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THE NATURE OF INNOVATION IN LOW-TECH FIRMS

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Tese de Doutorado apresentado ao Programa de Pós-Graduação em Administração da Universidade Federal do Rio Grande do Sul como requisito parcial para a obtenção do título de Doutor em Administração
Orientador: Prof. Dr. Paulo Antônio Zawislak

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The Ride…

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If you always do what you always did, you will always get what you always got.

Albert Einstein

ABSTRACT

Innovation is the impulse to economic development; however, it is mostly understood as a result of high-technology (high-tech) firms and industries. Yet, in many countries, low-technology (low-tech) industries are responsible for a large share of their economies. Reality is much more complex and diverse than the simple dichotomised idea of high/low-tech sectors. There are firms that, despite belonging to a low-tech industry, are innovative. Innovation has many different interpretations and a discussion about innovation from the internal perspective, i.e., capabilities (development – DC, operations – OC, management – MC and transaction – TC), opens up its definition and allows identifying a phenomenon that often has been overlooked. This research's main objective is to understand the nature of innovation in low-tech firms. The proposed goal is achieved through a hybrid-method approach comprising cluster analysis and fuzzy set/qualitative comparative analysis (fs/QCA) with 631 low-tech manufacturing firms. Three types of low-tech firms were identified and, based on their general characteristics, the level of their innovation capabilities and of their innovative performance, they were named Low capabilities, Intermediate capabilities and High capabilities. Overall, Low capabilities low-tech firms have the lowest performance, and High capabilities have the highest. The fsQCA, used to analyse the configurations of innovation capabilities, identified four different possible combinations that lead firms to achieve high innovative performance: TC.MC.dc, TC.mc.DC, TC.MC.oc, and TC.oc.DC. Transaction capability is present in all causal conditions, but it needs is combined with either high-level of development capability or high-level management capability. Therefore, innovative performance in low-tech firms occurs when they follow one of the two patterns of innovation: design-oriented or business-oriented. Currently, only 13% of low-tech firms are highly innovative, however, with the right incentives, this number could grow. Public policies aiming at promoting innovation within Brazilian firms must look into low-tech firms, since they represent a large share of the economy. Managers should identify which pattern of innovation is the most adequate for their firm and, from there, work to improve the necessary capabilities to achieve innovative performance. For example, they may focus on brand development, on enhancing the relationship with suppliers and clients, on integrating all firm's processes and on being up-to-date with the industry's technologies.
Keywords: low-tech industries, low-tech firms, innovation capabilities, patterns of innovation, hybrid-method, fsQCA

RESUMO EXPANDIDO

Inovação é o impulso para o desenvolvimento econômico, e é entendida, sobretudo, como um resultado advindo de setores de alta intensidade tecnológica. No entanto, em muitos países, os setores de baixa intensidade tecnológica, tais como de alimentos, têxteis e calçado, são responsáveis por uma grande parte de suas economias. No Brasil, 76% das empresas pertencem a setores industriais de baixa ou média-baixa tecnologia (IBGE, 2009). A inovação é realmente um produto de esforços realizados exclusivamente por setores de alta tecnologia? A presente Tese preocupa-se em explorar a inovação em setores de baixa tecnologia, especialmente em uma economia emergente como o Brasil. Setores de baixa tecnologia são setores tradicionais que trabalham com tecnologia madura e conhecimento altamente difundido. As empresas nestes setores não necessariamente têm como base de seu sucesso os investimentos em pesquisa e desenvolvimento (P&D). Na verdade, elas são empresas não intensivas em P&D, que produzem os mesmos produtos por longos períodos. A realidade é muito mais complexa e ampla do que a simples ideia dicotômica de setores de alta/baixa tecnologia. Há empresas que, apesar de pertencer a um setor de baixa tecnologia, são inovadoras. Se a inovação é necessária para a sobrevivência e perpetuidade de qualquer empresa, então ela deve estar presente em qualquer setor, independentemente da sua classificação de intensidade tecnológica, seja de alta ou de baixa tecnologia. A inovação tem diferentes interpretações e Schumpeter ([1942] 2008b, p. 83) já a relacionava ao desenvolvimento econômico, dizendo que o impulso para manter o motor capitalista em movimento vem de "novos bens de consumo, novos métodos de produção ou transporte, novos mercados, e novas formas de organização industrial". A expressão muito usada por Schumpeter – *novo* – lembra mudança e, por essa razão, fazer algo novo ou mudar alguma coisa é uma característica inata da inovação, ou seja, é de sua natureza. Em essência, a inovação é o resultado de mudanças impulsionadas pelas capacidades de inovação da empresa (de desenvolvimento, de operação, de gestão e de transação). A configuração interna das capacidades permite que as empresas promovam essa mudança. Essa inovação pode ser em aspectos tecnológicos e de novos produtos, ou referente a outras áreas, muitas vezes esquecidas em estudos de inovação, tais como aquelas relacionadas a novas formas de transação, gestão ou operação. Afinal, qual é a natureza da inovação em empresas de baixa intensidade tecnológica? Este estudo visa contestar a sabedoria convencional e explorar a ideia de que é possível ter empresas inovadoras em setores de baixa intensidade tecnológica. A discussão sobre a inovação a partir da perspectiva interna, ou seja, das capacidades, amplia a definição de inovação e permite identificar um fenômeno que tem sido muitas vezes negligenciado. O principal objetivo da pesquisa é compreender a natureza da inovação nas empresas de baixa tecnologia. O objetivo proposto é atingido por uma combinação de métodos incluindo análise de clusters e *fuzzy set/qualitative comparative analysis (fs/QCA)*. Foram identificados três tipos de empresas de baixa intensidade tecnológica que, com base em suas características, no nível das suas capacidade e do seu desempenho, foram nomeados de Baixa Capacidade, Capacidade Intermediária e Alta Capacidade. No geral, as empresas de Baixa Capacidade têm o menor desempenho dentre as empresas, e as empresas de Alta Capacidade, o melhor. O método fsQCA foi usado para explorar possíveis configurações de capacidades que impactam na inovação das empresas e identificou quatro diferentes combinações possíveis que levam as empresas de baixa tecnologia a alcançar um alto desempenho inovador: TC.MC.dc, TC.mc.DC, TC.MC.oc, TC.oc.DC. A capacidade de transação está presente em todas as configurações, mas precisa estar combinada com um alto nível de capacidade de gestão ou de desenvolvimento, independentemente do nível das outras capacidades. Portanto, o desempenho inovador em empresas de baixa tecnologia ocorre quando eles seguem um dos dois padrões de inovação: orientadas para o design ou orientadas para os negócios. Atualmente, apenas 13% das empresas de baixa tecnologia são altamente inovadores, no entanto, com os incentivos adequados, esse número pode crescer. As políticas públicas que visam a promoção da inovação dentro das empresas brasileiras devem olhar para aquelas de baixa tecnologia, uma vez que representam uma grande fatia da economia. Os gestores devem identificar qual padrão de inovação é o mais adequado para sua empresa e, a partir disso, trabalhar para melhorar as capacidades necessárias para alcançar um desempenho inovador. Por exemplo, focar no desenvolvimento da marca, no reforço do relacionamento com fornecedores e clientes, na integração de todos os processos da empresa e em se manter atualizados com as tecnologias do setor. Com a identificação dessas configurações, é possível combinar quais delas são mais apropriados para as os diferentes tipos de empresas. Isso permitirá que as empresas escolham o padrão mais adequado de inovação, dependendo de suas características, pontos fortes e fracos, uma vez que não existe uma única "melhor" maneira de ser inovador. Após analisar o conjunto de todas essas informações, uma compreensão mais rica do que é, de fato, a natureza da inovação nas empresas de baixa intensidade tecnológica foi finalmente possível.

Palavras-chave: setores de baixa intensidade tecnológica, empresas de baixa intensidade tecnológica, capacidades de inovação, padrões de inovação, método híbrido, fsQCA

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1 Introduction

Innovation is the impulse to economic development; however, it is mostly understood as a result of high-technology (high-tech) firms and industries. Industries such as aircraft, pharmaceuticals, computing machinery and communications equipment, for instance, often require years of research to launch new products. Yet, in many countries, low-technology (low-tech) industries such as food and beverages, textiles and footwear, and wood and paper products are responsible for a large share of their economies.

Many would think that in developed countries, such as the United States, Japan and Germany, high-tech industries drive much of their economies; however, they represent only 3 to 10% of modern economies, while the majority of economic activity happens in established sectors (Hirsch-Kreinsen et al., 2008). In Brazil, 76% of companies belong to a low or medium-low-technology sector, when considering only manufacturing industries (IBGE, 2009). If services and agriculture were considered, this proportion would be even more preeminent. Additionally, considering the size of an industry by its employment capacity, the three largest (most labour-intensive) manufacturing sectors in Brazil are low-tech (food and beverages, apparel, and textiles) according to statistical data from the Ministry of Development, Industry and Foreign Trade – MDIC (2012). Agribusiness' related industries alone represent 23% of Brazilian GDP (Valor Economico, 2014). In that context, the relevance of low-tech industries to innovation should not be underestimated (Hirsch-Kreinsen, 2015).

Is innovation really a product exclusive from efforts of high-tech industries? Once high technologies mature, can high-tech industries continue to be innovative? Conversely, is value merely a transitory element in low-tech industries, or can they add value through innovation? Regardless of a country's development status, there are more firms from mature sectors than working close to technology limits. As put by Von Tunzelmann and Acha (2005, p. 407), there is a "policy obsession" in fulfilling the gaps in high-tech industries, which has been taking "the attention of both policy makers and academics away from making more positive efforts to develop and sustain development in other sectoral directions which some countries might find more viable". Therefore, it is a concern of this Thesis to explore innovation in low-tech industries, especially in an emerging economy like Brazil.

What does it mean to be high-tech or low-tech? There is a myriad of firms and industries classifications, typologies and taxonomies, but one of the most known is the Organization for

Economic Cooperation and Development – OECD's (2011), that classifies industries into four levels: high, medium-high, medium-low and low-technology intensity. It is for the purpose of comparison that the extremes high and low-tech are used in this Thesis.

High-tech industries are those developing state of the art technologies and products. Research and development (R&D) is the basis of high-tech industries. To work on the knowledge frontier, firms within these industries not only invest in R&D, but also on patenting and on the expertise of scientific and technical personnel. These firms must be very dynamic to survive, otherwise their knowledge and technologies quickly become obsolete.

In the other end, there are the low-tech industries, which are traditional sectors working with mature technology and highly diffused knowledge. Firms within these sectors do not necessarily base their success on research and development investments. In fact, they are non-R&D-intensive firms that produce the same products for long periods. Their products are no longer complex and their processes are standardised and routinized.

Scientific studies, public policies and common sense have a dichotomized view relying on high-tech industries to promote innovation and on low-tech industries to do nothing more than what they have always been doing. Computers and mobile phones, for instance, make the imaginary of most people. Even among scholars, there is a tendency to praise high-tech industries. Studies on innovation have long been focusing on high-tech industries, firms and products (Adler & Shenbar, 1990; Afuah, 2002; Jin & Zedtwitz, 2008); Prahalad & Hamel, 1990; Teece, 1986; Wang et al., 2008). There are some empirical regularities in industrial structures and dynamics (Pavitt, 1984), as well as characteristics that are common to all industries. Additionally, there are unique characteristics to each sector that influence the sectoral change process (Dosi et al., 1995). In this sense, firms from these sectors should be more subject to innovation than the low-tech ones.

It seems that all these views divide economies in industries acting on the technological frontier, where advanced knowledge is pivotal to development, the so-called *high-tech industries*, and in traditional stagnant ones, with few technical progress achievements, the *low-tech industries*.

While the formal description of high and low-tech industries indicates that high-tech industries are innovative and low-tech are not, there are exceptions. *Reality is much more complex and diverse than the simple dichotomised idea of high/low-tech sectors and innovative/non-innovative firms.* While all high-tech firms must invest in R&D activities to follow the rapid pace changes in their industries, not all firms that invest in R&D are exclusively from high-tech industries. Low-tech firms may also invest in R&D. Additionally, there are firms that, despite belonging to a high-tech industry, are not innovative; conversely, there are innovative low-tech firms[1].

Given this discussion, how do low-tech firms innovate? Considering that **innovation** is the result of efforts to create, to adapt and, ultimately, to change, as long as there is a positive economic impact, then, it does not necessarily has to be based on R&D investments. Moreover, *if innovation is the requirement for any firm's survival and perpetuity, then it should be present in any industry, irrespective of their technology intensity classification, whether high or low-tech*.

The ideas exposed so far give way to some questions: are all those widespread characteristics, definitions and assumptions about low-tech industries only a stigma, or are low-tech firms really trapped in a non-innovative fate? Are low-tech firms locked in traditional technologies and reluctant to new advances, or is it their choice not to change? Can low-tech firms dream only of low-tech innovation or can they dream of high-tech innovation? Can low-tech firms choose to act like high-tech firms? If so, what makes these firms follow a different innovation pattern than that set by their sector? What are these patterns?

Innovation has many different interpretations, and upcoming studies should explore them. Schumpeter ([1942] 2008b, p. 83), relating innovation to economic development, have already said that the impulse to keep the capitalist engine in motion comes from "the new consumers' goods, the new methods of production or transportation, the new markets, the new forms of industrial organization". The expression much used by Schumpeter - *new* - reminds of something that have changed. For that reason, to change or to do something new is an innate characteristic of innovation; it is its *nature*. Where do these changes come from? In essence, innovation is the result of changes driven by firm's innovation capabilities (related not only to new products, but also to new processes, new markets or new business models).

If innovation is not a privilege of high-tech firms, if it is not related exclusively to technology, if it is not determined only by sectoral patterns, and if common sense has a narrow view to its definition, then, *there is innovation in low-tech firms*.

Firms shifting from non-innovative to innovative trajectories go beyond what is established in their industry and change their internal organizational standards. The internal *configuration of capabilities* allows firms to promote change, and consequently, to innovate, whether in the technological and new products aspects, or in other areas, often overlooked in

1 From hereafter, the term *low-tech firms* refers to firms that belong to an industry classified as low-technology intensity, irrespective of their innovative status. The same is valid for *high-tech firms*. The term refers to firms that belong to an industry classified as high-technology intensity, irrespective if they are innovative or not.

innovation studies, such as those related to new forms of operation, management or transaction. Thus, although there are characteristics that are common to a sector, every sector has heterogeneous firms with specific knowledge, learning processes, competencies, organizational structure and objectives. In fact, "low-, medium- and high-technology sectors consist of a considerable mix of low-, medium- and high-technology firms" (Kirner et al., 2009, p. 447). The industry classification is not the only factor responsible for determining a firm's innovative performance. *What are, after all, the core aspects or the essence related to innovation in low-tech firms?* A central question, then, arises:

What is the nature of innovation in low-tech firms?

This study aims to challenge the conventional wisdom and to explore further the idea that it is possible to have innovative firms in low-tech industries. This research goes deeper in the issue of innovation in low-tech firms, since it is still not only a neglected area of study, but also the major part of Brazilian economy. A discussion about innovation from the internal perspective, i.e., capabilities, opens up the definition of innovation and allows identifying a phenomenon that often has been overlooked.

The research's *main objective* is *to understand the nature of innovation in low-tech firms*, in other words, to understand the essential qualities, the innate disposition of low-tech firms that are able to innovate. The following *specific goals* are set in order to achieve the referred main objective:

- To describe low-tech firms in terms of their general characteristics;
- To identify types of low-tech firms within the capabilities' approach;
- To define configurations of innovation capabilities that enable low-tech firms to achieve innovative performance; and
- To define the patterns of innovation in low-tech firms by undertaking a complementary approach based on the types of low-tech firms and the configuration of innovation capabilities.

The proposed goals will be achieved through hybrid-methods. Secondary data were used to perform statistical analysis. As a researcher at the NITEC Innovation Research Center (Federal University of Rio Grande do Sul – UFRGS), I was involved in a four-year-project (2010-2014) that aimed at identifying the "Paths of Innovation in the Brazilian Industry" using an innovation capabilities model develop by us.

Quantitative data used in this work were collected in the innovation survey carried out during the final year of the research project. Survey information on low-tech firms (631 low-tech firms out of 1331 manufacturing firms from all manufacturing industries) was used to describe low-tech firms and to define types of low-tech firms.

Once the types were identified and their characteristics were described, a set-membership analytical technique (Fuzzy Set/Qualitative Comparative Analysis – fsQCA) was used to explore possible configurations of innovation capabilities in order to achieve innovative performance. With the identification of the causal conditions, it was possible to match the most appropriate capabilities' configurations for each type of low-tech firm, and consequently, to define the patterns of innovation in low-tech firms. Thus, *there is not only one best way to be innovative*, and each firm should find the most appropriate pattern of innovation to them, depending on their characteristics, strengths and weaknesses.

After all information was gathered, it was finally possible to have a richer understanding of what is, in fact, the nature of innovation in low-tech firms.

Since emerging economies do not depend on high-tech firms to survive, but rely heavily on low-tech manufacturing firms, the opportunity to broaden the definition of innovation beyond technology-related terms should not only complement theoretical concepts, but also help policy-makers to appropriately support low-tech firms' development, and consequently, their region's economy.

In the following chapters, literature review uncovers innovation in low-tech firms. In chapter 2, there is a discussion on industry technological intensity and on firm innovation capabilities, including a critical view on OECD's industry classification, an overview of definitions for high and low-tech industries, and a discussion on sectoral approaches to innovation and on innovation capabilities of the firm. After that, in chapter 3, the nature of innovation in low-tech firms is discussed, including low-tech innovation examples and the presentation of theoretical patterns of innovation in low-tech firms. In chapter 4, the method used in this research is explained, elucidating the hybrid-method approach, which includes correlation-based analysis as well as comparative qualitative analysis. Next, the analysis results are presented and discussed. This includes low-tech firms' general characteristics in chapter 5, factor and cluster analysis to define the types of low-tech firms in chapter 6, qualitative comparative analysis to identify configurations of capabilities that lead to innovative performance in chapter 7, and a combined approach to identify the patterns of innovation in low-tech firms in chapter 8. Finally, conclusions about the nature of innovation in low-tech firms, implications and limitations of the study are outlined in chapter 9.

2 Uncovering Industry Technological Intensity and Firm Innovation Capabilities

Economic development has long been associated with innovation, and innovation, with technical progress (Schumpeter, 1911). However, as innovation has been largely studied, it may be understood in different types and intensities, for example, architectural (Henderson & Clark, 1990) or incremental and radical (Ettlie et al., 1984; Freeman, 1995; Freeman & Perez, 1988), but it is mostly measured through industry R&D intensity indicators.

Developing from earlier works, OECD's industry intensity classification has become a sort of "golden rule" in sectoral innovation studies. It classifies manufacturing industries according to their investments in R&D activities.

This section brings an overview of the industry technological intensity, definitions for high and low-technological industries, literature review of sectoral approaches to innovation, and delineations about firm innovation capabilities. In doing that, it is possible to go further and discuss, in the next chapter, the patterns of innovation in low-tech firms.

2.1 Industry Technological Intensity

In 1947, the US President's Scientific Research Board introduced R&D expenditure as a percentage of national income as a policy indicator. By the 1950s, most companies were using similar indicators to measure their technological performance, like R&D as a percentage of earnings, sales or value-added (Godin, 2008). Different ways to identify national or industries' R&D expenditure became the tangible way to analyse technological performance: "from an analytical point of view, the statistic served to assess and compare the relative efforts of industries in terms of R&D and to look at the impact of R&D on industries' economic performance" (Godin, 2008, p. 66). Som and Kirner (2015, p. 1) highlighted that R&D activities "have received the greatest degree of study in attempts to explain the levels of innovation and competitiveness of enterprises, specific economic sectors and entire economies". Policy-makers continue to establish targets of R&D expenditure as a way to promote national economic growth.

Research and development indicators have been the origin of technological intensity classification. Hoffmeyer coined the term research intensity in 1958, but it was not up to Freeman, Poignant and Svennilson's publication Economics Science, in 1963, of the OECD's research program, that industry groups were classified according to the ratio of R&D expenditures to sales (Godin, 2008). By then, what is now called *high-technology intensity industries* was identified as *research-intensive industries*. All other sectors were not pertinent to the study and were classified as *non-technology intensive*. The *high-technology* term started to be used in the mid-1980s. It was at that time that OECD established three categories based on intensity: high, medium and low (Godin, 2008). Nowadays, OECD (2011) classification comprises four levels of industry intensity: high-technology, medium-high-technology, medium-low-technology, and low-technology (Figure 1).

High-technology industries	Medium-high-technology industries
Aircraft ad spacecraft Pharmaceuticals Office, accounting and computing machinery Radio, TV and communications equipment Medical, precision and optical instruments	Electrical machinery and apparatus, n.e.c. Motor vehicles, trailers and semi-trailers Chemicals excluding pharmaceuticals Railroad equipment and transport equipment, n.e.c. Machinery and equipment, n.e.c.
Medium-low-technology industries	**Low-technology industries**
Building and repairing of ships and boats Rubber and plastics products Coke, refined petroleum products and nuclear fuel Other non-metallic mineral products Basic metals and fabricated metal products	Manufacturing, n.e.c.; Recycling Wood, pulp, paper, paper products, printing and publishing Food products, beverages and tobacco Textiles, textile products, leather and footwear

Figure 1 – Classification of Manufacturing Industries into Categories based on R&D Intensities
Font: OECD (2011)

Different authors use different R&D intensity in their studies (Hirsch-Kreinsen, 2008; Hirsch-Kreinsen et al., 2006; Kirner et al., 2009), mostly relying on OECD’s classification. The Joint Research Centre of the European Commission, in an OECD (2014) publication, presents the following classification: (i) low-tech, below 1.0% of R&D expenditures over revenue; (ii) medium-low-tech, between 1.0% and 2.5%; (iii) medium-high-tech, between 2.5% and 7%; and (iv) high-tech, above 7%.

OECD’s (2011) traditional classification based on R&D investments, although largely accepted, is often criticized by authors who study innovation in low-tech industries (for example: Bender, 2008; Christensen, 1995; Hirsch-Kreinsen et al., 2008; Raymond et al.; 2006; Robertson & Smith, 2008; Von Tunzelmann & Acha, 2005), who say that it is a simplistic view for economic prosperity (Hansen & Winther, 2011). Why was it so diffused then? According to Smith (2014, p. 24), the emphasis on the high-tech issue was not just a matter of OECD’s classification, but rather that it “rested on a complex background of research assumptions, political and science policy notions, statistical categories and business history”. However, OECD classification has become so strong that the qualifications of measurement have been forgotten (Robertson & Smith, 2008).

2.2 An Analytical View on OECD’s Industry Classification

“Most studies define non-R&D-intensive firms based on their sector affiliation; firms that are located in the OECD classification of low- or/and medium-low-tech industries are summarily defined as non-R&D-Intensive” (Som & Kirner, 2015, p. 9). However, Von Tunzelmann and Acha (2005) believe that OECD classification is becoming ever less useful for academic analysis as it does not represent low-tech firms’ reality.

Grinstein and Goldman (2006, p. 121) argued “the commonly used practice of classifying firms as high and low-technology according to the industry to which they belong is flawed”. A problem of this industry classification is that innovation is conceptualized only in terms of science or R&D investments and, as a result, low-tech industries would have little to contribute (Hoveskog, 2011). Finally, it “tends to promote the misconception that ‘low-technology’ industries (as defined in terms of R&D ratios) are necessarily also ‘low innovation’ industries” (Christensen, 1995, p. 737). However, they are not, as “new and old technologies generally co-exist in the complex production methods that characterize major sectors” (Robertson & Patel, 2007, p. 708).

This classification have unsettled many authors (Bender, 2008; Christensen, 1995; Godin, 2008; Grinstein & Goldman, 2006; Hirsch-Kreinsen et al., 2008; Mendonca, 2009; Raymond et al., 2006; Robertson & Smith, 2008; Von Tunzelmann & Acha, 2005) because it leaves low-tech industries out of the traditional measure of R&D expenditure, and thus, out of the innovation processes. When only R&D indicators are used to measure innovation, innovation by certain firms are not captured properly, resulting in a deceiving classification as ‘non-innovative’ (Arundel et al., 2008). These firms often end up being neglected by academic research and the policy-making community (Som & Kirner, 2015).

Raymond et al. (2006, p. 86) also bring an important aspect to this topic: “OECD taxonomy is based on a single innovation-input indicator, namely R&D intensity. This is too narrow”. Using only R&D intensity as an innovation measure “has reduced innovation to very few things” (Godin, 2008, p. 77). It ignores and underestimates “innovative dynamics that are primarily based on process development, functional product application and aesthetic design" (Christensen, 1995, p. 737).

These arguments make clear the need to widen the ways to analyse and to evaluate innovation. A way to do it is to include indicators relative to entrepreneurship, firm structure, organizational coordination and value added (Marins, 2010; Zawislak & Marins, 2013), or indicators about innovativeness and level of technology in an economy (for example, R&D intensity, design intensity, technological intensity, skill intensity, innovation intensity, and organizational innovativeness) (Hirsch-Kreinsen & Bender, 2007).

For Zawislak and Marins (2013), the need to expand traditional measures of innovation is because they are based on a linear logic (from basic research, to applied research, then to experimental development and, finally, to production and commercialization of new technologies). Similarly, when Bender (2008) challenged the basic assumption of linear model of innovation (there is a sequence from scientific research to marketable products); he said, "if this was true, technological innovations in non-research-intensive industries – low-tech industries […] – would by definition be derivational phenomena". He continues saying that "innovators in these sectors would only use what others produce, that is to say, live on the pool of knowledge fed from […] basic research. This is of course not true" (p. 25).

This is especially problematic in emerging economies, where there are fewer resources to innovate (Zawislak & Marins, 2013). For Katz (2006), spending on R&D has always been low in Latin America. He adds that, to achieve better performance and enhance international competitiveness, besides expanding R&D efforts, it is necessary to heighten the efficiency with which domestic knowledge-generation activities are organized. Dutrenit (2004, p. 217), when studying manufacturing latecomers firms, said that most studies have focused on "technological learning and on the accumulation of technological knowledge rather than on the interaction between technological and organizational factors".

In relation to knowledge, Von Tunzelmann and Acha (2005) said that innovation analysis should also relate to knowledge search rather than basic research. In relation to learning, Robertson and Smith (2008) said innovation should rest on learning (recombining or adapting existing forms of knowledge) rather than on discovery. Distributed knowledge base compensates many low and medium-low-tech sectors for their low R&D expenditures, in other words, "a low-R&D industry may well be a major user of knowledge generated elsewhere" (Robertson & Smith, 2008, p. 97). It means that not only do many innovations diffuse to multiple sectors, but also low and medium technology sectors are often customers of high-tech producers (Robertson & Patel, 2007). Therefore, *industrial development through innovation* *would depend on multiple relations within and across industries*, as "it is often forgotten that low-tech firms fulfil important roles both as partners in high-tech firms' innovation process and as buyers of high-tech products" (Hansen & Winther, 2011, p. 322).

In this sense, it is not necessary that all firms from all industries carry out basic research to succeed. Christensen (1995) proposed a differentiation of the 'R' component and the 'D' component of R&D. For him, "industrial innovation can generally be better understood in terms of asset profiles associated with product-market challenges than in terms of R&D intensity or ideal types of firms" (p. 728).

Raymond et al. (2006) suggested an alternative industry categorization. They analysed manufacturing firms based on a model of economic behaviour. The proposed taxonomy comprehends a high-tech category (including chemicals, electrical, machinery and equipment, plastic and vehicles industries), a low-tech category (including food, metals, non-metallic products and textiles) and the wood industry. Their results show that there are more sectors included in OECD's high-tech category within the Dutch's industry structure.

In trying to adapt OECD's classification to emerging economies, Furtado and Carvalho (2005) studied Brazilian industries. They did not mean to create a new classification but, rather, to show that, in environments outside the OECD countries' boundaries, the classification might be different. In the Brazilian case, they narrowed high-tech industries to electrical machinery and apparatus and transport equipment only, and expanded low-tech industries in a way as to include metals and fabricated metal products and non-metallic mineral products on top of all OECD's low-tech industries.

Other authors have also attempted to reclassify Brazilian manufacturing industries (Zawislak et al., 2012a) under the rationale that international standards such as OECD's often miss part of the reality when looking at developing countries. In their classification, using technology specificity and organizational structure, the low-tech intensity category has been reduced to only three industries: wood products, clothing and accessories, and leather goods and footwear. Industries such as textiles, publishing and printing, furniture, food and beverages, pulp and paper products, and tobacco, which are low-tech according to OECD categorization, have been reclassified as medium-low or medium-high.

* * *

Despite some efforts to propose new industry categorizations, they have not replaced OECD's classification. Many authors and institutional organizations continue to use this technological intensity classification in their studies and reports. The intention with the industry intensity discussion is not to propose a new categorization, but to use it as a way to delimit the approach of the study to low-tech industries. There is still more to be studied to understand innovation in low-tech firms, considering that an industry classification should not be a firm's innovative fate. Although there are criticism towards the restricted view of OECD, to allow for future comparisson with international studies, low-tech industries are in accordance to OECD's classification.

There are industries following different technological trajectories; some are more mature, while others are in the technological frontier and some use simple technologies, while others use complex ones. Industries acting on the technological frontier and developing complex products naturally have more R&D activities than those applying mature technology. Therefore, the most accepted and used industry classification is OECD's, since it considers the level of R&D intensity in each industry. In that sense, the more intensive and industry is, the more it invests in R&D. Consequently, the more it registers patents, employs scientists and so on. These activities are seen more frequently and more intensively in sectors named high-tech by OECD. On the other extreme, according to the classification, the mature industries investing less in these activities are low-tech.

It was expected that by analysing the classification from OECD more carefully, many authors would identify some limitations of this classification. It is, then, necessary to define high and low-tech industries, not only according to OECD, but also, to include other aspects deemed relevant to this research.

