery. These are companies that manufacture equipment using mature and/or less complex technologies. In Brazil, they are mostly small and medium-sized enterprises (SMEs) whose business decisions are predicated primarily on limitations of a technical, managerial, and financial order. Their innovation efforts are geared towards reducing costs, because price is the main competitive factor between the companies in this stratum (Gadelha, 2009). Although they are greater in number, they account for a smaller proportion of total sales to the domestic market and abroad.

According to Sturgeon et al. (2013), less costly equipment (produced using mature technology) tends to be distributed via middlemen (distributors and wholesalers selling on to retailers). Management-wise, Maldonado et al. (2012) report that many Brazilian manufacturers of medical, hospital, dental, and laboratory equipment still operate under sub-optimal management conditions and are often family-run, with demonstrably low levels of professionalization.

Investigating this area, Moreli et al. (2010) found that just two of the 23 companies they researched made some use of the tax breaks and subsidies offered by government. Further, none of the 18 companies that paid taxes on a fixed percentage of their revenues had ever run a simulation to ascertain whether they could gain any economic benefit from changing to the percentage-of-earnings tax regime. The fact is that this latter system requires companies to have a better understanding of tax legislation, bookkeeping, and other legislative issues than the former. The authors concluded that the companies from this sector in general had considerable difficulty meeting public health regulatory requirements (issued by ANVISA, the Brazilian health surveillance agency) and were ignorant of means of developing overseas markets for their products.

While the considerations commented on here illustrate the management difficulties faced by medical, hospital, dental, and laboratory equipment manufacturers, the expectation is that the same will apply to electromedical device manufacturers.

3 Theoretical foundations

The theoretical part of this study focuses on two basic concepts – innovation competences and competitiveness – which are addressed in the two subsections below.

3.1 Innovation competences

It is important to start by stating that the concept of innovation competence derives from the resource-based view (RBV) of the firm, whose roots lie in research done by Penrose (1959). In this approach, a firm is understood as being made up of "[…] a collection of productive resources the disposal of which between uses and over time is determined by administrative decision" (Penrose, 1959, p. 61). As such, the RBV draws attention to a firm's attributes to explain its performance in the market. Despite the conceptual distinctions that have been made between "resources," "capacities," and "competences" (e.g., Barney, 1996), these differences will not be considered here.

In such a context, innovation competences are seen as part of a firm's resources. As proposed by François et al. (1999), they are defined as the set of capacities owned by a firm that enable it to innovate more profitably. There are three dimensions to these capacities: the capacity to do today, the capacity to learn to do tomorrow, and the capacity to mobilize external competences to do today or know how to do tomorrow (François et al., 1999).

There are two non-mutually exclusive orientations embedded in these three dimensions: one for the development of new competences, such as through actively searching, varying, and experimenting; and the other for taking better advantage of existing competences, such as by refining, selecting, and improving efficiency. These two orientations are conceptually akin to *exploration* and *exploitation*, respectively (Laureiro-Martínez et al., 2015; March, 1991).

The main assumption behind innovation competences is that there are fundamental innovation competences – ones that do not depend on the circumstances in which the innovation takes place, which gives them a general, non-industry-specific nature. According to François et al. (1999), innovation competences serve to develop technological innovation and are organizational, not individual.

According to the meaning given by François et al. (1999), saying that innovation competences are organizational is the equivalent of recognizing that they emerge from the interaction between a firm's workers, but do not belong to any one of them individually. This is borne out by the fact that they withstand normal levels of employee turnover. When an organizational competence becomes the basis for a company's development and capacity to launch products (or even to compete), this competence is known as a core competence (Prahalad & Hamel, 1990). However, if the competence is common to all the companies operating in the same industry, it can be said to be operational.

From the perspective of the RBV, given that a firm has a unique set of resources that determine its performance (Collis & Montgomery, 1995), and that resources are distributed heterogeneously among competitors and only yield profit when there is adequate organizational structure and identity to exploit them (Sanches & Machado, 2014), it is important to understand the relationship that exists between innovation competences and innovation strategy.