2.3 Definitions for High and Low-Tech Industries[2]

From the point of view of the OECD's (2011) technological intensity classification, an innovative firm that represents a *high-tech industry* invest in research and development (R&D) activities, have PhDs performing in-house research and register intellectual property. In this sense, high-tech industries are understood as those developing state of the art technologies and products. Research and development is the basis of high-tech industries' activities. To work on the knowledge frontier, firms within these industries not only invest in R&D, but also, on

[2] There are more levels in which industries may be divided, such as OECD's low, medium-low, medium-high and high-tech industry technological intensity. However, for the purpose of comparison and of clarifying the definition of low-tech industries, the extremes high and low-tech are used.

patenting and on the expertise of scientific and technical personnel, so they can develop new products and technologies that aggregate value. The market expects these industries will be always offering them some *novelty*. These firms must be very dynamic to survive, otherwise their knowledge and technologies becomes obsolete quickly.

OECD’s (2011) characteristics deposited in high-tech firms leave little room for traditional industries to enter in the innovation cycle. *Low-tech industries* are traditional sectors working with mature and highly diffused technologies. Firms within these sectors do not necessarily base their success on research and development investments. In fact, they are non-R&D-intensive firms that produce the same products for long periods. Instead of offering novelties to the market, the offer variations of current products. They use existing technology and focus on minor improvements of low complexity products, of commercial techniques and of routine coordination. Low-tech firms are more business-oriented than technology-oriented.

For Bhattacharya and Bloch (2004), R&D intensity influences successive innovation in high-tech industries. Hatzichronoglou (1997, p. 4), on behalf of OECD, has defined high-technology industries as “those expanding most strongly in international trade and their dynamism helps to improve performance in other sectors (spill over)”. For him, research is an extremely important characteristic of high-technology, but it is not the only one. There are other factors defining high-tech industries, such as “scientific and technical personnel, technology embodied in patents, licenses and know-how, strategic technical co-operation between companies, the rapid obsolescence of the knowledge available, quick turnover of equipment, etc.” (p. 8).

One of these expressions in particular (Hatzichronoglou, 1997), “the rapid obsolescence of the knowledge available”, sets the limit of high and low-tech industries. The way all industries are organized is not static, since any industry is bound to follow the ‘S curve’ of innovation path. At some point, a nascent high-technology sector will mature. As Morceiro et al. (2011, p. 8) said, “the technological and industrial dynamic causes the high-tech industries of today to become the medium or low-tech ones of tomorrow”.

For that reason, high-tech industries must be reinventing themselves all the time, and thus, the nature of their innovation is based on R&D activities. To act on the knowledge frontier, they must invest on basic research. To bring their new discoveries to the market, they must have a strong product and technology development driver.

To describe low-tech intensity industries many authors use different terms such as non-research intensive (Hirsch-Kreinsen & Schwinge, 2011), non-R&D-intensive (Mattes et al., 2015; Wydra & Nusser, 2015), mature (Von Tunzelmann & Acha), traditional (Mendonca, 2009; Reichstein et al., 2008), established and old (Roberson & Smith, 2008). Robertson and Smith (2008, p. 94) define established industries as “sectors that have been offering variations on essentially the same product for many years and have gone through long periods of evolutionary change”. They are in a stage of well-known and shared knowledge (Morceiro et al., 2011), where innovation is strongly path-dependent and “processes and products are not only highly standardised and routinized but also at an advanced stage” (Hirsch-Kreinsen & Schwinge, 2011, p. 4).

As opposed to Hatzichronoglou’s (1997) view of high-tech industries, knowledge in low-tech industries is stable. These industries focus on manufacturing and engineering routine based-processes, on marketing and aesthetic design capabilities (Christensen, 1995), as well as they depend on their suppliers to promote technological change (Bell & Pavitt, 1995).

From the definitions presented, one could only expect innovation as an output of high-tech industries. This is fallacious though. Firms from low-tech industries are usually seen as non-innovative; however, it has been argued that it is a mistaken assumption. Innovation in low-tech sectors is normally related to changes in methods of production and in product design (Bell & Pavitt, 1995), equipment acquisition (Bell & Pavitt, 1995), knowledge search (Von Tunzelmann & Acha, 2005), knowledge recombination (Robertson & Smith, 2008), manufacturing, engineering and design (Christensen, 1995), relationships and integration with customers and suppliers (Hoveskog, 2011), networking and partnerships, especially with high-tech industries (Hansen & Winther, 2011), and investment in operational areas (Robertson & Smith, 2008).

In that sense, the nature of innovation in low-tech firms is much broader than in high-tech firms, which are strongly dependent on R&D activities. Low-tech firms may innovate in relation to their operational process and equipment, in relation to business models or commercial models and, similarly to what happens in high-tech industries, through new product development.

For Hirsch-Kreinsen et al. (2008, p. 4), sectors classed as low and medium-tech “are by the schema’s definition relatively stagnant due to their low levels of investment in R&D”. However, as their studies have shown, they are quite dynamic technologically. For them, these industries are an important element in the innovativeness and effectiveness of industrial value chains. The innovation strategies of low-tech firms extend from production of simple and standardized goods, usually developed though incremental innovation, to productive, highly flexible and market-oriented solutions (Mattes et al., 2015).

* * *

Given the difference in product and technology complexity, for instance, it is natural that high-tech industries will end up having R&D activities more complex than the ones carried out within low-tech industries, since the technology the later use is mature and diffused. Additionally, there are widespread definitions inferring that innovation is not the usual outcome of low-tech industries. However, many studies have demystified it and, from the definitions raised, it is now possible to say that innovation can be generated in low-tech industries.

Innovation is still closely related to technology, but as presented by many authors, it may have different facets and be related to commercial relationships, to knowledge recombination or to equipment acquisition. In general terms, while the nature of innovation in high-tech firms is technology-oriented, in low-tech firms is business-oriented.

Regardless of the more traditional definition, when considering that the nature of innovation relates to change, and that low-tech industries are capable of changing (by developing new production processes, developing new design for their existing products, incrementing their knowledge, making new partnerships with suppliers and clients, and so on), it is clear that low-tech industries can be innovative. Inversely, there can be high-tech industries that become stagnant and no longer innovative.

For example, the Brazilian pharmaceutical industry merely reproduces what has been developed elsewhere. Although it is classified as a high-tech industry, the majority of firms in this sector in Brazil do not create anything new and are not innovative, because they work mostly with expired international patents and focus on operations and logistics. Conversely, there is a Brazilian furniture company established more than 50 years ago that, today, is leader in the country on its segment as a furniture industry supplier of glass and aluminium doors. They offer differentiated products with innovative design and patterns. Albeit being a low-tech industry firm, its focus is on product development. As their management team mentioned, design and innovation are the engines of the company. This can be seen on this firm's daily routines, which involve research for new materials and technologies and development of new products. Part of these activities happen on its laboratory located in Europe, so they guarantee they are close to the latest novelties in the industry. To work on product development the company has a multidisciplinary team including renowned designers and architects to think constantly about innovative products. This is an innovative low-tech firm advancing the industry knowledge frontier.

Another example is a Brazilian public company (Brazilian Agricultural Research Corporation – Embrapa) that focuses on generating knowledge and technology to Brazilian agriculture. Since it was first established, in 1973, it has been developing a model of genuine tropical agriculture and livestock with the aim to overcome barriers to the production of food, fibre and energy in Brazil. These efforts have helped to promote changes in the industry, such as being able to expand beef and pork supply four times and chicken supply 22 times. The innovations within the industry have not only affected individual companies or the internal economy, but also, Brazilian international economic relations, since the country went from a basic food importer to one of the largest food producer and exporter (Embrapa, 2015).

The term "low-tech" is no longer synonymous of "no innovation".

In this sense, industry intensity classification is not enough to define innovation. While it takes more than an industry classification to determine a firm innovative performance, one cannot deny the sectoral influence on firms' trajectory. As given in the examples, there are exceptions within an industry; however, sectors still play an important role in determining the innovation pattern a firm is embedded due to its technological trajectory and market expectations. The following subsection deepens the industry approach to the sectoral approaches to innovation.

2.4 Approaches to Innovation Activities

Although it has been presented an alternative point of view that emphasizes the heterogeneity of firms within an industry, i.e. to be more or less innovative, in spite of the sector, it is impossible to ignore that environmental factors, such as the technological basis of an industry and the complexity of its routines, will influence firms within that sector. In some industries, the innovative activities are fast-paced and focused on novelties and, to follow that, their routines are more dynamic than in other industries. In other industries, the routine activities are simpler and, therefore, their innovative activities also are.

The differences in the organization of innovative activities at the industry level may be related to two Schumpeterian models (Schumpeterian Marks I and II – Freeman, 1982). The first model is characterized by "creative destruction" with technological ease of entry and a significant role played by entrepreneurs and new firms in innovative activities. The second model is characterized by "creative accumulation", where few large companies dominate the innovative activities within the sector, resulting in relevant barriers to new entrants. It is possible, however, that an industry moves from the first to the second model (Malerba, 2002).

Initial views of sectoral studies are criticized for their unilateral approach. They focused either on the industry structure, or solely on technology and production systems. Authors who study sectoral dynamics (Breschi et al., 2000; Malerba, 2002; Malerba & Orsenigo 1996a; 1997; 2000) – evolving from seminal contributions from Nelson and Winter (1982), Winter (1984), Freeman (1982), Pavitt (1984), Dosi (1988) and Dosi et al. (1995) – went further on sectoral systems of innovation studies. They sought to present a multidimensional, integrated and dynamic industry approach where innovation is an interactive process.

Studies mentioning the Schumpeterian Marks I and II tradition and following Mark II (Breschi et al., 2000; Castelacci and Zheng, 2010; Fontana et al., 2012; Malerba, 2002; Malerba & Orsenigo, 1996b; 1997) use two main approaches, one centred on the firm and another, on the relationship between market structure and the rate of innovation. Nevertheless, empirical analysis of these models does not address the role of opportunity and appropriability conditions in different sectors, neither have they considered the endogenous relationship between firm size, concentration and technological change (Malerba & Orsenigo, 1997).

Malerba and Orsenigo (1997) consider that the combination of technological properties include opportunity and appropriability conditions, degrees of cumulativeness of technological knowledge, and characteristics of the relevant knowledge base. For them, *opportunity* conditions reflect the easiness of innovating in relation to the resources invested in search; *appropriability* conditions summarize the possibilities of protecting innovations from imitation and of extracting profits from innovative activities; *cumulativeness* conditions refer to a firm innovation trajectory, and; *knowledge base* refers to the properties of the knowledge upon which firms' innovative activities are based (Malerba & Orsenigo, 1997).

Dosi (1988) and Malerba (2002) have also addressed differences between sectors in terms of knowledge, sources of technological opportunities and the learning process that leads to innovation. In this sense, it is observed that some sectors are related to science-based knowledge, while others incorporate new technologies based on knowledge that originates in other industries (Dosi, 1988; Malerba & Orsenigo, 1997; Robertson & Smith, 2008). These behaviours would be commonly seen, respectively, in sectors considered of high and low-technology. Knowledge used in *lower* technology industries may be related to what Malerba and Orsenigo (1997) called *generic, simple* and *tacit knowledge*, as opposed to *specific, codified* and *complex knowledge* needed in the *higher* technological sectors.

Instead of seeing sectors as more or less technological, Pavitt (1984) was worried with the determinants, directions and measures for sectoral technological trajectories. Pavitt (1984) developed a taxonomy based on *firms*: supplier dominated, scale-intensive, specialised equipment supplier, and science-based. His aim was to describe and explain similarities and differences amongst sector in the sources, nature and impact of innovations, based on sources of technology used, institutional sources and nature of the technology produced, and innovating firms' characteristics.

In an industry that, for example, is classified by OECD (2011) as low-tech, there could be any of Pavitt's (1984) industry types. In that sense, it is possible to have a firm within a low-tech industry that is supplier dominated and another firm, within the same industry, that is scale-intensive. From this point of view, Pavitt's (1984) taxonomy does not have an excluding connotation.

Later, together with Bell (Bell & Pavitt, 1995), he categorized the technological level of firms according to their industry. In doing that, they considered traditional manufacturing industries as typically dependent on their suppliers in relation to technological change. In such cases, most improvements and changes relate to production methods and product design, rather than radical changes. In this type of industry, technological transfer is a common change, since novelty often comes from equipment suppliers. Although Pavitt (1984) and Bell and Pavitt (1995) had a more complex approach, their supplier dominated industries could related to OECD's low-tech industries.

Dosi et al. (1995), mentions empirical regularities in industrial structures and dynamics. Although some features are common to all sectors, each sector presents some specificity that interferes in the sectoral forms of technical change. They relate to elements such as *skewed distribution and their stability* (relates to both firm and plant size), *firms' growth* (may be related to increased market share, growth of existing market, or increased market due to mergers and acquisitions), *entry, exits and market turbulence* (considers the birth-rate and mortality of firms in an industry), *persistence of asymmetric performances* (considers the differences in productivity and costs, profitability, and innovative output over time), and *life cycle patterns* (takes into account the technology and the products life cycles).

In recent studies, such as in Castellacci (2008), new taxonomies for sectoral innovation incorporates manufacturing and service industries, resulting in four groups: *personal goods and services*, *infrastructural services*, *mass production goods*, and *advanced knowledge providers*. The author develops the idea that the interactions that occur in an industry and the knowledge exchanged between its agents is critical to sectoral trajectories of innovation. Furthermore, similar to Malerba and Orsenigo's (1997) view, Castellacci (2008) argues that industries with a knowledge base and capabilities that are closely related to radical innovations face more opportunities than those less dynamic industries.

While Dosi's and Malerba and Orsenigo's views relate to the industry intensity classifications, Schumpeterian Marks I and II work across all industry intensity. For example, when Dosi (1988) and Malerba and Orsenigo (1997) say some sectors are related to science-based knowledge, it could be compared to OECD's high-tech industries, and when they say some sectors use knowledge generated elsewhere, it could be compared to low-tech industries. In Schumpeter's Mark I, a firm in any industry could depend on entrepreneurs to develop new technologies and establish new firms, while in Mark II a firm in any industry could be large enough to dominate the innovative activity within the sector. In that sense, there are more factors than the industry affecting firms' innovative activities.

* * *

Many authors have attempted to identify groups of firms with similarities in terms of the complexity of the technology they use and the products they produce, of their dependency on this technology and of the complexity of their innovative activities. They have identified differences between industries of high and low-technological intensity, regardless of the measures used. In the one hand, there are those nascent, dynamic, science-based industries that invest more in R&D and use have high-technology processes. On the other, there are mature, less dynamic, supplier dependent industries that make little investments in R&D and have low-technology processes. Since these industries follow their own trajectories, it would be only logical to assume that the approach a firm takes to innovation is somehow influenced by its industry characteristics, be it by the obstacles or by the opportunities it faces.

As stated by Castellacci and Zheng (2010, p. 2), "since firms in different industries of the economy face distinct set of opportunities, constraints and conditions, these industry-specific characteristics play an important role to explain the enterprises' technological and productivity performance". For Kirner et al. (2015, p. 79), "a firm's competitive success is largely influenced by the specific industry and market structures in which the firm is embedded, and its business success is determined by the firm's chosen strategic market positioning".

The sectoral approach does not cover all low-tech issues, since innovation will not only come from technical change. Firms may be more or less innovative, depending on the complexity of their technological activities (Lall, 1992), in other words, if they are research-based or if they only perform simple routine activities. Lall's (1992) view could actually relate to any firm, regardless of its industry, since their innovation outcome is based on each firm own routine, product complexity and basic research activities.

Irrespective of how industries are actually classified, there is consensus that the sector influences firms' innovative activities. The industry, nevertheless, is not fully responsible for a firm's approach to innovation. *As the industry does not account for firms' heterogeneity within a sector, it is not enough to explain the nature of all firms completely*. Innovation is not only an industry level output, but it also relates to firms' internal efforts, knowledge, decisions and changes. According to a study by Kirner et al. (2015, p.81), there is "substantial intra-sectoral heterogeneity regarding firms' R&D intensity, which is not adequately acknowledged by the sectoral grouping alone".

In sum, on the one hand, technological patterns affect all firms within an industry, which includes technology and product complexity, market expectations for novelty and pace of sectoral changes. On the other hand, there are firms' innovative activities that do not depend on the industry, since there are more and less innovative firms within the same sector. In that sense, although industry dynamics plays a major role in terms of innovative results, firms have the power to set their own approach to innovation, as long as they have the *capabilities* to promote changes and their decision-makers decide to act on it.

In the next section, the firms' innovation capabilities are deeper explored in order to explain their role in any firm, of any industry, innovative activity.

2.5 Firms' Innovation Capabilities

Capabilities are the answer to questions like why firms differ from each other and why there are performance differences across firms (Madhok, 2002). Theorists of evolutionary economics have criticized the R&D paradigm and suggested, "capabilities for innovation are more likely to be based on firm-specific routines and heuristics rather than mere single, homogeneous R&D-based innovation strategies" (Som & Kirner, 2015, p. 3).

Based on Penrose's (1959) studies, the term *capabilities* was first defined by Richardson (1972) as a set of knowledge, experience and skills. Since then, *capabilities* have been related to many terms, for example, to firms' daily routines (Chandler, 1992; Dosi et al. 2000; Nelson & Winter, 1982; Peng et al., 2008). When Teece et al. (1997, p. 516) linked resource-based view with capabilities, they left a static environment approach to a changing one and, therefore, defined dynamic capabilities as "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments". Bell and Pavitt (1995) also relate capabilities to change, saying they differ substantially between knowledge needed to change technical systems and knowledge needed to maintain existing ones.

From these definitions on, the term capabilities has been used as a way to discuss firms under various approaches. Following a macroeconomic measure of innovation (technological intensity), studies on firm innovation have long focused on a specific capability that highlights the R&D activities as the impulse for innovation, the technological capability (Lall, 1992). Consequently, the widespread use of R&D as an indicator of innovation has not been restricted to sectoral analysis; it has also been used to measure firm innovative performance, despite its condition of not being an exclusive activity of high-tech industries. Although at a lower level, medium and low-tech firms may also have internal research and/or development activities that will affect their innovative performance.

A large number of measures are used to link R&D to innovation, such as: resources allocation to R&D (Archibugi & Pianta, 1996; Reichert et al., 2011; Tsai, 2004); R&D intensity (Coombs & Bierly, 2006; Hall & Bagchi-Sen, 2002; Madanmohan et al., 2004; Reichert & Zawislak, 2014); R&D cooperation, collaboration and partnership (Lall, 1992); and implementation of R&D department or conduction of R&D activities (Archibugi & Pianta, 1996). Through empirical studies, many authors have found a relation between technological capability (and its traditional indicators) and firm performance (Garcia-Muiña & Navas-López, 2007; Hall & Bagchi-Sen, 2002).

Indeed technological capability influences firms' innovative outcomes, but there are still some gaps on how to capture innovation in firms that are not intense technologically.

Avoiding the technological intensity bias, innovation is seen, also, as the result of several efforts in areas other than technological development. Operational, organizational and marketing activities (Balcerowicz et al., 2009; Hirsch-Kreinsen et al., 2008; Kirner et al., 2009; Tello-Gamarra & Zawislak, 2013; Zawislak et al., 2013b), knowledge management, project management and portfolio management (Adams et al., 2006), commercialization and collaboration (Arundel, 2006), personality characteristics, leadership behaviours and influence tactics of champions of technological innovations (Howell & Higgins, 1990) are some examples of non-technological innovative activities. For Som et al. (2015), engineering, design, production, distribution and investment in capital equipment are increasingly appreciated as additional determinants of successful innovation.

All these labels refer to specific capabilities that the firm creates and uses strategically in order to identify market gaps to be filled with new offerings of value.
These studies have been important to understand the firm; however, there is no unanimity on what are the capabilities that ensure survival and superior performance, nor a consensus on the ultimate definition of innovation capability.

As Zawislak et al. (2012b) pointed out, there are matters still pending in this research area, such as why firms that do not invest much in technological capability may have innovative performance? The answer to innovation is clearly not related to only one capability (i.e., technological capability), but to a set of capabilities that constitute innovation capabilities. “To be innovative the firm should understand and lay its strategies over the innovative capability” (Zawislak et al., 2012b, p. 17), innovation capabilities are the mean by which a firm gets advantage over others.

The capabilities necessary for innovation in low-tech firm are not necessarily anchored in an R&D department, instead, they are spread across different divisions, including production, quality management, purchases and sales and marketing (Mattes et al., 2015). There is no definitive configuration of innovation capabilities, though.

Guan and Ma (2003) and Yam et al. (2004) considered seven innovation capability dimensions that could determine a firm’s performance: learning, R&D, manufacturing, marketing, organizational, resource allocating and strategy planning. Within this approach, R&D has decreased its importance as a performance determinant, since it is only one of seven measures. Similarly, Wang et al. (2008) used external determinants, especially external sources of innovation used to improve existing products and processes, as a way to complement the firm-specific determinant of innovation – R&D activities. To evaluate firm’s innovation capability, they used five aspects: R&D capabilities, innovation decision capabilities, marketing capabilities, manufacturing capabilities, and capital capabilities.

Hirsch-Kreinsen (2008, p. 15) stated “the different knowledge elements in the individual firms converge into a specific industrial competence in each case […], which can be regarded as a central requirement for the equally specific innovation capability of the companies”. Zawislak et al. (2013a) say a firm must have a minimum amount of knowledge, which is dependent on the sector and the technical path, to allow it to incorporate new knowledge into the existing technical and business routines.

Expanding on the idea that a unique capability (technological capability) will lead a firm to achieve innovative performance, the literature indicates that firms need a set of capabilities to be innovative. However, there is no consensus on what are these capabilities, since there are models that consist of up to nine capabilities dimensions.

For Zawislak et al. (2012b, p. 17), “to exist and to thrive, every firm must have some specific capabilities”. For them, any firm will perform four different strategic functions: development, operations, management and transaction. For each function, there should be a specific capability of innovation. The ensemble of these four capabilities composes the innovation capabilities of the firm.

The innovation capabilities are “the technological learning process from the firms translated into the technological development and operations capabilities, as well as the managerial and transactional routines represented by the management and transaction capabilities” (Zawislak et al., 2012b, p. 17). In other words, innovation capabilities refer to the “ability to absorb, adapt and transform a given technology into specific operational, managerial and transactional routines that can lead a firm to Schumpeterian profits, i.e., innovation” (Zawislak et al., 2012b, p. 23).

Considering that the idea of innovation in the present study follows Schumpeter’s postulations, considering that looking only to traditional indicators related to technological functions is not enough to capture innovation in low-tech firms, and considering that there is a need to understand innovation under both technological and business aspects; the Innovation Capabilities Model developed by Zawislak et al. (2012b; 2013a) (Figure 2) seems to be the most appropriate alternative to evaluate the nature of innovation in low-tech firms under the capabilities approach. This model understands that “every firm, in essence, develops, makes, manages and sells technical solutions”, which is a deliberate act (Zawislak et al., 2012b, p. 21). Zawislak’s et al. (2012b; 2013a; 2013b) innovation model presumes that every firm has some level of four innovation capabilities affecting their performance, and these four capabilities will help to finally capture innovation in firms that are not technologically intense.

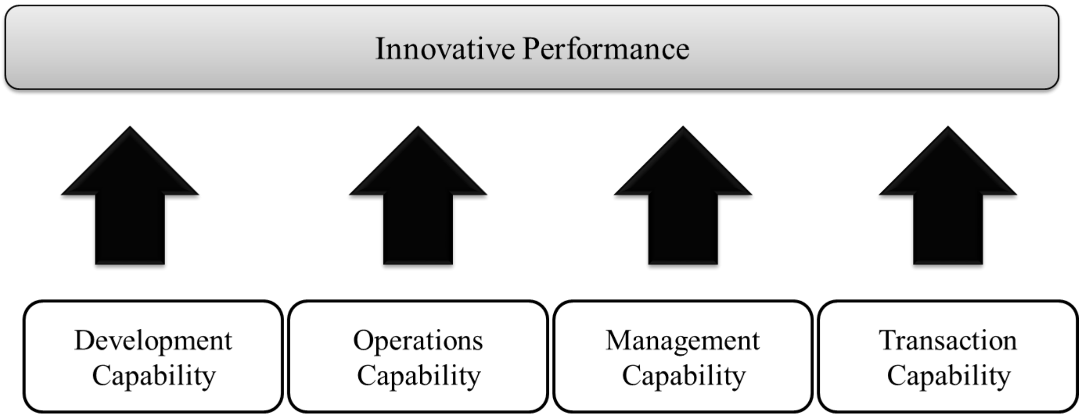


Figure 2 – Innovation Model based on Four Innovation Capabilities

Font: Adapted from Zawislak et al. (2012b; 2013a)

The four dimensions (capabilities) within the model are development, operations, management and transaction.

Development Capability (DC) – is the ability of firms to absorb and internalize new knowledge to be applied in new products, so the firm not only uses technology, but also generates and manages technical change. It involves monitoring, acquiring and adapting, designing, and developing a new set of knowledge and technical systems for internal use. It allows the firm to achieve higher levels of technical-economic efficiency, once it settles new technical standards.

Operations Capability (OC) – is the ability to perform a given production capacity through a collection of knowledge, skills and technical systems. It prioritizes taking advantage of low cost, quality and flexibility, and involves activities such as managing product's or service's degree of standardizations, managing production volumes and product mix as well as being flexible about it, and, finally, attending the technological innovation required by the market.

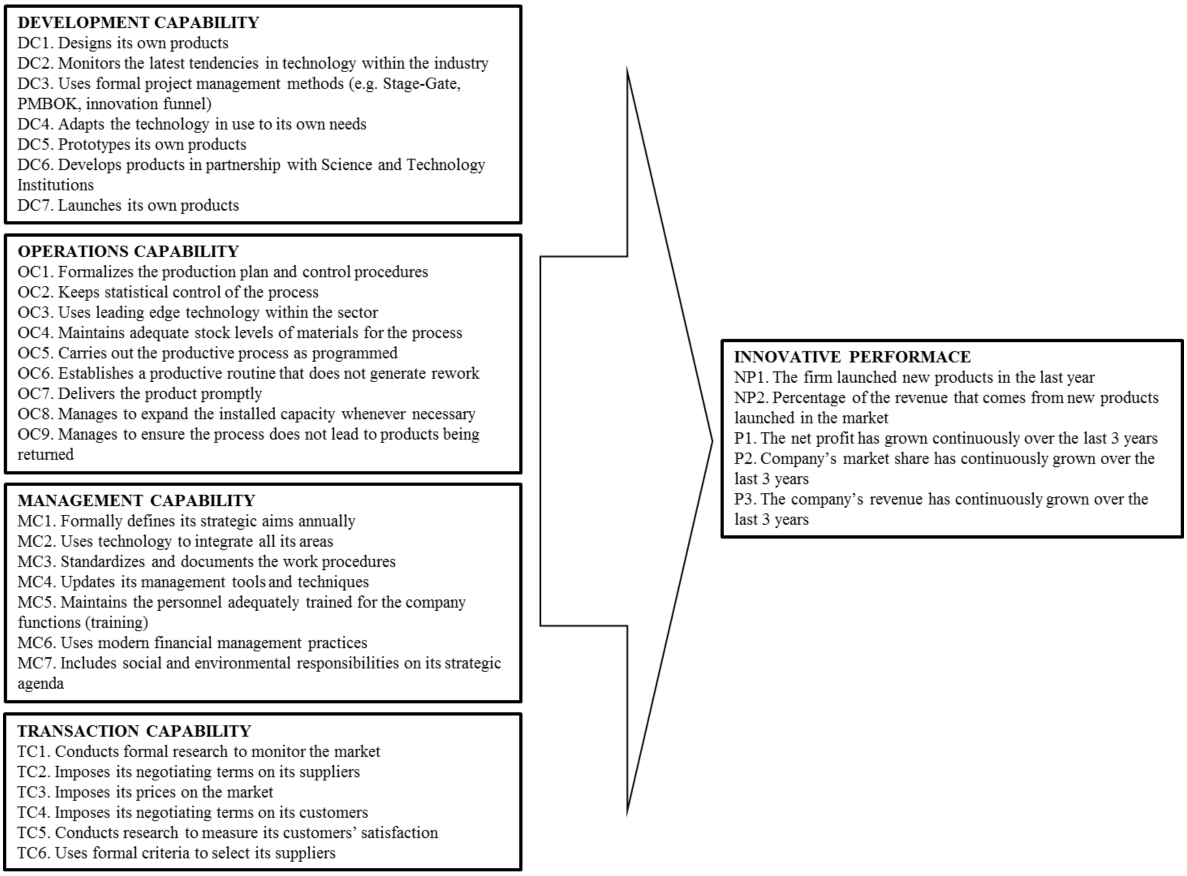
Management Capability (MC) – is the ability to coordinate efforts to transform the technological outcome into a coherent operational and transactional arrangement. Its priority is to maintain a smooth flow of information and outputs to achieve higher rates of efficiency, and thus, to achieve its strategic aims. It allows the firm to deal with unpredictable circumstances using a range of skills, practices and techniques to solve problems and to take action by choice and decision when technology fails to be perfectly routinized.

Transaction Capability (TC) – is the firms' ability to transact in the market what has been previously developed, operationalized and managed. A firm needs a set of specific skills and systems to trade, which include activities such as customer relationship, negotiation, contracting and marketing, to go to the market and obtain positive economic return.

Innovative Performance (IP) – it is important that economic returns arise from activities such as new products and process that will find a market for them (Dosi, 1988). Nevertheless, different types of innovation lead to different results. In this sense, Kirner et al. (2015b) say that although some results are better measured in terms of monetary gains, other types have to be evaluated differently, for example, by share of sales of new products. In that sense, innovative performance is measured by a combination of indicators related to novelty and to firm performance. In relation to novelty, launching new products and the percentage of revenue that comes from them are taken into consideration. In relation to firm economic performance, Schumpeter's ([1942] 2008) postulation that innovation is related to extraordinary profits is followed. For that, a combination of indicators that measure firms' success is used: net profit growth, market share growth and revenue growth.

Firms need a set of innovation capabilities to perform and profit from innovation (Teece, 1986), and these capabilities should be arranged in ways to explore firms' strengths.

Figure 3 shows the **firms' innovation capabilities framework**, considering that each innovation capability contributes to firm's innovative performance.



Note: As has been briefly explained and will be further detailed in the method section (section 4), the secondary data used in the Thesis, and therefore, indicators used for each capability, are original from the Paths of Innovation in the Brazilian Industry project.

Figure 3 – Firms' Innovation Capabilities Framework

The framework encompassing four capabilities should bring light to what is important for low-tech firms' innovation.

To understand the importance of capabilities on firm innovative performance, short case of a Brazilian footwear company is presented.

There is a large and renowned Brazilian footwear company that owns six productions plants, employs more than 24,000 people, and have more than 50 brands registered. It started it operations in the beginning of the 1970s as a plastic goods manufacturer, producing packaging for the local wine industry. By the end of the decade, it has already migrated from plastic to footwear production, producing the highly innovative (at the time) plastic sandals. Nowadays its products are sold in more than 90 countries (including more than 50,000 sales points abroad), making them the larger footwear exporter in Brazil.

The company is based on pillars such as design, creativity, technology and fashion trends. Management says the firm design structure was built to make it one of the most creative footwear companies in the world. Product development takes into consideration design, fashion trends, and the use of the latest technology and materials available, which may be developed internally. To be able to offer all that, the company has multidisciplinary work teams, including product and fashion designers, architects, engineers, economists, and a management team that are up to date with market needs. This company has its capabilities well developed, focusing mainly on development and transactional functions.

Although one example is not enough to explain all firms, it illustrates the cases where innovation is present in low-tech firms. In saying that, the idea that innovation is a result of efforts that go beyond an industry's characteristics is reinforced. Internal capabilities may lead a firm to achieve positive results.

* * *

Considering some firms have higher level of capabilities than others do, it is natural that most high-tech firms have high-level capabilities and that low-tech firms have low-level capabilities. Could a firm within a high-tech industry have low-level capabilities, or, alternatively, a low-tech firm have high-capabilities? Given all the sectoral heterogeneity discussed so far, the answer is yes, it is possible.

It is not only the industrial organization dynamics, but also the configuration of innovation capabilities that lead firms to achieve innovative performance.

Within the same sector, there are innovative and non-innovative firms and, additionally, among the innovative firms, there is some heterogeneity. They do not innovate all in the same way and, as mentioned before, there is not only *one* best way to innovate. While most high-tech firms, due to their technological nature, indeed succeed mostly technologically, that does not seem to be the case of low-tech firms. How do they innovate? Are low-tech firms' innovation capabilities enough for them to overcome an industry environment and succeed? What innovation capabilities they need to innovate? Next chapter explores innovation in low-tech firms and presents different theoretical patterns they might follow, to build the idea of the nature of innovation in low-tech firms.

3 The Nature of Innovation in Low-Tech Firms

As discussed so far, external factors such as sectoral environment, impact on innovation patterns, but then again, this is not enough to explain all firms' innovative performances. For that, it is necessary to go further industry discussion and consider internal-to-the-firm factors.

If high-tech *industries* are R&D-intense, dynamic, expanding, counts on scientific personnel, generates patents and licenses and produces high-technology products, it is only natural that high-tech *firms* embrace this description. High-tech *firms* change rapidly, have a high rate of new product introduction (Lynn et al., 1999), innovate more, win new markets, use available resources more productively and offer higher remuneration to employees (Hatzichronoglou, 1997).

Conversely, if low-tech *industries* are established, old, mature and traditional, offer the same product for long, work with common and constant knowledge and focus on manufacturing activities, it is also natural to expect a low-tech *firm* to reflect such features. But, do they?

3.1 Low-Tech Innovation

Companies belonging to low-tech industries receive new technology from other industries and carry them on further developments, thus, the link between different sectors is pivotal to economic development, and not only the amount invested in R&D by high-tech industries (Hirsch-Kreinsen et al., 2006; Hirsch-Kreinsen et al., 2008; Robertson & Smith, 2008). As Huang et al. (2010, p. 29) put it, "in low- and medium-technology sectors, the embodied knowledge is transferred from suppliers through marketing, design and process optimization, rather than through formal R&D". This approach is closely related to Pavitt's (1984) supplier dominated group of technological change, where there is a dependence on other firms and industries (Hirsch-Kreinsen, 2013; Huang et al., 2010; Trippl, 2010).

Besides, in general, low-tech firms contribute to their own productivity (Robertson & Smith, 2008). To be competitive, they invest in their operational areas. They make investments in operational efficiency, on providing products of good quality and on applying existing knowledge (Reichert & Zawislak, 2014; Von Tunzelmann; Acha, 2005; Zawislak et al., 2013b). Low-tech firms are part of more stable industries and may not depend on investments in technological capability and R&D to survive.

Moreover, low-tech firms depend on the ability to change and improve their production processes (Cefis & Marsili, 2011). For Hirsh-Kreinsen (2015), these firms tend to integrate and adapt new technologies into their manufacturing process instead of only applying ready-to-use process technologies. When occasional research or development activities occur, they usually are not formalized in R&D departments, and product development is mainly for improvements (Balcerowicz et al., 2009; Hirsch-Kreinsen et al., 2008; Hoveskog, 2011; Morceiro et al., 2011; Trippl, 2010). Innovation activities in low-tech firms are primarily directed at modifying and incrementally developing existing technologies (Arundel et al., 2008; Hirsch-Kreinsen, 2015). For Morceiro et al. (2011, p. 11), "radical innovations are exceptions and incremental are the rule". This is not necessarily a bad thing.

Innovation in low-tech industry firms is presented in many different ways. These firms' economic success very often "depends on the ability to bridge the gap between different knowledge domains creatively and to create bonds between different actors and/or processes and/or components" (Bender, 2008, p. 38-39). Although customers and other institutions have a part in this process, it is from the relationship with suppliers that low-tech firms benefit the most (Balcerowicz et al., 2009; Huang et al., 2010).

In low-tech industries, innovation may be a result of relationships that allow external knowledge to be absorbed and further developed. This new knowledge may be related to new processes, new commercial strategies, new forms of organization or improved technologies and products (Hansen & Winther, 2011; Robertson & Patel, 2007; Robertson & Smith, 2008; Von Tunzelmann & Acha, 2005).

Low-tech sector has an innovation potential based on the modification of existing technologies and on the combination of their existing knowledge with new high-tech components (Hirsch-Kreinsen, 2015). External knowledge is, therefore, essential for innovation activities, especially when it is successfully integrated with the existing knowledge base (Bender, 2008; Morceiro et al., 2011). In order to take advantage of these relationships, low-tech industry firms require skills that enable them to use, adapt and improve new technologies, and to discover, transform and go beyond previously absorbed knowledge (Balcerowicz et al., 2009; Hoveskog, 2011; Morceiro et al., 2011).

Additionally, innovation in low-tech firms is also related to market or firm's transactions capability (Zawislak et al., 2013b). Hirsch-Kreinsen (2008) described different focus of innovation in low and medium-tech firms, saying that they proceed in small steps when further developing their products, they promote market-induced product innovations in order to open up sales opportunities, or they focus on process-related innovations.

* * *

Low-tech firms' innovations, especially in terms of technology, are bounded by their sector's mature technologies; however, they do innovate. Most often, low-tech firms' innovative activities depend on their relationship with suppliers, customers or firms from more intensive industries. Additionally, their innovations commonly relate to incremental changes in existing products or to business and market innovations. Therefore, *there are other elements contributing to the nature of innovation in low-tech firms than only their industries' technological intensity*.

3.2 Theoretical Patterns of Innovation in Low-Tech Firms

Within low-tech industries, there is a mix of firms with varied approaches to innovation – firms behave differently, they have singular trajectories, strategies and capabilities' configurations. Each configuration of innovation capabilities should lead a firm to a different result. In other words, because the nature of innovation in low-tech firms overcomes the boundaries of R&D departments, low-tech firms have different innovation patterns to follow. It is critical to measure firm innovativeness to be able to distinguish between types of innovation (Kirner et al., 2015b).

Considering external and internal factors influencing firms' decisions about the configuration of their capabilities, every firm must find the best combination for its necessity. The distinctive ways by which firms manage their capabilities can result in superior performance (Madhok, 2002). Each type of innovation can be a source of competitive advantage (Kirner et al., 2015b), and therefore, a low-tech firm that aims to advance technologically and to be market leader have a different configuration than a firm that only produces other firms' projects. To define the way towards innovation and to achieve superior performance, low-tech firms need to follow different strategies and decide on different configurations of capabilities.

In short, there should be an innovation pattern built over the configuration of innovation capabilities that will determine the nature of innovation in low-tech firms.

Firms are heterogeneous and each one has a unique configuration of capabilities that emphasizes different capabilities. They are the capabilities that will drive these firms to achieve innovative performance (Zawislak et al., 2012b; 2013b). *Firms should find the best configuration of innovation capabilities possible to achieve the best performance possible.*

Three theoretical patterns of innovation in low-tech firms are presented; they are production-oriented, business-oriented and technology-oriented low-tech firms.

3.2.1 Production-Oriented Low-Tech Firms

Production-oriented low-tech firms well represent the low-tech industry descriptions. These firms have low levels of innovative capabilities. In other words, their innovation capabilities are weak. This should affect their performance, which means that when compared to other firms, their innovative performance is inferior.

The technology they use is standardized and well established throughout the sector (Hirsch-Kreinsen & Schwinge, 2011; Zawislak et al., 2013a). They act as a typical low-tech industry firm and base their strategies on reducing costs and lowering prices, and that is because they are mature and do not have many options to aggregate value. In that sense, Hirsch-Kreinsen & Schwinge (2011) pointed out that competitive pressure in low-tech industries forces the adoption of managerial strategies of cost cutting and optimizing existing routines.

A basic low-tech firm rarely, practices R&D activities, and minor contribution to their process or product come from suppliers of equipment and materials (Balcerowicz et al., 2009; Huang et al., 2010; Pavitt, 1984; Zawislak et al., 2013a). Innovation in these firms includes machinery and equipment acquisition, processes automation, and new processes development (Hirsch-Kreinsen, 2008; Zawislak et al., 2013b), all with the aim to achieve higher efficiency levels. Hirsch-Kreinsen (2008) named these firms *process specialists*. They are highly dependent on the quality and reliability of their equipment suppliers, which is why they often develop a close relationship with them (Som et al., 2015). It is possible that some of these firms only provide manufacturing services to others.

These firms' innovation strategies follow a traditional approach (Freeman & Soete, 1997), where firms do not see any reason to change its products, since their mature market does not require such changes. Besides, their technology undergoes minor improvements often based on worker's technical abilities. Therefore, when changes do occur, they are only a reaction to market needs.

For these reasons, it is expected that the operations capability is the most developed in these firms, since they have established processes. What is required from their operations capability is to produce the same products it has been producing for a long time. Thus, they focus on routine activities, on problem solving and on standardizing operations systems.

In that sense, ***operations capability*** *is the enabling condition for production-oriented low-tech firms to achieve innovative performance.*

These firms are a good representation of what to expect from firms belonging to low-tech industries. Although they may offer the occasional novelty, they are not innovation-intensive.

3.2.2 Business-Oriented Low-Tech Firms

Although the development capability of firms within this category is expected to be somewhat developed, mostly for market adaptations, it is not that capability that leads these firms' success.

Business-oriented firms should be ahead of production-oriented firms in terms of level of innovation capabilities. They have not only the operations capability, but also their management or transaction capability (or both of them) well developed.

For Hirsch-Kreinsen et al. (2008), firms that are close to their markets, have specific customer groups and use it in a flexible manner have favourable development perspectives. This is a reflex of an advanced transaction capability. For other researchers, a high proportion of employees working in commercial activities, such as sales, distribution, outsourcing and purchasing, clearly identify that a firm is prioritizing its transaction capability (Zawislak et al., 2013a).

Bender (2008, p. 29) highlights the importance of the organizational capability, herein understood as management capability of the firm, saying it is the "ability not only to combine pieces of knowledge and technology but also to link actors together that possess relevant knowledge, technology and competence". For him, "individual creativity is obviously important – but 'to innovate' is usually a collective action and, thus, organizations and organizational capabilities play a vital role" (p. 26). For Som et al. (2015), organizational innovation impulses (new concepts of work organization and human resources management) may come from inside firms, especially from top management. Zawislak et al. (2012b) said that in traditional and mature industries, where most knowledge about process is already dominated, one way a firm may innovate is by its management capability.

Specific knowledge base can be regarded as the central condition for innovation strategies of business-oriented low-tech firms. Low-tech firms take up externally generated knowledge that varies from practical experience of sales personnel to research results from engineering science concerning new machining procedures or product materials (Hirsch-Kreinsen et al., 2008).

Considering that a business-oriented low-tech firm focuses less on its own development capability and more on its management and transaction capabilities, its innovations are not necessarily a result of science-based knowledge, however. To innovate, they use other sources such as experience- and practical-based knowledge to innovate (Som et al. 2015).

A firm that have started in a new quality program, developed a new organizational structure, or implemented a new business model, even if it exists in other sectors, might have advantages before its competitors. In this case, these hypothetical firms are prioritizing their management capability. Similarly, a strong configuration of capabilities towards the transaction capability may result in a new market niche, in a new brand, and in the expansion of service activities (Hirsch-Kreinsen, 2008). A combination of the two capabilities leading the firm to an innovative performance is also possible.

Increasing the array of services they provide to their customers is also a way to see innovation business-oriented firms. As mentioned by Kirner et al. (2015b, p.92), "the services that manufacturing firms provide are usually closely related to their products, and they may include different forms of maintenance, training, consulting, project planning, software development, or support for the initial set-up of machines and equipment". They also say that innovative services "can advance to become a major differentiating factor for firms against competitors in the market" (p.92).

These firms follow an imitative strategy (Freeman & Soete, 1997; Teece, 1986), since they might keep their technology up to date, although they are not the ones developing it in the first place (due to their management and transaction capabilities orientation). Low-tech firms within this group, even when only reacting to changes, try to keep their technology up to date. When there is new product development, it is usually after a client's request. These products often are improved copies of existing ones. As stated by Freeman and Soete (1997, p. 476), "the imitative firm does not aspire to 'leap frogging' or even to keeping up with the game. It is content to follow some way behind the leaders in established technologies".

In sum, business-oriented firms focus on managerial and transactional activities aiming at increasing efficiency, market share and at promoting their image and brands. When they use their development capability, it is mainly related to transaction capability, for example, to create a new package design to follow new trends or to supply to new market needs.

In that sense, ***management or transaction capabilities*** *are the enabling conditions for business-oriented low-tech firms to achieve innovative performance.*

These firms offer alternative ways to understand innovation that are not dependent of technological development. It is expected that, in these cases, technology is not central to their performance, since they innovate in other areas, mostly related to management and transactions.

3.2.3 Technology-Oriented Low-Tech Firms

Finally, there are those firms that go beyond what is expected for low-tech firms. They stand out among its competitors, are leaders in their industries and set the pace of technological development on their sectors. They are technology-oriented. In such firms, development capability is paramount to their innovative performance, since they tend to emulate behaviours that are mostly seen in high-tech firms. Firm's knowledge base is the core of their activities, allowing them to develop new materials, to create new designs and to launch new products. In other words, they are pioneers in their industries.

Hirsch-Kreinsen et al. (2008) identified a considerable number of firms fitting this profile. They are low-tech firms capable of employing high-tech process technologies systematically and efficiently. Bender (2008) exemplified firms with capabilities to redesign and creatively reproduce their own knowledge base. In this case, when developing a new product the firm has capabilities to transform expertise in one field into knowledge in another environment. For him, "the more sophisticated [the capabilities] are the better can an organization integrate new knowledge and other resources and convert them into novel ideas and eventually products" (p. 34).

If integration of new knowledge is the result of complex capabilities, technology-oriented low-tech firms should have all capabilities well developed, and not only their development capability, although it plays an important role in leading the innovative process. Research and development is a valuable resource "for firms to generate the necessary new knowledge to successfully develop new products, implement them in the market, and create technical processes and thus to gain a competitive advantage and achieve economic success" (Som et al., 2015, p.115).

Innovative low-tech firms, in sum, promote changes systematically and proactively, and are likely to have an advanced knowledge base. They have what Freeman and Soete (1997) call an offensive innovation strategy, and what Teece (1986) calls innovative firms. These firms continually develop new products (ahead of their competitors), are competitive and have an economic performance above their industry's average. Despite the fact that these authors have researched high-tech firms, due to the arguments developed so far, there is no reason why a low-tech firm should not fit this profile.

In saying all that, it is likely that the ***development capability*** *is the enabling condition for technology-oriented low-tech firms to achieve innovative performance*.

Technology-oriented low-tech firms have their production process well set, they have good relation with their customers and suppliers, they apply management techniques on their daily routines and, most of all, they offer differentiated products in the market, which allows them to add value to what they do.

* * *

Innovation studies have frequently been neglecting low-tech industries, as well as innovation in areas other than technological. The aim is not to deny the influence the sector has on firms' innovation patterns, but to bring light into the innovation capabilities' point of view. The industry context that influences firms' standard behaviour includes technology maturity, industry concentration, industries' main markets, industries' main sources of change and opportunities that emerge in each sector, among others. However, as Dosi (1988) and Malerba and Orsenigo (1996b) indicate, profits depend on both, industry and firm characteristics.

For Freeman and Soete (1997), not to innovate is to die. To innovate means that firms need to change and to differentiate themselves from other firms within an industry. According to Mattes et al. (2015), the heterogeneity of firms leads to different innovation behaviours and generate competitive advantage. If low-tech firms are somewhat successful, how they achieve it is likely to be dependent on the configuration of their innovation capabilities.

Although we will continue to see different innovation results throughout firms and industries, there is a need to capture innovation phenomenon in a way that does not exclude firms belonging to low-technological intensity. Considering a configuration of four innovation capabilities, it is possible to see technological innovation as well as commercial or business innovation, regardless of the industry, which should confirm that the nature of innovation in low-tech firms is broader than the nature of innovation in high-tech firms, which is strongly based on R&D activities. Applying the innovation capabilities approach allows capturing innovation in a more comprehensive way and understand this broad nature of innovation.

Before advancing in the study, it is important to resume some important affirmatives expressed in this chapter. First, that **there are other elements contributing to the nature of**

innovation in low-tech firms than only their industries' technological intensity. Next, regarding each theoretical patterns of innovation, it has been said **that operations capability is the enabling condition** for production-oriented low-tech firms to achieve innovative performance; **management or transaction capabilities are the enabling conditions** for business-oriented low-tech firms to achieve innovative performance and; finally, that **development capability is the enabling condition** for technology-oriented low-tech firms to achieve innovative performance.

By considering that among low-tech industries there are production-oriented, business-oriented and technology-oriented firms, it is also possible to consider that each theoretical pattern follows a certain configuration of capabilities. The pattern a firm follows depends not only on external factors, but also on firms' strategic decisions. Decision-makers have to decide to be an innovative firm among all the non-innovative low-tech firms and, for that, invest in capabilities that will lead them to that result. Any low-tech firm could find a way to innovate, but it might be closer to low-tech firms' reality to be a production-oriented firm. However, when a low-tech firm decides to dream of high-tech innovation, its management have to bear the costs of it.

In sum, although low-tech firms may be innovative, there are a number of ways to achieve it. When the configuration of innovation capabilities fit a firm, they lead it to be innovative, whether through technological innovation or not. If high-tech firms majorly innovate through R&D activities, low-tech firms have an array of ways to innovate. Different capabilities' configurations are appropriate for different types of low-tech firms. When they are all combined, they set the patterns, and hence, the essence or the *nature of innovation in low-tech firms*.

Next chapter explains the methods used to identify the patterns of innovation in low-tech firms.

4 Research Method and Design

To explore the central question of this work – "*what is the nature of innovation in low-tech firms?*" – a combination of methods has been used. First, linear quantitative analysis based on correlations (principal component analysis and cluster analysis), then complex configuration analysis using qualitative comparative analysis (Fuzzy Set/Qualitative Comparative Analysis – fsQCA).

There are many ways to characterize a research method, but, most commonly, they are either quantitative or qualitative. However, using more than one method to design a research or to analyse its results have become ever more discussed (Caracelli & Greene, 1997; Greene, 1989; Howe, 1988; Myers, 2013; Sieber, 1973). For Sieber (1973, p. 1337), "the integration of research techniques within a single project opens up enormous opportunities for mutual advantages in each of three major phases – design, data collection, and analysis". He adds that these mutual benefits relate not only to the amount of information gathered, but also to the quality of it.

Greene (1989) and Caracelli and Greene (1993) identified five purposes for mixed-method evaluations: *triangulation*, *complementarity*, *development*, *initiation* and *expansion*. Each of those purposes are designed to evaluate something different from the research. Triangulation aims at corroboration of results from different methods. Complementarity seeks elaboration, enhancement, illustration or clarification of the results from one method with the results from the other method. Development uses results from one method to help develop or inform the other method. Initiation seeks to discover a contradiction or new perspectives from one method with questions from the other. Finally, expansion aims at extending the breadth of inquiry by using different methods for different inquiry components. *Complementarity* is the purpose that better fit the present research.

In line with that, and specifically about integrating fsQCA and correlation-based approaches, Fiss et al. (2013) say that they see considerable opportunities in using both approaches in an integrative manner. For them, "this would go beyond triangulation involving data analysis on either approach and comparing results (…), and going toward developing hybrid methods incorporating elements from both approaches" (p. 194). For Skarmeas et al. (2014), fsQCA can supplement correlational techniques, by offering a more holistic view of the relationships. They also say "most observable relationships are not 100% linear and, thus, correlation coefficients cannot accurately describe them" (p. 1798).

For these authors, while correlational techniques attempt to estimate whether or not the influence (net effect) of an independent variable associates significantly with a particular outcome (dependent variable) (Armstrong, 2012; Skarmeas et al., 2014; Woodside, 2013), fsQCA aims at identifying the conditions that lead to that outcome (Skarmeas et al., 2014). For Woodside (2013, p. 464), “reality usually includes more than one combination of conditions that lead to high values in an outcome condition”.

* * *

General characteristics of low-tech firms are described before the analyses of the sample in terms of types of innovation and configuration of innovation capabilities. A combined analysis of the types and capabilities’ configuration in low-tech firms will lead to identifying the patterns of low-tech innovation, which are the essence of innovation in low-tech firms and, ultimately, its nature.

To define the types of low-tech firms, principal component analysis (factor analysis) has been performed. The aim was to define the indicators used in each capability. Then, cluster analysis was carried out to identify the types of low-tech firms. Cluster analysis resulted in three types of low-tech firms.

At a second stage, with the aim to identify possible configurations of capabilities that lead firms to achieve innovative performance, a set-membership analytical technique appropriate for complex configuration analysis was applied (fsQCA). Four possible causal conditions, or solutions, for innovative performance have been identified.

Hsiao et al. (2014) recommend that data analysis include symmetrical statistical tests (i.e., correlation-based tests) as well as asymmetric algorithm construction and testing (i.e., fsQCA).

In sum, factor and cluster analyses are used to identify types of low-tech firms. FsQCA is used to identify configurations of capabilities that lead low-tech firms to achieve innovative performance. A combination of both approaches brings light to what are the patterns of innovation in low-tech firms, which then allows understanding the nature of innovation in low-tech firms (Figure 4).

With that in mind, after describing the research data (section 4.1), how each approach is used in this study is explained (in subsections 4.2, 4.3 and 4.4).

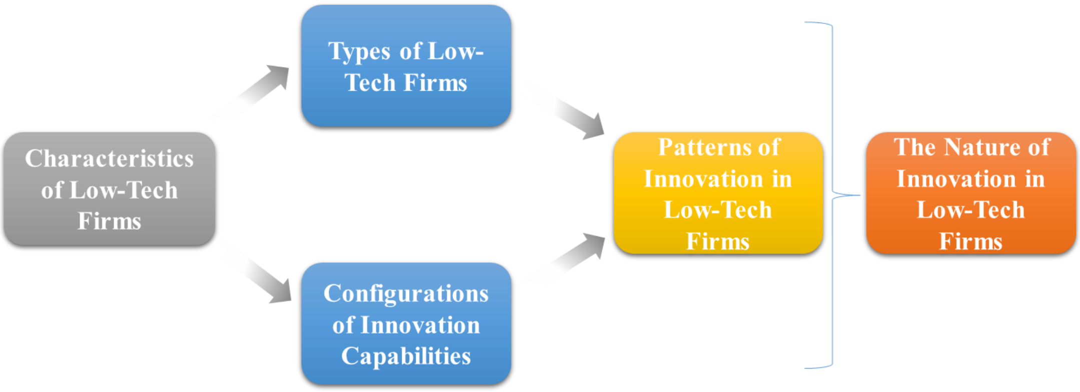


Figure 4 – Method Design according to Research Objectives

4.1 Research Data – Paths of Innovation in the Brazilian Industry

To achieve the goals of this research, secondary data from the NITEC Innovation Research Center's innovation survey, "Paths of Innovation in the Brazilian Industry", was used. For Hair et al. (2005), because of the high cost of collecting data, researchers may opt to use data already collected by others. They say that the advantage of using secondary data is that it reduces the length of a research project.

The referred research project, which lasted for four years (2010-2014), involved Brazilian manufacturing firms from all industries. The project ran with public financial support (FAPERGS and CNPq) and involved four higher education institutions, Federal University of Rio Grande do Sul (UFRGS), University of Caxias do Sul (UCS), University of Vale do Rio dos Sinos (UNISINOS) and Pontifical Catholic University of Rio Grande do Sul (PUC). It ran under the coordination of NITEC Innovation Research Center (UFRGS). I was part of NITEC's research team during the entire project. The project was carried out in three distinct phases: i) theory development phase; ii) exploratory phase; and iii) survey.

In the *theory development phase*, an innovation model based on four capabilities (development, operations, management and transaction) has been developed (see section 2.5 of this Thesis for the theoretical construction of this model [3]). It presents the innovative performance of firms as a result of efforts from the four aforementioned capabilities. In that sense, depending on firms' knowledge and experiences, as well as the changes they make in

[3] See Zawislak et al. (2012b; 2013a; 2013b) for the more details on the theoretical discussion that led to the Innovation Capabilities Model.

terms of organizational and commercial activities, technology and processes, the impact the capabilities have on their innovative performance will vary.

The aim of the second phase, the *exploratory phase*, was to understand how the level of firms' capabilities could be identified and measured. Therefore, the project's team members conducted 69 interviews with manufacturing firms from all industrial sectors of different sizes and locations.

Once theoretical and practical information was gathered, they served as input to build the *survey* questionnaire, which was then applied during the third phase. After pre-tests, the questionnaire's final version was applied to a database of 6,142 companies with five or more employees, from a universe of 10,930 registered in the Rio Grande do Sul Industries Federation – FIERGS' Industry Registry (2010). One thousand, three hundred and thirty one (1,331) firms answered this innovation survey (valid questionnaires obtained from a sample of 1,470 responding firms). Using OECD's (2011) classification as a cut-off point to select only firms from low-tech industries, 631 firms were analysed in the present study.

It is important to reinforce that it is not the aim of this research to discuss or to propose an alternative classification to OECD's. Therefore, in spite of its disadvantages (as discussed in chapter 2), the OECD's classification is used as a way to delimit the object of study. Despite some works that use a different way to classify industries (Christensen, 1995), or that adapt OECD's classification (Furtado & Carvalho, 2005; Kirner et al., 2009, Zawislak et al., 2012a), OECD's classification still is the most used (Hirsch-Kreinsen et a., 2008; Robertson & Smith, 2008; Balcerowicz et al., 2009; Hirsch-Kreinsen, 2013), and thus, allows further comparison with other studies[4].

The full questionnaire mixed a variety of measures and scales: dichotomous, five-point Likert-type scale and multiple choice. The questionnaire had three major parts. Part one included questions related to each of the four innovation capabilities (development, operations, management and transactions); part two had questions about performance (Figure 3, in section 2.5, brings the variables for each capability and for innovative performance from the Paths of Innovation in the Brazilian Industry's questionnaire); and part three covered firm's general information.

In the development capability dimension there are questions about monitoring technological tendencies, designing and prototyping products, and adapting and developing new products. In the operations part, questions relate to production planning and control,

[4] Refer to Figure 1, in chapter 2, to see the list of industries classified as low-technology intensity.

technology use, production flexibility, among others. Management part covers formalization and standardization of managerial processes, integration of different areas, personnel's capabilities, and others. Finally, transaction dimension inquires about formal market and costumer's research, negotiating conditions with customers and suppliers, and price strategies.

Performance questions relate to new products and economic measures. General information part includes size, management model, R&D investment, patents registered, among others.

4.1.1 General Characteristic Analysis

Before performing specific tests regarding the types of low-tech firms, the general characteristics of the sample are presented. To have a broad idea of information, such as which industries are in the sample, what is the size of these firms and who manages them, will help to understand better each pattern as well as to differentiate one from another.

For that, frequency tests were performed using the entire sample of 631 firms (*n*=631). Since some of the companies did not answer the entire questionnaire, the value for "*n*" varies from question to question. In such cases with *missing values*, the figure for *valid percent* during the analysis[5] was used.

4.2 Correlation-Based Approach

It has been argued that low-tech firms may be innovative. They achieve such results through different patterns, depending on which type of low-tech firms they are and on their capabilities' configuration. To, first, identify which types are these, in other words, how low-tech firms grouped together based on their innovation capabilities, a cluster analysis approach has been adopted.