According to Sanches & Machado (2014), innovation strategies provide the basis for innovation-related decision-making processes, orienting decisions about plans for innovation and the supporting resources with a view to obtaining competitive advantages and enhancing the development of the organization's innovation potential. They add that innovation strategies underpin choices made about innovation pathways when it comes to planning the development of new products (including services) and opening up markets, and that such plans can be inferred from a firm's innovation efforts.

Guan et al. (2009) argue that in highly competitive environments (such as the electromecial equipment industry), a firm's capacity to maintain its pace of innovation and continuously invest in innovation is fundamental for its survival and growth. However, maintaining, acquiring, and developing capacities (in this case, innovation competences) will depend on the innovation goals and resulting innovation strategy.

Keupp et al. (2012) suggest that strategic innovation management must be concerned with adopting suitable strategic management techniques and measures to augment the effects of a firm's innovation efforts on its growth and performance.

Notwithstanding any conceptual differences that may exist between innovation competences and innovation strategies, there are clearly strong links between the two: while the innovation strategy will justify and direct the development of innovation competences, these competences will themselves serve as inputs for developing the innovation strategy. Another point is that both concepts have to do with competitiveness.

One classification of innovation strategies worth noting is by Freeman & Soete (2008), who divide them into six types: offensive, defensive, imitative, dependent, traditional, and opportunistic. What differentiates these strategies is the importance of the science and technology functions (e.g., research, development, engineering, quality control) developed internally by the firm, which in turn affects the way it competes on the market. For instance, a firm whose innovation competences are highly developed will be able to adopt an offensive innovation strategy, pioneering the introduction of new products and services and opening up new markets. Meanwhile, a company with limited innovation competences will end up adopting a less advanced innovation strategy and

may opt for imitation instead, merely putting out me-too products without any aspiration of being a market leader or profiting from innovation.

To identify and measure the competences needed for innovation, François et al. (1999) prepared four types of questionnaires, each of which has inherent strengths and weaknesses. The competences questionnaire used in this study stands out for its more general applicability and its greater suitability for the statistical treatment of data, albeit with the weakness of picking up on the respondents' subjective views towards the competences under investigation. It is organized around the nine main groups of complex competences shown in Chart 1 and 72 elementary competences within these nine overarching categories.

The complex competences are broad-based descriptions of verifiable organizational behaviors, while the elementary competences provide a more detailed description of the complex competences, facilitating the perception of the complex competences and the workability of the surveys.

In this study, the complex competence "sell innovations" is broken down into several elementary competences that include "promote new equipment based on directed marketing strategies" and "export new equipment."

Alves (2005) adds a new complex competence, "cooperate to innovate," to the nine originally proposed by François et al. (1999). She also introduces the investigation of industry-specific elementary competences and adopts a second analytical approach based on classifying elementary innovation competences according to their technical, organizational, and relational nature.

The competences of a technical nature have to do with production and technology, such as quality control, production effectiveness, and the evaluation of new products, as well as production equipment and the availability of inputs on the market. There are no focal areas for the competences of this nature.

Chart 1. Complex innovation competences defined by François et al. (1999).

1. Capacity to include innovation in the overall corporate strategy
2. Capacity to predict market developments
3. Capacity to develop innovations
4. Capacity to organize and direct research
5. Capacity to appropriate external technologies
6. Capacity to manage and defend intellectual property
7. Capacity to manage human resources from an innovation perspective
8. Capacity to fund innovation
9. Capacity to sell innovation

Source: François et al. (1999).

The competences of an organizational nature have to do with management, especially in terms of knowledge creation and human resources. These competences are themselves broken down into three focal areas: human resource management, cross-functional innovation management inside the company, and identification and evaluation of individual and collective knowledge.

The competences of a relational nature concern interaction with agents in the external environment, foregrounding the firm's capacity to cooperate, form alliances, and appropriate external technologies. There are two focal areas: the obtainment and processing of information from the external environment, and the company's action in the external environment – namely, the use of the information obtained to adjust the way it operates in the external environment.