Based on De Jong and Marsili (2006) and Arundel et al. (2015), a three-steps approach to cluster analysis was performed: i) principal component analysis to identify how variables are grouped together as well as to reduce their number; ii) cluster analysis to identify the types of low-tech firms; and iii) validation analysis that uses questions that were not used in the factor analysis to verify if there are other statistically significant difference between the clusters.

[5] The statistical software used for these analyses was SPSS – Statistical Package for Social Sciences.

4.2.1 Principal Component Analysis

Exploratory factor analysis verifies the correlation between pairs of variables. When the correlation is high between subsets of variables, it means they could be measuring aspects of the same underlying dimension, which are known as factors (Field, 2000). Factor analysis summarizes information contained in a large number of variables into a lower number of variables or factors (Hair et al., 2005).

All 29 variables regarding innovation capabilities (DC1 to TC6, presented previously in Figure 3, in section 2.5) were included in the analysis. Following Field (2000) and Arundel et al. (2015), the extraction method used was principal component analysis. The number of factors extracted from the principal component analysis complied with Kaiser's criteria of retaining all factors with Eigenvalues greater than 1. The rotation method was Varimax, which is an orthogonal rotation method that simplifies the interpretation of factors (Field, 2000). Missing values were excluded pairwise. The result of this analysis was a Rotated Component Matrix of six factors.

With the aim to simplify the Rotated Component Matrix even further, a second analysis was performed, this time, excluding variables that did not fit well in the model (no significant correlation, high correlation scores in the Correlation Matrix, or low factor loading scores in the Rotated Component Matrix) and fixing the number of factors in four[6].

Once the factors were defined and the scores were saved, cluster analysis was performed. Aldenderfer and Blashfield (1984) highlight the importance of using transformed data for cluster analysis, such as scores from the factor or principal component analysis. They say "principal component analysis and factor analysis can be used to reduce the dimensionality of the data, thereby creating new, uncorrelated variables that can be used as raw data for the calculation of similarity between cases" (p. 21).

4.2.2 Cluster Analysis

Cluster analysis, or conglomerates, is an interdependent multivariate technique that combines objects into groups so that objects in the same group or cluster are more similar to each other than those in other clusters are (Aldenderfer & Blashfield, 1984; Hair et al., 2005,

[6] Further analyses' details and results are shown in chapter 6

Hair et al., 2009). For Aldenderfer and Blashfield (1984, p. 16), "clustering methods are used to discover structure in data that is not readily apparent by visual inspection or by appeal to other authority." In social sciences, cluster analysis is used for typologies, and therefore, in this Thesis, the intention is to group firms within the sample according to their capabilities.

"The main problem with cluster analysis is to decide on the number of clusters, to balance the need to represent the data appropriately and, at the same time, to keep the results manageable" (De Jong & Marsili, 2006, p. 222). To find a solution within these requirements, a combination of hierarchical and non-hierarchical techniques is recommended (De Jong & Marsili, 2006).

Using the four factors generated during the principal component analysis (DC, OC, MC and TC) to form clusters, the first technique used was the *dendrogram*, which visually represents the steps in a hierarchical clustering solution (Norusis, 1994). De Jong & Marsili (2006) consider that two to six clusters are manageable for finding plausible interpretations. Following that, results[7] indicate there might be an appropriate solution with two, three or four clusters.

Then, K-means cluster analysis was used as a non-hierarchical technique, which partitions *n* observations into *k* clusters in which each observation belongs to the cluster with the nearest mean. This technique is suitable for large number of cases (Arundel et al., 2015; Norusis, 1994). Next stage follows Arundel et al. (2015), which recommends testing the possible solutions. To test all possible solutions indicated by the hierarchical test (dendogram), two-, three- and four-cluster solutions were examined. The tests included running the K-means for each solution and performing validation analysis to compare the different groups formed, which resulted in the three-cluster solution providing the most interpretable results. Cluster membership was saved for further analyses.

4.2.3 Validation Analysis

To determine if the formed clusters are statistically different from one another, validation analysis was carried out. An option for validating cluster analysis solution, as suggested by Aldenderfer and Blashfield (1984), is significance tests on variables used to create

[7] See Appendix B for the dendrogram figure.

clusters, which can be done through analysis of variance (ANOVA). Tests confirm clusters are significantly different both in terms of capabilities and in terms of performance.

Since sectoral elements must be considered in the analysis of firms' innovative performance, statistical difference between clusters in terms of sectoral composition, as well as in terms of other elements such as firm size and R&D investment were also verified. Further analyses comparing the groups and their results, characteristics and implications are presented in the following chapters.

Once firms were grouped into three clusters, it was possible to identify different types of low-tech firms. By analysing the differences between them, is possible to start to draw the way these firms might achieve innovative performance based on their innovation capabilities. To find out the nature of their innovation, however, there is a need to analyse further how these capabilities are combined. The fsQCA approach fits with the aim of verifying options to achieve a given outcome. Once both analyses are combined, it will be possible to determine the patterns of innovation in low-tech firms, in other words. Finally, it will be possible to say what the nature of innovation in low-tech firms is.

4.3 Fuzzy Set/Qualitative Comparative Analysis (fsQCA)

Fuzzy set/Qualitative Comparative Analysis (fsQCA)[8] was developed, initially, for sociology and political science, but it has been gaining attention in management and innovation research for investigating complex configurations of constructs (Ordanini et al., 2014). This new method brings novelty to data analysis, especially in relation to firms and, more precisely, in relation to the capabilities approach. To my knowledge, it has never been used to evaluate firms' capabilities. Therefore, besides the theoretical and managerial contributions of this thesis, it should also have methodological contributions, since it presents a new method to evaluate firms' capabilities and innovative performance.

FsQCA is a set-theoretic method (as opposed to correlational) that empirically verifies the relationships between all possible combinations of predictors (in this case, innovation

[8] To complement my PhD degree I developed research activities abroad. I worked with the Australian Innovation Research Centre (AIRC) at the University of Tasmania in the first semester of 2015. During that period, I was presented to this method of analysis, which, according to the researchers at AIRC, would be of great help to answer my research questions. Following their advice and guidance, I studied the method until I was able to successfully apply it on my database.

capabilities) and an outcome (innovative performance) (Fiss, 2011; Ordanini et al., 2014; Ragin, 2008). Set-based approaches provide "suitable means to accommodate complex complementarities and nonlinear relationships among constructs" (Ganter & Hecker, 2014, p. 1287).

"The final task in applying fsQCA is to prune the sufficient configurations by eliminating redundant elements" (Ordanini et al., 2014, p. 139). Consequently, instead of finding one possible solution, it uses Boolean algebra and algorithms that allow logical reduction of numerous and complex causal conditions into a reduced set of attribute combinations to act as necessary or sufficient conditions for a particular outcome (Fiss, 2011; Ordanini et al., 2014). "Necessary conditions are attributes shown by each member of the final set of firms, sufficient conditions describe (alternative) combinations of attributes leading themselves to the outcome of interest" (Ganter & Hecker, 2014, p. 1287).

Ordanini et al. (2014, p. 137) say that there are three principles for the configuration theory: "outcomes of interest rarely result from a single causal factor; causal factors rarely operate in isolation; and, the same causal factor may have different – even opposing – effects depending on the context". Therefore, fsQCA accounts for equifinality, in other words, the same outcome may be achieved through multiple causal paths (Ganter & Hecker, 2014; Ordanini et al., 2014).

Although qualitative comparative analysis was originally developed as a small-N approach (generally between 15 and 40 cases) (Fiss, 2011), it has been applied for large-N settings (Fiss, 2011; Fiss et al., 2013; Ganter & Hecker, 2014; Ragin & Fiss, 2008; Skarmeas et al., 2014).

To perform fsQCA analysis, researchers should follow some steps (Fiss, 2011; Ordanini et al., 2014; Skarmeas et al., 2014). First, researchers should define the property space, then develop set-membership measures and, finally, evaluate consistency in set relations and logical reduction.

4.3.1 Property Space

"QCA starts by defining property space, which consists of all possible configurations of drivers of an outcome. Since the property space delimits potential explanations of the outcome, the drivers should be chosen carefully and anchored in extant theoretical knowledge" (Ordanini et al., 2014, p. 137).

4.3.2 Set-Membership Measures - Calibration

Qualitative comparative analysis is based on a set-membership concept, and thus, original measures need to be transformed (Ordanini et al., 2014). Set-membership may be analysed using binary analysis, where a predictor has either a full-membership or a full-nonmembership status (crisp-set), or using fuzzy set, which preserves information by allowing gradual membership. According to Ragin et al. (2008), uncalibrated measures are inferior to calibrated ones; therefore, in order to transform conventional variables into fuzzy variables, it is necessary to calibrate them. Calibration makes measurements directly interpretable. It is a necessary and routine research practice in certain fields, but still rare in the social sciences (Ragin, 2007).

Fuzzy set allows researchers to calibrate partial membership in sets using three numerical anchors: 1.0 (threshold of full-membership), 0.0 (threshold of full-nonmembership), and 0.5 (the cross-over point separating “more in” from “more out” of the set being analysed), (Ragin, 2007; Ragin, 2008; Rihoux & Ragin, 2009). With fuzzy sets, precision comes in the form of quantitative assessments of degree of set membership (Ragin, 2007). However, as mentioned by Ragin (2008), the key to useful fuzzy set analysis is well-constructed fuzzy sets, which depends on the calibration of data. The anchor points should be based on researchers’ knowledge of the theoretical concepts they aim to measure and on the context of their cases (Basurto & Speer, 2012; Ragin, 2007). For Ragin (2008), although the ordering is relative in nature, an indicator must order cases in ways to represent its underlying concept. In this study, ordering must consider cases with high innovation capabilities scores relative to the ones with low scores. Chapter 7 explains how the *attributes* **DC**, **OC**, **MC** and **TC** and the *outcome* **IP** were calibrated.

4.3.3 Consistency in Set Relations

The next step in the analysis is to evaluate which combinations of attributes lead to the desired outcome, in this case, high innovative performance. To do that, it is necessary to construct a data matrix known as *truth table* with 2^k rows, where *k* is the number of causal conditions (attributes) used in the analysis (Fiss, 2011; Rihoux & Ragin, 2009). Since there are four attributes (capabilities) in this work, the truth table contains 16 rows (2^4). The number of rows should be reduced according to two criteria: the number of cases and the consistency level (Fiss, 2011; Rihoux & Ragin, 2009). After determining the frequency and consistency cut-off scores, and eliminating combinations that do not meet the criteria, “an algorithm based on Boolean algebra is used to logically reduce the truth table rows to simplified combinations” (Fiss, 2011, p.403). Three solutions are offered, complex, parsimonious and intermediate (Ragin & Sonnett, 2005), whereas the *intermediate* one is the most interpretable solution (Ragin et al., 2008) and the one used in the present research.

4.4 Combining Correlation-Based and fsQCA Approaches

From data analysed through factor and cluster analyses, which allowed the identification of types of low-tech firms, and from fsQCA analysis, which allowed the identification of the combination of innovation capabilities that lead to firms' innovative performance, a combined analysis was then made. The aim of this hybrid-method approach is to identify the patterns of innovation in low-tech firms. In other words, the aim is to match types of low-tech firms and configurations of capabilities that lead to high innovative performance to identify the nature of innovation in low-tech firms. It is only through a holistic approach that the phenomenon of innovation in low-tech firms may be understood. Fiss et al. (2013) say that the advantage of such hybrid approaches introduce additional analyses that allow insights from fsQCA to become more robust.

* * *

Figure 5 summarizes the methodological procedures according to each specific goal of this research. In this sense, the choice for the hybrid-method approach and each analytical technique are justified.

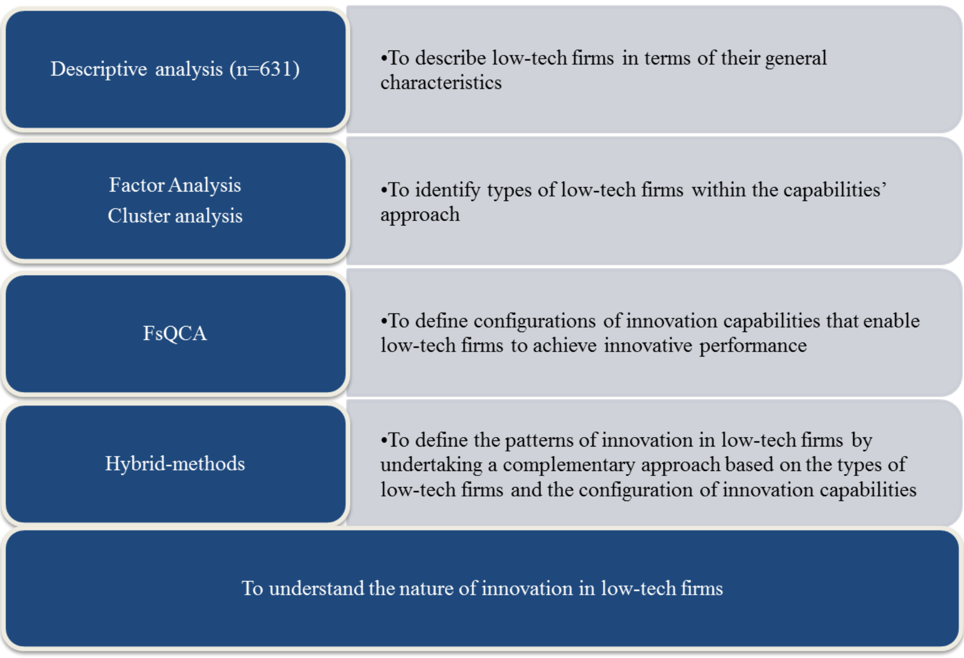


Figure 5 – Method Design according to Research Goals

Further chapters present the results of these analyses, including general characteristics of Brazilian low-tech firms, the types of low-tech firms, the configuration of innovation capabilities that lead low-tech firms to achieve innovative performance, and, finally, the patterns of innovation in low-tech firms. When combining all these analyses is possible to describe the nature of innovation in low-tech firms.

5 Brazilian Low-Tech Firms – General Characteristics

Figure 6 – Thesis' First Specific Goal

To achieve the first specific goal of this Thesis (Figure 6), NITEC's 2014 innovation survey database was used. The 631 low-tech firms were analysed regarding their general characteristics and their innovation capabilities. Considering Brazilian industry classification (CNAE), each sector categorised as low-tech followed OECD's parameters. There are eleven low-tech industries in the sample, but the majority of firms (80%) are concentrated in only five of them (Figure 7): leather and footwear (21%), food products (19%), furniture (17%), textile products and clothing (15%) and wood (8%).

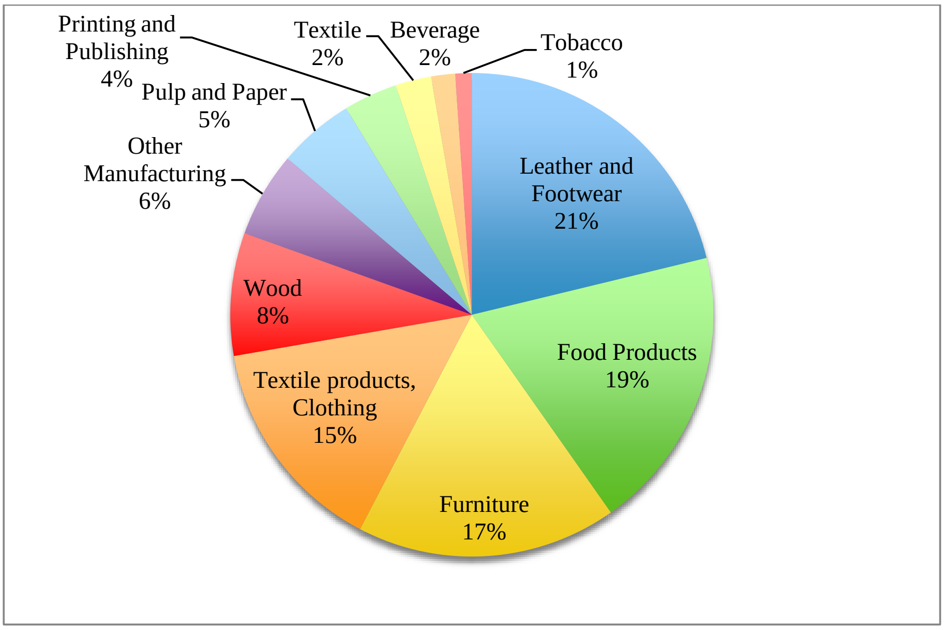


Figure 7 – Sample Distribution based on Manufacturing Industries

These industries are important to local economy, since they represent, together, 29.4% of manufacturing industries in Rio Grande do Sul State's in terms of net output (FIERGS, 2014). Leather and footwear, textile products, wood and furniture closely relate to the origin of manufacturing in this region. European migrants, mostly from Germany and Italy, who colonized Rio Grande do Sul, have worked on professions such as shoemakers, carpenters and artisans. With the industrialization process, they went from individual professionals to small business owners, but they continued to produce the same type of products, only this time, they were industrialized. The food industry also has an important relationship with the region's traditions. The state has a diversified climate and land, which has always hosted family agricultural properties. These small properties have become food processing manufacturing firms. Additionally, larger food companies have decided to install productive plants close to the producers, resulting in a region that has a strong and diversified food products industry.

Although there are industries very relevant to the region, they are formed by a majority of small firms (Table 1).

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Small	558	88.4	**90.6**	90.6
	Medium	41	6.5	6.7	97.2
	Large	17	2.7	2.8	100.0
	Total	616	97.6	100.0	
Missing		15	2.4		
Total		631	100.0		

Note: Size determined by firm gross revenue in 2013

Table 1 – Sample Distribution based on Firms' Size

Considering all sectors, approximately 80% of companies are micro and small in Rio Grande do Sul State (Reichert et al., 2015). Once looking exclusively into low-tech firms, there is an even larger proportion – more than 90% of firms are small.

These figures confirm not only a region's, but also a country's characteristic. In a place where getting a job was once a hard accomplishment, many people have chosen to open their own business as an alternative to be employed by other firms. These characteristics are not exclusive to emerging economies, though. Although not as high, the percentage of low-tech SMEs in Germany was higher than 60% in 2009 (Hirsch-Kreinsen, 2015).

In Brazil, smaller firms are managed by their owners and employ other members of the family. These characteristics are related to the management model these firms have – 68.5% of businesses have a management model based on their owner and family members (Table 2).

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Personalized, cantered on the figure of the owner/s (Family-based)	243	38.5	38.6	38.6
	An organization with family members in executive positions	188	29.8	29.9	**68.5**
	A professionally-based family organization	131	20.8	20.8	89.3
	Professional organization	58	9.2	9.2	98.6
	Corporative governance	9	1.4	1.4	100.0
	Total	629	99.7	100.0	
Missing		2	.3		
Total		631	100.0		

Table 2 – Sample Distribution based on Management Model

Maybe because their management model is less formalized (family-based as opposed to professional administration), their decision-making process is not as elaborated as it could be. Decisions are made based on past experiences (66% of firms base their decisions on tradition and firm's recent performance[9]) instead of being supported by market intelligence or internally developed knowledge. This characteristic could affect firms' flexibility, because it takes longer for them to change, since they are only acting upon what have already happened. These firms might even lose their markets completely, if they are not quick enough to respond to new demands.

Brazilian low-tech firms are small firms run by family members who base their decisions on their experiences. Additionally, 75% of them use 80% or more of their production capacity[10]. This corroborates with the idea that these firms are not too flexible, not only in terms of management, but also in relation to their production activities. If, for instance, these small firms decide to become larger, they cannot do it using their current structure, since it is being used almost to its full. Characteristics such as these, lead to a larger problem related to their entire production strategy – 35.5% of low-tech firms plan their production according to their installed capacity[11].

Once firms are producing based on their installed production capacity instead of, for example, in response to signed contracts or predicted future sales, they believe they are reducing the costs per unit produced, which is a common strategy within low-tech industries (Hirsch-Kreinsen & Schwinge, 2011). Nevertheless, if they do not have enough market for that, in the

[9] See Appendix C for sample distribution
[10] See Appendix C for sample distribution
[11] See Appendix C for sample distribution

end, their costs might be higher, since they may not sell their entire stock. This situation also reflects how little value is being added to their products, because they are determining their production in terms of quantity, and therefore, fighting in the market for the lowest prices.

The way low-tech firms establish their strategy and plan their production activities also reflects how they organize their product development's processes. Low-tech firms, in general, have a reactive approach to product development. They develop new products to satisfy customers' requests or to improve existing products (72.9%), and only 3% of them work with inventions from scratch (Table 3). Hirsch-Kreinsen (2015) have also identified similar product development strategy in low-tech firms in Germany. He says these firms as often limited to continuous further development of given products, which he calls *step-by-step product development* strategy or *low-innovative manufacturers*. In this case, "product components are often improved incrementally in terms of their materials, function and quality to be consistent with changing customer demands" (p. 21).

		Frequency	Percent
Valid	To meet legal requirements	66	10.5
	After customer requests	**229**	**36.3**
	To improve existing products	**231**	**36.6**
	To expand the product's portfolio	85	13.5
	To develop an invention from scratch	20	3.2
	Total	631	100.0

Table 3 – Triggers for Development Process

Although their development activities are not proactive, low-tech firms still invest in R&D activities. They invest, on average, 3.71% of their gross revenue in R&D activities. They also hold, on average, two patents, although 63% of them have never registered any[12]. When they launch new products in the market, 12.75% of their revenue is a result of these products (Table 4).

	Mean
% of company's gross revenue invested in R&D	3.71
Number of patents hold	2.04
% of the revenue from new products	12.75

Table 4 – Sample Distribution of Investments in R&D Activities, Number of Patents and Revenue from New Product Development

[12] See Appendix C for sample distribution

Brazilian low-tech firms' investments in R&D are higher than the percentage (up to 1%) indicated by OECD (2010). This could mean that, because firms from low-tech sectors are so important to the country's economy, they end up being involved in more innovation-related activities, and thus, their investments are higher. However, some peculiarities must be taken into account: often, Brazilian firms consider *R&D investment* any activity related to product development, even if these activities are routine product improvement or occasional among their production routines.

The dependent relation low-tech firms have with other stakeholders, especially their clients, is also reflected on their distribution channels. Only 21.5% of firms sell their products direct to their final customers[13]. This means that these firms have relations that are mostly business-to-business. Besides, 81.2% of low-tech firms determine their products' prices according to the costs of producing them, which also represent a high-dependency on a third party[14]. If these firms do not have room to negotiate with suppliers and clients, to aggregate value to their products, and thus, to charge more for it, they end up in a very dangerous position of failing.

* * *

Brazilian low-tech firms are small firms managed by their owners and other family members. They make decisions based on the past and they plan their production according to their production capacity. In both cases, they are not paying attention to what is happening in the market. These two conditions, together with the fact that they set their prices based on their costs, might cause them to notice any change in the market when it is already too late. Only after something has happened that they will realize they made the wrong strategic decision. Only after they end up with high levels of final product in stocks (because costumers do not want that product anymore or because the price was not correct for that market), they will realize they did not pay attention to market needs. They are also very reactive to the market in terms of product development. *In other terms, these firms are always a step behind the market*.

Many low-tech firms have these characteristics, however, not all of them. There are low-tech firms that are innovative. As Hirsch-Kreinsen (2008, 2015) and Zawislak et al. (2013b) have already identified in other studies, and is true for this sample, machinery and equipment

[13] See Appendix C for sample distribution
[14] See Appendix C for sample distribution

acquisition and process improvements are among the most common improvements. This means they put efforts on adapting it to their own operations, because many low-tech firms engage in activities of integrating and adapting new technologies into their manufacturing processes (Hirsch-Kreinsen, 2015; Huang et al., 2010). In relation to management activities, these firms innovate mainly through changing their administrative infrastructure. Moreover, in relation to their commercial activities, their main innovations regard their negotiation skills and offering new customers' services.

Although they may not be developing state-of-the-art products, low-tech firms still may achieve innovative performance, but this may be in areas such as commercial, managerial or operational.

These characteristics show that, in general, Brazilian low-tech firms are not proactive in terms of developing novelties. However, there are firms among this group that are successful and innovative. Who are they? What are their characteristics? What is the configuration of their innovation capabilities? What do they do that others do not?

6 Types of Brazilian Low-Tech Firms

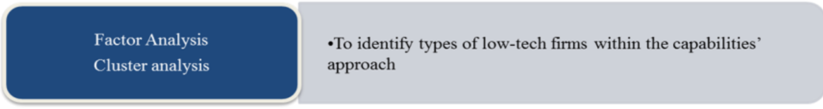


Figure 8 – Thesis' Second Specific Goal

To achieve the second specific goal of this Thesis (Figure 8), factors and cluster analyses were performed.

6.1 The Innovation Capabilities of Brazilian Low-tech Firms

Following the procedures set in the Research Method and Design (see section 4.2.1), five variables were excluded: DC6, OC7, OC9, MC7 and TC2 in the principal component analysis.

Variable DC6 relates to development of products in partnership with Science and Technology Institutions. This is not a common practice in Brazil; therefore, most firms rated very low scores in this question (the lowest of all questions). There were a number of no significant values in the correlation matrix for this variable. Variables OC7 (delivers the products promptly) and OC9 (manages to ensure the process does not lead to products being returned) were the operations capability's variables excluded from the model. They were both rated very high scores, and had a number of no significant values in the correlation matrix. In addition, they relate more to normal routine procedures than to a capability that could differentiate one firm from another. In management capability the situation is similar, MC7 (includes social and environmental responsibilities on its strategic agenda) was the highest score of all questions and, additionally, it refers more to a general characteristic of a firm than to its management capability. Finally, in relation to the transaction capability, variable TC2 (imposes its negotiating terms on its suppliers) was excluded, probably because most low-tech firms in the sample are small firms and do not have negotiation power with their suppliers.

Principal component analysis was performed once again and, in order to meet the test's parameters, in the following round, data were fixed into four factors. At this stage, all parameters met the requirements resulting in four factors (Table 5) that fit the model[15]. The Correlation Matrix does not present any value greater than 0.9 and its determinant is 0.00005 (greater than the necessary value of 0.00001), therefore, multicollinearity is not a problem for the database. According to Field (2000, p. 454), these parameters indicate that all questions "correlate fairly well with others and none of the correlation coefficients are particularly large". All the variables have satisfactory measure of sampling adequacy (MSA) (>0.860), implying they are suitable for principal component analysis. Additionally, Keiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity met common standards (KMO=0.918 and *p*(Bartlett)=0.000) (De Jong & Marsili, 2006). Residual from the reproduced correlations is 39%, below the maximum of 50% recommended by Field (2000). *The total variance explained for the four factors representing the innovation capabilities is 53.8%.*

	Component			
	1	2	3	4
MC4	**.767**			
MC1	**.704**			
MC6	**.699**			
MC3	**.657**			
MC5	**.603**			
MC2	**.468**			
OC1	**.466**			
DC5		**.767**		
DC1		**.727**		
DC7		**.726**		
DC4		**.650**		
DC2		**.609**		
DC3		**.516**		
TC3			**.739**	
TC4			**.730**	
TC6			**.678**	
TC1			**.626**	
TC5	.432		**.505**	
OC5				**.676**
OC6				**.672**
OC8				**.603**
OC4				**.585**
OC3				**.509**
OC2	.408			**.436**

Table 5 – Rotated Component Matrix

[15] See Appendix A for the tests tables of the Factor Analysis.

All variables were grouped according to the capabilities they originally were supposed to (according to the Innovation Capabilities Model), except operations capability OC1, which is now part of the management capability (Figure 9). The relocation is appropriate though, since "formalization of processes and procedures" relates to management activities. Finally, the factor scores for each variable, which represent the relative importance of them for the factor (Field, 2000), were saved as new variables.

DEVELOPMENT CAPABILITY
DC1. Designs its own products
DC2. Monitors the latest tendencies in technology within the industry
DC3. Uses formal project management methods (e.g. Stage-Gate, PMBOK, innovation funnel)
DC4. Adapts the technology in use to its own needs
DC5. Prototypes its own products
DC7. Launches its own products

OPERATIONS CAPABILITY
OC2. Keeps statistical control of the process
OC3. Uses leading edge technology within the sector
OC4. Maintains adequate stock levels of materials for the process
OC5. Carries out the productive process as programmed
OC6. Establishes a productive routine that does not generate rework
OC8. Manages to expand the installed capacity whenever necessary

MANAGEMENT CAPABILITY
OC1. Formalizes the production plan and control procedures
MC1. Formally defines its strategic aims annually
MC2. Uses technology to integrate all its areas
MC3. Standardizes and documents the work procedures
MC4. Updates its management tools and techniques
MC5. Maintains the personnel adequately trained for the company functions (training)
MC6. Uses modern financial management practices

TRANSACTION CAPABILITY
TC1. Conducts formal research to monitor the market
TC3. Imposes its prices on the market
TC4. Imposes its negotiating terms on its customers
TC5. Conducts research to measure its customers' satisfaction
TC6. Uses formal criteria to select its suppliers

Figure 9 – Final Factors

Cluster analysis was performed using the factor loading scores generated during the factor analysis (see section 4.2.2 for previous steps of the test), resulting in three clusters.

6.2 Three Types of Brazilian Low-tech Firms

From the validation analysis that follows, these clusters were named *Low capabilities* (Cluster 1), *Intermediate capabilities* (Cluster 2) and *High capabilities* (Cluster 3). To identify why firms were grouped in these three clusters, validation tests are carried out to compare means between them. Table 6 shows the number of cases in each cluster.

Cluster	1	135
	2	154
	3	252
Valid		541
Missing		90

Table 6 – Number of cases in each cluster

Firstly, it is important to look into specific characteristics of each type of low-tech firm and, with that in mind, *chi-square* was used to test differences in terms of firms' general characteristics, input indicators and output indicators (Tables 7 to 14, which will be discussed individually). Chi-square is used to test statistical significance between frequency distribution of two or more groups (Hair et al., 2005).

Total	N[1] 541	**Low capabilities**	**Intermediate capabilities**	**High capabilities**
General Characteristics				
Firm Size	528			
Small	477	97.7%	93.3%	84.6%
Medium	37	2.3%	4.7%	11.0%
Large	14	0.0%	2.0%	4.5%
Total		100%	100%	100%
Chi-square (4 *df*)	19,595**			

[1] Initial n=631, after cluster analysis n=541

Note: *p<0.05, **p<0.01, ***p<0.001

Table 7 – Percentage of Firms regarding Firm Size by Cluster

Considering that in the sample more than 90% of firms are small, it was only expected that each cluster would have higher percentages of firms of this size. However, there is significant difference (p<0.001) between clusters in terms of **firms' size** (Table 7). High capabilities cluster has the highest percentages of large (4.5%) and of medium size (11%) firms, whereas the Low capabilities cluster does not have any large firm and almost 98% of them are small.

Low capabilities low-tech firms are generally small, and most of the larger firms (medium and large) within the sample belong to the High capabilities cluster. It indicates that the larger the firm, the higher the level of their innovation capabilities and, in that sense, larger firms could have a better chance to be innovative.

	N[1]			
Total	541	**Low capabilities**	**Intermediate capabilities**	**High capabilities**
General Characteristics				
Industry	541			
Food products	104	23.0%	18.8%	17.5%
Beverages	10	1.5%	1.9%	2.0%
Leather & Footwear	116	23.7%	20.8%	20.6%
Other manufacturing	26	3.7%	4.5%	5.6%
Tobacco	7	1.5%	0.0%	2.0%
Printing & Publishing	16	6.7%	1.9%	1.6%
Wood	46	11.9%	9.7%	6.0%
Furniture	95	14.1%	16.2%	20.2%
Pulp & Paper	31	3.7%	6.5%	6.3%
Textile	11	1.5%	1.9%	2.4%
Apparel	79	8.9%	17.5%	15.9%
		100%	100%	100%
Chi-square (20 *df*)	25.945			

[1] Initial n=631, after cluster analysis n=541

Note: *p<0.05, **p<0.01, ***p<0.001

Table 8 – Percentage of Firms regarding Industry by Cluster

With the idea of verifying sectoral influence on innovation in low-tech firms, the difference between clusters in terms of **industry** arrangement has been tested (Table 8). Surprisingly, there is no significant difference between them. All eleven sectors are present in all clusters, with the exception of Tobacco industry in Intermediate capabilities cluster. Considering that Tobacco is one of the most developed low-tech industries in Rio Grande do Sul, it is understandable its absence. In addition, this industry represents only 1% of the sample, so concentration in one or two clusters was anticipated.

The two larger industries within the sample are also the two larger in the Low and in the Intermediate capabilities clusters, which are leather and footwear, and food products. In the High capabilities group, leather and footwear, and furniture are the two main industries.

Although the *no significant result* was surprising, it brings back the discussion about the industry technological intensity approach to innovation. It corroborates with the idea presented that there are more factors affecting a firm's innovative performance than the sectoral approach.

	N[1]			
Total	541	**Low capabilities**	**Intermediate capabilities**	**High capabilities**
General Characteristics				
Management Model	540			
Family-based	373	70.4%	73.2%	65.9%
Professional administration	167	29.6%	26.8%	34.1%
		100%	100%	100%
Chi-square (2 *df*)	2.536			

[1] Initial n=631, after cluster analysis n=541

Note: *p<0.05, **p<0.01, ***p<0.001

Table 9 – Percentage of Firms regarding Management Model by Cluster

Firms' **management model** has also been analysed (Table 9). Firms were divided into two groups, those that are family-based and those that have professional administration. There was no significant difference between these groups among the three clusters. Thus, there are examples of family-based firms that are Low capabilities, Intermediate and High capabilities.

Professionally managed firms are also present in all clusters, and although not significant, the High capabilities cluster has the largest proportion of them. Since the High capabilities low-tech firms are the ones concentrating the larger firms within the sample, a Pearson correlation test has been performed to verify if there is the association between firm size and business model within low-tech firms (Appendix D). The test indicates that, although weak, there is a significant correlation (*p*=.000) between both indicators. It can indicate that the professional administration is more common in larger firms, and therefore, in firms with High capabilities.

	N[1]			
Total	541	**Low capabilities**	**Intermediate capabilities**	**High capabilities**
General Characteristics				
Partnership with Science and Technology Institutions[2]	535			
Interacts at levels 1, 2 and 3	394	87.1%	79.7%	62.8%
Interacts at levels 4 and 5	141	12.9%	20.3%	37.2%
		100%	100%	100%
Chi-square (2 *df*)	30.427***			

[1] Initial n=631, after cluster analysis n=541

[2] Likert-type scale questions (from 1 to 5)

Note: *p<0.05, **p<0.01, ***p<0.001

Table 10 – Percentage of Firms regarding Interaction with Science and Technology Institutions by Cluster

Development of products in partnership with Science and Technology Institutions was used to measure **interaction** between firms (Table 10). Utilizing a Likert-type scale from one to five, it is possible to say that High capabilities firms interact more than the others at levels four and five (p<0.001) did. In 37.2% of cases, High capabilities low-tech firms interact at levels four and five, whereas in Intermediate capabilities this percentage is 20.3% and in Low capabilities is 12.9%. The size of the companies forming the clusters could be a reflect of this, since, as put by Hirsch-Kreinsen (2015, p.26), the predominance of small firms on low-tech industries plays a significant role regarding interaction "as these businesses are hesitant to engage in formal cooperation and prefer informal, personnel-based relationships".

For Som et al. (2015), the size is not the greatest limitation for interaction, but the lack of R&D expenditures. They say "once firms have at least some R&D expenditure, even if the amount is small, they seem to engage considerably more frequently in R&D collaborations with external partners than firms without any R&D investments" (Som et al., 2015, p. 133). A Pearson correlation test has been performed (Appendix D) between R&D investments and interaction with Science and Technology Institutions to verify this association. The test indicates there is a significant correlation (p=.000) between both indicators, although the association strength is weak. Besides the correlation between them, it is possible that the higher the level of capabilities in a low-tech firm, the more it invests in R&D and the more it interacts to develop new products. Next table verifies the relation between R&D investments and each cluster.

Total	N[1] 541	**Low capabilities**	**Intermediate capabilities**	**High capabilities**
Input				
Investments in R&D	515			
0%	160	36.9%	35.7%	25.2%
More than 0% to 2%	124	20.8%	32.2%	21.1%
More than 2% to 4%	55	14.6%	4.2%	12.4%
More than 4% to 6%	88	16.9%	15.4%	18.2%
More than 6%	88	10.8%	12.6%	23.1%
		100%	100%	100%
Chi-square (8 *df*)	28,986***			

[1] Initial n=631, after cluster analysis n=541

Note: *p<0.05, **p<0.01, ***p<0.001

Table 11 – Percentage of Firms regarding Investments in R&D by Cluster

Investments in R&D was used as an input indicator (Table 11). Although firms invest different amounts in R&D, in Low capabilities cluster a high percentage of firms (36.9%) does not invest anything in these activities. This proportion is similar in the Intermediate capabilities cluster, where 35.7% of firms do not invest in R&D. When looking at cumulative values, around 67% of firms in this cluster invest no more than 2% in R&D. The situation is different among firms from the High capabilities cluster. Among High capabilities low-tech firms, only 25.2% do not have any expenditure with R&D and 23.1% invest more than 6% (or around 41% invest more than 4%). In this indicator the difference was significant at level p<0.001.

Kirner et al. (2015a) related the size of firms with R&D investments, where small firms invest less. These results are corroborated here, since Low capabilities cluster has the highest percentage of small firms and invest less in R&D activities. Additionally, after performing a Pearson correlation between investments in R&D and firm size (Appendix D) within the low-tech firms sample, it is possible to say that this correlation is significant (p=.000), although weak. For Kirner et al. (2015b), the lack of R&D investments is not the main factor influencing low innovation levels. For them, large firm size and higher product complexity have a positive influence on firms' product development ability.

	N[1]	**Low capabilities**	**Intermediate capabilities**	**High capabilities**
Total	541			
Output - Patent				
Registered Patent(s)	532			
Yes	202	36.6%	28.3%	44.7%
No	330	63.4%	71.7%	55.3%
		100%	100%	100%
Chi-square (2 *df*)	10,912**			

[1] Initial n=631, after cluster analysis n=541

Note: *p<0.05, **p<0.01, ***p<0.001

Table 12 – Percentage of Firms regarding Registered Patents by Cluster

Patent registration is among the output indicators measured in this research (Table 12). Firms were divided into two groups, those that have never registered patents and those that have. The difference is significant (p<0.01) for this indicator. Although registering patents is not in the culture of Brazilian firms, and although Low and Intermediate capabilities clusters have low proportions of firms with patents (36.6% and 28.3%, respectively), High capabilities cluster register patents above average (44.7%).

Since R&D investments and registering patents are significantly correlated (Appendix D; *p*=.000), it is possible to assume that High capabilities low-tech firms register more patents in relation to the other types of low-tech firms. This happens, in part, due to their expenditures in R&D. High capabilities low-tech firms, despite belonging to mature industries, work with products of higher complexity when compared to their competitors. Consequently, they have higher interaction for product development, higher investments in R&D and, because of these activities, have higher patent registrations.

	N[1]			
Total	541	**Low capabilities**	**Intermediate capabilities**	**High capabilities**
Output – New Product (Novelty)				
Launched new product(s)	541			
Yes	293	43.7%	57.8%	57.5%
No	248	56.3%	42.2%	42.5%
		100%	100%	100%
Chi-square (2 *df*)	7,923*			
Revenue from new products	501			
0%	221	58.7%	37.6%	40.2%
More than 0% to 5%	92	19.0%	11.3%	22.2%
More than 5% to 10%	45	7.1%	10.6%	9.0%
More than 10% to 40%	89	9.5%	26.2%	17.1%
More than 40%	54	5.6%	14.2%	11.5%
		100%	100%	100%
Chi-square (8 *df*)	30,313***			

[1] Initial n=631, after cluster analysis n=541

Note: *p<0.05, **p<0.01, ***p<0.001

Table 13 – Percentage of Firms regarding Novelty Indicators by Cluster

Although the level of significance is not high (p<0.05), there is significant difference in terms of firms launching **new products** (Table 13) between clusters. The cluster with the highest percentage of firms that launch new products is Intermediate capabilities (57.8%). In previous indicators analysed, High capabilities has been the cluster presenting the best performance in the significant different indicators. Although they present similar values, it is interesting that this was the outcome for this indicator. Low capabilities cluster is the only cluster where the percentage of firms that have not launched any product in the previous year is higher than the percentage of those that have done so.

However, it is interesting that the best performance for the novelty indicators is among the Intermediate capabilities firms. The High capabilities low-tech firms have invested more in

R&D, interacted more to develop new products, registered more patents, but are not launching more products than the Intermediate capabilities firms do.

Intermediate capabilities cluster's performance was also better than the others in terms of **revenue from new products** (*p*<0.001) (Table 13). While Low capabilities and High capabilities clusters present revenue lower than 5%, around 77% and 62%, respectively, Intermediate capabilities cluster presents only 49%. In other words, around 51% of Intermediate capabilities firms have revenues from new products higher than 5%. This could mean that even having low levels of management capability, these firms have other capabilities, which could be transaction or development capabilities, which allows them to launch new products more frequently than the other firms, and to earn more from it.

Total	N[1] 541	**Low capabilities**	**Intermediate capabilities**	**High capabilities**
Output – Firm Performance				
Net profit growth [2]	540			
1, 2	86	20,7%	19,5%	11,2%
3	191	44.4%	33.1%	31.9%
4, 5	263	34,8%	47,4%	57,0%
		100%	100%	100%
Chi-square (8 *df*)	22,801**			
Market share growth [2]	538			
1, 2	59	11,2%	17,6%	6,8%
3	164	37.3%	27.5%	28.7%
4, 5	315	51,5%	54,9%	64,5%
		100%	100%	100%
Chi-square (8 *df*)	26,578**			
Revenue growth [2]	540			
1, 2	59	12,7%	14,9%	7,5%
3	202	49.3%	30.5%	35.3%
4, 5	279	38,1%	54,5%	57,1%
		100%	100%	100%
Chi-square (8 *df*)	19,430*			

[1] Initial n=631, after cluster analysis n=541

[2] Likert-type scale questions (from 1 to 5)

Note: *p<0.05, **p<0.01, ***p<0.001

Table 14 – Percentage of Firms regarding Firm Performance Indicators by Cluster

Firm performance indicators (net profit growth, market share growth and revenue growth) were measured through Likert-type scales of one to five (Table 14).

Fifty-seven percent (57%) of firms in the High capabilities cluster have a **net profit growth** equivalent to four or five, while the others presented lower performance (around 35% in the Low capabilities cluster and 47% in the Intermediate capabilities). The test was significant at level $p<0.01$.

High capabilities firms have also presented better performance in terms of **market share growth**. Around 64% of High capabilities firms scored four or five in the scale, while this percentage is 55% for Intermediate capabilities firms and 51% for Low capabilities. This test was also significant at level $p<0.01$.

Similarly to the other two firm performance indicators, High capabilities firms have performed better in terms of **revenue growth** ($p<0.05$). More High capabilities firms (around 57%) scored four or five in the scale than the others (54% of Intermediate capabilities and only 38% of Low capabilities).

Although the High capabilities low-tech firms are neither launching more products nor profiting from them, they are achieving better economic performance in terms of profit, market share and revenue growth. This could be a result of having more innovation capabilities with high scores, which allows them not only to have some product development, but also to transact them more effectively in the market and to better manage their activities. Intermediate capabilities low-tech firms are launching more products, but their economic results are not as good as the High capabilities firms are.

* * *

These tests confirm that the firms in the sample were grouped appropriately in these three clusters because they show consistency in terms of their characteristics, input indicators and output indicators. With the exception of industry and management model, all other items analysed are significantly different.

In most cases of output indicators, High capabilities firms have performed better, followed by Intermediate capabilities cluster. Intermediate capabilities cluster had a better performance in terms of launching new products and earning from it. In the other end, Low capabilities cluster has presented the worst performance results, with the exception of patent registration, which it achieved the second place and the Intermediate capabilities cluster was last. In terms of general characteristics, High capabilities firms are larger and have more partnerships with Science and Technology Institutions than the other two groups of firms. Low capabilities cluster grouped smaller firms that do not interact too often.

In sum, High capabilities low-tech firms are larger than the other low-tech firms, invest more in R&D, interact more to develop new products, register patents more frequently and achieve better performance in terms of profit, market share and revenue growth. Intermediate capabilities low-tech firms usually are in "second place" in terms of these indicators. However, they have outperformed the High capabilities firms in relation to novelty indicators, especially in terms of revenue from new products. Low capabilities low-tech firms are, in fact, poor performers overall, combining small firms that do not invest internally in R&D nor develop partnerships for product development. Thus, their performance is also limited.

6.3 Innovation Capabilities for each Type of Low-Tech Firm

To explore these differences and to build an understanding of what means to a firm to belong to a Low capabilities, Intermediate capabilities or High capabilities group of low-tech firms, a comparison of means between clusters for each variable is presented. Scheffe analysis comparing clusters in terms of innovation capabilities and in terms of performance indicators will elucidate these differences. In doing these analyses, some differences between clusters (and explanations on why some firms are grouped together) start to become clearer.

	Low capabilities	**Intermediate capabilities**	**High capabilities**
	Mean	Mean	Mean
Development Capability			
DC1. Designs its own products	2.94	3.97	4.12
DC2. Monitors the latest tendencies in technology within the industry	3.27	3.99	4.08
DC3. Uses formal project management methods (e.g. Stage-Gate, PMBOK, innovation funnel)	2.70	3.34	3.67
DC4. Adapts the technology in use to its own needs	3.33	4.01	3.96
DC5. Prototypes its own products	2.74	4.20	4.06
DC7. Launches its own products	2.83	4.35	4.27
DC	**2.97**	**3.98**	**4.03**

Note: Figures in green are the highest and in red are the lowest

Table 15 – Mean Analysis of Development Capability comparing Clusters

Regarding development capability (Table 15), it is clear that the Low capabilities low-tech firms have the lowest scores. This corroborates with the previous analyses, since they do not invest much in R&D, they not collaborate in partnerships to develop new products and they do not register patents. These activities are not among their repertoire because they have very weak development capability. At most, they monitor the latest tendencies in technology within their industry or adapts some technologies to their use; otherwise, they do not prototypes their own products nor use formal project management.

Intermediate capabilities low-tech firms occupy, as the name says, an intermediate position in terms of development capability. These type of firm have an overall strong development capability, however, it is not as strong as in the High capabilities firms. It is interesting to note a pattern of high scores in High capabilities clusters in activities related to first steps of a development process. In that sense, activities related to monitoring tendencies, designing products and implementing projects show highest scores in the High capabilities cluster. When looking into activities related to actually prototyping and producing a new product, Intermediate capabilities cluster has the highest scores.

Intermediate capabilities firms, although having a development capability not as strong as the High capabilities firms, still show high scores, in other words, it still have what is needed to develop new products and technologies. Moreover, this is corroborated with the novelty indicators results, where Intermediate capabilities low-tech firms are the ones launching more products and earning more from them among the different types of low-tech firms. High capabilities low-tech firms, as discussed in previous analyses, invest in R&D, develop new products in partnership with Science and Technology Institutions, register more patents than the other types of low-tech firms, and these activities are a result of a strong development capability.

	Low capabilities Mean	Intermediate capabilities Mean	High capabilities Mean
Operations Capability			
OC2. Keeps statistical control of the process	3.74	3.79	3.90
OC3. Uses leading edge technology within the sector	3.60	3.78	3.82
OC4. Maintains adequate stock levels of materials for the process	4.11	4.28	3.98
OC5. Carries out the productive process as programmed	4.09	4.26	3.87
OC6. Establishes a productive routine that does not generate rework	4.13	4.20	3.87
OC8. Manages to expand the installed capacity whenever necessary	3.70	4.09	3.74
OC	**3.90**	**4.07**	**3.86**

Note: Figures in green are the highest and in red are the lowest

Table 16 – Mean Analysis of Operations Capability comparing Clusters

By comparing the High and the Intermediate capabilities firms, it is possible to observe that, similarly to what happened in the development capability, in the operations capability (Table 16), the highest variables' means are also divided between these two clusters. In terms of operations capability, High capabilities firms are better prepared to implement leading edge technology, while Intermediate capabilities cluster is more prepared to run the process and to control its routine activities.

Operations capability is the only capability that the High capabilities low-tech firms are not the best performer. In fact, they have the worst results among the different types of low-tech firms for this specific capability. When looking into previous analyses, it does not seem to influence their overall economic performance though, since they have the highest scores in terms of profit, market share and revenue growth. Further analyses should confirm this impression.

Results from development and operations capabilities could denote that High capabilities low-tech firms are willing to take higher risks in terms of searching and implementing innovation, while Intermediate capabilities cluster is more prepared to put in place novelties that (probably) have been developed somewhere else or that have been ordered by their clients. In the last case, they are prepared to produce new products "owned" by their clients.

It is also interesting to note that the Low capabilities firms have presented a reasonably high performance in terms of operations capability. However, previous analyses of characteristics input and output indicators point toward a weak performance. Either this could denote that having only one strong capability, or having a strong operations capability do not affect their innovative performance. Subsequent analyses will explore these topics.

	Low capabilities Mean	**Intermediate capabilities** Mean	**High capabilities** Mean
Management Capability			
OC1. Formalizes the production plan and control procedures	3.53	3.27	3.63
MC1. Formally defines its strategic aims annually	3.88	3.10	4.00
MC2. Uses technology to integrate all its areas	3.14	3.11	3.58
MC3. Standardizes and documents the work procedures	3.66	3.28	3.93
MC4. Updates its management tools and techniques	3.61	3.03	3.97
MC5. Maintains the personnel adequately trained for the company functions (training)	3.94	3.64	4.26
MC6. Uses modern financial management practices	3.70	3.23	4.08
MC	**3.64**	**3.24**	**3.92**

Note: Figures in green are the highest and in red are the lowest

Table 17 – Mean Analysis of Management Capability comparing Clusters

Management capability (Table 17) is an interesting case. Among all four capabilities, this is the one that seemed to have influenced more in the division of these firms in the clusters they have been divided. Low capabilities low-tech firms have all medium results, Intermediate capabilities firms have all the lowest results and High capabilities firms have all the highest results. The Intermediate cluster could even have been named Low Management cluster, however, due to its overall results in terms of the characteristics, input and output indicators, and in terms of the other three capabilities, it was noted that it is actually an Intermediate capabilities cluster.

The High capabilities low-tech firms confirm their status of having the highest scores in terms of capabilities. They seem to be able to develop new products according to formalized standards, to use leading edge technology within the sector to produce the products they have developed and to manage well the entire process. They are able to formalize their strategic plans, as well as their processes and procedures. Besides, they apply modern management techniques, maintain trained personnel and use technology to integrate all areas. In other words, they know what they want to achieve and control the process to make sure they do.

Considering that the Intermediate capabilities cluster has low-level management capability, it is only natural that activities related to formal processes, even when related to other areas of the firm, are also low in other capabilities. Being Intermediate capabilities affects some important variables in other capabilities that relate to it, such as project management (DC), application of statistical control of processes (OC) and conduction of formal research (TC).

	Low capabilities Mean	Intermediate capabilities Mean	High capabilities Mean
Transaction Capability			
TC1. Conducts formal research to monitor the market	2.87	3.12	3.50
TC3. Imposes its prices on the market	3.03	3.51	3.34
TC4. Imposes its negotiating terms on its customers	3.19	3.60	3.38
TC5. Conducts research to measure its customers' satisfaction	2.96	3.07	3.73
TC6. Uses formal criteria to select its suppliers	3.51	3.55	3.83
TC	**3.11**	**3.37**	**3.55**

Note: Figures in green are the highest and in red are the lowest

Table 18 – Mean Analysis of Transaction Capability comparing Clusters

Once again, Low capabilities low-tech firms have had the worst results, this time, in terms of transaction capability (Table 18). Low capabilities firms neither have the capabilities to develop new products nor to commercialize them. They are able though, to produce their products and to manage their firms. This could be the reason for their low economic performance, as shown in previous analyses, since they are not aggregating any value to what they do. They are firms that, probably, provide operation services to other firms, who are actually the holders of the brand and of the intellectual property of the product.

High capabilities firms, with their high scores in terms of transaction capability, confirm that they are not only able to develop new products, produce them with leading edge technology, and well manage their firm, but also able to commercialize their products effectively.

Intermediate capabilities firms have also presented some variables with the highest scores in transaction capability. Especially in terms of negotiating with the market. They are able to impose their prices on the market as well as the negotiating terms on their customers. Therefore, although they lack the formal aspects, such as conducting formal research and using formal criteria to select suppliers (this is probably due to their low management abilities), they are still able to have an overall medium score in the transaction capability.

	Low capabilities Mean	**Intermediate capabilities** Mean	**High capabilities** Mean
DC	2.97	3.98	4.03
OC	3.90	4.07	3.86
MC	3.64	3.24	3.92
TC	3.11	3.37	3.55
All Capabilities	**3.42**	**3.66**	**3.86**

Table 19 – Mean Analysis of Variables (capabilities) comparing Clusters

* * *

In sum (Table 19), Low capabilities low-tech firms have the lowest overall average (3.42) for its fours innovation capabilities. At the other extreme, High capabilities firms, have the highest capabilities scores average (3.86). In between them, the Intermediate capabilities firms (3.66). Low capabilities cluster has the clearest results, having the lowest average in development capabilities (2.97) and transaction capabilities (3.11), and not having one single variable with the highest score. High capabilities cluster has the highest averages in all capabilities (especially in management capability, where all variables show the highest means), except in operations capability, where the highest score belongs to the Intermediate capabilities cluster. Intermediate capabilities cluster has good scores overall, however, has the lowest average in management capability, even when compared to the Low capabilities cluster.

Although there is an order of firms in terms of level of their capabilities, it is not possible to say that when a firm belongs to the Low capabilities group, it will be non-innovative. As seen in the results, although their capabilities show lower levels than in the other two types of low-tech firms, there are, still, some capabilities with a reasonable level. They might not be technologically innovative, but they might be able to innovate through their operations or management capabilities.

6.4 Differences in Innovation Capabilities between each Type of Low-Tech Firm

The idea of discussing Tables 15 to 19 was to give an overview of each cluster in terms of capabilities. The differences in mean are not necessarily significant; therefore, ANOVA was carried out to test the significant difference between them. ANOVA is used to evaluate statistical difference between two or more groups, when the independent variables are categorical (Hair et al., 2005).

The *F test* evaluates the mean difference between groups through dividing the variance between groups by the variance within groups. F test reveals significant differences ($p<0.001$) in all clustering variables. ANOVA allows only identifying if there is statistical difference at some point in the groups means, however, it does not identify where are these differences. For this reason, post hoc tests are carried out. There are many tests available for that, whereas Scheffe is the most conservative one (Hair et al., 2005).

The aim is to *confirm* these differences and the indication that High capabilities low-tech firms have higher levels of capabilities than the Intermediate ones and that the latter, have higher levels of capabilities than the Low capabilities low-tech firms do. Scheffe analysis confirms there are differences between the factors (capabilities) and the clusters (Table 20). In the next section, the sequence in terms of performance is also verified.

Scheffe

Dependent Variable	(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
DC	1 - Low capabilities	3	-1.05979*	.06981	.000	-12.311	-.8884
		2	-1.00952*	.07717	.000	-11.990	-.8201
	2 - Intermediate capabilities	1	1.00952*	.07717	.000	.8201	11.990
		3	-.05026	.06695	.755	-.2146	.1141
	3 - High capabilities	1	1.05979*	.06981	.000	.8884	12.311
		2	.05026	.06695	.755	-.1141	.2146
OC	1 - Low capabilities	3	.03064	.05655	.863	-.1082	.1694
		2	-.17096*	.06251	.024	-.3244	-.0175
	2 - Intermediate capabilities	1	.17096*	.06251	.024	.0175	.3244
		3	.20160*	.05423	.001	.0685	.3347
	3 - High capabilities	1	-.03064	.05655	.863	-.1694	.1082
		2	-.20160*	.05423	.001	-.3347	-.0685
MC	1 - Low capabilities	3	-.28254*	.06133	.000	-.4331	-.1320
		2	.39969*	.06779	.000	.2333	.5661
	2 - Intermediate capabilities	1	-.39969*	.06779	.000	-.5661	-.2333
		3	-.68223*	.05881	.000	-.8266	-.5379
	3 - High capabilities	1	.28254*	.06133	.000	.1320	.4331
		2	.68223*	.05881	.000	.5379	.8266
TC	1 - Low capabilities	3	-.44286*	.07778	.000	-.6338	-.2519
		2	-.25642*	.08598	.012	-.4675	-.0454
	2 - Intermediate capabilities	1	.25642*	.08598	.012	.0454	.4675
		3	-.18644*	.07459	.045	-.3695	-.0033
	3 - High capabilities	1	.44286*	.07778	.000	.2519	.6338
		2	.18644*	.07459	.045	.0033	.3695

* The mean difference is significant at the 0.05 level.

Table 20 – Scheffe Analysis between Clusters and Capabilities

Scheffe analysis is comparing, for each innovation capability, the mean difference between clusters. For example, the first two rows of DC are comparing the Low capabilities cluster's mean in DC with each of the other two clusters' means.

The test show that there are significant differences

- between Low capabilities cluster and the other two clusters in **development capability**;
- between Intermediate capabilities cluster and the other two clusters in **operations capability**;
- between all clusters in **management capability**; and
- between all clusters in **transaction capability**.

It is clear that the Low capabilities cluster has the worst performance in terms of **development capability**. In addition, although High capabilities cluster has higher mean than Intermediate capabilities cluster, this difference is not significant (*p*=0.755). This is maybe why High capabilities firms invest more in R&D, collaborate more for product development and register more patents, while the Intermediate capabilities firms launch more products and earn more from them. Both types of firms have strong development capability and benefit from it though different activities.

Regarding **operations capability**, Intermediate capabilities cluster has means significantly different (*p*=0.024 and *p*=0.001), higher, than the other two clusters. Alternatively, there is no significant (*p*=0.863) difference between High capabilities low-tech firms and Low capabilities ones in terms of operations capabilities. In this sense, although High capabilities firms presented the worst results, they are not significantly different from the Low capabilities results, which is in "second place" in the operations capability factor.

Management capability is the firm's area where firms perform most differently (all *p*=0.000) from each other. All clusters differ between them, with the High capabilities presenting the best results, followed by the Low capabilities cluster and, finally, the Intermediate capabilities cluster, which there has been already identified as a poor performer in terms of management capability.

Similarly, all clusters differ significantly (*p*=0.000; *p*=0.012; *p*=0.045) in terms of **transaction capability**, but in this case, after the best performing cluster, High capabilities cluster, the order is Intermediate capabilities and then Low capabilities. During the analysis of the capabilities means, management capability seemed to show the clearest results in dividing the cluster. It was taken as one of the main factors differentiating one type of firm from the other. However, it seems that the transaction capability has an important role in doing that, since all types of firms are significant different and are ordered according to all other analyses, which is Low, Intermediate and High capabilities low-tech firms. This order may also indicate how innovative these firms are, since this is the same order as the firm economic performance results discussed previously. This will be discussed ahead.