Competences of a relational nature have to do with the importance of the firm engaged in innovation having access to resources held by other agents. These agents include not just members of the same supply chain, but other actors from the innovation system as a whole. The resources accessed are said to be complementary, covering items such as project funding, promotions, and marketing, and the resources needed for research, development, production, and sales.

François et al. (1999, p. 1) add that "[…] in the industrial economy, an innovation strategy is considered one of the most important determinants of a firm's competitiveness", making clear reference to the connection between innovation and competitiveness. Investigating the diverse aspects impinging on this connection, the authors cite technological innovation as constituting the basis for deliberate strategies to win over new markets and also for defending against restrictions imposed by the competition.

Tidd et al. (2008) argue that innovation results in a larger market share and thus higher profitability. These benefits are also potentially reflected in higher dividends for investors and the economic sustainability of the business itself. In other words, innovation is related to competitiveness, the concept to be reviewed in the next subsection.

3.2 Competitiveness

Barney & Hesterly (2011) define competitiveness as a measure of a firm's capacity to create value for its buyers that exceeds the value generated by its competitors. It must also capture part of the value created in order to recompense the efforts made.

For Guan et al. (2006), a firm's competitiveness is expressed as holding an advantageous position in terms of strategy, technology, and management in a given field; a preferential market position vis-à-vis its competitors, enabling it to obtain more reliable advantages than them. Meanwhile, Ambastha &

Momaya (2004) see competitiveness as a firm's capacity to plan, produce, and/or sell products that are better than those offered by the competition, considering price-related factors as well as non-price-related ones, like quality and performance.

Clearly, there is no consensus on what competitiveness is, conceptually speaking. Brito & Brito (2012) argue that theory cannot supply a complete or operational definition, while Albuquerque et al. (2013) add that competitiveness is a relative concept and a multidimensional phenomenon. As such, the context must be clearly defined in analyses of competitiveness and the indicators used for measuring it must be selected carefully.

Taking such considerations into account, the definition of competitiveness adopted in this article is taken from Ferraz et al. (1996, p. 6): "[…] a firm's capacity to formulate and implement competitive strategies that enable it to expand or maintain a sustainable market position in the long term". The advantage of this definition is that it is broad enough for the purposes of this paper, allowing competitiveness to be assessed using complementary variables and indicators without running into conceptual contradictions.

The indicators investigated here were selected specifically for the business setting of electromedical device manufacturers (e.g., Marques et al., 2013; Landim et al., 2013; Gadelha et al., 2012; Pieroni et al., 2010). The indicators and the scale used to measure them are shown in Table 1.

It is worth noting here that even though evaluating competitiveness is anything but simple, inevitably leaving gaps and involving subjective interpretations, it is nonetheless necessary (Haguenauer, 2012). Below, we describe the steps taken to evaluate the competitiveness of the target companies and the relationship between this competitiveness and their innovation competences.

4 Methodology

This research constitutes a survey: a rapid, economical method for obtaining data from and determining facts about a population sample on a particular subject, be it a country's economy, or people's attitudes, beliefs, expectations, or behaviors (Scheuren, 2004).

An internet page was created to host the survey questionnaire, which contained three parts. The first part, with 12 questions, was designed to characterize the respondent companies. The second part, with 55 questions, was designed to identify the respondent companies' innovation competences, asking questions about innovation and strategy, market monitoring, the actual development of innovations, etc., resulting in an innovation competency profile. The final section, with seven questions, was for evaluating competitiveness indicators, resulting in a competitive profile.

The questionnaire was validated by four representatives of manufacturers, two doctoral researchers with publications and supervised research on the subjects addressed in this study, two regulatory agencies (the Brazilian weights and measures institute, Inmetro, and ANVISA), and three industry funding agencies (the Brazilian Agency for Industrial Development, ABDI; the STI funding agency, FINEP; and the Brazilian Development Bank, BNDES [technical team from the Health Products Department]). The information obtained represents the opinions of the people consulted, not those of the institutions where they work.

To gather data on innovation competences, a six-point Likert scale was used offering a range of potential responses designed to assess attitudes, behaviors, and perceptions from one extreme to the other. The respondents recorded their perceptions of their companies concerning each of the 55 competences investigated. The reliability of this part of the questionnaire was verified using Cronbach's alpha internal consistency test, which is a "[…] measure for which a measured construct, concept, or factor is present in each item" (Almeida et al., 2010, p. 5).

Table 1. Competitiveness indicators and assessment scale.

Indicators of Competitiveness	Behavior		
	Increasing	Unchanged	Decreasing
1. Domestic market share			
2. Sales			
3. Percentage of sales exported			
4. Earnings			
5. General productivity			
6. Revenues from new products vis-à-vis total sales			
7. Number of new (or improved) products vis-à-vis total number of products			

Source: Guan et al. (2006) – adapted.

In this study, the complex competences are to the construct as the elementary competences are to the items.

According to this test, sixty hundredths is an acceptable reliability / consistency value for a questionnaire (Bandeira, 2014; Maroco & Garcia-Marques, 2006; Freitas & Rodrigues, 2005). All the complex competences met this criterion, so it was understood that the questionnaire passed the internal consistency test.

To collect the responses relating to the indicators of competitiveness, seven questions were asked, one for each indicator evaluated. The indicators selected were the same as the ones used by Guan et al. (2006), but with adaptations in the way they were evaluated. In view of the fact that SMEs do not usually have standardized, up-to-date financial information and are not normally willing to share information on their competitive footing, the evaluation scale was adapted to pick up not a specific value for a given moment, but their behavior over the last three years.

More specifically, the scale was designed to ascertain whether the selected indicators were increasing, unchanged, or decreasing (see Table 1). This decision made it easier for information to be obtained, but impossible for any individual company to be compared with the industry as a whole. Given the heterogeneity of products and companies in the industry in question, this fact should be seen as a restriction imposed by the research setting. Further, comparisons would not be possible due to limited knowledge about the population distribution and the use of a non-probabilistic sample of companies.

The scale used ("increasing", "unchanged", "decreasing") yields ordinal categorical data, which is common in applied social studies. This meant nonparametric statistical methods had to be used. In this case, Spearman's rank-order correlation test was the selected method.

Invitations to take part in the survey were sent to 89 manufacturers identified from the Brazilian Association of Medical, Hospital, Dental, and Laboratory Equipment (ABIMO) database and web-based research. The questionnaire was available on the web from May 27 to July 24, 2015. However, just 34 (38%) of the estimated 89 companies operating in the target industry in Brazil took up the invitation.

Having obtained the raw data, qualitative and quantitative analyses were conducted to measure the companies' innovation competences and competitiveness and to ascertain the existence (or not) of statistical correlations between these two variables.

The method adopted in this study meant that the competitiveness measure was an ordinal category. As such, nonparametric statistical methods had to be used. Spearman's rank-order correlation test was chosen because it ranks the sample data to test the association between two ranked variables.

The main prerequisite for Spearman's rank-order correlation test is that the paired data on the variables under study originate from a simple random sample of the population. When this requirement is met, Spearman's rank-order correlation coefficient (r_s) can be used to test the association between the two variables in the population (Triola, 2013; Siegel & Castellan, 2008). If this requirement is not fulfilled, as in this research, the results should be interpreted within the sample obtained.

According to Siegel & Castellan (2008), the r_s value is used to test the null hypothesis that the two variables under study are not associated (are independent); the alternative hypothesis is that there is some association between them. When the r_s value is higher than the critical value for a given confidence level, the null hypothesis is rejected; otherwise, there is insufficient evidence for it to be rejected. The critical value can be obtained from tables according to the number of observations $n \leq 50$ (which is the case in this article).

In the next section, the results obtained are presented and discussed.