* * *

In sum, Low capabilities cluster is the worst performer in development and transaction capabilities and medium performer in management and operations capabilities. High capabilities cluster is the best performer in all capabilities, except in operations, where it is the worst performer. It is noteworthy though, that operations capability has the highest averages among all capabilities. Although the High capabilities cluster mean is lower than the others are, it is still high when compared to other capabilities' figures. Finally, the Intermediate capabilities cluster is the best performer in operations capability, medium in development and transaction capabilities and the worst performer, in management capability.

Development and operations capabilities, the capabilities that are closer to the traditional technological view, are differentiating some types of firms; however, they do not differentiate all of them. Thus, other factors might be influencing firms' innovative performance. Management and transaction capabilities are the ones differentiating all clusters from each other. This could indicate that they might have a role more important than previously assumed in the main studies in innovation.

6.5 Differences in Performance between each Type of Low-Tech Firm

Significant tests on external variables were appointed by Aldenderfer and Blashfield (1984) among the best procedures to validate a cluster solution. In testing the innovative performance (IP) variable, *F* test (ANOVA) was significant (p=0.000 for economic performance and for innovative performance and p=0.009 for novelty). In Scheffe analysis, there are significant differences between Low capabilities cluster and High capabilities cluster, and between Low capabilities cluster and Intermediate capabilities cluster (Table 21).

Scheffe							
Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
	(I)	(J)					
Economic Performance	1 - Low capabilities	3	-.09949*	.02543	.001	-.1619	-.0371
		2	-.05368	.02812	.163	-.1227	.0153
	2 - Intermediate capabilities	1	.05368	.02812	.163	-.0153	.1227
		3	-.04581	.02439	.172	-.1057	.0141
	3 - High capabilities	1	.09949*	.02543	.001	.0371	.1619
		2	.04581	.02439	.172	-.0141	.1057
Novelty	1 - Low capabilities	3	-.09759*	.03172	.009	-.1754	-.0197
		2	-.07169	.03506	.125	-.1577	.0144
	2 - Intermediate capabilities	1	.07169	.03506	.125	-.0144	.1577
		3	-.0259	.03042	.696	-.1006	.0488
	3 - High capabilities	1	.09759*	.03172	.009	.0197	.1754
		2	.0259	.03042	.696	-.0488	.1006
IP[16]	1 - Low capabilities	3	-.10928*	.02585	.000	-.1727	-.0458
		2	-.08060*	.02858	.019	-.1507	-.0105
	2 - Intermediate capabilities	1	.08060*	.02858	.019	.0105	.1507
		3	-.02868	.02479	.513	-.0895	.0322
	3 - High capabilities	1	.10928*	.02585	.000	.0458	.1727
		2	.02868	.02479	.513	-.0322	.0895

* The mean difference is significant at the 0.05 level.

Table 21 – Scheffe Analysis between Clusters and Performance Indicators

There are significant differences

- between Low capabilities and High capabilities clusters in terms of **economic performance**;
- between Low capabilities and High capabilities clusters in terms of **novelty**; and
- between Low capabilities cluster and the other two clusters in terms of **innovative performance**.

Looking separately into the two dimensions that form innovative performance, **economic performance** and **novelty**, there is significant difference between Low capabilities and High capabilities clusters (p=0.001 and p=0.009, respectively), where, in both cases, High capabilities firms have better performance. These results were already expected, considering all the reasoning of this research that *innovation capabilities are the enabling conditions that lead firms to achieve innovative performance*.

[16] See Chapter 7 for the components of the Innovative Performance indicator

In that sense, Low capabilities are not only weak on their capabilities levels, but also on their performance. This gives an indication that to innovate, firms must have at least a combination of strong capabilities, otherwise, their results are scarce.

In previous analyses, it was mentioned about the Intermediate capabilities low-tech firms having higher means in terms of novelty indicators and the High capabilities firms having higher means in the economic performance indicators. Scheffe analysis (Table 21) shows that these differences are not significant, though.

Similarly to economic performance and novelty dimensions, Low and High capabilities clusters differ significantly in terms of **innovative performance** (p=0.000). At this time, Intermediate capabilities cluster is also significantly different from Low capabilities cluster in relation to innovative performance (p=0.019) and, although not significant, its mean is lower than the High capabilities cluster. In that sense, having the other capabilities well developed is not inhibiting Intermediate capabilities cluster firms to achieve innovative performance. Their performance may not be as high as those for High capabilities cluster firms, but is significantly different (higher) than the Low capabilities ones.

* * *

It is not only in terms of capabilities and in terms of innovative performance that the clusters differ. In addition, other characteristics that corroborate with the analysis have divided low-tech firms in these three groups. It is clear though, that the innovation capabilities have an impact on innovative performance due to the clear separation of firms into three distinct groups and the difference they have in the level of capabilities and in the innovative performance. There is indication that having **one low-level capability does not compromise firms' innovative performance**, since Intermediate capabilities cluster is low in management capability and High capabilities cluster is lower in operations capabilities than the others are, and still perform better than the Low capabilities cluster.

In sum, *Low capabilities low-tech firms* are small, do not invest in R&D, do not register patents and do not have partnership with Science and Technology Institutions to develop new products; consequently, they neither launch new products nor profit from them. Overall, their level of innovation capabilities is low and they have the lowest scores in terms of development and transaction capabilities. They differ significantly from the other two types of low-tech firms in terms of capabilities level, but especially, in relation to performance, where they show the lowest means is all three indicators. From these results, it is possible to infer that **firms with**

low-level innovation capabilities have lower innovative performance compared to others with higher levels[17].

Intermediate capabilities low-tech firms include some medium and large firms, although, in its majority, small firms compose it. They have more partnerships for product development than the Low capabilities and less than the High capabilities firms do. They do not invest in R&D as much nor register as many patents as the High capabilities low-tech firms. However, they have slightly higher scores in launching new products. Probably because of that, their revenue from new products is higher than the High capabilities'. In contrast, their economic performance indicators have lower scores than these firms, although they are higher than the Low capabilities firms' levels. Overall, their level of innovation capabilities is medium; besides, they have the highest scores in terms of operations capability and the lowest scores in terms of management capability. **Even having low-level management capability, their overall scores in terms of performance are not significantly different from the High capabilities firms' scores**.

High capabilities low-tech firms contain the majority of the medium and large firms within the sample. These firms invest in R&D, have partnerships with Science and Technology Institutions to develop new products, register patents and have high scores in terms of economic performance. Overall, their level of innovation capabilities is high, since they have the highest scores in three out of four capabilities, which are, development, management and transaction capabilities. It is likely that **these firms are able to have high scores in traditional technological indicators, such as investment in R&D, patent registrations and partnerships, because of their high-level development capability**. High capabilities firms differ significantly from the other groups in terms of capabilities. They also differ significantly in terms of performance, especially when compared to the Low capabilities firms. **Even having the lowest scores in terms of operations capability, High capabilities firms still presented the best overall performance**, especially when looking into all characteristics, input, output, capabilities and innovative performance indicators altogether. Additionally, **operations capability seems to have no influence in low-tech firms' results**, at least in the case of those firms with high-level capabilities. These results indicate that **firms with high-level innovation capabilities have higher innovative performance compared to others with lower levels**.

[17] Additional tests to verify the correlation between innovation capabilities and performance have been carried out. The test indicates that correlation is significant at the 0.01 level.

So far, it is possible to affirm that having all capabilities well developed (High capabilities low-tech firms) or having some strong and some weak capabilities (Intermediate capabilities low-tech firms) is statistically leading to very similar results in terms of performance. Additionally, having only low levels of capabilities (Low capabilities low-tech firms) is not enough to achieve a satisfactory performance.

Once the types of low-tech firms have been identified, there is the need to discuss the configuration of innovation capabilities in low-tech firms. The configuration of capabilities will elucidate how some firms even having some low-level capabilities (i.e. Intermediate capabilities firms are weak in management capabilities); have high performance levels.

7 Configuration of Innovation Capabilities in Brazilian Low-Tech Firms

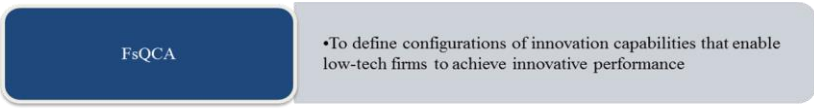


Figure 10 – Thesis' Third Specific Goal

Looking solely at capabilities' and firm performance's mean differences is possible to infer that firms with high scores of capabilities tend to have better results. Next analysis, which evaluates the combinations of attributes (innovation capabilities) that lead to the desired outcome (high innovative performance), will further investigate this relationship. Therefore, to achieve the third specific goal of this Thesis (Figure 10), fsQCA was performed (see section 4.3 for preceding analyses using fsQCA).

7.1 Data Preparation

To define the *property space* is the first step to run the analysis using fsQCA. The property space has been defined based on the Innovation Capabilities Model, the drivers, or *attributes*, used were the four capabilities, development capability **(DC)**, operations capability **(OC)**, management capability **(MC)** and transaction capability **(TC)**. As for the outcome, the indicator used was innovative performance **(IP)**.

Next, it is necessary to *calibrate* the data. Most applications of fuzzy set do not use data based on Likert-type scale, which is the case of the present research. There are some general recommendations, however, on how to calibrate data. Ragin (2008) explains that a case with a score above the central tendency has a high score, while a score that is below the mean has a low score. It does not mean, however, that the middle score (3) should be the crossover point for all cases. As pointed by Ragin (2008), calibration varies from one sample to the next.

Ragin (2007; 2008) and Fiss (2011) recommend using external benchmarks to define the crossover point. In the case of the innovation capabilities measured through Likert-type scale, that is not possible, but in the case of some innovative performance indicators, it can be done.

To calibrate 1 to 5 scales of the *attributes* into fuzzy sets, the following steps were taken[18]:

1. To average the values for each factor (as per factor analysis):
    a. **DC** (DC1, DC2, DC3, DC4, DC5, DC7);
    b. **OC** (OC2, OC3, OC4, OC5, OC6, OC8);
    c. **MC** (OC1, MC1, MC2, MC3, MC4, MC5, MC6);
    d. **TC** (TC1, TC3, TC4, TC5, TC6);
2. Based on the frequency of the averaged values, to determine the cross-over point around 50%:
    a. **DC** – 3.81;
    b. **OC** – 3.84;
    c. **MC** – 3.68;
    d. **TC** – 3.30;
3. In the fsQCA software[19], to calibrate data into fuzzy sets.

Following similar steps, the *outcome* variable, **innovative performance**, was also calibrated. Innovative performance is a two-part indicator, containing information about novelty and about economic performance.

For the **economic performance** part, which is a combination of three variables measured through Likert-type scale, the steps for calibration were the same as the ones used to calibrate the capabilities: averaging P1, P2 and P3, using the value of 50% frequency to determine the cross-over point (3.51) and, finally, calibrating it into a fuzzy set.

For the **novelty** part of the indicator, two variables were used: launching new products and share of revenue from new products. The following was done to combine both parts:

1. For the new product variable, there was no cross-over point, the firm has either launched a new product in the previous year (1.0), or have not (0.0);
2. For percentage of revenue from new products, an external benchmarking have been used:
    a. Based on Rio Grande do Sul State's average for this indicator (Pintec/IBGE, 2011), the cross-over point has been determined at 10%;

[18] Given the lack of information on how to calibrate 1 to 5 scales into fuzzy sets, I contacted Ragin and Fiss via email. Upon their email replies, and under the supervision of Dr. Ann Torugsa (Australian Innovation Research Centre at the University of Tasmania), the steps presented were taken.
[19] Data were calibrated and further analysed using fsQCA software.

3. “Logical and” (compounds sets are formed when two or more sets are combined, an operation commonly known as *intersection* (Rihoux & Ragin, 2009)) was used to combine both novelty indicators;
4. “Logical or” (*union* (Rihoux & Ragin, 2009)) was used to combine the novelty part with the economic performance part and to create the innovative performance indicator (IP), used as outcome in the fsQCA analysis.

After transforming and calibrating the data, the final *attributes* are **DC**, **OC**, **MC** and **TC,** and the *outcome* is **IP**.

The next step in the analysis, which refers to the *consistency in set relations,* assesses which combinations of attributes (innovation capabilities) lead to the outcome (high innovative performance). As explained in section 4.3.3, a truth table must be built. The truth table lists all possible conditions, considering high (1 indicates high) and low (0 indicates low) capabilities' scores (Table 22).

DC	OC	MC	TC	Number of Cases (*n*=565)	Raw Consistency
1	1	1	1	180	0.924925
0	0	0	0	114	0.817013
1	1	1	0	35	0.935813
0	0	0	1	32	0.907551
1	1	0	1	29	0.948674
0	1	0	0	24	0.883706
1	0	0	0	21	0.915579
0	1	1	1	21	0.944328
1	0	1	1	18	0.959681
1	1	0	0	17	0.919966
1	0	0	1	16	0.947868
0	0	1	0	16	0.920605
0	0	1	1	15	0.940552
0	1	1	0	11	0.927184
0	1	0	1	10	0.935411
1	0	1	0	6	0.943452

Table 22 –Truth Table before Reduction

Once built, the table was reduced following two criteria: the number of cases and the raw consistency level (Fiss, 2011; Rihoux & Ragin, 2009).

Any combination without *cases* should be eliminated. Authors tend to exclude combinations with less than two (Fiss, 2011; Ganter & Hecker, 2014) or three (Ordanini et al.,

2014) cases. However, Rihoux & Ragin (2009) say that when the number of cases is large (hundreds of cases), it is important to establish a higher frequency cut-off such as at least five or 10 cases. Since it is a large-N study (631 cases), the **frequency cut-off was set in 10 cases**.

In terms of *consistency* of each complex causal combination that can lead to the outcome, the researcher must decide which of all possible combinations to include in the final solution and, for that, it is necessary to select a cut-off consistency value (Skarmeas, et al., 2014). The minimum consistency cut-off recommended is 0.75 (Ragin, 2008; Ragin et al., 2008), however many authors have used higher cut-off values (Fiss, 2011; Hsiao et al., 2015; Ragin et al., 2008; Skarmeas et al., 2014). **Consistency cut-off, in this research, was set in 0.94**. "Consistency here refers to the degree to which cases correspond to the set-theoretic relationships expressed in a solution" (Fiss, 2011, p.402).

After determining the frequency and consistency cut-off scores, and eliminating combinations that do not meet the criteria, "an algorithm based on Boolean algebra is used to logically reduce the truth table rows to simplified combinations" (Fiss, 2011, p.403). Since it is the most interpretable solution (Ragin et al., 2008), the *intermediate* solution was used to interpret the results of the present study. To derivate the intermediate solution, the conditions that contribute to the outcome were selected as *present* (Ragin et al., 2008), in other words, DC, OC, MC and TC are understood as contributing to high innovative performance when present.

7.2 Final Solution Analysis

There are measures of fit that help evaluate if the final solution is adequate. The first approach to search for multicausal explanations to a certain outcome was the crisp-set QCA (csQCA) and, by then, no measurements of fit were included in this method (Fiss et al., 2013). Later on, Ragin (2006) introduced measures of **consistency** and **coverage**, which presented a move toward expressing the importance of solutions within qualitative comparative analysis (Fiss et al., 2013).

Once the relevant causal combinations have been identified, the next step is to evaluate each combination's consistency with the set theoretic relation in questions. In other words, there is a need to identify which causal combinations are subsets of the outcome (Rihoux & Ragin, 2009). As put by these authors, in social sciences, data are rarely perfect, so it is important to assess the degree to which the empirical evidence is consistent with the set theoretic relation proposed.

In the User's Guide to fsQCA, Ragin et al. (2008, p.85) said:

> The output includes measures of coverage and consistency for each solution term and for the solution as a whole. Consistency measures the degree to which solution terms and the solution as a whole are subsets of the outcome. Coverage measures how much of the outcome is covered (or explained) by each solution term and by the solution as a whole. These measures are computed by examining the original fuzzy data set in light of the solution (composed of one or more solution terms). The degree to which cases in the original dataset have membership in each solution term and in the outcome form the basis of consistency and coverage measures.

In the same Guide, Ragin et al. (2008, p.86-87) explains each concept related to the solution outcome.

> *Consistency* measures the degree to which membership in each solution term is a subset of the outcome. […] *Solution consistency* measures the degree to which membership in the solution (the set of solution terms) is a subset of membership in the outcome. […] *Solution coverage* measures the proportion of memberships in the outcome that is explained by the complete solution. […] *Raw coverage* measures the proportion of memberships in the outcome explained by each term of the solution. […] *Unique coverage* measures the proportion of memberships in the outcome explained solely by each individual solution term (memberships that are not covered by other solution terms).

In sum, consistency is the degree to which the cases sharing a given combination of conditions agree in displaying the outcome in question, and the coverage assesses the degree to which a causal combination accounts for instances of the outcome (Ragin, 2006; Fiss et al., 2013). Hsiao et al. (2015) say that consistency is analogous to correlation in statistical analysis, since it measures the degree to which the cases share the antecedent condition in displaying the outcome in question. Coverage is analogous to R^2 in statistical analysis, since it assesses the degree to which the causal conditions account for instances of the outcome.

Table 23 brings the results of the present study.

Solution	Causal Conditions	Raw coverage	Unique coverage	Consistency
1	TC.MC.dc	0.452023	0.030175	0.933240
2	TC.mc.DC	0.454615	0.043925	0.940710
3	TC.MC.oc	0.455022	0.000459	0.941268
4	TC.oc.DC	0.430682	0.000459	0.948536

Solution coverage = 0.572856
Solution consistency = 0.921720

Note: Upper case means high-level capability, lower case means low-level capability
Table 23 – fsQCA Final Results

As presented in this Thesis, the industry a firm belongs to and its technological trajectory matters to a firm innovative activity. However, what brings heterogeneity within a sector in terms of innovative performance is the configuration of capabilities a firm has. What are the configurations the decision-makers might follow if they want to achieve innovative performance? Results of the fsQCA tests bring four solutions to achieve high innovative performance with a **solution consistency of 0.92** (Table 23). Ragin (2006) says consistency should be as close to 1.0 as possible, and scores below 0.75 make it difficult to maintain that a subset relation exists.

This means that the set of four causal conditions (combinations of innovation capabilities) have membership in the outcome (innovative performance) in a degree of 92%. With such a high percentage, it is possible to be confident that the causal conditions brought in the solution represent alternative ways to innovation.

Four equifinal causal conditions lead to the outcome (high innovative performance). Solution 1 says that a firm with high-level TC and MC and low-level DC may achieve innovative performance. Similarly, solutions 2, 3 and 4 four say, respectively, that a firm with high-level TC and DC and low-level MC; high-level TC and MC and low-level OC; and high-level TC and DC and low-level OC may achieve innovative performance.

In that sense, an innovative low-tech firm has, at least, one of these causal conditions.

As the identified configurations combine to **cover (solution coverage) 57%** of membership in the outcome, one can assume that there are other attributes influencing the outcome that are not covered by the innovation capabilities. There are studies accepting solution coverages below 30% (Ganter & Hecker, 2014; Hsiao et al., 2015; Skarmeas et al., 2014). Ragin (2006) says it is reasonable to calculate coverage only after establishing that a set relation is consistent. Hsiao et al. (2015), stress the importance of achieving high consistency over high coverage, since the primary importance of consistency relates to the equifinality characteristic, in other words, to the existence of multiple configurations of causal conditions useful in predicting high scores of an outcome condition. This means that any one configuration will have a low coverage of cases: according to raw coverage, solution 1 accounts for 45.2%, solution 2 for 45.4%, solution 3 for 45.5% and solution 4 for 43% of cases associated with the outcome. However, when combining all solutions, their coverage is 57%.

The four solutions, or causal conditions, represent conditions that enable high innovative performance in low-tech firms. Solution 1 indicates that 45.2% of all firms with high-level of TC and MC and low-level of DC are members of the set **innovative performance**. Solution 2 indicates that 45.4% of all firms with high-level of TC and DC and low-level of MC are members of the set innovative performance. Solution 3 indicates that 45.5% of all firms with high-level of TC and MC and low-level of OC are members of the set innovative performance. Solution 4 indicates that 43% of all firms with high-level of TC and DC and low-level of OC are members of the set innovative performance.

Various configurations of innovation capabilities, and thus, various causal conditions equifinal, lead to high innovative performance. This is an important fact for which conventional statistical analysis does not sufficiently account (Ganter & Hecker, 2014).

The set of causal conditions show that there is not any capability leading low-tech firms to innovation by itself, in other words, there is always a combination of capabilities doing that. When looking more carefully at the results, it is possible to notice that there is one capability, transaction capability (TC), which is present in all causal conditions. Thus, innovative performance occurs when high-level TC is combined with either high-level of MC (solutions 1 and 3) or high-level DC (solutions 2 and 4), even though some other capabilities are low-level or not relevant to the outcome. This corroborates with Mattes et al. (2015), who say that low-tech firms are customer driven.

This means that high levels of TC is a *necessary condition* for low-tech firms to achieve high innovative performance, although it is not a sufficient condition, since it needs to be combined with other capabilities, DC or MC.

As opposed to the transaction capability, the operations capability is not the capability leading firms to innovative performance, although it is the capability with the highest level overall within the sample, the other three capabilities have an important role in doing that. Operations capability is either not relevant in the causal conditions (solutions 1 and 2) or, when its level is low (solutions 3 and 4), other capabilities are responsible in leading the firms to an innovative performance. Considering low-tech firms have been producing the same products for a long time and that the technology they use is standardized and well established throughout the sector (Hirsch-Kreinsen & Schwinge, 2011; Zawislak et al., 2013a), they have to stand out in something other than in their operations or production processes.

In that sense, having high-level OC does not contribute to low-tech firms' high innovative performance. As seen in the capabilities' means analysis (in section 6.3), low-tech firms focus on standard operations systems and routine activities, such as maintaining adequate stock levels of materials for the process and carrying out the productive process as programmed. To survive in a low-tech industry, operations capability is a *sine qua non* condition and not, as shown in the causal conditions, something that will differentiate these firms from the others and lead them to achieve innovative performance.

Since they produce the same products for a long time, the technology they use is standardized. Established low-tech firms have to make sure they invest in their transaction capability first.

Transaction capability received this important status due to the stabilized conditions of the industries these firms belong. Because knowledge within low-tech firms is well diffused, they must be able to offer something slightly different to attract customers, even if that means using a different distribution channel, using social media to reach their clients, or changing the package of their products.

What each firm does might be different, one might invest in negotiation skills with customers or suppliers, and other might invest in enhancing its distribution channels, while another might invest in marketing and branding. Either way, a **high-level TC is half-way for a low-tech firm to achieve high innovative performance**.

There are firms that manage to design their own products, to apply formal project management methods, to adapt or develop new technologies and to launch new products. These firms have a high-level of DC and, if they combine that with a high-level TC, even though they have low-level MC or OC, they can achieve high innovative performance.

Firms such as these have a strong focus on **development** with an eye in the market; they know what their clients want, or even better, because they monitor the latest tendencies in technology and in marketing, they even might be able to anticipate their needs. The Brazilian footwear company presented in section 2.4 is an example of a firm with high-level DC *and* TC. Innovative companies that work with fashion trends, such as footwear and textile and clothing, will often present this configuration.

These firms must have both, a technical (DC) and a commercial capability (TC) to offer what the market wants. And that may be something as simple as adapting an existing product to satisfy the market's needs, such as a food company offering biscuits within its portfolio in a snack-size package with a new design. Alternatively, a footwear company could discover a new technological material that can be applied on sports shoes to enhance sportspeople's performance and make a large marketing campaign to advertise it. In both cases, *DC and TC are working side-by-side to contribute to firms' innovative performance*.

Hirsch-Kreinsen (2015) has found low-tech firms with similar characteristics. They relate product-oriented innovation to the fashion-oriented design of products. He calls it *customer-oriented strategy* or *occasional business-to-customer product developers*. For him, firms following this strategy have their development process "closely associated with organisational and marketing process innovation" (p.21). In acting as such, low-tech firms "that pursue this strategy are aiming for a rapid response to changing customer wishes and are attempting to take advantage of market niches by means of skilful branding strategies and expanded product-related service activities" (Hirsch-Kreinsen, 2015, p. 21).

There also are firms that have high-level **management** capability, in other words, they have their processes and procedures well standardized and formalized, they formally define their strategic plan, they use technology to integrate all areas, they update their management tools, techniques and practices, and they maintain personnel adequately trained for the company's functions.

These firms, when combining their MC with a high-level TC, are very much *business-oriented*. Their focus is not on developing new products or processes, but, rather, on their management and transaction skills. For example, they might offer differentiated services to their customers, focus at increasing efficiency, focus at managing their supply chain, have plans to gain market share or aim at promoting their image. These firms offer alternative ways to understand innovation that go beyond technological development, confirming the initial reasoning of this research, that is not only investments in R&D the lead firms to innovation. In that sense, low-tech firms might achieve high innovative performance even if they belong to an industry where investments in R&D activities are not a priority, which will often be the case of large firms that are in the middle of the value chain. In such cases, they are business-to-business firms that must focus on their relationship and communications skills, be they internal to integrate all areas and guarantee smooth processes are in place, or be they externally, to deal with suppliers and buyers.

Considering the causal conditions and the observations made so far, it seems that there are two main patterns of innovation in low-tech firms, they either develop products focused on the market and are **design-oriented**, or they value their relationships and negotiation skills and are **business-oriented**. In that sense, they either develop products that have a marketing or fashion appeal, or they are business-to-business companies that focus on managing their internal processes and relationships with suppliers and buyers. Having high-level TC is a necessary condition for low-tech firms be innovative. Additionally, they have to focus on DC or MC to have a chance to succeed. The more they have high-level capabilities, the more causal conditions they can follow to achieve innovative performance.

* * *

In sum, four equifinal causal conditions lead low-tech firms in achieving high innovative performance, which are TC.MC.dc, TC.mc.DC, TC.MC.oc and TC.oc.DC. A low-tech firm that is innovative has at least one of these configurations of innovation capabilities. However, since the solution coverage is 57%, there are other factors influencing this outcome, for example, external factors such as industry technological maturity.

In terms of presence and absence of each capability in the causal conditions, there is not one single solution where one capability by itself is capable of leading a firm to innovative performance, consequently, firms must have a holistic approach in terms of investing in their innovation capabilities. High-level OC is not present in any solution either, which means it does not contribute to low-tech firms' high innovative performance. The set of solutions confirm that there is one necessary condition leading firms to innovation, having high-level TC, which is present in all possible causal conditions. Transaction capability alone does not lead any low-tech firm to innovation though; it has to be combined with high-level DC or high-level MC.

An innovative low-tech firm has high-level TC combined with other high-level capabilities, as long as it is not limited to high-level OC. Therefore, there is an indication of two main patterns of low-tech innovation. One where low-tech firms might follow an approach of product development with attention to the market (high-level TC and DC) and other where they might be in the middle of the value chain and be business-oriented (high-level TC and MC).

In the next chapter, the integration of the **types** of low-tech firms and the **configuration** of innovation capabilities is discussed with the aim of identifying which causal conditions are appropriate to which types of low-tech firms. By crossing such information, it will be possible to identify patterns of innovation in low-tech firms, in other words, it will be possible to know how each firm should work with its innovation capabilities to achieve innovative performance, and that, will finally elucidate what is the nature of innovation in low-tech firms.

8 The Patterns of Innovation in Brazilian Low-Tech Firms: Integrating Correlation-based and fsQCA Approaches

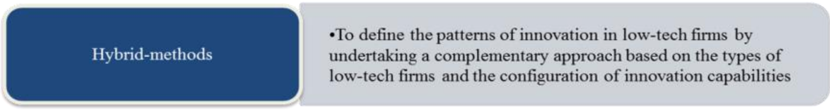


Figure 11 – Thesis' Fourth Specific Goal

To achieve the fourth specific goal of this Thesis (Figure 11), a hybrid-method approach to integrate the correlation-based and the fsQCA approaches was carried out.

8.1 Integrating Correlation-based and fsQCA Approaches

Fiss et al. (2013) say that, although fsQCA approach and standard econometric methods seem to be based in different philosophies regarding the spirit and nature of social sciences research, there is considerable opportunities for using these two approaches in an integrative manner. As put by the authors, this involves going beyond triangulation and goes toward developing hybrid methods incorporating elements from both approaches.

Fiss et al. (2013) propose an alternative to work with fsQCA causal conditions in further analyses. Although using it in different analytic tools, they recommend that researchers create dummy variables coded 1 for cases that have membership scores in the configuration. Following that, all innovative firms were coded according to each causal condition (TC.MC.dc, TC.mc.DC, TC.MC.oc, TC.oc.DC) membership and analysed chi-square results to verify mean differences between the different types of low-tech firms (Low capabilities, High capabilities, Intermediate capabilities) (Table 24).

In the sample there are 631 low-tech firms, however, when they were divided in types through cluster analysis, this number was reduced to 541 firms. Since the following analysis aims to match each type of low-tech firm with a configuration of innovation capabilities, the number of firms considered is 541. Table 24 shows that solution 3 (TC.MC.oc) is the configuration that fits more innovative low-tech firms; it includes 36 firms. Solution 4 (TC.oc.DC) is next, with 35 low-tech firms. They are followed by solutions 2 (TC.mc.DC) and 1 (TC.MC.dc), including, respectively, 33 and 23 low-tech firms.

Since there are some overlaps, one firm may fit in more than one configuration, but in this sample, they were never allocated to more than 2 solutions. In total, there seems to be 127 highly innovative firms, however, considering this overlap, there are, in fact, **81 Low, Intermediate and High capabilities low-tech firms that present high innovative performance**. This represents only around 13% of the sample

In that sense, 13% of the low-tech firms analysed are innovative.