5 Analysis and discussion of results

The analysis and discussion of the results is divided into three parts: one concerning the profiles of the innovation competences, another concerning the competitiveness profile, and a third referring to the evaluation of the relationship between these two dimensions.

5.1 Innovation competences profiles

The profile of the innovation competences was traced out using two different conceptual approaches: complex competences and competences of a technical, organizational, and relational nature. In the first approach, which resulted in the profile shown in Table 2, the complex competency "follow, predict, and act on market developments" was found to be the most highly developed. This indicates that the manufacturers in the sample had a relatively well developed capacity to monitor and predict the competitive environment and customers, because these are the aspects covered by this competence group. This complex competence also covers the capacity to influence markets, but in this respect the sample was found to be rather less well developed.

Another complex competence, "sell innovations," was found to be less well developed. This competency covers factors which, on the whole, the manufacturers in the sample had more trouble dealing with, namely: "has targeted marketing strategies for new products;" "conveys an innovative, avant-garde image;" "benefits from the preference margin;" "exports using incentives;"

Table 2. Profile of complex innovation competences of the 34 electromechanical equipment manufacturers under study.

Complex Competences	Mean
Follow, predict, and act on market developments	3.73
Appropriate external technologies	3.43
Develop innovations	3.40
Include innovation in the corporate strategy	3.28
Organize and direct knowledge production	3.10
Produce and protect intellectual property	3.09
Fund innovation	3.01
Cooperate to innovate	2.79
Manage human resources from an innovation perspective	2.78
Sell innovations	2.73

and "promotes new equipment at international fairs." The results indicate that the 34 manufacturers in the survey could further develop their commercial competences for their new equipment.

In the second conceptual approach – elementary competences grouped according to their technical, organizational, and relational nature – the technical competences were found to be the most developed (mean: 3.65), while the relational and organizational competences were at around the same level of development (means of 3.09 and 2.95, respectively). Given that all three aspects are deemed necessary for successful innovation, it is recommended that the companies from the industry put effort into developing further their relational and organizational competences in order better to exploit the technical competences already at their disposal.

As for the difference between the means obtained for the three natures of innovation competences and the maximum values on the scale, this was interpreted as reflecting the gap between the companies in the sample and the market leaders.

The lower means for the organizational and relational innovation competences could be due to the limited professionalization of the companies' managerial practices – a typical trait of SMEs in general, including ones involved in technology.

As this industry is so dynamic in terms of technology and innovation, technological shortfalls tend to be exacerbated every time a technological step change comes about. It would therefore be worthwhile for these companies to explore new technical competences while carefully maintaining a balance between these and their organizational and relational competences.

When the development levels of the companies' technical, relational, and organizational competences were crossed with the data on their size (measured by the number of employees), capital structure (Brazilian, foreign, or mixed), export behavior, and R&D structure, no correlations were identified. However, when they were crossed against sales to the Brazilian government sector, it was found that 75% of the companies that sold more than 50% of their equipment to the government were amongst the most developed companies. The implications of this finding will be considered later.

Finally, when the companies' sizes were crossed with their export behavior, a direct correlation was found. In other words, the larger the company, the more likely it is to export its products.

5.2 Competitiveness profile

Only three of the 34 companies that completed the survey reported increases in all seven individual indicators at the same time. According to the literature consulted (e.g., Ambastha & Momaya, 2004; Haguenauer, 2012), there is a degree of consensus about productivity as an isolated variable in competitiveness. The same does not apply to the other variables, because they are always considered in pairs. For instance, if an increased domestic market share comes about with reduced profit, you cannot say that competitiveness has improved.

For this reason, this analysis of competitiveness considered productivity in isolation, earnings in combination with market share, total sales in combination with exports, and revenue from new products in combination with the number of new products. The number of companies with each combination of variables is shown in Figure 1.

To order the different positions of the combined variables, a score was attributed to each possible position for each individual indicator, as follows: 1 for decreasing, 2 for unchanged, and 3 for increasing. As shown in Figure 1, the two companies that reported a drop in earnings (score: 1) with a reduction in their market share (score: 1) were attributed a combined score of 1. Likewise, the six companies that reported improved earnings (score: 3) and a higher market share (score: 3) had a combined score of 9. As such, the higher the cores obtained, the better the quadrant, or competitive position, of the company and vice versa.

When a company reported no change in earnings (score: 2) in conjunction with an increased market share (score: 3), or vice versa, their combined score was 6. Situations like these, despite illustrating different moments and/or strategies, were taken as being equivalent to one another.

Using this descriptive procedure, the 34 companies in the sample were ranked from the most to the least competitive (Table 3).

One special case was the 15 companies that stated they did not export their products. In order not to lose the information pertaining to these companies' total sales, this score was simply repeated rather than being multiplied by zero. However, the situation of

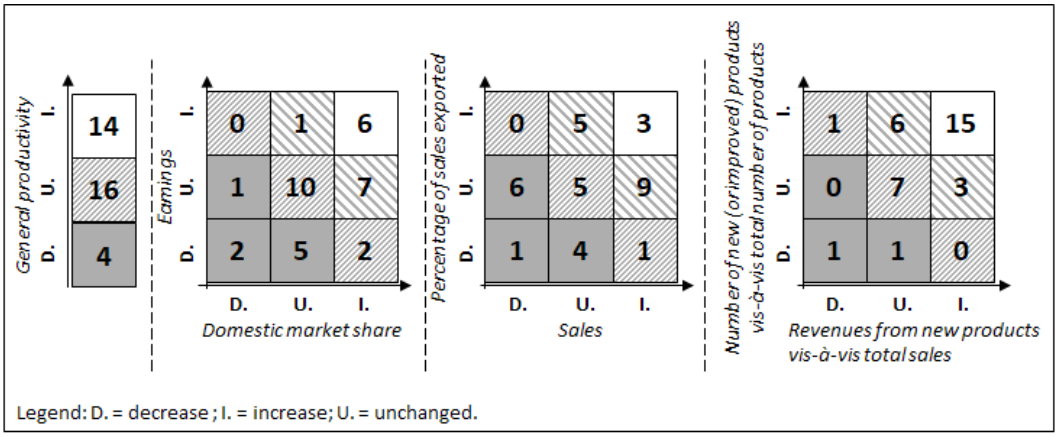

Figure 1. Competitive positions according to combinations of competitiveness indicators.

Table 3. Status of companies according to combined competitiveness indicators.

Company	Productivity	Company	Earnings / Market Share	Company	Total Sales / Exports	Company	Revenues from New products / No. of New products
E01	3	E11	9	E11	9	E11	9
E03	3	E15	9	E15	9	E14	9
E05	3	E27	9	E34	9	E15	9
E08	3	E31	9	E18	6	E20	9
E11	3	E32	9	E22	6	E22	9
E12	3	E33	9	E23	6	E25	9
E14	3	E04	6	E26	6	E26	9
E16	3	E05	6	E29	6	E27	9
E20	3	E06	6	E5	6	E3	9
E25	3	E16	6	E6	6	E31	9
E29	3	E21	6	E17	4	E32	9
E31	3	E22	6	E21	3	E34	9
E33	3	E29	6	E10*	3	E35	9
E34	3	E30	6	E16*	3	E4	9
E04	2	E34	6	E2*	3	E5	9
E07	2	E01	4	E27*	3	E6	9
E10	2	E02	4	E3*	3	E1	6
E13	2	E10	4	E30*	3	E10	6
E15	2	E13	4	E31*	3	E18	6
E17	2	E17	4	E32*	3	E19	6
E18	2	E19	4	E12	2	E21	6
E19	2	E23	4	E13	2	E23	6
E21	2	E25	4	E19	2	E29	6
E22	2	E26	4	E24	2	E30	6
E23	2	E03	3	E35	2	E8	6
E24	2	E14	3	E7	2	E13	4
E26	2	E07	2	E9	2	E16	4
E27	2	E08	2	E1*	2	E17	4
E28	2	E18	2	E25*	2	E2	4
E32	2	E20	2	E33*	2	E33	4
E02	1	E24	2	E4*	2	E7	4
E06	1	E28	2	E20	1	E9	4
E09	1	E09	1	E14*	1	E12	3
E30	1	E12	1	E28*	1	E24	2

*Enterprises that do not export.

company 21 (E21), whose total sales were rising (score: 3) but whose exports were diminishing (score: 1) could be mistaken for the situation of increased total sales (score: 3) combined with zero exports. To distinguish situations of this kind, the 15 companies in question were marked with asterisks.