This information also confirms how important it is to have a more embracing approach to evaluate innovation and to be able to capture reality more precisely. Generally, innovation surveys require the respondents to answer if they are innovative or not, or if they have implemented an innovation or not in a certain period. These results are biased though, since they often bring larger percentages of innovative firms than actually are. In the case of Rio Grande do Sul State, a national innovation survey (PINTEC/IBGE, 2011) indicates there are 42% innovative firms within manufacturing industries[20]. This percentage is definitely high, considering the reality of these firms.

Not all firms featuring the causal conditions are innovative though. Among the sample, 113 low-tech firms have at least one of the causal conditions, but, as mentioned, only 81 present high innovative performance. This means that out of those firms that are able to implement one of these configurations, 72% of them are innovative. This result is very encouraging.

Once knowing that 13% of low-tech firms in the sample are innovative, is important to verify which configurations of capabilities each type of firm has, so it is possible to determine the patterns of innovation in low-tech firms.

[20] The percentage presented by PINTEC/IBGE (2011) includes manufacturing industries from all technological intensities; however, since low-tech firms are the majority of firms in the region, the inference remains the same.

Solutions	Causal Conditions		Low capabilities	Intermediate capabilities	High capabilities	Total
Configurations of Innovation Capabilities						
1	Count		17	0	6	23
	% within TC.MC.dc		73.9%	0.0%	26.1%	100%
	Chi-square (2 *df*)	32.078a***				
2	Count		0	27	6	33
	% within TC.mc.DC		0.0%	81.8%	18.2%	100%
	Chi-square (2 *df*)	49.997b***				
3	Count		7	0	29	36
	% within TC.MC.oc		19.4%	0.0%	80.6%	100%
	Chi-square (2 *df*)	21.004c***				
4	Count		0	5	30	35
	% within TC.oc.DC		0.0%	14.3%	85.7%	100%
	Chi-square (2 *df*)	24,284d***				

***p<0.001

Note: Membership in a causal condition includes only those firms with high score in the outcome

Table 24 – Percentage of Firms with Membership in a Causal Condition distributed by the Type of Low-Tech Firms

Table 24 indicates that innovative low-tech firms within the causal condition TC.MC.dc are, in their majority (73.9%), Low capabilities firms. Innovative low-tech firms within the configuration TC.mc.DC are Intermediate capabilities (81.8%). Finally, within both configurations, TC.MC.oc (80.6%) and TC.oc.DC (85.7%), are the High capabilities low-tech firms.

It is possible to observe that there are no examples of firms presenting configurations that include high-level DC within Low capabilities (solutions 2 and 4). Of all capabilities means among all types of low-tech firms, DC in Low capabilities is the lowest mean (as seen in the capabilities means analysis in section 6.3); therefore, a configuration of capabilities that comprises high-level DC does not fit this type of low-tech firm.

Similarly, there are no firms within Intermediate capabilities with high-level MC (solutions 1 and 3). As seen in the capabilities analysis (sections 6.3 and 6.4), Intermediate capabilities low-tech firms have the lowest level of management capability. In that sense, they have to follow other configurations that do not require high-level MC to achieve innovative performance.

Since the High capabilities low-tech firms include firms with high-levels of all capabilities, it was expected that there would be occurrences of them in all solutions. Consequently, this type of low-tech firm has more alternatives or more configurations that they might follow to be innovative, even though some solutions work better for these firms, such as solutions 3 and 4.

To further explore these differences, ANOVA has been carried out (p=0.000). Table 25 shows the post hoc test – Scheffe analysis. There are significant differences:

- between Low capabilities firms and the other two types of low-tech firms in terms of **solution 1 (TC.MC.dc)**;
- between Intermediate capabilities firms and the other two types of low-tech firms in terms of **solution 2 (TC.mc.DC)**;
- between Intermediate and High capabilities firms in terms of **solution 3 (TC.MC.oc)**; and
- between High capabilities firms and the other two types of low-tech firms in terms of **solution 4 (TC.oc.DC)**.

Scheffe

Dependent Variable	(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
TC.MC.dc	1 - Low capabilities	3	.10212*	.02093	.000	.0507	.1535
		2	.12593*	.02314	.000	.0691	.1827
	2 - Intermediate capabilities	1	-.12593*	.02314	.000	-.1827	-.0691
		3	-.02381	.02007	.495	-.0731	.0255
	3 - High capabilities	1	-.10212*	.02093	.000	-.1535	-.0507
		2	.02381	.02007	.495	-.0255	.0731
TC.mc.DC	1 - Low capabilities	3	-.02381	.02439	.621	-.0837	.0360
		2	-.17532*	.02696	.000	-.2415	-.1092
	2 - Intermediate capabilities	1	.17532*	.02696	.000	.1092	.2415
		3	.15152*	.02339	.000	.0941	.2089
	3 - High capabilities	1	.02381	.02439	.621	-.0360	.0837
		2	-.15152*	.02339	.000	-.2089	-.0941
TC.MC.oc	1 - Low capabilities	3	-.06323	.02613	.054	-.1274	.0009
		2	.05185	.02889	.201	-.0191	.1228
	2 - Intermediate capabilities	1	-.05185	.02889	.201	-.1228	.0191
		3	-.11508*	.02506	.000	-.1766	-.0536
	3 - High capabilities	1	.06323	.02613	.054	-.0009	.1274
		2	.11508*	.02506	.000	.0536	.1766
TC.oc.DC	1 - Low capabilities	3	-.11905*	.02571	.000	-.1822	-.0559
		2	-.03247	.02842	.521	-.1022	.0373
	2 - Intermediate capabilities	1	.03247	.02842	.521	-.0373	.1022
		3	-.08658*	.02466	.002	-.1471	-.0261
	3 - High capabilities	1	.11905*	.02571	.000	.0559	.1822
		2	.08658*	.02466	.002	.0261	.1471

*. The mean difference is significant at the 0.05 level

Table 25 – Scheffe Analysis between Types of Low-Tech Firms and fsQCA Causal Conditions

Regarding s**olution 1 (TC.MC.dc)**, since it is a configuration that assumes high-levels of TC and MC (business-oriented capabilities) to achieve high innovative performance, there are no Intermediate capabilities firms, which previous analyses has shown, have low-level MC. Most innovative firms that fit into this causal condition are Low capabilities.

It would be harder for a firm with low-level capabilities to develop high-level development capability, since it involves activities that are more complex and need more investment. Results in Table 25 confirm that Low capabilities firms are significantly different from the other two types of low-tech firms and, additionally, their means are higher than the other two types of firms for this causal condition (Table 25), confirming that this is the best causal condition for Low capabilities low-tech firms.

Even when a firm has low-level capabilities in general, such as the Low capabilities low-tech firms, it still has a chance to achieve innovative performance, as long as it is business-oriented and invests in transaction and management capabilities.

As mentioned, it is hard for Low capabilities firms to have high-level DC and, therefore, there are no occurrences of them in **solution 2 (TC.mc.DC)**.

This causal condition fits well the Intermediate capabilities firms, since it assumes that firms with low-level MC have a chance to be innovative as long as they have high-levels of TC and DC. Table 25 confirms Intermediate capabilities firms are significantly different from the other two types of low-tech firms; they present higher means than the others do. Results indicate that this configuration is definitely an option for Intermediate capabilities firms to innovate. *In lacking MC, they compensate with other high-level capabilities*.

S**olution 3 (TC.MC.oc)** and solution 1 (TC.MC.dc) share the same high-level capabilities (TC and MC); however, they differ in the low-level capability. While solution 3 has low-level OC, solution 1 has low-level DC. Capabilities configuration on solution 1 was the best fit for innovative Low capabilities low-tech firms. This situation is not repeated in solution 3 tough, because most Low capabilities firms have OC as their most developed capability.

This solution is not a good fit for Intermediate capabilities firms either, because of the high-level MC in the configuration. Any solution with high-level MC will not lead Intermediate capabilities firms to achieve innovative performance, since their management capability is their weakness. To be innovative, this type of low-tech firm must invest in configurations other than those formed by high-level MC.

High capabilities firms have a good fit in this solution, since they have higher means than the other two types of low-tech firms. High capabilities low-tech firms, as shown in previous analyses, have all capabilities well developed, and hence, most configurations will fit them. Having this characteristic allows them to choose their pattern of innovation, which might be facilitated by other external factors, such as their position in the value chain or the industry they belong.

High capabilities firms fitting this profile are business-oriented. Since they must have low-level of OC, these firms might even outsource their production and focus on managerial and transactional activities. That is where they differentiate themselves from their competitors. Researchers emphasise that this type of innovation is growing, since low-tech firms are increasingly introducing new business models that are strongly oriented towards market demands and the needs of specific customer groups (Hirsh-Kreinsen, 2015).

Similarly to what happened in solution 3, **solution 4 (TC.oc.DC)** is a good fit for High capabilities low-tech firms. Among all firms fitting this configuration of capabilities, 85.7% are High capabilities firms (Table 24). In addition, their means are significantly higher than the other two types of low-tech firms (Table 25). Firms within this configuration focus on their TC and DC. As mentioned, DC is a complex capability that not many Low capabilities firms have, hence the absence of these firms within this configuration.

This solution is also acceptable for some Intermediate capabilities firms because it does not take into consideration MC. In other words, having high or low-level MC does not affect firms following this configuration. However, it is still a better configuration for the High capabilities firms than for the Intermediate capabilities ones.

* * *

In sum, Low capabilities low-tech firms have only two capabilities configurations they might follow to achieve innovative performance (TC.MC.dc and TC.MC.oc), and both are business-oriented. Intermediate capabilities low-tech firms, on the contrary, do not fit in the business-oriented configurations because they have low-level MC. For this reason, they follow configurations that prioritize TC and DC (TC.mc.DC and TC.oc.DC) to be innovative. In contrast, High capabilities low-tech firm have all capabilities well developed, and thus, might follow any of the four possible configurations of innovation capabilities to achieve innovative performance.

These considerations lead to identify the patterns of innovation in low-tech firms.

8.2 The Patterns of Innovation in Low-Tech Firms

In section 3.2 three distinct theoretical patterns of innovation in low-tech firms were described. It was expected that patterns would be formed in terms of the **type of firms' capabilities**. It was anticipated that there would be one pattern based on operations capability (production-oriented low-tech firms), other based on management or transaction capabilities (business-oriented low-tech firms), and another based on development capability (technology-oriented low-tech firms). However, this was not confirmed in the empirical analysis.

In fact, what caused low-tech firms to be grouped together was the **level of their innovation capabilities**, resulting in three types of low-tech firms – Low, Intermediate and High capabilities low-tech firms.

Moreover, these results dispute the initial assumption that the capability with the highest scores is the one that drives a firm to achieve innovative performance (Zawislak et al., 2012b; 2013b). *Types* of low-tech firms indicate that there are firms with *different levels* of innovation capabilities. The four *configurations* of capabilities indicate that *high innovative performance* is a result of these configurations. In that sense, it is confirmed that innovation is a result of firms' internal efforts in different functions, i.e., development, operations, management and transaction. More precisely, that innovation is a result of firms' internal efforts in a configuration of capabilities that may be TC.MC.dc, TC.mc.DC, TC.MC.oc or TC.oc.DC.

Results comparing the three types of firms and the configurations of capabilities indicate that if only one innovation capability is high-level and the other three are low, this firm will not achieve high innovative performance, it needs a combination of capabilities to do it. Besides, **for each type of low-tech firm, there is a best configuration leading to high innovative performance**.

First, firms from all types may be innovative, even the Low capabilities low-tech firms, providing they have some capabilities with high scores. Innovative firms within this group have capabilities configurations that prioritize TC and MC. Second, not all capabilities must be high-level for a low-tech firm innovate. Intermediate capabilities low-tech firms have low-level management capability and still may achieve high innovative performance, as long as they prioritize a configuration of capabilities that includes high-level TC and DC. Finally, high-level in all capabilities definitely facilitates innovation in low-tech firms. High capabilities low-tech firms are high-level in all capabilities and might follow any configuration of capabilities to achieve high-innovative performance.

When the types of low-tech firms were matched with the different configurations of capabilities, it was possible to identify the *patterns of innovation in low-tech firms*.

Although there are four possible capabilities configurations that lead to high innovative performance, they are divided into two main patterns of innovation. One prioritizes TC and DC and another focuses on TC and MC. This means that either low-tech firms may be **design-oriented** or they may be **business-oriented**.

The *pattern of innovation* called *design-oriented* includes those firms that have the necessary capability to develop new products, but they do it with an eye on the market. *Intermediate and High capabilities low-tech firms* fit better to this pattern, since Low capabilities firms do not have the required level of DC. Firms within this pattern develop products with the aim to either anticipate some market needs or to satisfy an existing market necessity they have identified (for example, through monitoring market tendencies or through formal market research).

The development activity of low-tech firms within this pattern is usually different from the high-tech firms' activities. In high-tech firms, new product development is part of their core activities. Therefore, these firms need to have project management tools in place to carry each development on and need to dominate the technology they use. In the case of low-tech firms that focus on TC and DC, and hence, that are within the design-oriented pattern of innovation in low-tech firms, the product development activities are dedicated to the design of these products. In that sense, the innovation of their products is not in relation to technical performance, but to market performance.

Firms that fit the design-oriented pattern of innovation usually produce final products, for example, they are from footwear, clothing and beverages industries. In that sense, a footwear company within this pattern of innovation has the capabilities to technically develop products that their clients demand (colour, materials, level of comfort, design, etc.) as well as to commercialize them appropriately (distribution channel, brand appeal, product display, etc.). In addition, respecting the variations for each industry, the same rules apply in other sectors. For instance, a food or beverage company needs DC to develop a new flavour for a product, as well as it needs TC to "convince" customers to try it. A much common way to do the latter is through innovation in packaging. It can make new products out of familiar ones. It enhances the appearance of a product, catches the eye of clients and may make a difference in sales.

Considering both examples, it is clear that design is a key-activity within this pattern of innovation. *It bridges the gap between product development and product commercialization*.

The other *pattern of innovation* in low-tech firms, *business-oriented*, include firms with capabilities that facilitate the management of their internal activities as well as the relationship with their suppliers and buyers. Since *High capabilities low-tech firms* have all capabilities well developed, they fit this pattern as well as the other one. In addition, this pattern fits better the *Low capabilities low-tech firms*, for different reasons, though. These firms do not have high-level DC, consequently, innovation through TC and MC is the only possible way for them. Since Intermediate capabilities firms do not have high-level MC, this pattern does not fit them.

Firms within the business-oriented pattern manage their activities through formal processes that aim to integrate all areas within the company, therefore, internal communication and information flow is vital to succeed in this capability. These firms know what they want to achieve, since they have formal strategic plans in place and, when necessary, they adjust their course by implementing new management tools and techniques. For that, they need to keep their personnel adequately trained for the company's functions. When their communication reaches outside firm's boundaries, they need to have well develop negotiating skills to deal with suppliers and customers.

Business-oriented low-tech firms generally supply materials to other firms within their value chain. For example, within the leather and footwear industry, they may be suppliers of footwear components to other footwear companies. Thus, the relationship they build with both suppliers and clients is very important. Marketing *per se* is not the most useful tool to sell their products; instead, they need good network, communication and negotiation skills. A firm that supply accessories to a footwear company, for example, a leather flower that should embellish a sandal, may not even own the "flower project". It is common, in such cases, that the client asks not only for the product, but it also specifies the product's project. Firms in the middle of the value chain may innovate in their business model, on how they handle client's orders or contracts, on improving their negotiation skills or on providing a differentiated customer service.

For long, innovation in this types of firms was not being captured; however, it is clear now that there is innovation in business-oriented firms, even when the product development is not the focus of the firm.

* * *

Matching capabilities' configurations with types of low-tech firms confirms that to belong to a low-tech industry is not a fate to be non-innovative. Innovative performance is a result of firms' innovation capabilities configurations and it is achieved through two patterns of innovation, a *design-oriented* pattern and a *business-oriented* one. When firms are Intermediate capabilities low-tech firms, they follow the design-oriented pattern to achieve high-innovative performance. When they are Low capabilities low-tech firms, they follow the business-oriented pattern. High capabilities low-tech firms follow both patterns of innovation to achieve high innovative performance. These patterns of innovation set the essence in these firms. These patters elucidate the nature of innovation in Brazilian low-tech firms.

9 Final Remarks – The Nature of Innovation in Low-Tech Firms

Figure 12 – Thesis' Main Objective

Alternative ways to see innovation in low-tech firms have been presented throughout this study. Industry intensity classification (OECD, 2011) prerogative assumes that the higher the sectoral technology intensity, the higher the innovation rates. However, in line with many evidences from a number of researches, it has been proposed in this Thesis that low-tech firms may also be innovative.

Firms are technical-economic agents that provide solutions (products and services) to market requirements. These markets keep changing over time, for instance, by introducing new technologies, new competitors, or even changes in the market's requirements. All markets have emerging requirements, even those where mature industries offer their products. This means that even low-tech firms have to innovate to continue to provide to their markets and, most of all, to enhance their performance and maintain their advantage. Thus, regardless of how industries are actually classified, it is not enough to explain firms' innovative performance.

Innovation also relates to firms' internal functions, i.e., innovation capabilities. In that sense, although industry dynamics is important in firms' innovation trajectories, each firm should be able to have a configuration of these capabilities that promote changes. The distinctive ways by which firms manage their capabilities can result in superior performance (Madhok, 2002). A low-tech firm aiming at launching new fashion trends should have a different configuration than a firm dealing with commodities. What are the general characteristics of Brazilian low-tech firms?

Brazilian low-tech firms are small firms managed by their owners and other family members. They base their decision-making process on the past, they plan their production according to their production capacity and they set their prices based on their costs. These characteristics make them reactive firms. They only notice what is happening in the market once it has already happened and, often, they are a step behind the market. When they do promote improvements, it is in relation to machinery and equipment acquisition and process improvements.

Low-tech firms belong to industries that have reached technological maturity. They have been producing the same products in the same way for a while and work under cost reduction strategies, since they focus on low prices. Consequently, investments and technical progress within the industry tend to be minimal.

Although this is the general characteristic of these firms, there are examples of innovative low-tech firms. Moreover, there is heterogeneity of firms within an industry, therefore, even though they all belong to a low-tech industry, their characteristics are not the same, their capabilities are not at the same level and their performance is different. Having that in mind, data analysis have shown that there are three types of low-tech firms in Brazil: Low capabilities, Intermediate capabilities and High capabilities low-tech firms.

In most innovation capabilities and performance indicators, High capabilities low-tech firms have performed better than the other low-tech firms have, followed by the Intermediate capabilities ones. In the other end, Low capabilities low-tech firms have presented the worst results in most indicators.

Low capabilities low-tech firms are small firms that neither invest in internal R&D activities nor interact with other institutions to develop new products. In fact, they hardly launch new products. This is a result of the level of their innovation capabilities, which are low overall (especially, development and transaction capabilities). Due to low-level capabilities, and thus, to low-level of innovation-related activities, their performance level is low as well.

These firms, in general, present low innovative performance; however, some of them manage to achieve high innovative performance. For that, they need a configuration of innovation capabilities that prioritizes transaction and management capabilities. Thus, even when a firm has low-level capabilities, it still has a chance to achieve innovative performance, as long as this firm follows a business-oriented pattern of innovation.

Intermediate capabilities low-tech firms are, on their majority, also small, but there are some medium and large firms within this group. They make little investments in R&D and occasionally interact with Science and Technology Institutions for partnership in product development. However, they do launch new products with regularity and have the highest percentage of revenue coming from new products among the different types of low-tech firms. Both their overall innovation capabilities scores and their economic performance indicators are at a medium level (higher than the Low capabilities firms are, but lower than the High capabilities).

As opposed to the Low capabilities low-tech firms, Intermediate capabilities firms do not fit in the business-oriented pattern of innovation. Since they have low-level management capability, they fit in configurations that do not need high-level of this capability. Causal conditions that prioritize transaction and development capabilities are adequate to Intermediate capabilities firms, since they assume that firms with low-level management capability have a chance to be innovative through other capabilities. Thus, firms that have difficulty in formalizing and standardizing their processes and procedures, in using technology to integrate all firm's areas and difficulty in updating management tools and techniques should improve their commercial abilities and invest in product development activities. In other words, they follow a design-oriented pattern of innovation.

High capabilities low-tech firms concentrate most of medium and large firms of the sample. Overall, High capabilities firms' level of innovation capabilities is high. Because of that, they are able to invest in R&D, to make partnerships to develop new products and to register more patents than the other types of low-tech firms. High capabilities firms differ from the other groups in terms of performance, especially when compared to the Low capabilities ones. These results indicate that firms with high-level innovation capabilities also have higher innovative performance.

Low-tech firms within the High capabilities type are the ones in the best position to achieve innovative performance. All configurations of innovation capabilities that lead to high innovative performance suit them, since they have high scores in all innovation capabilities that compose the causal conditions. Innovative High capabilities firms follow either an innovation pattern that focuses on transaction capability and development capability, or a pattern that focuses on transaction capability and management capability. In other words, High capabilities firms may be design-oriented or business-oriented. By following any of these causal conditions, they should achieve innovative performance.

There are four different possible configurations of capabilities leading firms to high innovative performance within the two patterns of innovation in low-tech firms, design-oriented and business-oriented. These configurations are: TC.MC.dc, TC.mc.DC, TC.MC.oc, TC.oc.DC. A low-tech firm that is innovative has, therefore, at least one of these configurations of innovation capabilities.

These configurations of capabilities show that high-level operations capability is not present in any solution, and thus, does not contribute to low-tech firms' high innovative performance. This is the capability with the highest scores and it is also the focus of most of these firms' improvements, however, it does not affect their performance in terms of innovation. They have to look to other capabilities if they want to succeed. Transaction capability must be among these capabilities, because it is a necessary condition for low-tech firms to achieve high innovative performance. However, transaction capability is not a sufficient condition, since it needs to be combined with other capabilities – development capability or management capability. Having only one high-level innovation capability is not enough to achieve innovative performance. Conversely, low-tech firms do not need high scores in all four capabilities to innovate, therefore, low-tech firms' decision-makers have to find the best configuration of capabilities for their firms and invest in the development of some of them.

Firms that innovate within the designed-oriented pattern, through development and transaction capabilities, develop new products to satisfy some market needs, or even to anticipate them. Additionally, they have the capability to develop products with aggregated value. This configuration is a good alternative for firms that work with fashion trends, such as footwear and textile and clothing. They must have high-level transaction capability to understand market trends *and* high-level development capability do develop the products they envision.

Firms that are not design-oriented may still be innovative through the business-oriented pattern of innovation. Firms focusing in transaction and management capabilities need to offer alternative ways to achieve innovative performance that go beyond technological development, such as having specialized services, managing their supply chain in a more efficient way or promoting their image. This configuration of capabilities is a good alternative for firms that are in the middle of the value chain.

Once managers understand what is required to follow an innovative pattern, they will enhance their decision-making abilities, and thus, be able to choose the configuration of innovation capabilities that is most appropriate to their firms.

In saying all that, it is clear that the initial assumptions of this study, which suggested that each capability, alone, would be the enabling condition to innovation, are not confirmed. This is because the patterns of innovation in low-tech firms were formed not by the type of the capability, but by their level. Moreover, since there are combinations of innovation capabilities leading low-tech firms to achieve innovative performance, it is also clear that it is not only the external factors, such as industry's technological level, that lead to firms' innovation, but also, the configuration of innovation capabilities. In other words, efforts made internally are able to lead firms to innovation.

Most of all, firms that belong to low-technology intensity industries may be innovative, and that will depend on their innovation capabilities level, on the configuration of these capabilities and on the most appropriate pattern of innovation for each type of low-tech firm.

By combining all this information, it is possible to affirm that to belong to a low-tech industry is not a fate to be non-innovative.

It is not the nature of low-tech firms is to be non-innovative. The nature of innovation in low-tech firms is broader than the technological nature of innovation in high-tech firms. Low-tech firms have a choice on the pattern of innovation they will follow, design-oriented or business-oriented, depending on their characteristics.

In sum, there is innovation in low-tech firms, therefore, there is heterogeneity of firms within an industry. This heterogeneity resulted in three types of low-tech firms: Low capabilities, Intermediate Capabilities and High capabilities.

High capabilities low-tech firms have the highest level of innovation capabilities overall and the highest level of innovative performance. Intermediate capabilities low-tech firms have medium level of innovation capabilities and innovative performance. Low capabilities low-tech firms have the lowest level of innovation capabilities overall as well as the lowest level of innovative performance. In that sense, low-level innovation capabilities leads to low-innovative performance and high-level innovation capabilities leads to high-innovative performance. When some capabilities are high-level, the innovation performance may still be satisfactory.

Thirteen percent (13%) of low-tech firms analysed are innovative. Operations capability does not contribute to the innovative performance of low-tech firms, although it is the capability they invest the most. Hence, the low-percentage of innovation within firms from low-tech industries among Brazilian firms. Having only one high-level capability does not contribute to innovative performance either, low-tech firms need a combination of capabilities to innovate. Transaction capability must be one of the high-level capabilities within the combination, since it is central to innovation in low-tech firms. In a low-tech environment, low-tech firms need to know how to commercialize their products. This is not enough though, these activities must be combined with either high-level development capability or high-level management capability.

In that sense, there are two ways for low-tech firms to innovate, through transaction and development capabilities, or through transaction and management capabilities. In the first way, low-tech firms develop new products with an eye on the market, while in the second way, they focus on their business activities. These two ways to innovate have set the patterns of innovation in low-tech firms: design-oriented (transaction and development capabilities) and business-oriented (transaction and management capability).

Design-oriented low-tech firms are those firms that focus on fashion trends or produce final products, and are Intermediate or High capabilities low-tech firms. Business-oriented low-tech firms are in the middle of the value chain, therefore, they are business-to-business firms, and are Low and High capabilities low-tech firms. Having high-level in all capabilities gives the High capabilities firms the choice to follow both patterns of innovation. Out of all firms that do implement one of these configurations of capabilities, 72% have high-innovative performance. Thus, if low-tech firms wish to break the non-innovative destiny set in their sectors, they must develop their capabilities in order to fit in one of these two patterns of innovation.

The nature of innovation in low-tech firms, therefore, is not limited to technological changes, but related to a solid transaction capability combined with product development *or* with business management activities.

* * *

The development of this study have theoretical, public policies and managerial implications.

Regarding theoretical perspectives, this study should bring a new approach to innovation by reinforcing the importance of studying innovation in low-tech firms, an area still neglected on innovation studies, and by identifying the innovation patterns of these firms through the configuration of their capabilities.

By using a set-theoretic approach, which has never been used to evaluate capabilities, it was possible to advance in the innovation theory in both fields, low-tech firms' innovation and innovation capabilities. By avoiding the most common approaches to these subjects, linear models such as regression and structural equation analyses, it was possible to identify a necessary condition (transaction capability) and different configurations of capabilities leading to an outcome, in this case, innovative performance.

Ultimately, in correlating the types of low-tech firm and the configurations of capabilities, it was possible to identify the patterns of innovation in low-tech firms – design-oriented and business-oriented. Not believing in the importance given to R&D indicators, Som and Kirner (2015, p. 2) say "firms that do not invest in regular in-house R&D activities but nevertheless manage to survive in market competition over long periods of time pose a major challenge to neoclassical mainstream innovation theory because a lack of R&D or low R&D intensity is usually associated with the stagnation or decline of firms." The present work makes it clear that innovation is more than investments in R&D, that there are combinations of firms' capabilities determining their patterns of innovation and, ultimately, that there is not one recipe of capabilities that fits all firms.

Broadening the concept of innovation beyond R&D intensity should help policy-makers to support low-tech firms' development appropriately. Smith (2014) understands that when discussing public policies for low-tech industries, there must be support for the development of capabilities that cannot be easily imitated. Public support to R&D is unquestionably important, however, there are other elements that can promote innovation in low-tech firms (Bender, 2008). They are related to other capabilities, such as management and transaction. Similarly, Teece (1986, p. 304) said public policies for innovation "must focus not only on R&D but also on complementary assets, as well as the underlying infrastructure".

Brazilian policy-makers should be aware of the differences of these firms, even though they all belong to low-technology intensity industries. In acknowledging these differences, they will be aware that these firms have different ways to achieve innovative performance. The nature of innovation in low-tech firms is extensive, and thus, public policies should not only promote investments in R&D activities. There is more to it to achieve innovation. Neither should they focus on operations capability, since it is now clear that it does not contribute to achieve innovative performance. They should also be aware that even Low capabilities firms might achieve innovative performance if they invest in the right capabilities, i.e., transaction and management capabilities.

Currently, only 13% of low-tech firms are highly innovative, however, with the right incentives, this number could grow. Public policies aiming at promoting innovation within Brazilian firms must look into low-tech firms, since they represent a large share of the economy. In other words, low-tech firms represent a potential economic development. To do it, policy-makers must first, to identify which companies fit which pattern (design-oriented or business-oriented) of innovation through the evaluation of their innovation capabilities. Then, they must promote actions directed to the capabilities they need to enhance.

In the case of design-oriented firms, there is a need to provide training programs related to sales techniques, evaluation of points of sales and brand consolidation practices. There is also a need to offer market research so firms are able to develop new collections according to client's expectations. Product display and packaging development courses can also enhance these firms' chances to be innovative. In terms of business-oriented firms, to improve their transaction and management capabilities, there is a need to provide training programs related to negotiation skills and communication. Courses presenting novelties in relation to management tools and techniques are also valuable. In this case, it is important that firms be the most efficient possible, by knowing how to buy supplies, how to manage their budget and how to integrate all firm's processes.

In regards with managerial implications, once managers understand they may have strengths other than technological, such as managerial or transactional, they should be able to lead their firms to innovative outcomes. Boly et al. (2000, p. 166) said: “to the extent that the final result of the innovation process remains uncertain for a long period, success depends on the ability of managers to identify and seize opportunities at any moment”. Firms must have some organizational strategy in place, even though it is a simple one, to be able to act on these opportunities.