5.3 Statistical correlation and causal relationship between the innovation competences and competitiveness

The first point to make is that a statistical correlation test is a quantitative data analysis method, but does not signify any causal relationship between the variables under study.

Having characterized the companies for their innovation competences and competitiveness, the next step was to ascertain whether there was any statistical correlation between these variables, using Spearman's rank-order correlation test. The parameters used in this test were: number of companies (n = 34) and alpha (significance) level (0.05). In these conditions, the critical value for comparing the Spearman rank-order coefficient r_s supplied by the test was 0.34.

The test was run four times – one for each combination of competitiveness indicators in comparison with the mean of the mean of each of the three natures of innovation competence. The results are summarized in Table 4.

The r_s value obtained was lower than the critical value in all four situations investigated. This shows that the innovation competences were not statistically associated with competitiveness for the 34 electromedical device manufacturers in the sample. It would seem that in this case, the companies' competitiveness stemmed from factors other than just their capacity to innovate. Further, the indicators of competitiveness could possibly pick up synergic effects from other sources.

If innovation competences are not the most influential factor, this begs two questions: What, then, is the role of innovation? And what other factors have more of an influence on competitiveness? These questions are addressed in the qualitative analysis conducted in the light of the knowledge available in the literature on the industry in question and the definition of competitiveness adopted in this article.

5.4 Causal relationship between innovation competences and competitiveness

In the qualitative analysis of the causal relationship, it became clear that although innovation competences are recognized as one of the main competitive instruments generally at companies' disposal, they are not the variable that has most influence on the competitive performance of the 34 companies studied here.

The capacity to innovate technologically is an essential precondition for penetrating and surviving in the electromedical device industry, but in the companies under analysis, this does not of itself bring about growth or improved performance in the sense used by Guan et al. (2009) or Keupp et al. (2012). In other words, innovation does not necessarily yield a bigger market share or higher profits, as defended by Tidd et al. (2008); nor does an innovation strategy seem to have been one of the most important determinants of corporate competitiveness, as sustained by François et al. (1999).

As mentioned earlier, the manufacturers that answered the survey operate on the competitive periphery of a differentiated oligopoly. Further, they are situated in a developing country whose science and technology capacity is not fully developed in every area related to the target industry (microelectronics, optics, IT, precision mechanics, chemistry, new materials, manufacturing, nanotechnology, and micro-electro-mechanical systems).

Table 4. Results of Spearman's Rank-Order Correlation Test.

Innovation competences of a technical, relational, and organizational nature	Combined indicators of competitiveness	r_s	Critical value with 0.05 significance for n=34
Mean of mean technical, relational, and organizational innovation competences	productivity	0.19	0.34
Mean of mean technical, relational, and organizational innovation competences	"earnings" in combination with "market share"	0.12	
Mean of mean technical, relational, and organizational innovation competences	"exports" in combination with "total sales"	0.18	
Mean of mean technical, relational, and organizational innovation competences	"revenues from new products" in combination with "number of new products"	0.02	

The manufacturers in the sample work with mature technologies that could be made available to any company. They depend on suppliers to provide them with technology-intensive inputs that are likewise available to other companies. Accordingly, their innovations could relatively easily be reproduced by competitors, just as their own products could themselves be reproductions of innovations made by competitors.

One important factor is the commercial performance of companies with new equipment. In the domestic market, the government (directly and indirectly) constitutes the biggest market segment. Thus, when a manufacturer sells a significant portion of its products to this sector, this does not actually represent dependency, but reveals its capacity to adapt to an intrinsic feature of the Brazilian market.

Government purchasing is regulated by specific laws and follows a procedure often considered overly bureaucratic, slow, and skilled-labor-intensive. It is no coincidence, then, that some manufacturers regard selling to the government sector a difficult task given the more complex managerial capacity it demands.

On the State side, the mechanisms used for procurement processes and the policies designed to boost domestic production indicate that government entities are aware of the importance of public demand for the survival and development of domestic manufacturers. However, the manufacturers in our survey reported that these measures are hard to take advantage of, implying they are less than fully effective. It would therefore be worthwhile for policymakers to assess the reach and results of measures such as these.

As for foreign trade, exporting requires a vigorous strategy and compliance with costly and often bureaucratic regulations in the target market. Exporting is also associated – as identified in the survey – with larger companies, and also depends on the availability of distribution networks and technical support abroad, which is beyond the reach of smaller companies. Unsurprisingly, the industry under study shows similarities with the medical, hospital, dental, and laboratory equipment industry as a whole, whose companies also export very little.

Despite the sector project *Brazilian Health Devices* and some success cases of exports, such as incubators for newborns, more still needs to be done. Public policymakers and managers would do well to investigate the feasibility of promoting the scaling up of electromedical device manufacturing companies through mergers and acquisitions. A feasibility study could also be done of an industry joint venture to set up and operate distribution and technical support networks for Brazilian companies from the sector in key selected overseas markets, underpinning both the commercial aspects and the installation and maintenance of the equipment and training needs.

When it comes to the capacity to meet regulatory requirements, this is of crucial importance for success in the industry. On a national level, non-fulfillment of such requirements can at the very least slow down or hamper the introduction of new equipment, and can even lead to a manufacturer's retreating from the market altogether. Internationally, failure to comply with regulations prevents products being sold abroad, restricting Brazilian manufacturers' access to potential markets. Obviously, both situations have a negative impact on the companies' competitiveness and propensity to innovate.

6 Conclusion

In this article, the aim has been to ascertain whether there is a causal relationship between innovation competences and competitiveness in electromedical device manufacturers in Brazil. A sample of 34 companies from an estimated total of 89 answered the survey, which involved a questionnaire containing 55 questions relative to innovation competences and seven about indicators of competitiveness.

The companies were ranked according to their innovation competences of a technical, relational, and organizational nature (Alves, 2005). Next, they were independently ranked for their performance in different combinations of the seven indicators of competitiveness used, namely: productivity (in isolation), earnings in combination with market share, total sales in combination with exports, and revenues from new products in combination with the number of new products.

Finally, the two ranks were paired and examined using Spearman's rank-order correlation test to ascertain whether there was a statistical correlation between them. The test demonstrated that no such statistical correlation existed.

A qualitative analysis revealed that the most prominent competitiveness factor was commercial performance in the market and against the competition. The capacity to sell innovation was the complex innovation competence in which the respondent companies demonstrated the lowest level of development.

In the domestic market, sales to government entities – constituting the largest market segment – require a level of internal organization that not all the manufacturers in the sample had developed. Meanwhile, exporting requires a clear strategic orientation as well as several complementary resources, such as distribution and technical support networks.

In the domestic and foreign markets, the capacity to meet regulatory requirements is paramount, since it is a basic prerequisite for the equipment to be accepted by buyers. However, these requirements are increasingly strict, demanding more internal organization on the part of companies. Clearly, the regulations are necessary to assure safety and effectiveness of equipment, but

they do have the effect of hampering the penetration of foreign equipment in more developed markets, such as Europe or the USA.

Ultimately, it is clear that the most competitive electromedical device manufacturers are not necessarily the ones that are most innovation-forward; they are the ones that adopt the competitive strategies that are most compatible with the level of competition (Ferraz et al., 1996) in this global industry, especially when it comes to commercial capabilities, which are also affected by the capacity to fulfill regulatory requirements.

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