For Madhok (2002, p. 542), “since different firms have different capabilities and different strategies (hopefully) in line with their capabilities, it can be expected that they will organize their activities differently”. Naturally, the firm’s capability configuration carries some characteristics of its industry. However, it also depends on other factors such as firm’s knowledge base, market requirements, and the firm’s position in the value chain, among others. Managers should choose a configuration of capabilities that fit the pattern of innovation their firms should follow and, by doing that, they might renew their firms’ value-creating potential.

Managers should follow similar actions as those proposed to policy-makers. They have to identify which pattern of innovation is the most adequate for their firm and, from there, work to improve the necessary capabilities to achieve innovative performance.

When a firm is design-oriented, they must invest in marketing, in developing and consolidating their brand and in understating their clients and prospects. They must have an appropriate infrastructure for product development, as well as multidisciplinary teams, which will allow them to give creative and quick responses to market needs and be ahead of their competitors.

In the case of business-oriented firms, managers must develop their business-to-business relationship skills and focus on both, suppliers and clients. Participating of sectoral fairs and being up-to-date with the industry’s technologies is also important to be able comply with clients’ requests promptly and effectively. All administrative dimensions must be well understood, for example, employees must be qualified and routinely trained and management and internal communication systems must be in place to permit the flow of the internal activities as well as to provide accurate information to decision-makers.

Future studies should broaden this study to other industries, including high-tech manufacturing as well as various services sectors. A comparison of high-tech and low-tech industries should allow a better understating of the necessary conditions for a firms to be innovative. In addition, a comparison between fsQCA and other linear models should be tested to evaluate how these approaches impact on innovation studies’ results. To deeper explore the findings of this research; case studies could be carried out to explore each pattern of innovation in low-tech firms with more details.

9.1 Study Limitations

It was expected that, in general, capabilities and performance indicators would have lower scores, since the sample regarded low-tech firms. However, this is a research within the social sciences that deals with respondents' opinions and, consequently, scores are subject to their own views. Not all firms have a clear picture of their entire industry and are able to position themselves accordingly. Such narrow view may have caused biased results where firms rated themselves higher scores than they actually should have. This observation have not affected the results of this research though, since it was still possible to verify significant difference between scores.

There is also a limitation in terms of the selection of the sample cases. It was based on OECD (2011) classification and not on any other classification developed specifically for the Brazilian industries (i.e., Furtado & Carvalho, 2005; Zawislak et al., 2012a). Although the choice was intentional and its reasoning was already explained, this choice might raise some questioning. Additionally, since they are all Brazilian firms and the tests used (cluster and fsQCA) are sensitive tests, results will certainly differ in other countries, in terms of types of low-tech firms and, especially, in terms of configuration of capabilities. Still in relation to the sample, it is worst to point out that the majority of firms are small firms, which may have influenced the results.

In relation to cluster analysis, Aldenderfer and Blashfield (1984) say that different clustering methods can and do generate different solutions to the same dataset. This means that, although all steps up to the validation analysis were taken, if the cluster analysis had been done with a different method (as opposed to K-means), low-tech firms could have been grouped differently and resulted in other patterns of innovation.

In terms of the fsQCA analysis, since it is a technique that is sensitive to cases, minor alterations in the dataset could have produced different combinations of capabilities leading to the outcome. In addition, according to Fiss et al. (2013), small changes in calibration or the choice of cut-off values regarding frequency and consistency thresholds can precipitate significant changes in the solutions obtained. Besides, data used in the present work is secondary data, and for this reason, it was not developed specifically to this research, which might have affected data calibration.

Only a few studies have tried to combine correlation-based and set-theoretic approaches, therefore, there might be some gaps that would need to be worked in the future.

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Appendix A – Factor Analysis Tables

Correlation Matrix[a]

		DC1	DC2	DC3	DC4	DC5	DC7	OC1	OC2	OC3	OC4	OC5	OC6	OC8	MC1	MC2	MC3	MC4	MC5	MC6	TC1	TC3	TC4	TC5	TC6
Correlation	DC1	1.000	.439	.444	.500	.457	.518	.297	.322	.331	.237	.219	.175	.281	.223	.276	.251	.276	.255	.290	.292	.250	.274	.319	.169
	DC2	.439	1.000	.495	.628	.466	.429	.360	.429	.475	.312	.329	.290	.357	.258	.332	.391	.353	.263	.371	.411	.199	.276	.370	.220
	DC3	.444	.495	1.000	.438	.424	.414	.450	.452	.389	.176	.263	.242	.393	.260	.405	.363	.386	.280	.473	.415	.255	.405	.389	.370
	DC4	.500	.628	.438	1.000	.537	.376	.298	.359	.499	.317	.374	.308	.374	.220	.415	.308	.345	.265	.268	.283	.200	.238	.238	.163
	DC5	.457	.466	.424	.537	1.000	.507	.149	.350	.427	.249	.308	.272	.289	.101	.360	.239	.223	.219	.149	.202	.072	.153	.178	.100
	DC7	.518	.429	.414	.376	.507	1.000	.182	.261	.319	.273	.224	.214	.292	.125	.245	.291	.239	.257	.246	.296	.234	.235	.225	.150
	OC1	.297	.360	.450	.298	.149	.182	1.000	.641	.415	.257	.240	.215	.294	.355	.287	.348	.396	.228	.445	.429	.274	.325	.370	.287
	OC2	.322	.429	.452	.359	.350	.261	.641	1.000	.485	.277	.279	.326	.366	.284	.328	.414	.380	.268	.360	.413	.219	.310	.324	.237
	OC3	.331	.475	.389	.499	.427	.319	.415	.485	1.000	.319	.363	.334	.398	.282	.377	.394	.389	.276	.347	.321	.147	.232	.246	.175
	OC4	.237	.312	.176	.317	.249	.273	.257	.277	.319	1.000	.340	.289	.290	.161	.234	.265	.202	.085	.183	.222	.142	.215	.174	.122
	OC5	.219	.329	.263	.374	.308	.224	.240	.279	.363	.340	1.000	.356	.396	.197	.236	.204	.232	.213	.245	.222	.157	.252	.157	.118
	OC6	.175	.290	.242	.308	.272	.214	.215	.326	.334	.289	.356	1.000	.389	.145	.223	.233	.216	.261	.202	.213	.162	.184	.146	.122
	OC8	.281	.357	.393	.374	.289	.292	.294	.366	.398	.290	.396	.389	1.000	.171	.281	.313	.333	.267	.332	.332	.268	.413	.200	.260
	MC1	.223	.258	.260	.220	.101	.125	.355	.284	.282	.161	.197	.145	.171	1.000	.260	.395	.497	.350	.497	.284	.215	.174	.350	.270
	MC2	.276	.332	.405	.415	.360	.245	.287	.328	.377	.234	.236	.223	.281	.260	1.000	.491	.411	.206	.375	.228	.117	.244	.200	.175
	MC3	.251	.391	.363	.308	.239	.291	.348	.414	.394	.265	.204	.233	.313	.395	.491	1.000	.519	.380	.466	.343	.186	.262	.309	.272
	MC4	.276	.353	.386	.345	.223	.239	.396	.380	.389	.202	.232	.216	.333	.497	.411	.519	1.000	.488	.594	.344	.201	.271	.376	.296
	MC5	.255	.263	.280	.265	.219	.257	.228	.268	.276	.085	.213	.261	.267	.350	.206	.380	.488	1.000	.423	.292	.117	.171	.310	.263
	MC6	.290	.371	.473	.268	.149	.246	.445	.360	.347	.183	.245	.202	.332	.497	.375	.466	.594	.423	1.000	.438	.263	.369	.408	.385
	TC1	.292	.411	.415	.283	.202	.296	.429	.413	.321	.222	.222	.213	.332	.284	.228	.343	.344	.292	.438	1.000	.371	.427	.592	.445
	TC3	.250	.199	.255	.200	.072	.234	.274	.219	.147	.142	.157	.162	.268	.215	.117	.186	.201	.117	.263	.371	1.000	.522	.273	.399
	TC4	.274	.276	.405	.238	.153	.235	.325	.310	.232	.215	.252	.184	.413	.174	.244	.262	.271	.171	.369	.427	.522	1.000	.304	.447
	TC5	.319	.370	.389	.238	.178	.225	.370	.324	.246	.174	.157	.146	.200	.350	.200	.309	.376	.310	.408	.592	.273	.304	1.000	.379
	TC6	.169	.220	.370	.163	.100	.150	.287	.237	.175	.122	.118	.122	.260	.270	.175	.272	.296	.263	.385	.445	.399	.447	.379	1.000
Sig. (1-tailed)	DC1		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	DC2	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	DC3	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	DC4	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	DC5	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.006	.000	.000	.000	.000	.000	.000	.037	.000	.000	.006
	DC7	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	OC1	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	OC2	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	OC3	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	OC4	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.017	.000	.000	.000	.000	.000	.001
	OC5	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.002
	OC6	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001
	OC8	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	MC1	.000	.000	.000	.000	.006	.001	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	MC2	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.002	.000	.000	.000
	MC3	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000
	MC4	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000
	MC5	.000	.000	.000	.000	.000	.000	.000	.000	.000	.017	.000	.000	.000	.000	.000	.000	.000		.000	.000	.002	.000	.000	.000
	MC6	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000
	TC1	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000
	TC3	.000	.000	.000	.000	.037	.000	.000	.000	.000	.000	.000	.000	.000	.000	.002	.000	.000	.002	.000	.000		.000	.000	.000
	TC4	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000
	TC5	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000
	TC6	.000	.000	.000	.000	.006	.000	.000	.000	.000	.001	.002	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	

a. Determinant = 5.839E-5

Table 26 – Determinant Matrix

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.918
Bartlett's Test of Sphericity	Approx. Chi-Square	5860.427
	df	276
	Sig.	0.000

Table 27 – KMO and Bartlett's Test

Anti-image Matrices

		DC1	DC2	DC3	DC4	DC5	DC7	OC1	OC2	OC3	OC4	OC5	OC6	OC8	MC1	MC2	MC3	MC4	MC5	MC6	TC1	TC3	TC4	TC5	TC6
Anti-image Covariance	DC1	.561	-.004	-.047	-.110	-.066	-.162	-.031	-.008	.012	-.016	.030	.041	-.005	-.034	.005	.025	.016	-.029	-.014	.024	-.041	-.029	-.066	.041
	DC2	-.004	.465	-.054	-.170	-.033	-.056	.002	-.029	-.036	-.025	-.015	-.012	.001	-.001	.046	-.056	.010	.031	-.035	-.045	.023	.003	-.052	.016
	DC3	-.047	-.054	.489	-.018	-.070	-.064	-.072	-.027	.011	.084	.004	-.004	-.048	.025	-.067	.010	.003	.021	-.076	.004	.032	-.058	-.042	-.079
	DC4	-.110	-.170	-.018	.437	-.088	.044	-.008	.027	-.071	-.034	-.051	-.017	-.027	-.001	-.085	.032	-.034	-.029	.041	.005	-.042	.017	.029	.005
	DC5	-.066	-.033	-.070	-.088	.502	-.144	.087	-.079	-.067	-.004	-.049	-.022	.009	.017	-.077	.031	.002	-.018	.055	.013	.049	.018	-.004	-.012
	DC7	-.162	-.056	-.064	.044	-.144	.567	.030	.030	-.010	-.077	.011	.001	-.015	.042	.025	-.050	.003	-.053	-.009	-.044	-.076	.012	.031	.036
	OC1	-.031	.002	-.072	-.008	.087	.030	.473	-.219	-.056	-.047	-.012	.020	.020	-.043	-.004	.019	-.022	.028	-.046	-.036	-.032	-.001	-.021	-.001
	OC2	-.008	-.029	-.027	.027	-.079	.030	-.219	.463	-.064	-.006	.008	-.064	-.027	.003	.004	-.063	-.011	-.010	.029	-.040	.005	-.018	.007	.020
	OC3	.012	-.036	.011	-.071	-.067	-.010	-.056	-.064	.556	-.032	-.048	-.038	-.057	-.024	-.025	-.037	-.027	.001	-.013	-.017	.027	.014	.019	.013
	OC4	-.016	-.025	.084	-.034	-.004	-.077	-.047	-.006	-.032	.746	-.118	-.087	-.036	-.015	-.018	-.055	-.003	.090	.012	-.006	.025	-.035	-.019	-.012
	OC5	.030	-.015	.004	-.051	-.049	.011	-.012	.008	-.048	-.118	.700	-.102	-.105	-.044	-.003	.038	.016	-.034	-.024	-.002	3,00E-02	-.047	.010	.039
	OC6	.041	-.012	-.004	-.017	-.022	.001	.020	-.064	-.038	-.087	-.102	.729	-.120	.008	-.018	.003	.021	-.095	.005	-.001	-.047	.026	.006	.018
	OC8	-.005	.001	-.048	-.027	.009	-.015	.020	-.027	-.057	-.036	-.105	-.120	.612	.045	.009	-.018	-.039	-.023	-.015	-.030	-.016	-.106	.050	-.017
	MC1	-.034	-.001	.025	-.001	.017	.042	-.043	.003	-.024	-.015	-.044	.008	.045	.631	.000	-.063	-.101	-.048	-.110	.023	-.060	.055	-.061	-.033
	MC2	.005	.046	-.067	-.085	-.077	.025	-.004	.004	-.025	-.018	-.003	-.018	.009	.000	.611	-.172	-.059	.066	-.052	.013	.033	-.035	.018	.017
	MC3	.025	-.056	.010	.032	.031	-.050	.019	-.063	-.037	-.055	.038	.003	-.018	-.063	-.172	.545	-.080	-.073	-.030	-.013	-3,8E-05	.001	.001	-.022
	MC4	.016	.010	.003	-.034	.002	.003	-.022	-.011	-.027	-.003	.016	.021	-.039	-.101	-.059	-.080	.479	-.128	-.121	.022	.001	.001	-.043	.001
	MC5	-.029	.031	.021	-.029	-.018	-.053	.028	-.010	.001	.090	-.034	-.095	-.023	-.048	.066	-.073	-.128	.648	-.064	-.015	.054	.023	-.040	-.059
	MC6	-.014	-.035	-.076	.041	.055	-.009	-.046	.029	-.013	.012	-.024	.005	-.015	-.110	-.052	-.030	-.121	-.064	.465	-.040	.010	-.041	-.007	-.039
	TC1	.024	-.045	.004	.005	.013	-.044	-.036	-.040	-.017	-.006	-.002	-.001	-.030	.023	.013	-.013	.022	-.015	-.040	.495	-.050	-.049	-.208	-.085
	TC3	-.041	.023	.032	-.042	.049	-.076	-.032	.005	.027	.025	3,00E-02	-.047	-.016	-.060	.033	-3,8E-05	.001	.054	.010	-.050	.639	-.207	-.007	-.111
	TC4	-.029	.003	-.058	.017	.018	.012	-.001	-.018	.014	-.035	-.047	.026	-.106	.055	-.035	.001	.001	.023	-.041	-.049	-.207	.552	.004	-.108
	TC5	-.066	-.052	-.042	.029	-.004	.031	-.021	.007	.019	-.019	.010	.006	.050	-.061	.018	.001	-.043	-.040	-.007	-.208	-.007	.004	.558	-.051
	TC6	.041	.016	-.079	.005	-.012	.036	-.001	.020	.013	-.012	.039	.018	-.017	-.033	.017	-.022	.001	-.059	-.039	-.085	-.111	-.108	-.051	.639
Anti-image Correlation	DC1	.922[a]	-.008	-.091	-.221	-.124	-.287	-.060	-.016	.022	-.024	.047	.065	-.008	-.058	.009	.046	.031	-.049	-.028	.046	-.069	-.051	-.118	.068
	DC2	-.008	.934[a]	-.114	-.378	-.068	-.109	.005	-.062	-.071	-.042	-.026	-.021	.002	-.003	.085	-.111	.022	.057	-.076	-.093	.043	.005	-.103	.029
	DC3	-.091	-.114	.945[a]	-.038	-.141	-.122	-.150	-.057	.021	.139	.008	-.006	-.088	.044	-.123	.019	.006	.037	-.159	.008	.058	-.111	-.080	-.142
	DC4	-.221	-.378	-.038	.901[a]	-.188	.088	-.017	.060	-.144	-.059	-.092	-.031	-.053	-.001	-.164	.066	-.075	-.054	.091	.010	-.079	.035	.059	.009
	DC5	-.124	-.068	-.141	-.188	.888[a]	-.270	.179	-.164	-.126	-.006	-.082	-.037	.017	.030	-.139	.059	.003	-.032	.114	.026	.087	.035	-.007	-.021
	DC7	-.287	-.109	-.122	.088	-.270	.888[a]	.057	.059	-.018	-.118	.017	.001	-.025	.071	.043	-.089	.005	-.087	-.017	-.083	-.127	.022	.054	.059
	OC1	-.060	.005	-.150	-.017	.179	.057	.890[a]	-.468	-.110	-.079	-.021	.034	.037	-.079	-.007	.038	-.046	.051	-.099	-.074	-.059	-.002	-.041	-.001
	OC2	-.016	-.062	-.057	.060	-.164	.059	-.468	.904[a]	-.125	-.010	.014	-.111	-.052	.006	.008	-.125	-.024	-.018	.062	-.084	.010	-.035	.013	.036
	OC3	.022	-.071	.021	-.144	-.126	-.018	-.110	-.125	.964[a]	-.049	-.077	-.059	-.097	-.041	-.044	-.067	-.052	.001	-.026	-.032	.045	.025	.034	.022
	OC4	-.024	-.042	.139	-.059	-.006	-.118	-.079	-.010	-.049	.916[a]	-.164	-.118	-.054	-.022	-.027	-.086	-.005	.130	.021	-.010	.036	-.054	-.029	-.017
	OC5	.047	-.026	.008	-.092	-.082	.017	-.021	.014	-.077	-.164	.932[a]	-.143	-.160	-.066	-.005	.061	.027	-.051	-.042	-.004	4,48E-02	-.075	.016	.058
	OC6	.065	-.021	-.006	-.031	-.037	.001	.034	-.111	-.059	-.118	-.143	.924[a]	-.179	.011	-.027	.004	.035	-.138	.009	-.002	-.069	.041	.009	.026
	OC8	-.008	.002	-.088	-.053	.017	-.025	.037	-.052	-.097	-.054	-.160	-.179	.944[a]	.073	.014	-.031	-.072	-.036	-.028	-.055	-.025	-.182	.085	-.027
	MC1	-.058	-.003	.044	-.001	.030	.071	-.079	.006	-.041	-.022	-.066	.011	.073	.923[a]	-.001	-.107	-.184	-.076	-.203	.041	-.094	.093	-.103	-.052
	MC2	.009	.085	-.123	-.164	-.139	.043	-.007	.008	-.044	-.027	-.005	-.027	.014	-.001	.913[a]	-.298	-.109	.106	-.097	.024	.053	-.061	.030	.027
	MC3	.046	-.111	.019	.066	.059	-.089	.038	-.125	-.067	-.086	.061	.004	-.031	-.107	-.298	.928[a]	-.156	-.123	-.059	-.024	-6,4E-05	.002	.002	-.037
	MC4	.031	.022	.006	-.075	.003	.005	-.046	-.024	-.052	-.005	.027	.035	-.072	-.184	-.109	-.156	.933[a]	-.229	-.256	.045	.002	.001	-.083	.002
	MC5	-.049	.057	.037	-.054	-.032	-.087	.051	-.018	.001	.130	-.051	-.138	-.036	-.076	.106	-.123	-.229	.909[a]	-.117	-.027	.084	.038	-.067	-.092
	MC6	-.028	-.076	-.159	.091	.114	-.017	-.099	.062	-.026	.021	-.042	.009	-.028	-.203	-.097	-.059	-.256	-.117	.934[a]	-.084	.019	-.081	-.014	-.071
	TC1	.046	-.093	.008	.010	.026	-.083	-.074	-.084	-.032	-.010	-.004	-.002	-.055	.041	.024	-.024	.045	-.027	-.084	.921[a]	-.090	-.095	-.396	-.152
	TC3	-.069	.043	.058	-.079	.087	-.127	-.059	.010	.045	.036	4,48E-02	-.069	-.025	-.094	.053	-6,4E-05	.002	.084	.019	-.090	.860[a]	-.348	-.012	-.174
	TC4	-.051	.005	-.111	.035	.035	.022	-.002	-.035	.025	-.054	-.075	.041	-.182	.093	-.061	.002	.001	.038	-.081	-.095	-.348	.898[a]	.006	-.182
	TC5	-.118	-.103	-.080	.059	-.007	.054	-.041	.013	.034	-.029	.016	.009	.085	-.103	.030	.002	-.083	-.067	-.014	-.396	-.012	.006	.906[a]	-.085
	TC6	.068	.029	-.142	.009	-.021	.059	-.001	.036	.022	-.017	.058	.026	-.027	-.052	.027	-.037	.002	-.092	-.071	-.152	-.174	-.182	-.085	.921[a]

a. Measures of Sampling Adequacy(MSA)

Table 28 – MSA

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.132	33.882	33.882	8.132	33.882	33.882	3.825	15.937	15.937
2	2.026	8.441	42.323	2.026	8.441	42.323	3.345	13.936	29.873
3	1.493	6.221	48.544	1.493	6.221	48.544	2.929	12.205	42.078
4	1.263	5.264	53.808	1.263	5.264	53.808	2.815	11.730	**53.808**
5	1.034	4.307	58.115						
6	.924	3.850	61.965						
7	.844	3.516	65.481						
8	.755	3.146	68.627						
9	.732	3.051	71.678						
10	.651	2.714	74.392						
11	.602	2.507	76.899						
12	.586	2.442	79.341						
13	.564	2.349	81.690						
14	.532	2.218	83.909						
15	.510	2.124	86.033						
16	.472	1.966	87.999						
17	.441	1.839	89.838						
18	.422	1.759	91.596						
19	.395	1.647	93.244						
20	.384	1.602	94.845						
21	.345	1.439	96.285						
22	.329	1.370	97.654						
23	.293	1.221	98.876						
24	.270	1.124	100.000						

Extraction Method: Principal Component Analysis.

Table 29 – Total Variance Explained

Appendix B – Cluster Analysis – Dendogram

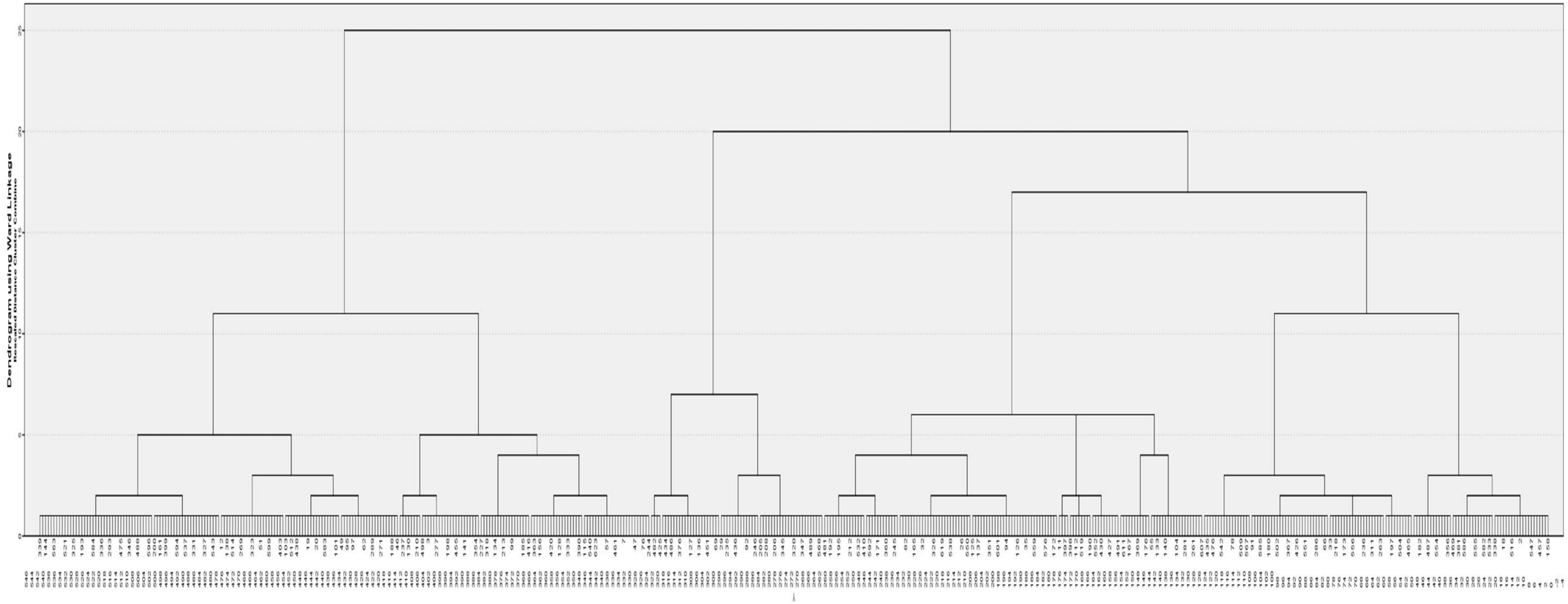

Figure 13 – Hierarchical Cluster Analysis - Dendogram

Appendix C – General Characteristics of Low-Tech Firms Tables

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Information obtained from suppliers	8	1.3	1.3	1.3
	New internally developed knowledge	72	11.4	11.5	12.7
	Information obtained by observing competitors	15	2.4	2.4	15.1
	Information provided by customers	118	18.7	18.8	33.9
	Recent performance	218	34.5	34.7	68.6
	Tradition	197	31.2	31.4	100.0
	Total	628	99.5	100.0	
	Missing	3	.5		
Total		631	100.0		

Table 30 – Sample Distribution based on the Decision-Making Reasoning

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	100	82	13.0	13.2	13.2
	98	2	.3	.3	13.5
	95	29	4.6	4.7	18.2
	90	157	24.9	25.2	43.4
	89	2	.3	.3	43.7
	87	1	.2	.2	43.9
	85	28	4.4	4.5	48.4
	80	169	26.8	27.2	75.6
	75	12	1.9	1.9	77.5
	70	56	8.9	9.0	86.5
	65	8	1.3	1.3	87.8
	60	28	4.4	4.5	92.3
	50	20	3.2	3.2	95.5
	45	1	.2	.2	95.7
	40	8	1.3	1.3	96.9
	30	9	1.4	1.4	98.4
	25	1	.2	.2	98.6
	20	5	.8	.8	99.4
	10	2	.3	.3	99.7
	1	1	.2	.2	99.8
	0	1	.2	.2	100.0
	Total	622	98.6	100.0	
	Missing	9	1.4		
Total		631	100.0		

Table 31 – Sample Distribution based on Production Installed Capacity (%)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	The signed contracts	13	2.1	2.1	2.1
	The current pace of sales (JIT)	20	3.2	3.2	5.3
	The orders placed	210	33.3	33.4	38.7
	The predicted future sales preview	78	12.4	12.4	51.1
	The production background and past sales	84	13.3	13.4	64.5
	The installed capacity	223	35.3	35.5	100.0
	Total	628	99.5	100.0	
Missing		3	.5		
Total		631	100.0		

Table 32 – Sample Distribution based on How the Production is Planned

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Patent	230	36.5	37.0	37.0
	No patent	391	62.0	63.0	100.0
	Total	621	98.4	100.0	
Missing		10	1.6		
Total		631	100.0		

Table 33 – Sample Distribution based on Patent Registration

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Direct sales to the final consumer	135	21.4	21.5	21.5
	Sales to retailers	63	10.0	10.0	31.6
	Sales to distributors	73	11.6	11.6	43.2
	Sales by representatives	186	29.5	29.7	72.9
	Direct sales to other manufacturing companies	170	26.9	27.1	100.0
	Total	627	99.4	100.0	
Missing		4	.6		
Total		631	100.0		

Table 34 – Sample Distribution based on Firms' Distribution Channel

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Mark up	7	1.1	1.1	1.1
	Brand	40	6.3	6.4	7.5
	By the customer	30	4.8	4.8	12.2
	Costs	511	81.0	81.2	93.5
	The competitor's price	41	6.5	6.5	100.0
	Total	629	99.7	100.0	
Missing		2	.3		
Total		631	100.0		

Table 35 – Sample Distribution based on How Firms determine the Price of their Products

Appendix D – Correlation Tables

Correlations

		Size	Business Model
Size	Pearson Correlation	1	,154**
	Sig. (2-tailed)		,000
	N	616	614
Business Model	Pearson Correlation	,154**	1
	Sig. (2-tailed)	,000	
	N	614	629

**. Correlation is significant at the 0.01 level (2-tailed).

Table 36 – Correlation between Size and Business Model

Correlations

		R&D Investments	Interaction with S&TI
R&D Investments	Pearson Correlation	1	,247**
	Sig. (2-tailed)		,000
	N	601	594
Interaction with S&TI	Pearson Correlation	,247**	1
	Sig. (2-tailed)	,000	
	N	594	624

**. Correlation is significant at the 0.01 level (2-tailed).

Table 37 – Correlation between R&D Investments and Interaction with Science and Technology Institutions

Correlations

		R&D Investments	Size
R&D Investments	Pearson Correlation	1	,258**
	Sig. (2-tailed)		,000
	N	601	593
Size	Pearson Correlation	,258**	1
	Sig. (2-tailed)	,000	
	N	593	616

**. Correlation is significant at the 0.01 level (2-tailed).

Table 38 – Correlation between R&D Investments and Size

Correlations

		R&D Investments	Patents
R&D Investments	Pearson Correlation	1	,308**
	Sig. (2-tailed)		,000
	N	601	593
Patents	Pearson Correlation	,308**	1
	Sig. (2-tailed)	,000	
	N	593	621

**. Correlation is significant at the 0.01 level (2-tailed).

Table 39 – Correlation between R&D Investments and Patent registration